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HUYGENS

TITLE : HUYGENS USER MANUAL DESCRIPTION

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00	-	27/01/93	Draft issue
01	-	11/05/94	First issue
02	-	10/07/95	Complete re-issue
02	A	20/02/96	See items in left margin Page A1 § 1 all pages are provided (1 to 8) § 2.1 all pages are provided (1 to 23) § 2.2 pages 6, 28, 48, 52, 55 to 79 § 3 all pages are provided (1 to 18) § 4.1 pages 1, 9, 17, 18, 20, 22, 25 to 30 § 4.2 pages 30, 31, 34, 35, 41, 44 to 53 § 4.3 pages 38, 51, 56, 57 § 4.4 all pages are provided (1 to 78) § 4.5 pages 1, 2, 4, 5, 19, 20, 28, 33, 35, 43, 44, 48, 51, 55, 56, 62, 65 § 4.6 all pages are provided (1 to 16) § 4.7 page 14 § 4.8 page 22 § 5 page 1 § 6 all pages are provided (1 to 18)
03	-	01/07/96	Complete re-issue, see change bars in left margin
04	-	15/01/97	Complete re-issue to introduce design and operations evolution See change bars in left hand margin
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TITRE

HUYGENS USER MANUAL DESCRIPTION

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RESUME D'AUTEUR

Ce document constitue la première partie du manuel d'utilisation du système Huygens.
Il constitue essentiellement la description de la sonde.

Numéro de documentation	Nature du document	Cote archive
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SUMMARY

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ANNEXES

1 Budget Report See § 2.2.6

2 HUYGENS TM/TC data tables, doc. n° HUY.AS/c.100.DB.0204

3 Experiments TM/TC data tables, doc. n° HUY.AS/c.100.DB.0299

4 Electrical system block diagram, doc. n° HUY.AS/c.100.BD.0179

5 System CIDL, doc. n° HUY.AS/c.100.LI.0315

6 Experiment User Manuals

1. INTRODUCTION

1.1 SCOPE

The User Manual (HUM) provides the inputs required to support the ground segment team in the preparation of the flight operations to control the HUYGENS Probe system when the Probe is attached to the Orbiter and to interprete the telemetry during all phases of the mission.

The HUM comprises two distinct volumes:

- the first one, this document, reference HUY.AS/c.100.OP.0201, which is essentially a description of the Probe.
- the second one, reference HUY.AS/c.100.OP.0384, which describes esssentially Operation procedures and Contingencies.

These two documents are devoted mainly to the Probe description and Operations. Details about Experiments Description and their operations are found in the Experiment User Manuals Annex 6 provided by ESA/ESTEC.

After this brief introduction, Part 2 gives the description of the mission phases with purpose, requirements and constraints then a system description of the HUYGENS Probe system with subsystem constitution and budget summary.

Part 3 depicts operational concept and details operations with associated sequence of events for each mission phase.

Part 4 provides subsystem description for each subsystem submitted to operations.

Part 5 gives a list of the Experiment user manuals.

Part 6 details TC and TM constitution.

1.2 APPLICABLE AND REFERENCE DOCUMENTS

AD1:	ESA PSS-04-105	Radio Frequency and Modulation standard
AD2:	ESA PSS-04-106	Packet Telemetry standard
AD3:	ESA PSS-04-107	Packet Telecommand standard
AD4:	ESA-PSS-04-103	Telemetry channel coding standard
AD5:	CCSDS 101.0-B-2 Blue Book	Telemetry coding Recommendations
AD6	CCSDS 401 0-B-1 Blue Book	Recommendations of Radio Frequency and Modulation systems
AD7	ESA-PSS-05-0	Software Engineering Standards
AD8	HUY.AS/c.100.OP.0394	Flight Rules

RD1:	HUY.LOG.390/3A0.PR.100 with: POSW memory maps SASW memory maps SASW ADD, doc n° HUY.LOG.3A0.SP.0024 POSW ADD, doc n° HUY.LOG.390.SP.0023 SASW DDD, doc n° HUY.LOG.3A0.SP.0058 POSW DDD, doc n° HUY.LOG.390.SP.0045	On-board Software Maintenance Manual (SMM)
RD2:	HUY.AS/c.100.ID.0237	Interface Control Document for the SASW/POSW (SICD)
RD3:	HUY.AS/c.100.ID.0409	EICD
RD4:	HUY.AS/c.100.ID.0208	MTICD
RD5:	HUY.AS/c.100.SP.0244	IST Specification
RD6:	HUY.AS/c.100.RE.0505	System Design Report FAR
RD7:	HUY.AS/c.100.SP.0241 with Test Report	Experiment Probe Level tests

1.3 ABBREVIATIONS LIST

ACP	Aerosol collector and Pyrolyser
A/D	Analog/Digital
AGC	Automatic Gain Control
AU	Astronomical Unit - Average distance from the Earth to the Sun
BCM	Back Cover Mechanism
BCSS	Back Cover Subsystem
BDR	Battery Discharge Regulator
BER	Bit Error Rate
BIU	Bus Interface Unit
BPSK	Bi-Phase Shift Keying
CASU	Central Acceleration Sensor Unit
CCAFS	Cape Canaveral Air Force Station
CCSDS	Consultative Committee for Space Data Systems Standardisation
CDL	Cumulative Distorsion Losses
CDMS	Command and Data Management Subsystem
CDMU	Command and Data Management Unit
CDS	Command and Data Management Subsystem (of the Orbiter)
CFRP	Carbon Fiber Reinforced Plastic
COR	Check Out Review
CRC	Cyclic Redundancy Code
CUT	Computed Unit Time
DC	Direct Current
DCSS	Descent Control Subsystem

DDB	Descent Data Broadcast
DDE	Direct Digital Experiment
DISR	Descent Imager and Spectral Radiometer
DMA	Direct Memory Access
DSN	Deep Space Network
DSP	Digital Signal Processing
DWE	Doppler Wind Experiment
Eb	Energy per information bit
EDAC	Error Detection And Correction
EEE	Electronic, Electrical and Electromechanical
EEPROM	Electrically Erasable Programmed Read Only Memory
EICD	Electrical Interface Control Document
EID	Experiment Interface Document
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ENA	Entry Assembly
EPSS	Electrical Power Subsystem
Es	Energy per symbol
ESA	European Space Agency
ESD	Electrostatic Discharge
ESOC	European Space Operations Centre
ESTEC	European Space Research and Technology Centre

FER	Frame Error Rate
FET	Field Effect Transistor
FFT	Fast Fourier Transform
FMECA	Failure Mode Effects and Criticality Analysis
FOP	Flight Operations Plan
FRSS	Front Shield Subsystem
FSM	Front Shield Mechanism
GCMS	Gas Chromatograph and Mass Spectrometer
GFRP	Glass Fiber Reinforced Plastic
HDB	Huygens Data Base
HASI	Huygens Atmospheric Structure Instrument
HGA	High Gain Antenna
HK	Housekeeping
H/L	High Level
HOOD	Hierarchical Object Oriented Design
HPA	High Power Amplifier
IF	Intermediate Frequency
I/O	Input/Output
IRD	Interface Requirements Document
ISTS	Inner Structure Subsystem
JPL	Jet Propulsion Laboratory
Kbps	Kilobits per seconds
Ksps	Kilosymbols per second
LHCP	Left Hand Circular Polarization
LNA	Low Noise Amplifier
MCI	Mass Centering Inertia
MEA	Main Error Amplifier

M/L	Memory Load
MLC	Memory Load Command
MOS	Mission Operations System (at JPL)
MTU	Mission Timer Unit
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network (of DSN)
NCO	Numerically Controlled Oscillator
NRZ	Non-Return to Zero
NSI	NASA Standard Initiators
OBDH	On Board Data Handling
ODM	Orbiter Deflection Manoeuvre
ODT	Orbiter Delay Time
O/O	ON/OFF
ORT	Orbiter Receiving Antenna
PAA	Probe Aspect Angle
PCDU	Power conditioning and Distribution Unit
PCM	Pulse-Code Modulation
PDD	Parachute Deployment Device
PDRS	Probe Data Relay Subsystem
PDRSVF	Probe Data Relay Subsystem Verification Facility
PHSS	Probe Harness Subsystem
PI	Principal Investigator
PISO	Parallel Input Serial Output
PJM	Parachute Jettison Mechanism
PLL	Phase-Locked Loop
POC	Probe Operations Centre
POE	Probe-Orbiter-Earth Angle

POSW	Probe On-board Software
POV	Probe-Orbiter Velocity
PRA	Probe Relay Antenna
PRL	Probe Relay Link
PROM	Programmed Read Only Memory
PRM	Periapsis Raise Manoeuvre
PSA	Probe Support Avionics
PSE	Probe Support Equipment
PTA	Probe Transmitter Antenna
PTT	Probe Transmitting Terminal
RAM	Random Access Memory
RASU	Radial Accelerometer Sensor Unit
RAU	Radar Altimeter Unit
REU	Remote Engineering Unit
RF	Radio Frequency
RFE	Receiver Front End
RHCP	Right Hand Circular Polarization
RHU	Radioisotope Heater Unit
RS	Radius of Saturn
RSS	Root of Sum of Squares
RTG	Radioisotope Thermoelectric Generator
RTI	Real Time Interrupt
RUSO	Receiver Ultra Stable Oscillator

SASW	Support Avionics Software
S/D	Serial/digital
SED	Spin Eject Device
SEE	Single-Event Effects (upsets, latchings and burnouts)
SEPS	Separations Subsystem
SER	Symbol Error Rate
SEU	Single-Event Upset
SICD	Software Interface Control Document
SOI	Saturn Orbit Insertion (Manoeuvre)
SSP	Surface Science Package
SUM	Software User Manual
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand
TCXO	Temperature Compensated Crystal Oscillator
TF	Transfer Frame
THSS	Thermal Control Subsystem
TM	Telemetry
TUSO	Transmitter Ultra Stable Oscillator
USM	Umbilical Separator Mechanism
VCO	Voltage Controlled Oscillator
VCXO	Voltage-Controlled Crystal Oscillator
VVEJGA	Venus-Venus-Earth-Jupiter Gravity Assist

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2. SYSTEM DESCRIPTION

2.1 MISSION DESCRIPTION

Titan is the HUYGENS Probe target. The objective of the HUYGENS Probe is to:

- determine abundances of atmospheric constituents (including any noble gases); establish isotope ratios for abundant elements; constraint scenarios of formation and evolution of Titan and its atmosphere

- observe vertical and horizontal distributions of trace gases; search for more complex organic molecules; investigate energy sources for atmospheric chemistry; model the photochemistry of the stratosphere; study formation and composition of aerosols

- measure winds and global temperatures; investigate cloud physics, general circulation and seasonal effects in the atmosphere of Titan; search for lightning discharges

- determine the physical state, topography and composition of the surface and the internal structure of the Saturn satellite

- investigate the upper atmosphere, its ionisation, and its role as a source of neutral and ionised material for the magnetosphere of Saturn.

The HUYGENS Probe is supported by the CASSINI Saturn Orbiter which will make repeated close flybys of Titan and will use Probe data to "calibrate" the Orbiter Titan observations.

HUYGENS/CASSINI spacecraft mission is shared into seven phases of which the fourth last ones are related to the Probe mission itself.

Mission sequence and nomenclature are given in the table hereafter:

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PHASE	EVENT	DEFINED BY	NOMINAL TIME
1• Launch	Launch vehicle ignition	Solid Rocket Motor ignition	06 OCT 1997
	Separation from launch vehicle	Firing of separation pyros	06 OCT 1997
2• Cruise	Saturn Orbit Insertion	Ignition of Orbiter engine	1 JULY 2004
3• Saturn orbit	Periapsis Raise Manoeuvre		12 SEPT 2004
	Separation from Orbiter	USM and Spin-Eject device actuation	06 NOV 2004
4• Coast			
5• Mission			
5.1• Entry	Start of atmospheric entry	1270 km altitude	27 NOV 2004
5.2• Descent	PDD actuation	Firing of PDD	
5.3• Surface	Touchdown	Contact with surface	
	Loss of contact: end of mission	Loss of Probe signal	2.5hr (max) + 30 mn

A brief description of each phase is given hereafter.

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2.1.1 Launch phase

The CASSINI spacecraft will be launched from Cap Canaveral Air Force Station (CCAFS) on October 6, 1997 with a Titan IV/Centaur launcher. The backup launch opportunity occurs in March 1999 which gives arrival at Saturn late in 2008.

Only the baseline Launch is considered in this document.
Mission design will maintain at least a 44 days launch period and a 140mn daily launch window.

2.1.2 Cruise phase

The cruise phase starts at the CASSINI spacecraft Earth escape and ends at Saturn Orbit Insertion (SOI). Its duration is about 7 years for the nominal launch, more than 9 years in case of back-up launch.

The transfer trajectory to Saturn is illustrated on Figure 2.1-1 and will be of the VVEJGA type, which means that the vehicle will undergo 2 Venus, 1 Earth and 1 Jupiter gravity assists.

The spacecraft/Probe will flyby Venus on April 21, 1998, 197 days after launch.
A second Venus flyby will occur on June 20, 1999, 622 days after launch.

The closest approach of Venus could take place at an altitude of 300 km and a velocity of 12.5 km/s.

Then, the spacecraft/Probe will flyby Earth on August 16, 1999 at a closest altitude of about 300 km with a velocity of 19 km/s.

Four days after the Earth gravity assist an orbit manoeuvre will be performed, directing the spacecraft to Jupiter for the final gravity assist on December 30, 2000 at a distance of about 100 Jupiter radii and with a velocity of about 11.5 km/s.

Arrival at Saturn will occur on July 1, 2004.

Science activities are planned during all flybys and during the cruise phase. These investigations, however, are limited to the Orbiter and are not expected to have an impact on the Probe operations.

During cruise phase the Probe is in dormant mode except checkouts: post launch and periodic ones. See Tables 1.9-1 to 1.9-3 in Doc n° HUY.AS/c.100.OP.0384.

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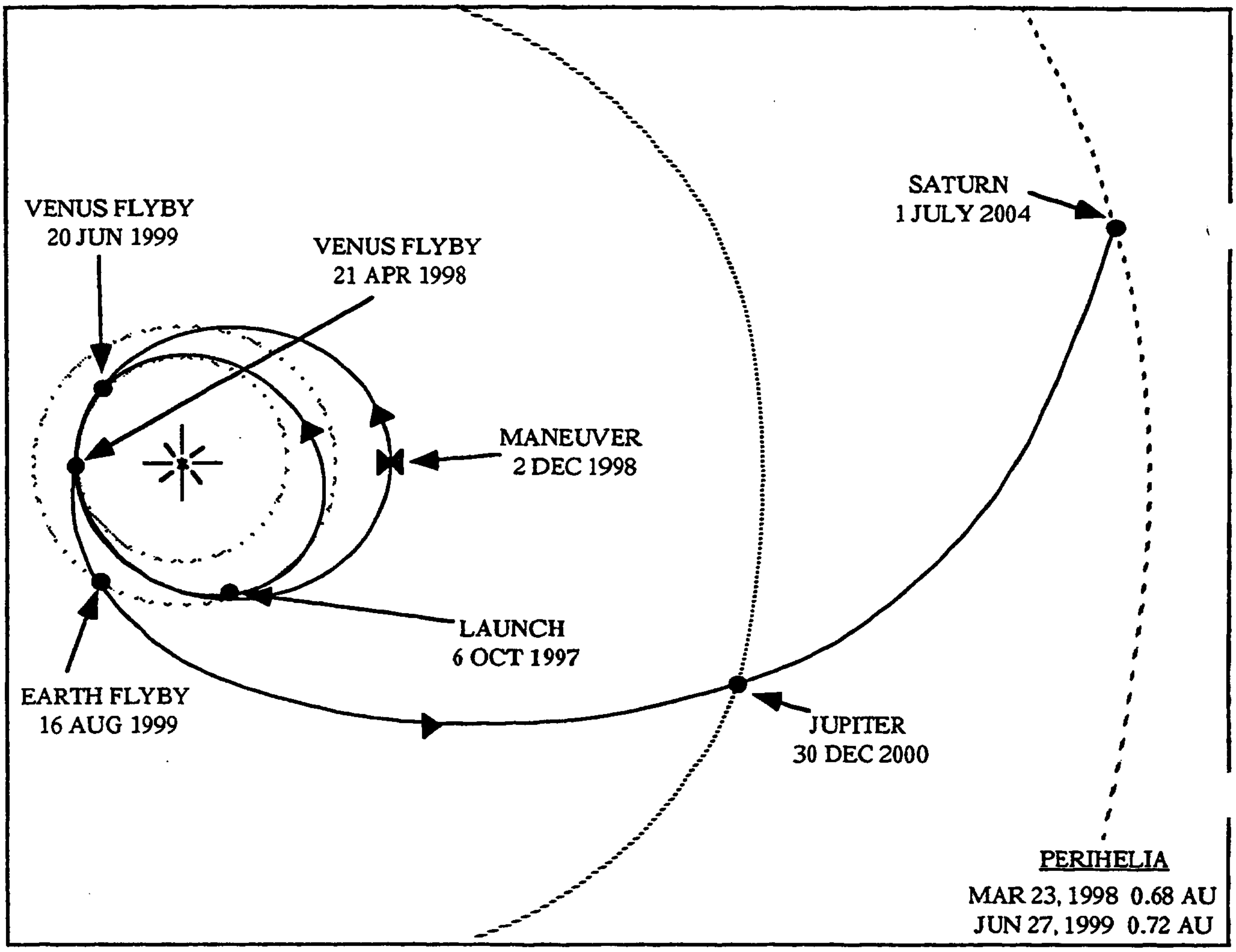

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FIGURE 2.1-1 INTERPLANETARY CRUISE TRAJECTORY

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2.1.3 Saturn orbit phase

The Saturn orbit phase illustrated on Figure 2.1-2, starts at the Saturn Orbit Insertion and ends at separation of the Probe from the Orbiter. Its nominal duration is about 4.5 months. A back-up scenario consists in a separation during the second orbit around Saturn as shown on Figure 2.1-3.

The CASSINI spacecraft will be inserted into a highly eccentric Saturn-centered orbit (capture orbit) with periapsis radius of about 1.3 Saturn radii (Rs) and about 152 day period. The hyperbolic approach trajectory will cross the ring plane of Saturn from South to North at about 2.65 Rs radial distance. The Saturn Orbit Insertion (SOI) manoeuvre will take place above the ring plane and will last for about 2 hours, after which the ring plane will be crossed a second time (from North to South).

About 2.5 months after SOI, when the spacecraft is near the apoapsis of the capture orbit, a major trajectory correction is achieved by means of a Periapsis Raise Manoeuvre (PRM) with a twofold objective:

- to raise the periapsis radius to about 8.2 Rs

- to target the CASSINI spacecraft for its encounter with Titan.

Before separation from the Orbiter, the spacecraft will be oriented in the proper direction. The PRM and the separation are crucial events for the Probe mission, as they completely determine the entry location on Titan (apart from dispersions).

Before separation the Probe will be submitted to a last checkout and Battery Depassivations and MTU Loading. See Tables 1.9-4 A to C in Doc n° HUY.AS/c.100.OP.0384.

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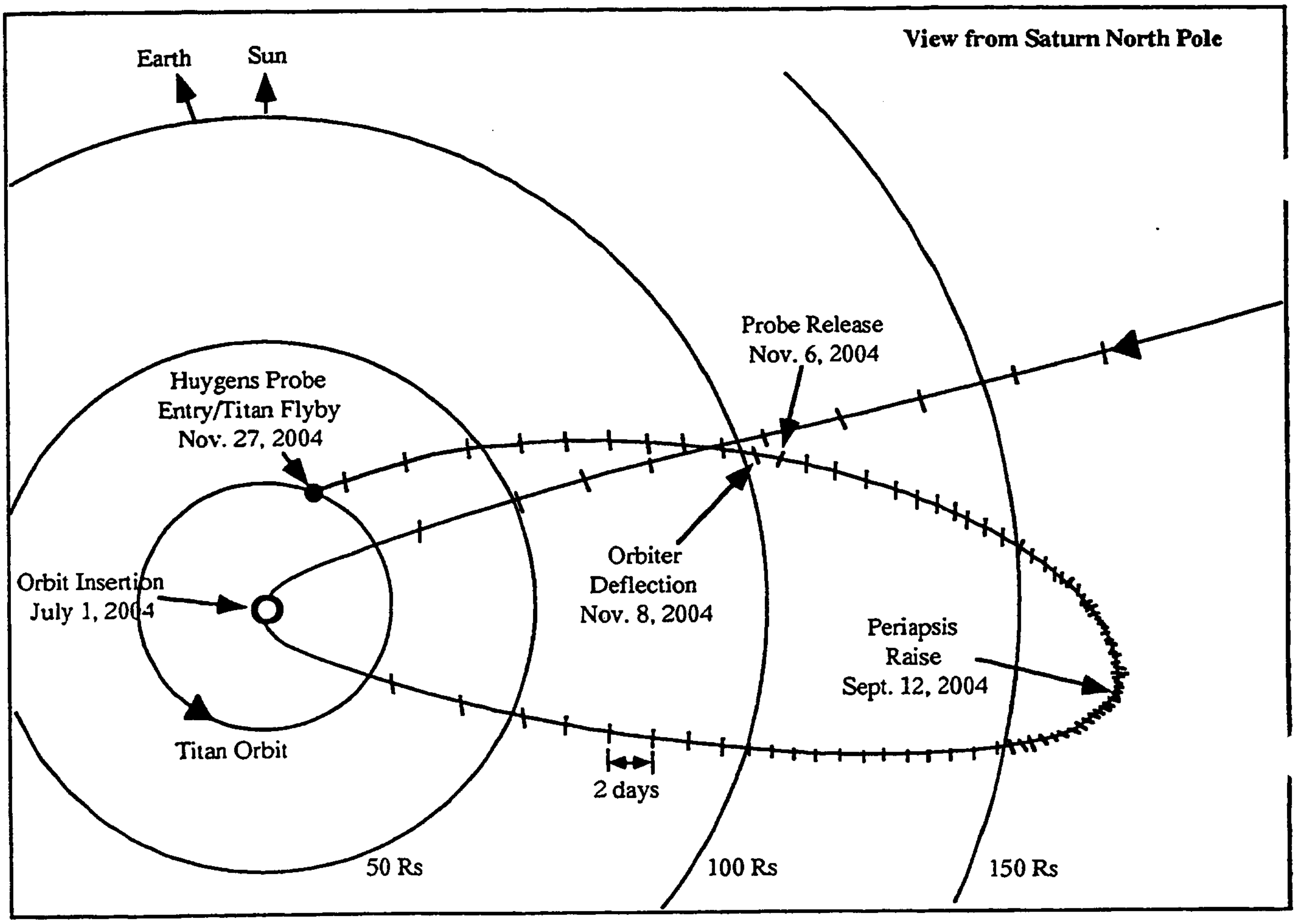

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FIGURE 2.1-2 VISUALISATION OF CASSINI/TITAN ENCOUNTER GEOMETRY (NOMINAL RELEASE)

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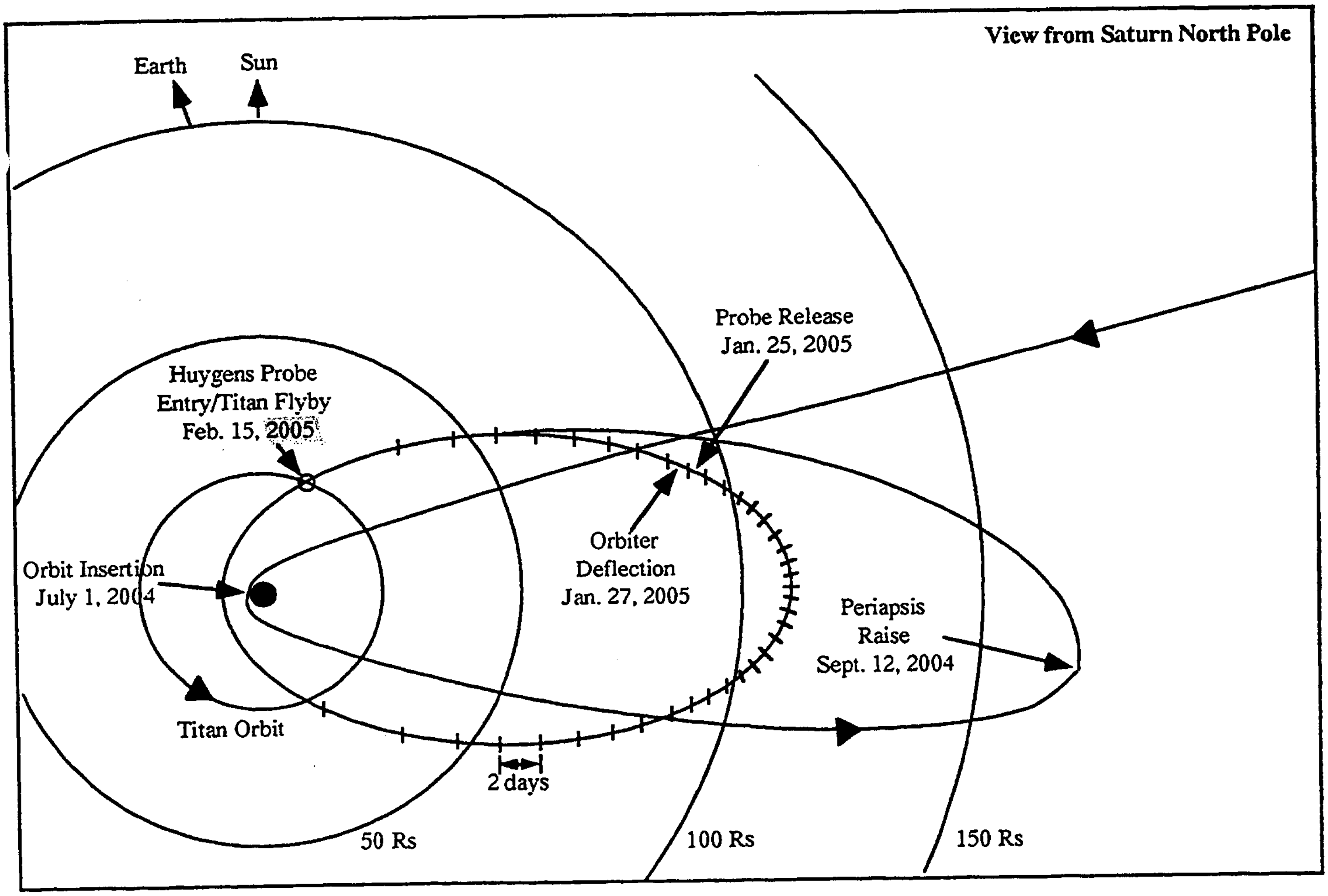

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FIGURE 2.1-3 VISUALISATION OF CASSINI/TITAN ENCOUNTER GEOMETRY (BACKUP RELEASE ON SECOND SATURN ORBIT)

2.1.4 Coast phase

The coast phase starts at the separation of the Probe from the Orbiter and ends at the entry into Titan atmosphere at a nominal altitude of 1270 km. Its nominal duration is 22 days.

In order to ensure Probe targeting on Titan, stability during entry, no collision and no damage on Orbiter, the following separation performances are required:

- a relative Probe linear separation velocity with respect to the Orbiter = 0.3 m/s + 25%, -10%
- a relative Probe angular separation velocity with respect to the Orbiter between 5 and 10 rpm
- an absolute transverse velocity of the Probe less than 3.2 cm/s
- a clearance of 25 mm at least between the Orbiter and the Probe
- a Probe tip-off error plus nutation after separation less than 9°
- adequate net axial and angular impulses imparted to the Orbiter by the Probe

After separation, the spin-stabilized Probe will continue on a ballistic trajectory and will encounter Titan. During this phase, there is no further active control of orbit or attitude of the Probe.

About two days after Probe separation, the Orbiter Deflection Manoeuvre (ODM) takes place with two goals:

- to achieve adequate geometrical conditions for the Probe Relay Link (PRL) by delaying the Titan flyby time of the Orbiter
- to achieve proper initial conditions (such as semi-major axis, inclination, argument of periapsis) for the subsequent Orbiter tour of the saturnian system.

The Probe-Orbiter distance will increase steadily after the ODM until the Probe slows down due to its interaction with the atmosphere of Titan.

During coast phase, activation of Probe subsystem and Experiments is given by the Timeline of the Table 1.9-5 in HUM Operations Doc n° HUY.AS/c.100.OP.0384.

2.1.5 Mission phase

2.1.5-1 Entry phase

The entry phase starts at entry into the Titan atmosphere at a nominal altitude of 1270 km until activation of the Descent Control Subsystem (DCSS). Its duration is between 4.23 and 4.77 mn.

The targeting of the Probe at Titan is conveniently described in the plane perpendicular to the approach velocity of the Probe (B-plane). Figure 2.1-4 shows the loci of constant flight-path angle, angle between the Titan local horizontal and the approach velocity direction, at the reference altitude of 1270 Km.

The Probe targeting requirements can be formulated as follows:

- atmospheric entry and descent shall be on the sunlit side of Titan, with a Sun zenith angle during descent between 35° and 65° for DISR operation

- entry latitude shall occur within the latitude band (60 deg. N, 60 deg. S)

- the component of the zonal wind along the Probe-Orbiter direction shall be maximized for DWE operation.

These requirements will be met for the following Probe entry conditions:

- the baseline flight-path entry angle at the reference altitude is -64° with a B-plane angle Θ of - 60° (see Figure 2.1-4)

- the baseline asymptotic velocity is 5.75 ± 0.05 Km/s which corresponds to an entry velocity at the reference altitude of 6.14 ± 0.05 Km/s

- the 3 sigma delivery relative uncertainty against Titan is contained in an ellipse with a 480 km semi-major axis parallel to the B-plane T-axis and a 150 km semi-minor axis parallel to the B-plane R-axis which leads to an entry angle comprised between -59° and -68°, the uncertainty resulting from the Probe lateral velocity due to Orbiter-Probe separation being root-sum-squared

- an atmospheric density and temperature given by the Lellouch-Hunten model [ESLAB 87/199 October 87 (SRD ESA AD20)] illustrated on Figure 2.1-5.

Operations during the Entry phase are listed in Table 1.9-6 for nominal and back up cases of HUM Operations Doc n° HUY.AS/c.100.OP.0384.

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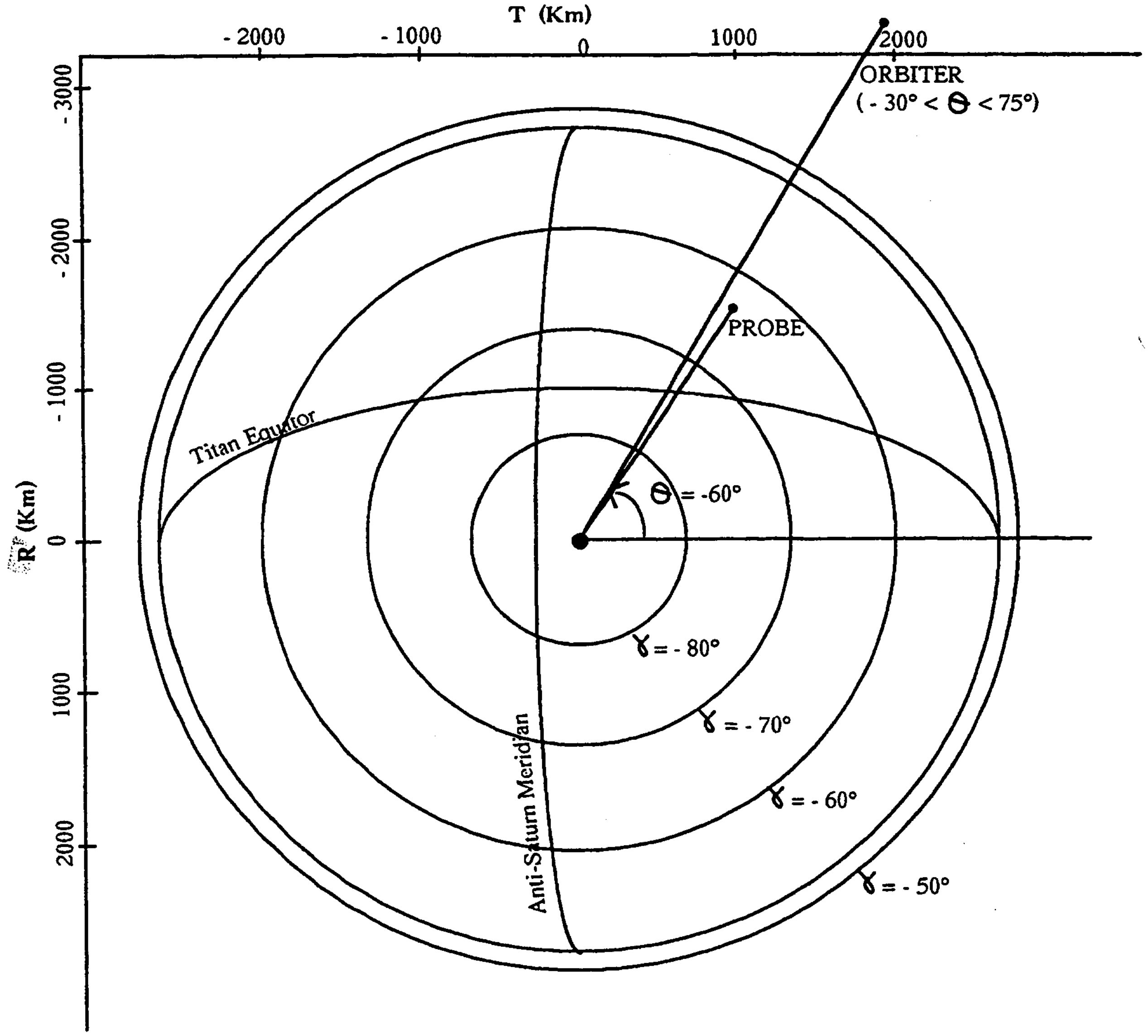

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FIGURE 2.1-4 TITAN B-PLANE GEOMETRY

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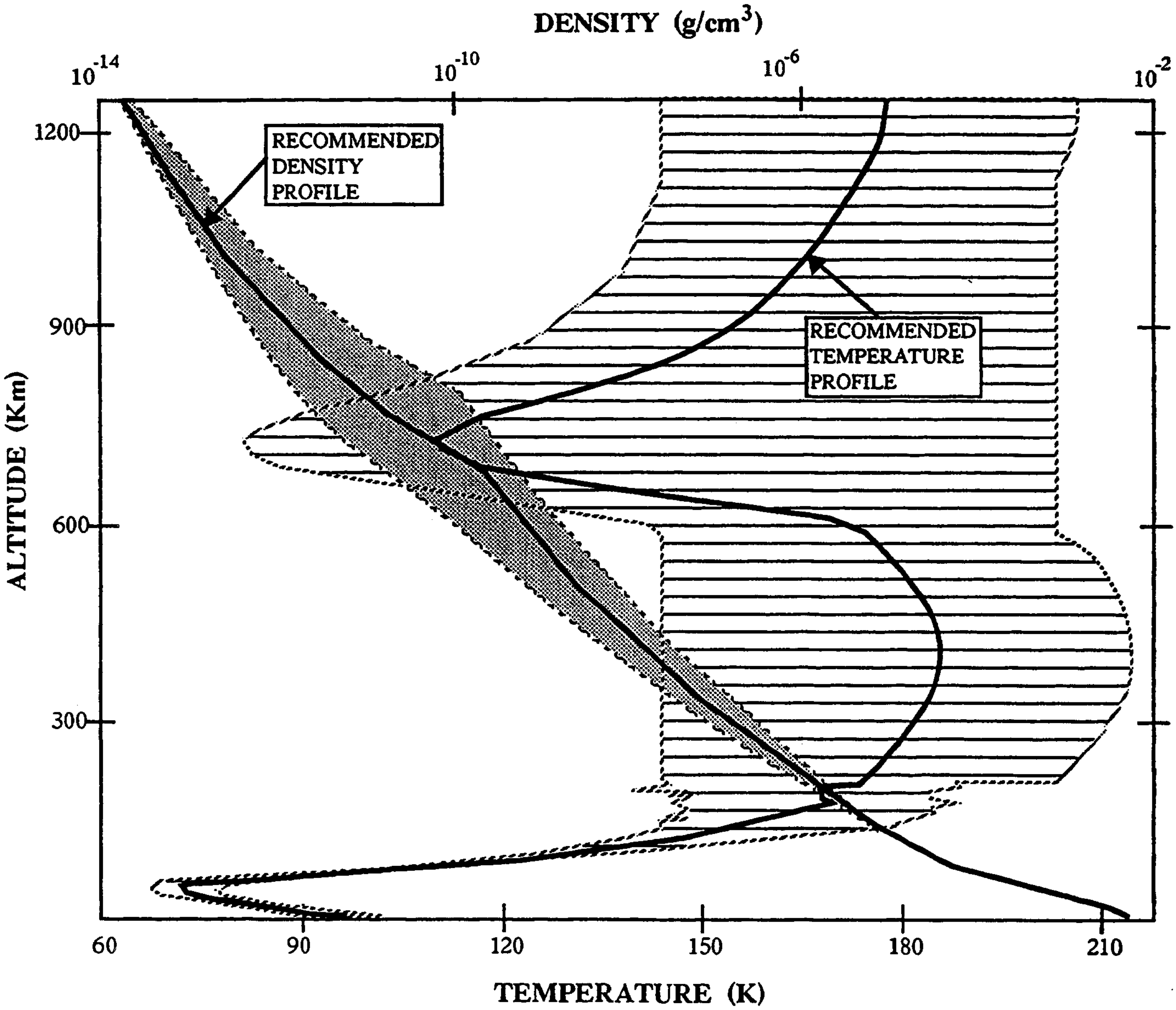

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FIGURE 2.1-5 DENSITY AND TEMPERATURE MODEL OF THE TITAN ATMOSPHERE (LELLOUCH-HUNTEN)

2.1.5-2 Descent phase

The descent phase starts at the PDD (Parachute Deployment Device) firing and ends at the Titan surface "Touch Down".

After Back Cover separation (Pilot Chute) and Main Parachute deployment, the Front Shield is released.

This Front Shield separation occurs between 140 Km and 180 Km altitude depending on the atmosphere model. At this stage, it must be possible to activate all scientific experiments and to acquire the Probe Relay Link (PRL).

Figure 2.1-6 illustrates the relative position between Titan, the Probe and the Orbiter and defines the Probe Aspect Angle (PAA) and the Sun Zenith Angle (SZA):

- PAA is the angle between Probe axis and Probe-Orbiter direction

- SZA is the angle between the Sun direction and the Probe axis direction.

Note: The directions shown to Earth, Sun and Saturn are projections onto the Orbiter-Probe-Titan plane.

Parameters to be accounted for PRL and descent profile are given in Table 2.1-1. The Orbiter Delay Time (ODT) is the delay between the Probe Titan entry and the Orbiter periapsis crossing.

Zonal winds may exist in the atmosphere of Titan as inferred from Voyager 1 measurements. The winds blow either in West-East or East-West direction. The nominal wind profile is displayed in Figure 2.1-7, as a function of latitude, together with the uncertainty (labelled 2 x ΔT).

See Table 1.9-7 in Doc n° HUY.AS/c.100.OP.0384.

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	PARAMETER	VALUE
ORBITER	Periapsis Titan flyby altitude	1228 Km for the first Saturn orbit 1250 Km for the second Saturn orbit
	Asymptotic velocity Vinf Vinf declination Vinf right ascension	5.56 Km/s 16° 107.8°
	B-plane Θ angle Relative navigation error (3 sigma)	-22.6° ± 105 km along T-axis ± 120 km along R-axis ± 30 s parallel to Vinf
	ODT	4 Hr
	HGA pointing error	0.2° during the whole descent (3 σ)
	HGA gain (worst case)	34.3 dB on axis 26.9 dB at 1.7° off axis — Chain B 2098MHz ± 5 33.9 dB on axis 26.6 dB at 1.7° off axis — Chain A 2040MHz ± 5
PROBE	Asymptotic velocity Vinf declination Vinf right ascension Entry angle	5.75 Km/s 15.4° 106.3° - 64°
	B-plane Θ angle Relative navigation error (3 sigma)	- 60° ± 480 km along T-axis ± 150 km along R-axis ± 120 s parallel to Vinf
	SCx uncertainty Entry module mass Mass uncertainty Attitude motion oscillations Maximum lateral velocity	± 10% 320 kg ± 1.5 % ± 10° 3.5 cm/s
TITAN	Zonal winds	nominal winds applied in W-E or E-W directions, function of latitude and ΔT
	Atmosphere density Radius Topography	minimum to maximum 2575 ± 0.5 Km ± 2 Km
SUN	Entry Titan latitude Entry Titan East longitude	- 23.3° 204.7°

TABLE 2.1-1 PRL AND DESCENT PROFILE PARAMETERS

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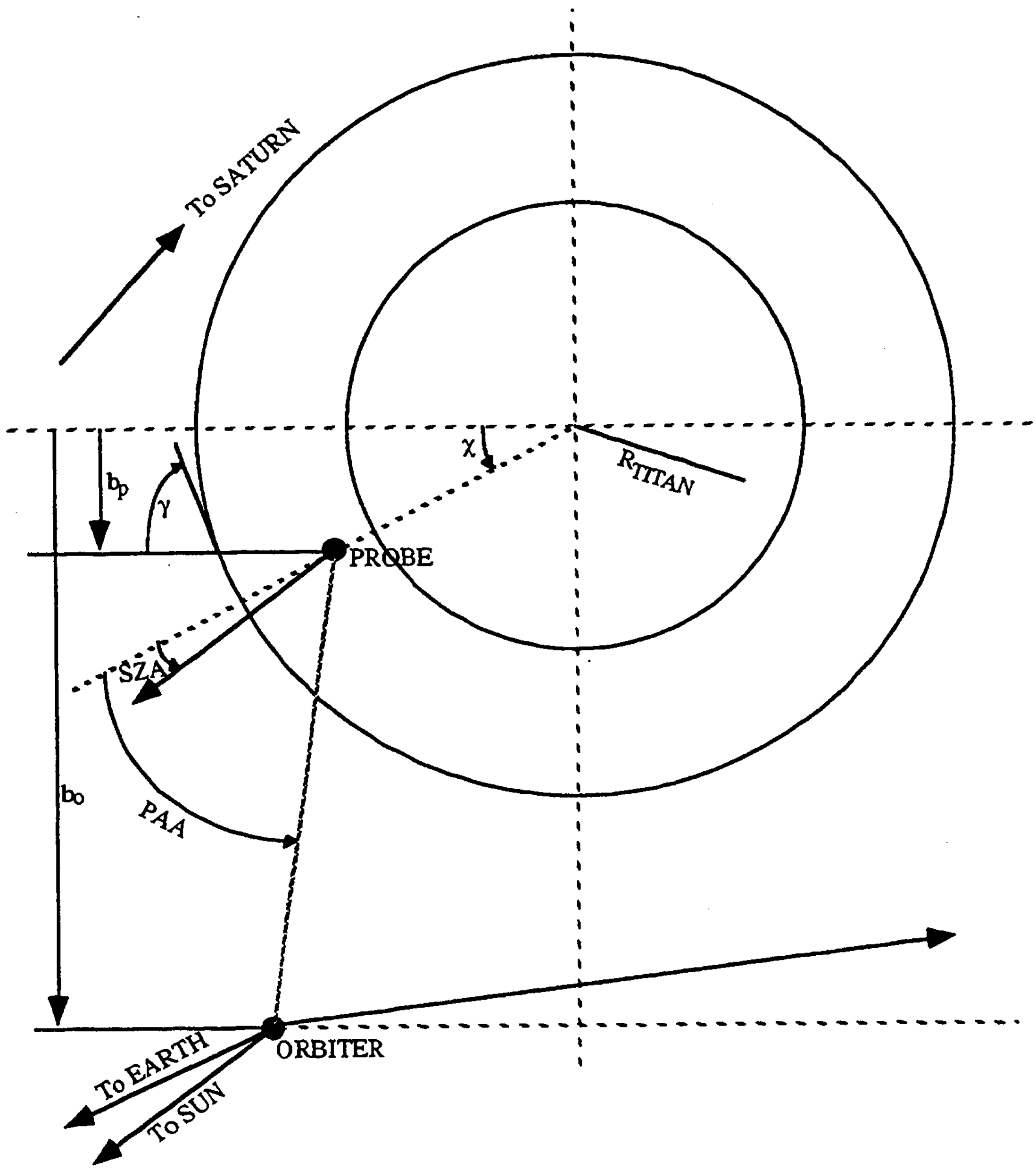

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FIGURE 2.1-6 RELATIVE GEOMETRY OF TITAN, PROBE AND ORBITER

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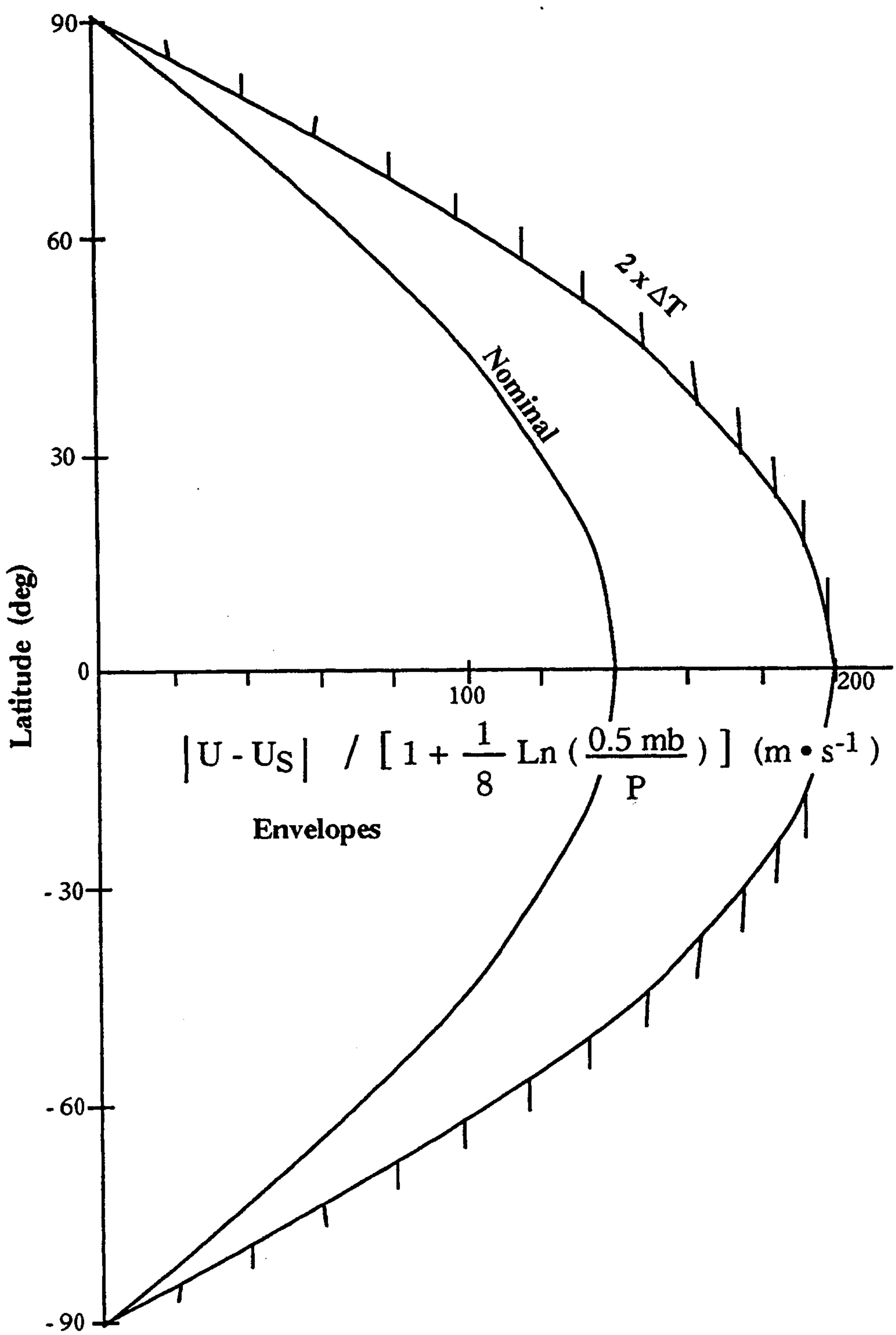

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FIGURE 2.1-7 TITAN ZONAL WIND MODEL PROFILE

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Wind gusts of which the shape is indicated in Figure 2.1-8 may occur; this curve gives the variation of the maximum amplitude A of the wind gust as a function of altitude.

g is the wind gradient i.e. the variation of the gust amplitude with altitude during a gust.

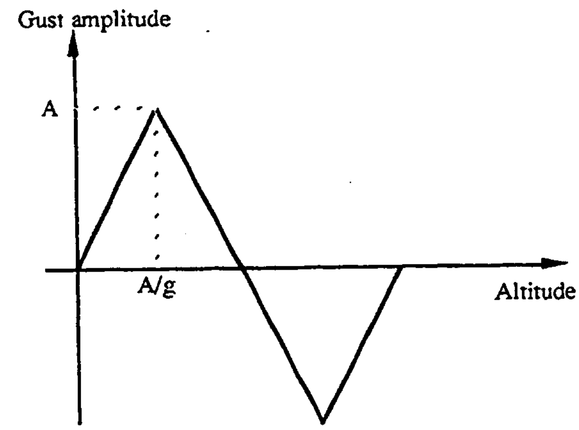

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FIGURE 2.1-8 WIND GUST SHAPE

Table 2.1-2 gives the value of gust amplitude and wind gradient for some altitudes.

The PRL configuration antennae comprise the Orbiter High Gain Antenna (HGA) and two fixed-mounted low-gain Transmit antennae on the Probe (PTA).

The PRL is sized in order to:

- provide adequate margin against the error between the HGA pointing and the Probe directioı specified in Figure 2.1-9
- comply with the PAA (Probe Aspect Angle) envelope specified in Figure 2.1-10
- comply with the Probe-Orbiter Distance during Descent in Figure 2.1-11
- comply with the Probe-Orbiter range rate during Descent specified in Figure 2.1-12.

The maximum duration of the descent phase shall be 2.5 hours including dispersions, the minimum duration of the descent phase shall be 2 hours including dispersions.

Science and engineering data are transmitted in real-time to the Orbiter via the PRL.

The total amount of available TM data transmitted by the Probe before impact shall be at least 132.7 Mbits (2 channels) with a 8192 bit/s bit rate, for a Mission of 138 mn duration.

Figure 2.1-13 shows descent profile with envelope of altitudes versus time.

The spin rate shall be between 1 and 15 rpm from entry to 10 km altitude, consistent with the Probe stability. Below an altitude of 10 km, the Probe shall spin at a rate between 1 and 2 rpm.

The Probe design shall limit any pendular motion during the descent phase to an amplitude of 10°. In case this amplitude is larger than 10°, the Probe shall get back within the 10° in less than 15 s.

Subsystem units and experiments operational during Descent Phase are listed in Table 1.9-7 of HUM Operations Doc n° HUY.AS/c.100.OP.0384.

2.1.5-3 Surface phase

The surface phase starts at the Titan surface "Touch Down" and as goal, should last at least 3 minutes.

It must be noticed that the link can be maintained up to 30mn after landing on Titan ground.

D4

ALTITUDE (km)	GUST AMPLITUDE A (m/s)	WIND GRADIENT AT 95% [10^{-3} (m/s)/m]
< 10 km	10	3.1
10	10	3.1
20	10	4.6
30	10	5.6
40	10.95	6.3
50	14.18	7.1
60	16.28	9.2
70	13.79	9.1
80	11.00	7.3
90	9.90	6.2
100	9.69	5.6
110	9.93	5.2
120	10.90	5.1
130	12.58	5.0
140	15.42	4.8
150	20.41	4.7
160	29.88	4.5

TABLE 2.1-2 WIND GUST AMPLITUDE AND GRADIENT VS ALTITUDES

D4

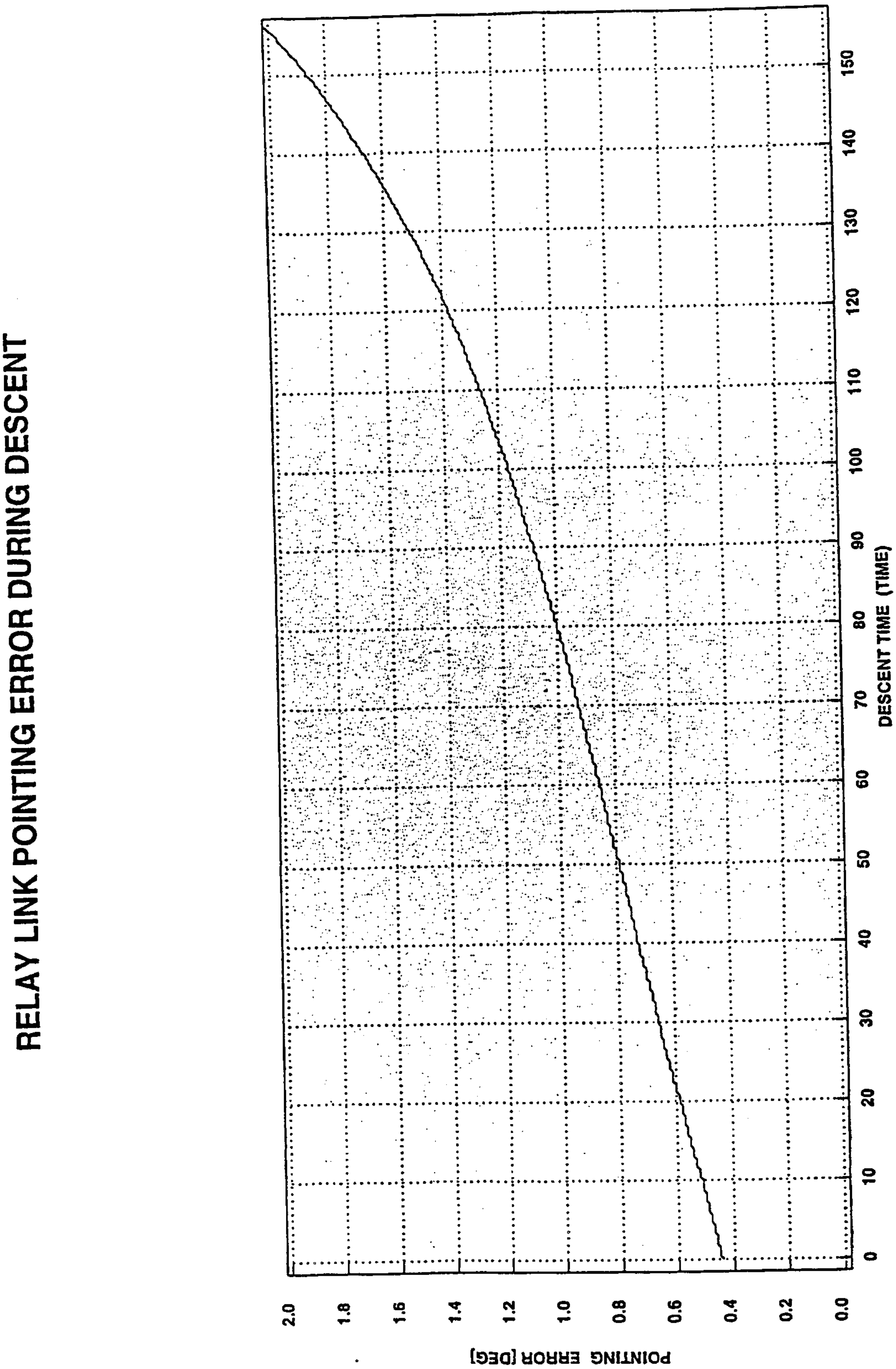

FIGURE 2.1-9 PRL POINTING ERROR PROFILE

D4

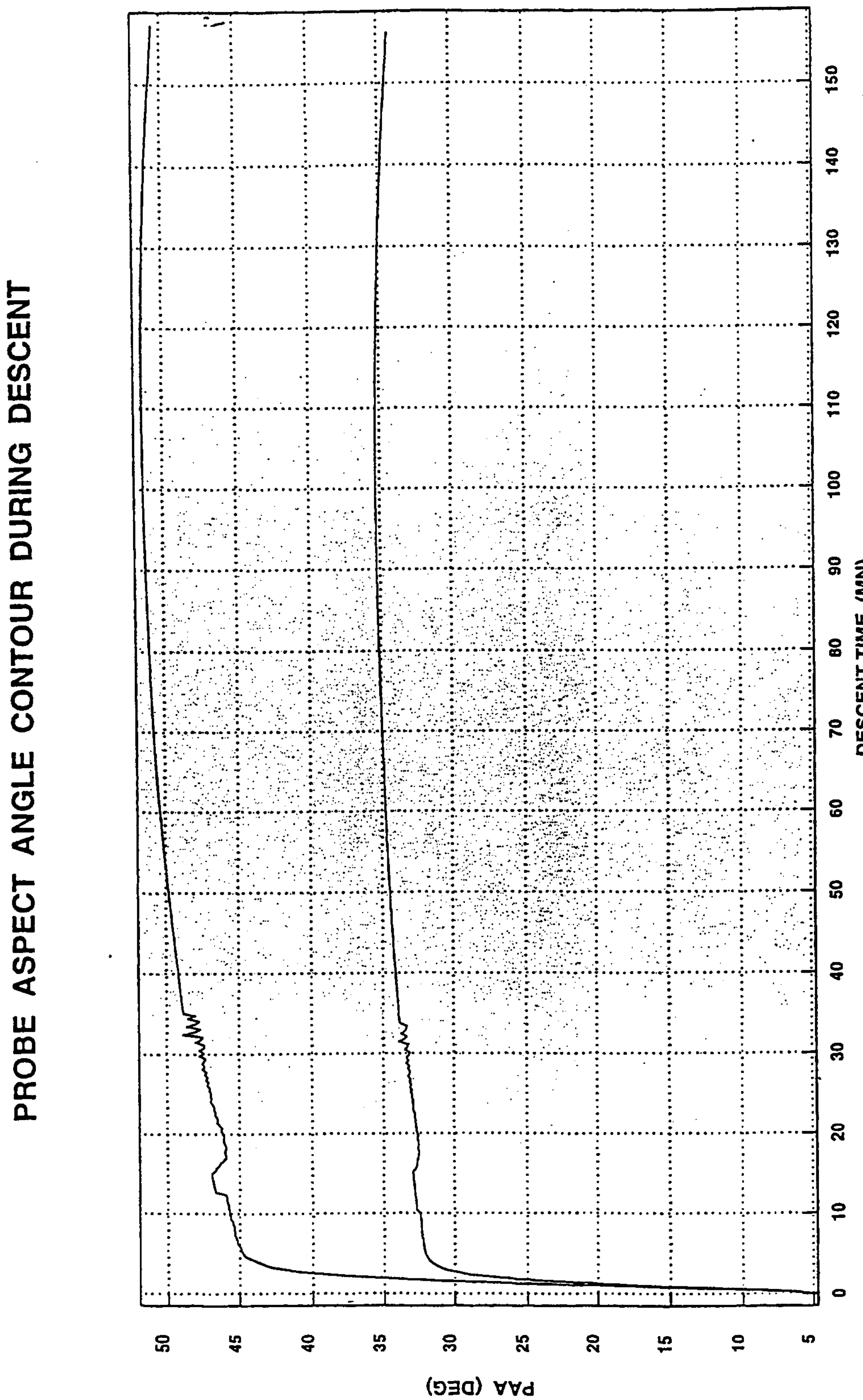

FIGURE 2.1-10 PAA ENVELOPE

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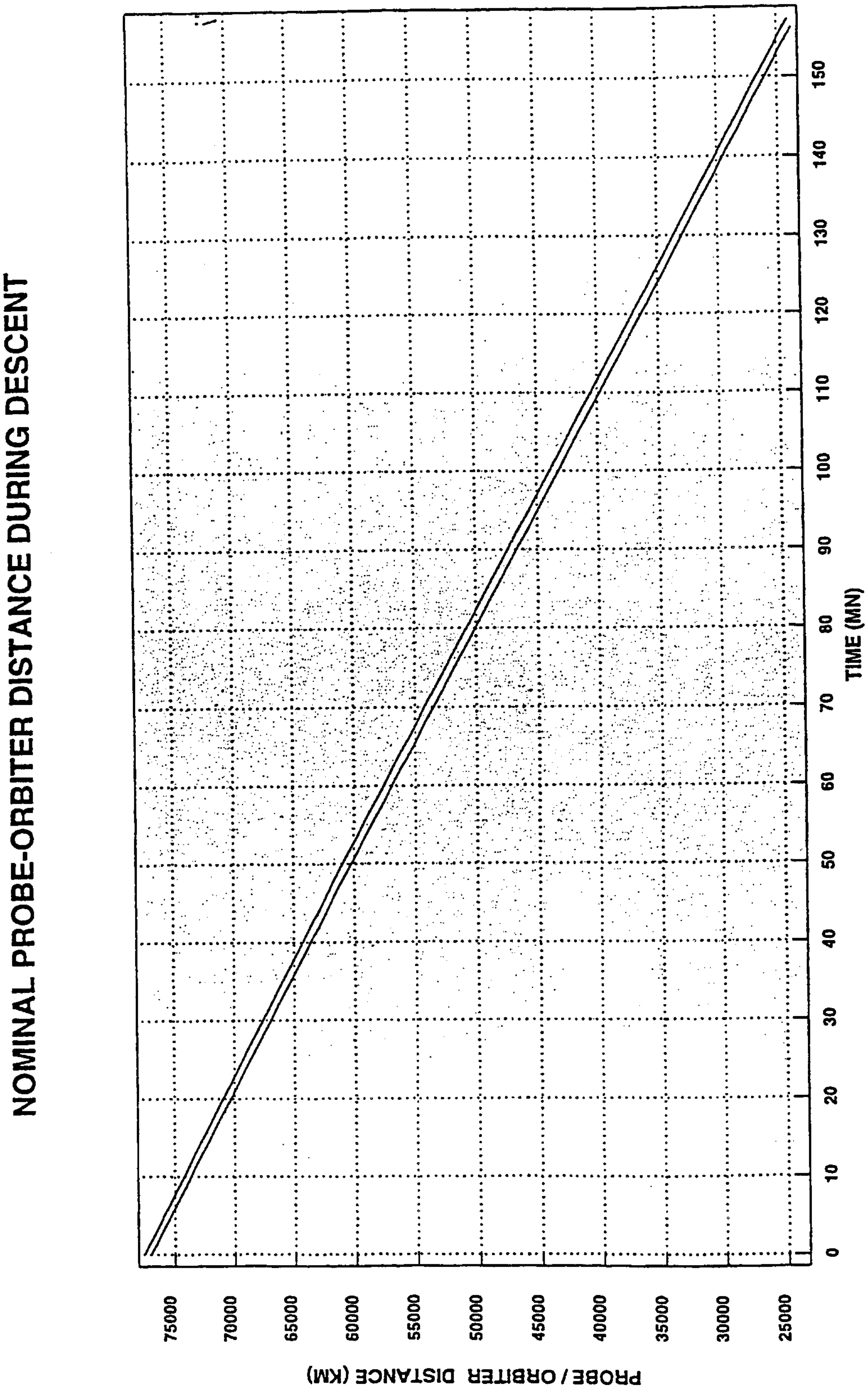

FIGURE 2.1-11 PROBE-ORBITER DISTANCE DURING DESCENT

D4

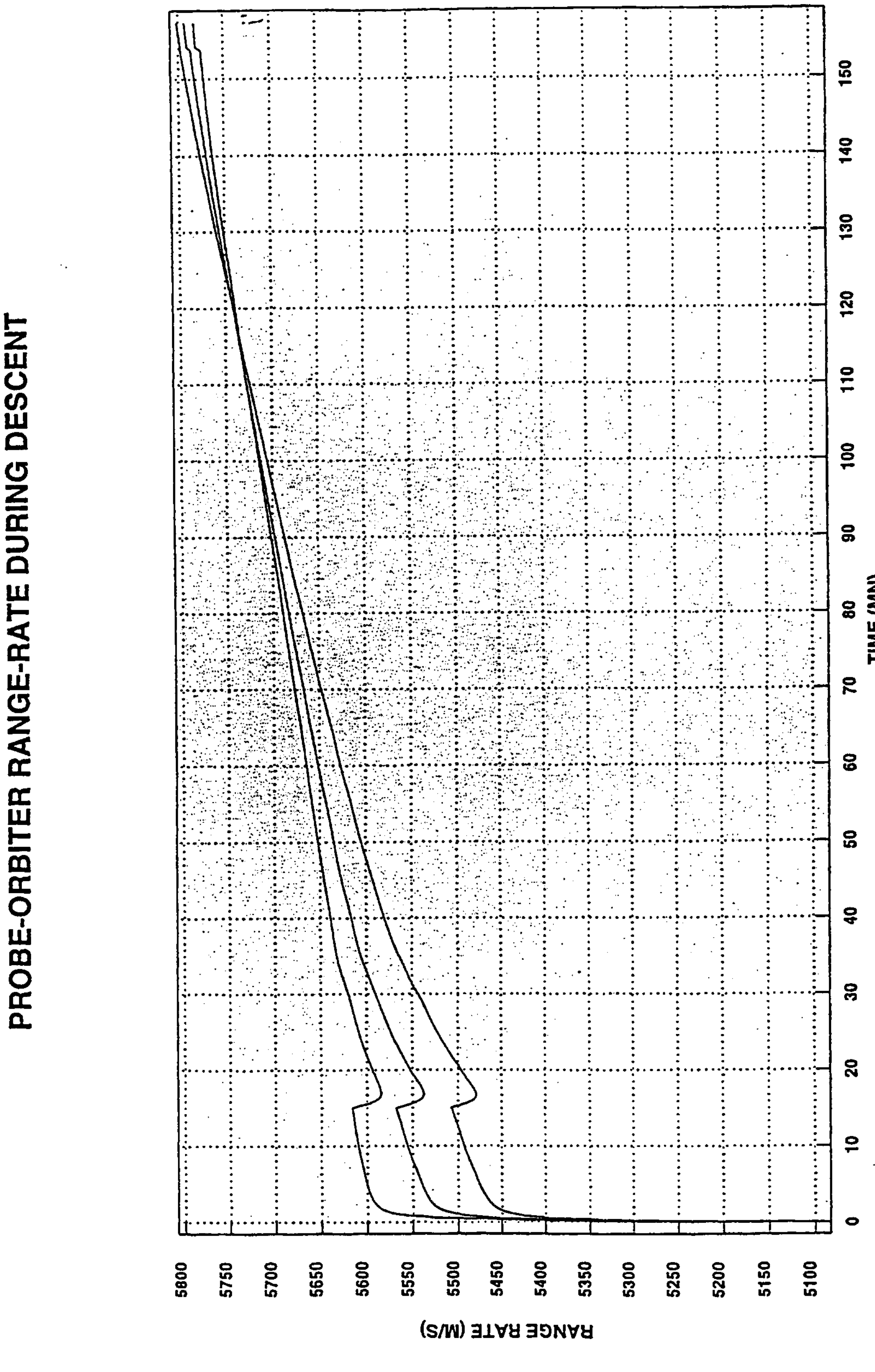

FIGURE 2.1-12 RANGE RATE PROFILE

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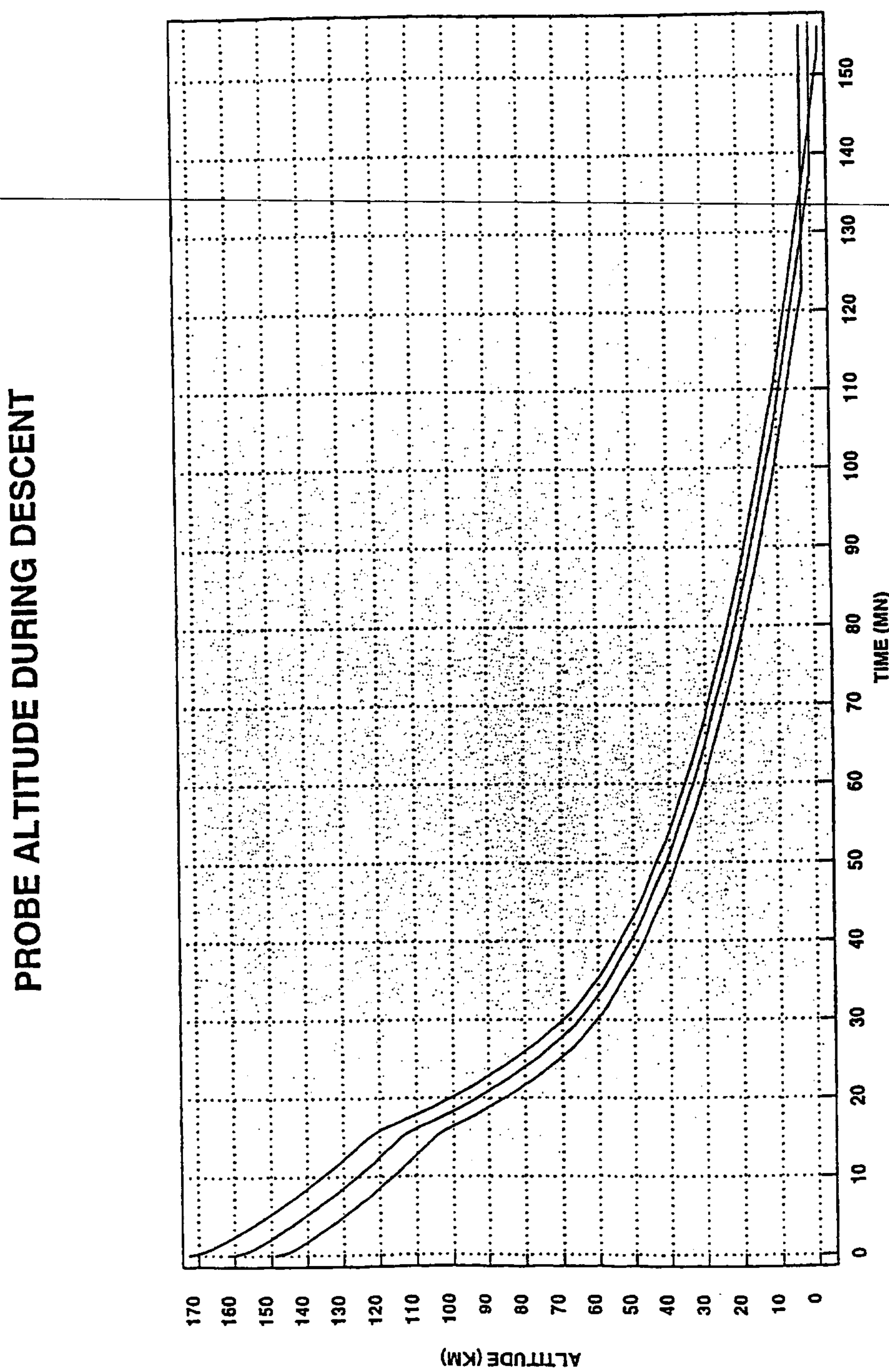

FIGURE 2.1-13 DESCENT PROFILE ENVELOPE

2.2 PROBE SYSTEM DESCRIPTION

2.2.1 System design summary

The Probe System consists of two principal elements:

i. the Huygens Probe (referred as the Probe) which will enter the Titan atmosphere after separation from the Saturn Orbiter

ii. the Probe Support Equipment (PSE), which is that part of the Probe System which remains attached to the Saturn Orbiter after separation of the Probe.

The Probe includes structural, thermal and electrical elements which protect the internal equipment during Entry, provide the Descent profile, support the scientific payload (both electrically and physically), collect science data from the Experiments, and transmit these data towards the Orbiter.

The PSE supports the Probe physically and electrically during the Launch, Cruise and Saturn orbit phases using primary services provided by the Orbiter, ejects the Probe to begin its Coast phase, receives science data from the Probe during Descent and Surface phases, and transmits these data to the Orbiter for transmission to Earth.

The PSE is constituted by:
- two Probe Support Avionics boxes (PSA) mounted into the Orbiter and connected to the Orbiter antenna via a Receiver Front End (RFE) including Low Noise Amplifier chain (LNA)
- a Spin Eject Device (SED) part attached to the Orbiter Probe support, and the remaining part attached to the Probe.
- the RUSO part of the DWE (Doppler Wind Experiment)

The Probe itself (Figure 2.2-1) is constituted by:
- a cocoon, called Entry Assembly (ENA)
- a Descent Module (DM)

ENA is in charge of Orbiter fixation, umbilical separation and ejection (SED), cruise thermal protection (by means of MLI coatings), entry high-temperature thermal control (by means of specific thermal materials) and of entry deceleration control. ENA is jettisoned after Entry, releasing the Descent Module.

The DM consists mainly of an aluminium inner shell containing all the Experiments and their supporting subsystems.
Two platforms, the Experiment and top platforms, mechanically support the Payload and Service equipment units.

The inner structure supports the Spin Control Device constituted of small winglets installed in the laminar flow at its periphery. The inner structure also provides flexible housing for scientific instruments deployable parts. Inner thermal protection minimizes convective cooling.

The Descent device system installed on the upper platform is constituted by the mortar and a set of 3 parachutes which ensure:
- first the separation of back cover (Pilot Chute) after mortar firing
- second the separation of the Front Shield and Probe deceleration (Main Chute)
- third the separation of the DISR cover
- fourth the control of the Descent time (2h30 max) and Stabilization (Stabilizer); see Figure 2.2-2.

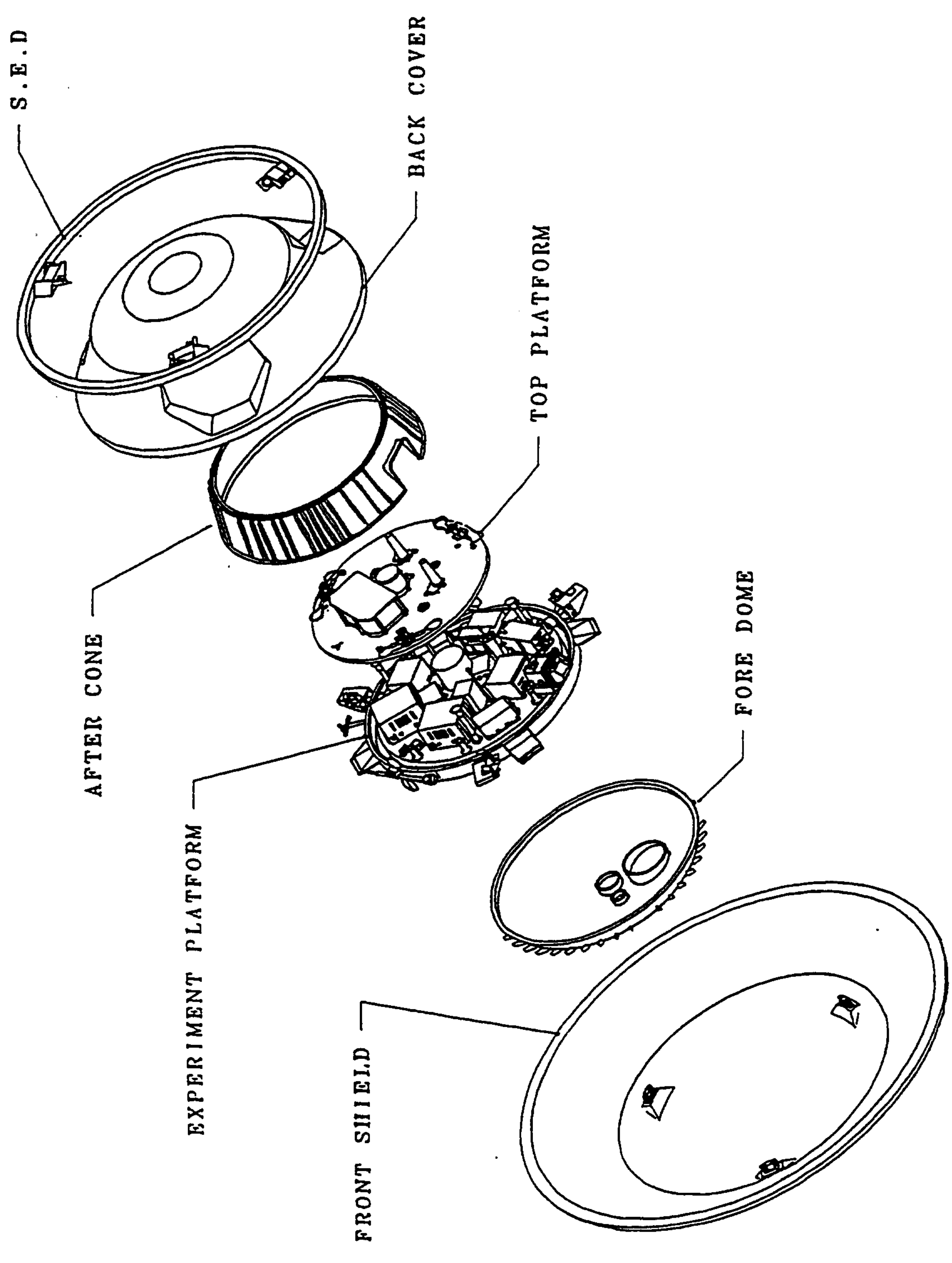

FIGURE 2.2-1 PROBE ASSEMBLY

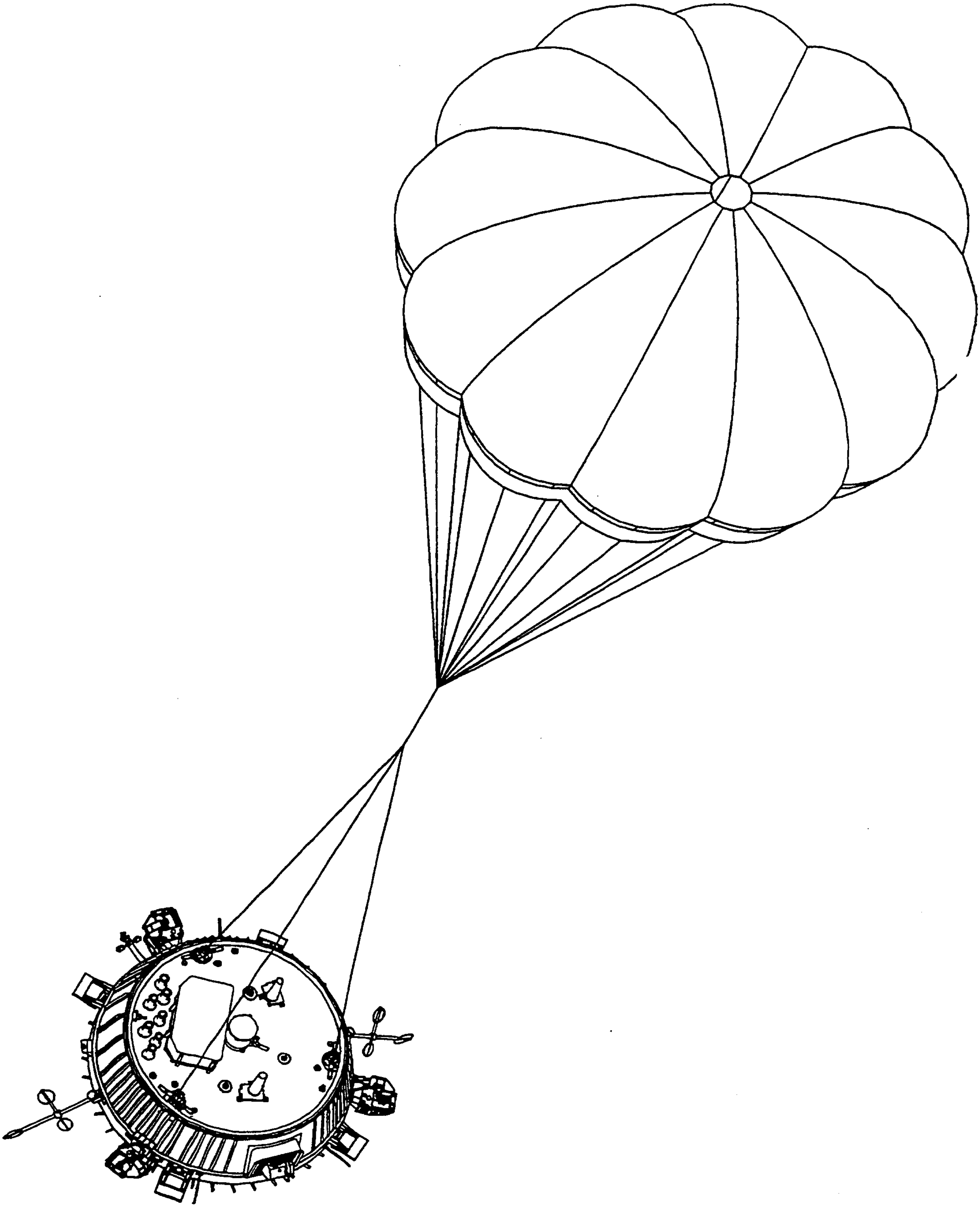

FIGURE 2.2-2 PROBE UNDER PARACHUTE DURING DESCENT

The Electrical Power Subsystem (EPSS) of the Huygens Probe system, constituted by five $LiSO_2$ batteries and a Power Conditioning Distribution Unit, ensures efficient distribution and conversion of Orbiter energy and Probe battery energy to all subsystems and equipments of the Probe System. It provides with one pyro box arming and firing functions of pyro lines.

Before separation of the Probe from the Orbiter the power is drawn from the Orbiter, especially for check outs a few days after launch then periodically. After separation the $LiSO_2$ batteries supply the full energy and power requirements identified for the autonomous mission of the Probe whereas for the PSE equipments, the power remains drawn from the Orbiter.

The Command and Data Management Subsystem (CDMS) provides monitoring and control for all Probe equipments, interfaces experiments and units with the PSE data handling for all telemetry and telecommand requirements, and implements autonomous control and management of the Probe after separation.

The CDMS includes 2 CDMUs which are the control processing unit, a Mission Timer Unit (MTU) which is in charge to wake up the Probe at the end of the coast phase, 2 G-switches as MTU back up for waking up the Probe, 2 dedicated G-switches per chain as back-up of CASU operations, a Sensor Package (CASU and RASU) which allows to determine the entry time of the Probe in the Titan atmosphere (CASU) and to measure the spin (RASU) and two Proximity Sensors (RAUs) which measure the Probe altitude.

Communication between the PSE and the CDMS are effected during cruise phase via dedicated lines , which pass through an umbilical.

The PSE communicates bi-directionally with the Orbiter via a MIL-standard 1553 bus, receiving command data from it, and passing formatted science and housekeeping data to it.

The Probe is controlled by the PSE and the CDMS during check out periods prior to Orbiter/Probe separation and by the CDMS after separation.

Until separation, the Probe software is partially reconfigurable.

After separation all the Probe is in dormant state during the Coast Phase, with the exception of the Mission Timer Unit which activates the Probe 23mn34s before the end of the Coast Phase. All other Probe CDMS functions and actions are based on environmental (acceleration, altitude), housekeeping (voltage, current, temperature ..) and model-induced data (altitude vs time, spin vs time). Experiments redundancy management, power and telemetry budget management are fully achieved.

The Probe Data Relay Subsystem (PDRS), within the Probe includes a hot-redundant S-band transmitter, which provides a dual radio relay link to the PSE part of the PDRS during the descent phase and two antennae (PTA). On the Orbiter, the PSE part of the PDRS includes a hot-redundant S-band receiver, which amplifies and coherently demodulates the signals from the Probe, and passes the data streams to the Orbiter through the PSE data handling.

The PSE PDRS shares with Cassini the High Gain Antenna (HGA) which is a part of Orbiter equipment.

The Probe is mounted on the Orbiter using a Spin Eject Device (SED) which is activated by pyro lines coming from the Orbiter when the coast phase is initiated. Operation of the SED also activates the mechanism which severs the umbilical connecting the Probe with the PSE named the Umbilical Separation Mechanism (USM).

Figure 2.2-3 shows schematically the various subsystems, their articulation is shown in Figure 2.2-4.

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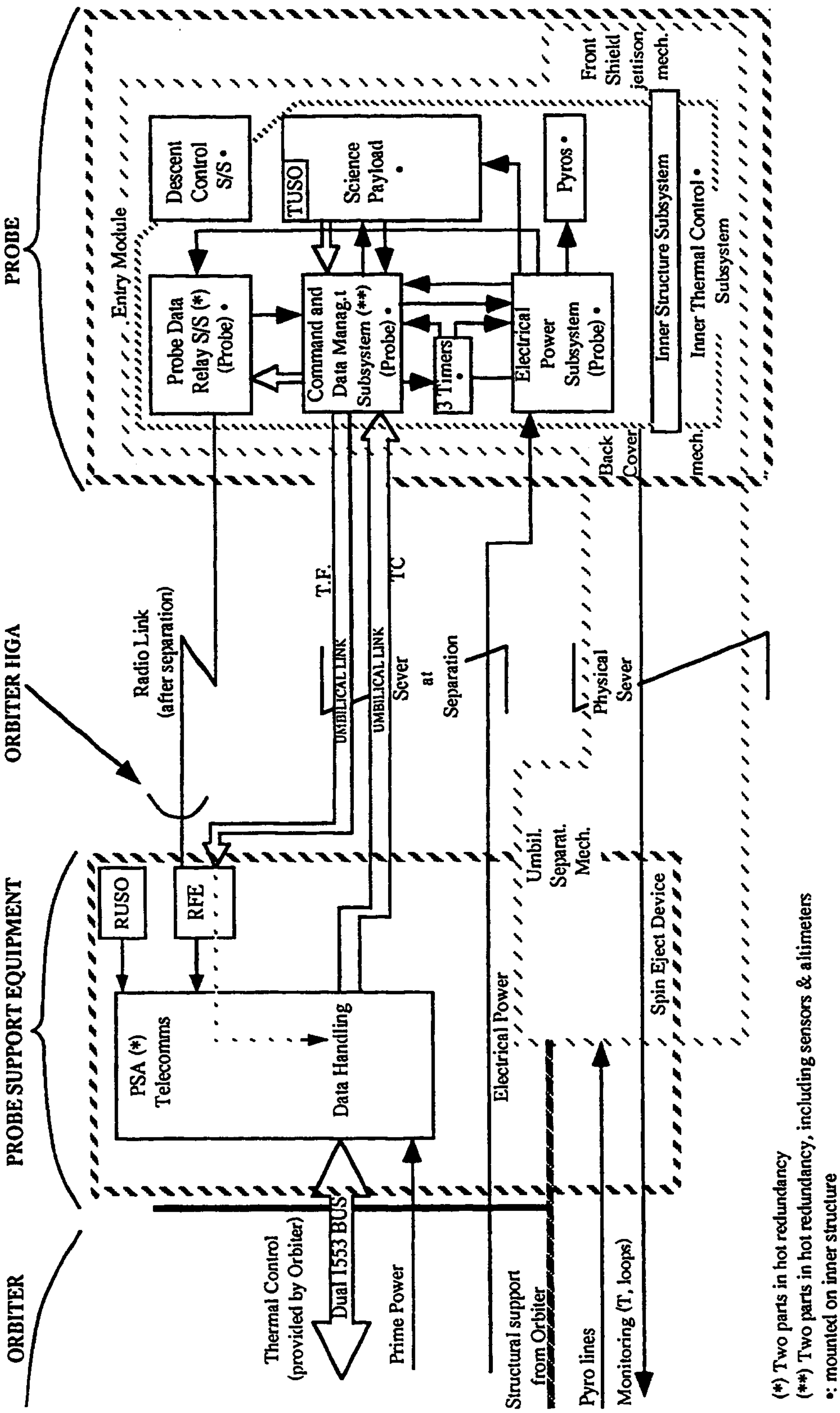

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FIGURE 2.2-3 PROBE SYSTEM ARCHITECTURE

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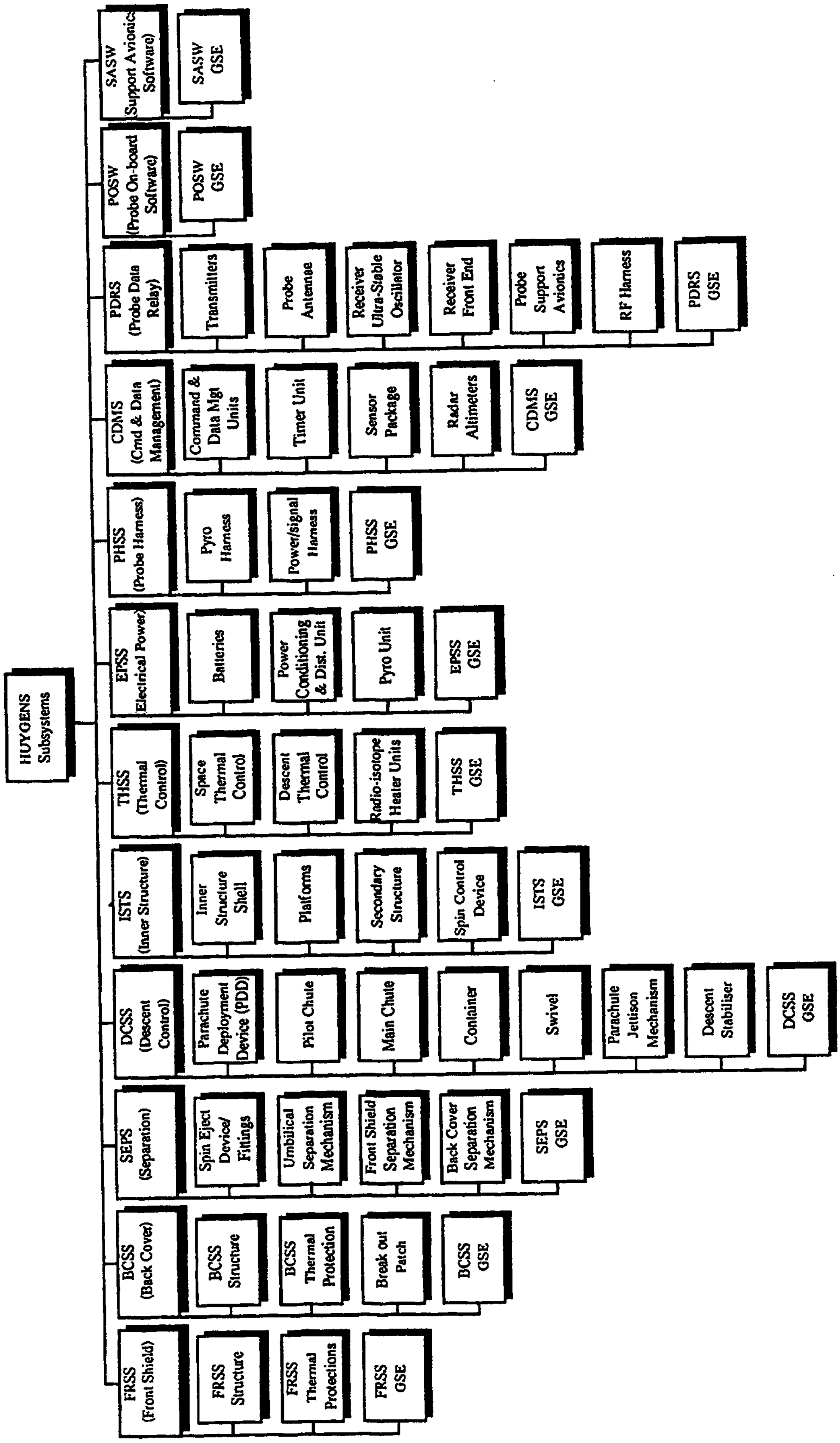

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FIGURE 2.2-4 SUBSYSTEM TREE

D5

Six Experiments constitutes the Huygens payload. These experiments are:

- Huygens Atmospheric Instrument (HASI) measuring the atmospheric temperature and pressure profile, conductivity and permittivity, as well as lightning
- Gas Chromatograph Mass Spectrometer (GCMS) measuring the atmospheric chemical composition profile
- Aerosol Collector Pyrolyser (ACP) measuring aerosols using the GCMS as detector
- Descent Image Spectral Radiometer (DISR) measuring atmospheric composition, cloud structure and imaging the surface
- Surface Science Package (SSP) measuring the surface state and composition at landing site
- Doppler Wind Experiment (DWE) measuring the zonal wind by Probe doppler tracking.

2.2.2 Mechanical architecture

The Probe Support Equipment comprises:

- four electronic boxes, two Probe Support Avionics (PSAs), one Receiver Front End (RFE), one Receive Ultra Stable Oscillator (RUSO) which permanently remain on board the Orbiter inside an Orbiter bay
- part of the Spin and Eject Device (SED) including umbilical connector on Orbiter side
- the harness (provided by JPL) distributing power from the Orbiter and distributing RF/data links between the PSA and Probe before Orbiter/Probe separation.

The Probe can be schematically described as a kernel surrounded by a shell, the kernel carrying all the experiments and service units operating during the descent while the shell protects it during the Cruise, Coast and Entry phases and is then jettisoned at the beginning of the Descent.

The kernel is mainly constituted by two platforms supporting the Experiments and the equipment units and assembled by light secondary structures (struts, foredome, aftercone).

The jettisonable shell is constituted by:

- a spherical-conical front shield protecting the kernel and extending as a 2.7 m conical decelerator
- a back cover to complete the thermal protection of the kernel during atmospheric entry.

During Entry, the Front Shield reduces the Probe speed. Front Shield and Back Cover protect the kernel from aerodynamic and thermodynamic aggressions. The Front Shield jettison is automatically commanded below Mach 0.6 at an altitude of 157.5 km.

This jettison is aerodynamically operated by a Main Parachute large enough to pull the kernel rearwards from the Front Shield. This Main Parachute itself is extracted, along with the Back Cover, by the Pilot Chute which deployment is triggered by an acceleration threshold and extracted by a Pilot chute Deployment Device (PDD).

The threshold is detected by the Command and Data Management Subsystem (CDMS) accelerometers; its value has been fixed both to minimize Mach (altitude dispersion due to atmosphere model uncertainties) and to provide the safest Mach number and dynamic pressure for supersonic parachute opening.
Then the Main Chute is jettisoned and a smaller Stabilizer Chute is deployed which allows the required Descent time.

Swivels ensure decoupling of the Probe from possible parachute rotations. Probe controlled spin is provided by a series of aerodynamic winglets named spin vanes to match imaging scientific requirements.

Figures 2.2-5 and 2.2-6 provide the Probe overall dimensions in Launch and Descent configurations respectively.
The Orbiter truss providing link between Probe and Orbiter primary structure is shown on Figure 2.2-7.

Following paragraphs provide a brief description of each mechanical subsystem.

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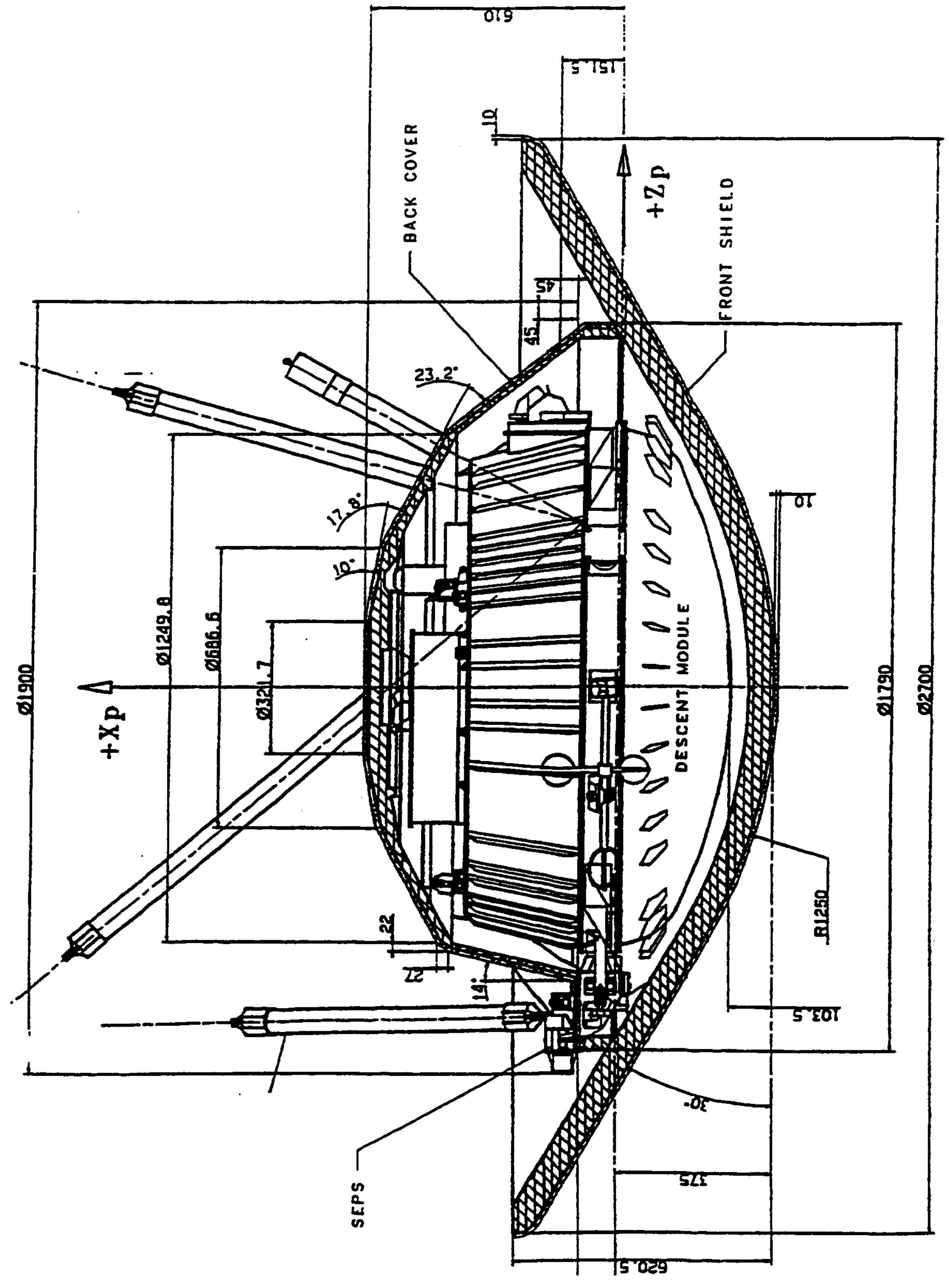

FIGURE 2.2-5 PROBE OVERALL DIMENSIONS IN LAUNCH CONFIGURATION

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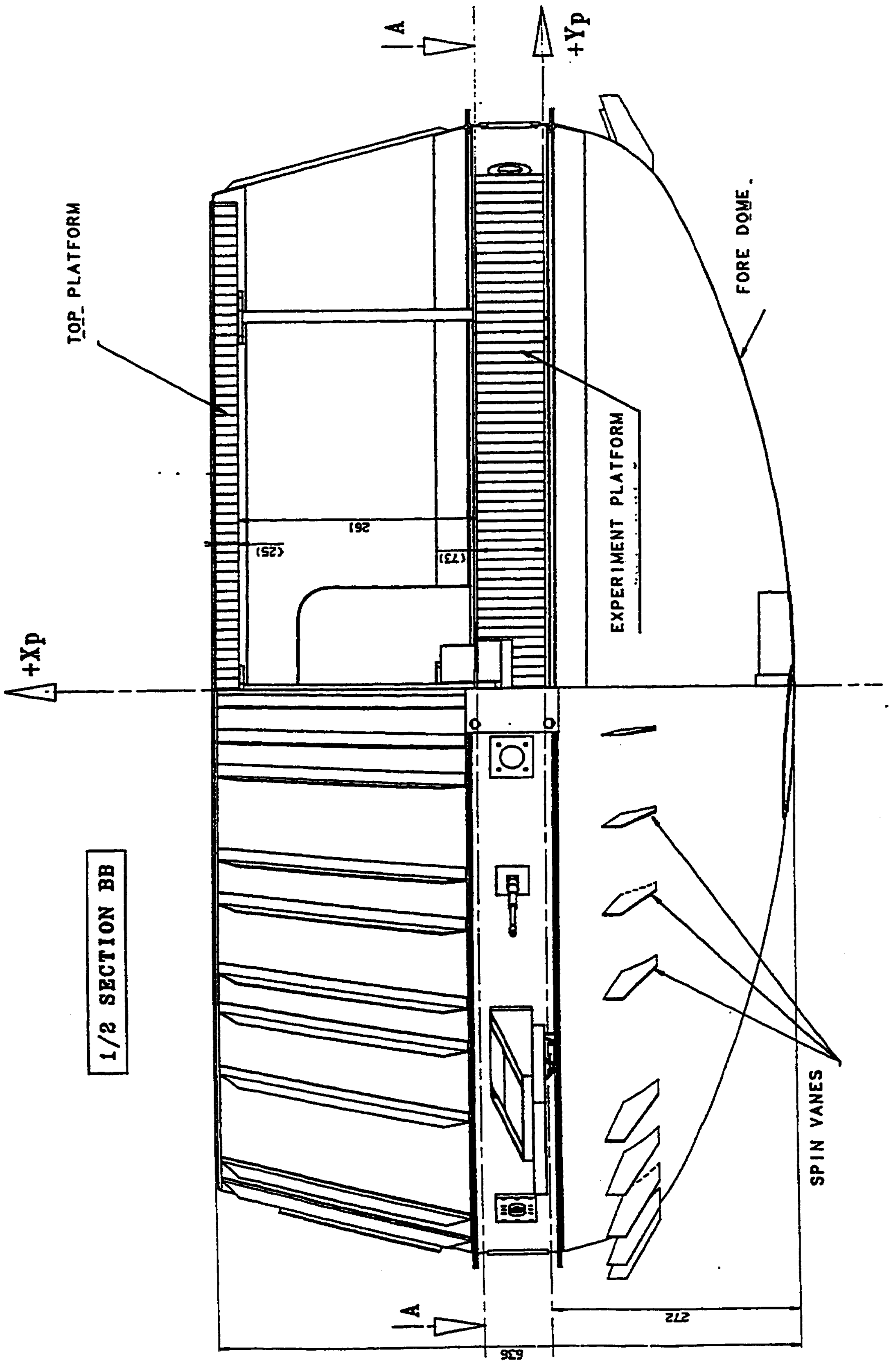

FIGURE 2.2-6 PROBE OVERALL DIMENSIONS IN DESCENT CONFIGURATION

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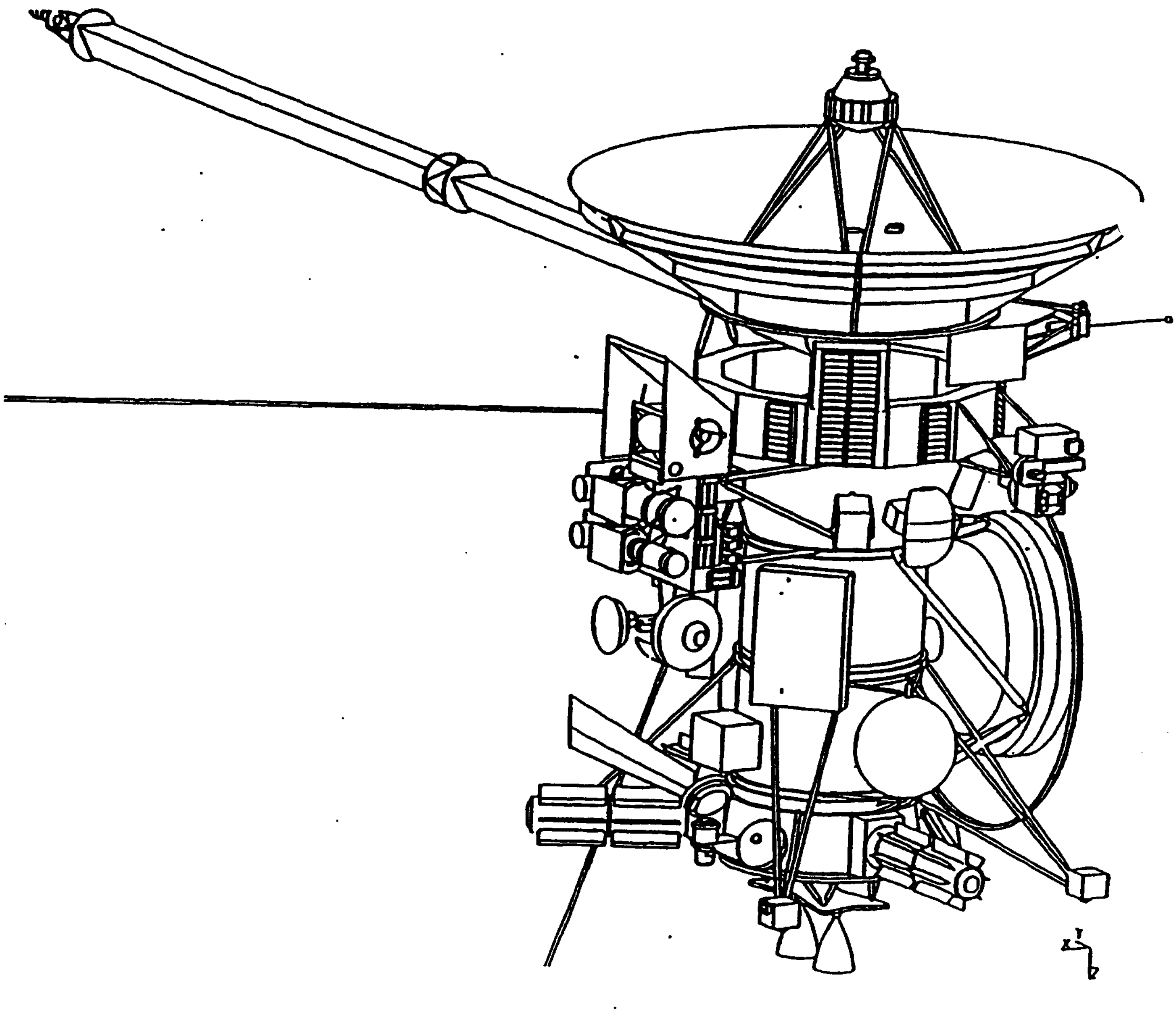

FIGURE 2.2-7 PROBE ACCOMMODATION ON ORBITER

D5

2.2.2-1 Front shield (FRSS)

The purpose of the Front Shield is to decelerate the Probe in upper Titan atmosphere from a velocity of about 6 km/s to a velocity equivalent to about Mach 1.5 at an altitude around 170 km to participate to the payload and subsystem units protection against induced entry fluxes. Then it is jettisoned.

Its 60° half angle spherical-conical shape and 2.7 m diameter exhibit good stability, drag, adequate ballistic coefficients and consistent aerodynamic characteristics over the ranges of Titan altitude, Probe mass and size considered.

During Entry, the kinetic energy of the Probe is converted into convective and radiative heat fluxes, the total of which can reach 1 MW/m^2.

This total flux is absorbed by the thermal protection tiles applied on the front side made of an ablator material called AQ60, a felt of silica fibres reinforced by phenolic resin.

Heat is accommodated by thermal capacity, radiation, ablation and limited conduction, within the short transient period, providing thermal insulation of the structure.

On the back side, due to the less demanding fluxes (10 times lower), an other thermal material called Prosial was selected. Prosial is a silicon elastomer with silice hollow spheres which is directly sprayed on the structure.

Structure baseline is an CFRP honeycomb shell which acts also as an heat sink during entry.

AQ60 and Prosial thicknesses are sized such that the structure properties are still sufficient to sustain loads during all the Entry phase and maintain structural integrity:

- The AQ60 Tiles (total number 260) thickness varies between 16.1 and 18.2 mm
- The Prosial thickness varies between 1.5 and 2.2 mm.

Attachment between AQ60 tiles and structure rely on adhesive, the silicone based glue CAF 730, without mechanical link.

Figure 2.2-8 illustrates the Front Shield design.

The front shield interfaces the SEPS Front Shield Mechanism (FSM) through three points, the back cover through a labyrinth and the front THSS MLI and radiative window through attachment points and adhesive.

The Front Shield,front and back sides, is wrapped with MLI which ensures the Probe thermal control during the Cruise and Coast phases.

D5

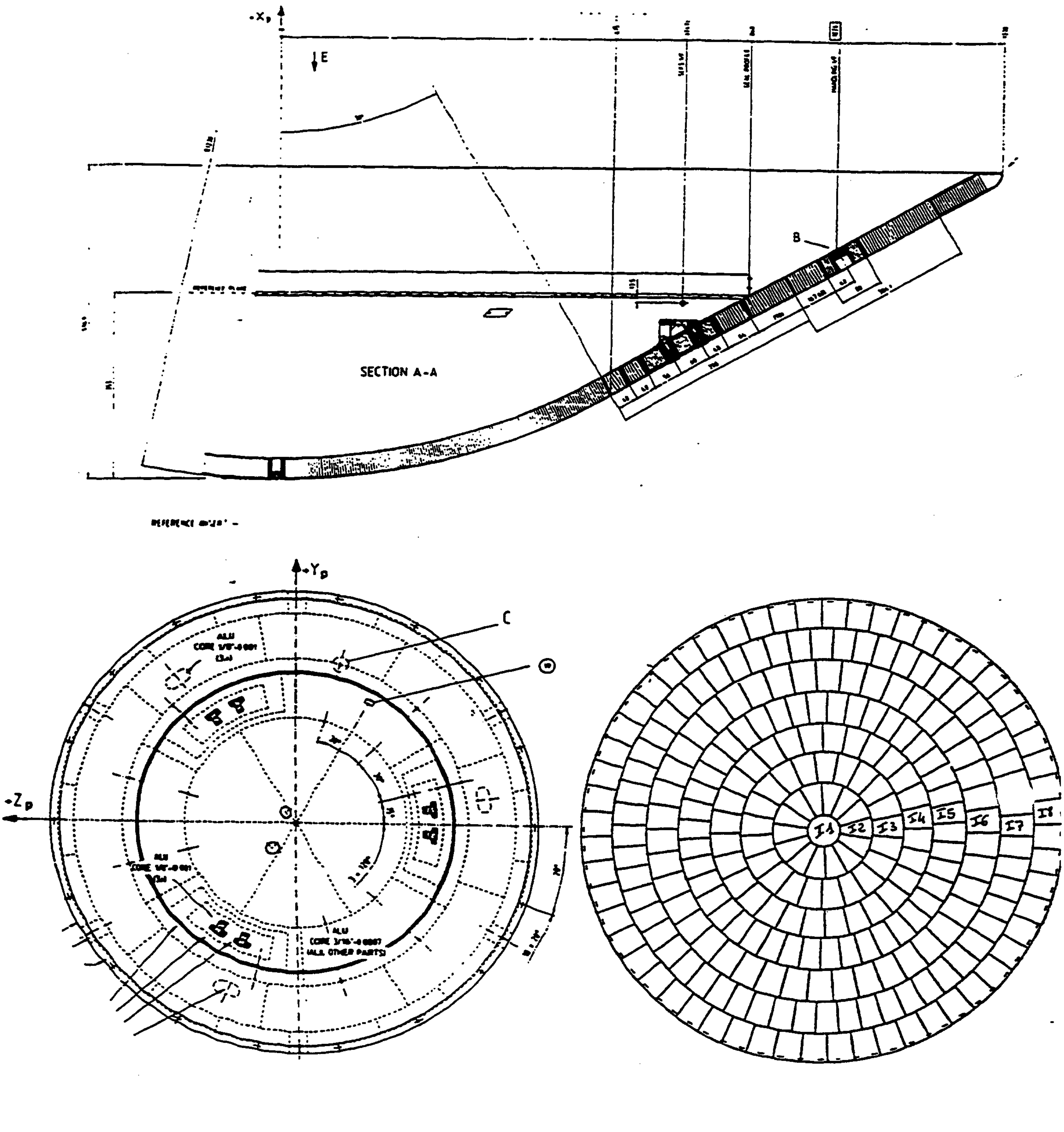

FIGURE 2.2-8 FRONT SHIELD DESIGN

2.2.2-2 Back Cover (BCSS)

The main function of the Back Cover is the protection of the Descent module during Titan atmosphere entry. To this end, the BCSS limits the heat applied to the inside of the Probe and protects the science instruments from contamination.

Secondary functions are to ensure depressurization during Launch and to support a part of the space thermal control (MLI) during Launch, Cruise and Coast phases.

Due to its main function, the Back Cover forms the back part of the cocoon that protects the payload during entry.

Whereas the shape of the Front Shield satisfies stringent aerothermodynamic requirements, the Back Cover simply needs to enclose the back part of the Probe. Thus, the shape is defined with the objective of minimum mass inside the two boundaries defined by the descent module on one side and the Orbiter struts on the other side.

Back cover is an aluminium stiffened shell protected by Prosial including the following items:

- two access doors
- a break-out patch for the PDD located on the flat top of the shell
- a sealing joint at the bottom of the shell
- two shaped antennae caps on the top cone
- 3 recesses for the SEPS accomodation
- 1 bump located on the lower cone to accomodate the DISR cover

Figure 2.2-9 illustrates the Back Cover design.

The BCSS interfaces with the SEPS Back Cover Mechanism (BCM) through three points, with the FRSS through labyrinth, with the DCSS pilot chute through attachment spools and break-out patch and with the THSS MLI through attachment on both faces.

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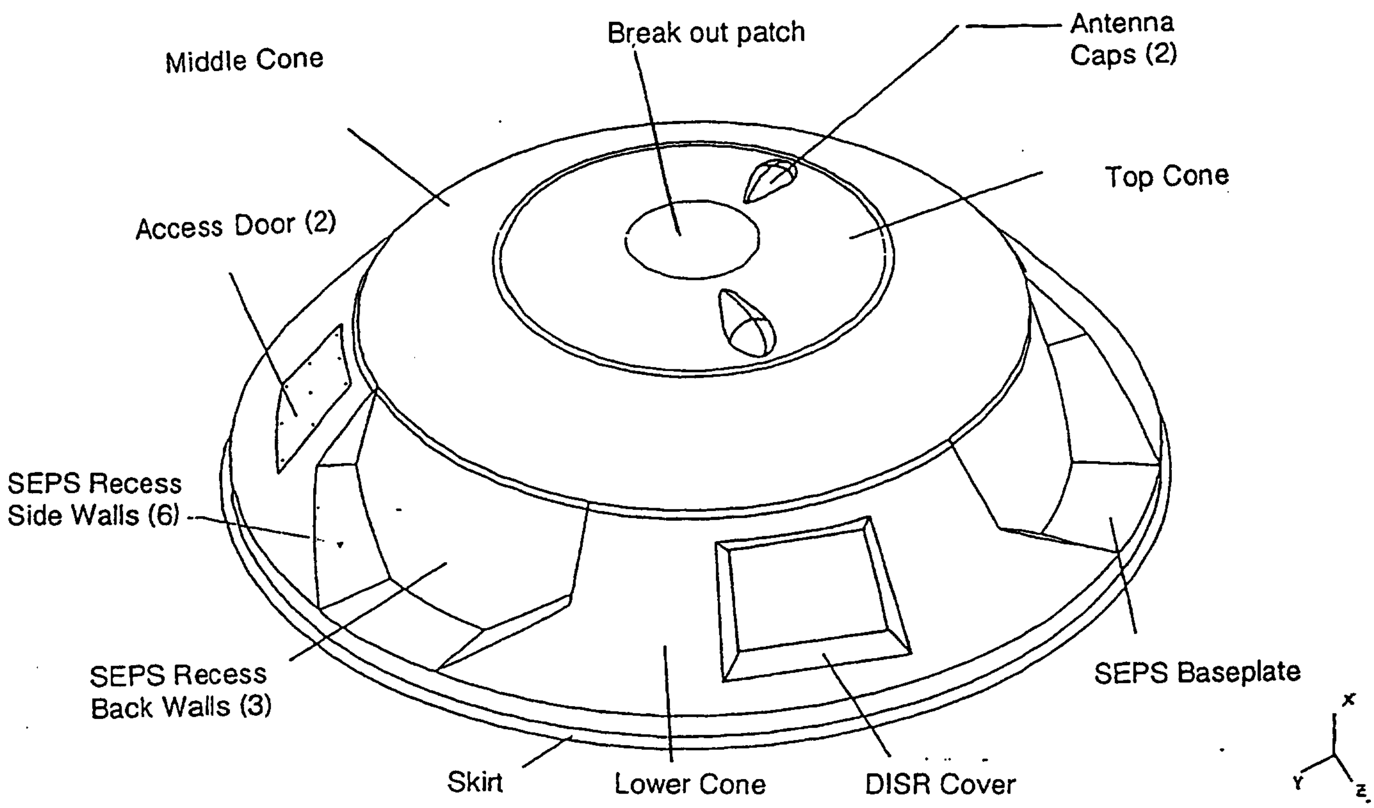

FIGURE 2.2-9 BACK COVER DESIGN

2.2.2-3 Descent Control (DCSS)

The main objectives of the Huygens Descent Control Subsystem (DCSS) are:

- to control the descent profile of the Huygens Probe to satisfy the requirements of the scientific payload
- to control the attitude of the Probe in order to maintain the link between the Probe and the Orbiter and get the DISR required attitude.

The subsystem includes the following items:

- one PDD which extracts the Pilot Chute
- one Pilot Chute which breaks a frangible part of the Back Cover and then separates the Back Cover after inflation. The pilot chute is a 2.6 m diameter Disk Gap Band (DGB) type.
- one Main Chute extracted by the Back Cover which decelerates the Probe through the transonic region. The Main Chute is sized to provide a positive separation of the Front Shield from the Descent module: it is a 8.3 m diameter DGB. At approximately Mach 0.6, the front shield is released.
- one Parachute Jettison Mechanism (PJM). This mechanism is needed to jettison the Main Chute after 15mn (this parachute is too large for a nominal descent time of less than 2.5 hours). The pyro mechanisms used for PJM are 3 AMD-BA rod cutters.
- one Stabiliser Chute which ensures the remainder of the Descent. The stabiliser is a 3 m diameter DGB parachute.
- swivels for both Main and Stabilising Chutes. They ensure compatibility with spin motion of the Probe provided by spin vanes.Both swivels are identical and incorporate redundant low friction bearings.
- one container which ensures housing of the Main and Stabiliser Chutes with their swivels.

The DCSS is activated nominally at a Mach number of 1.5 and an altitude of 159 km. The sequence is shown in Figure 2.2-10.

All parachutes are made of Kevlar and nylon.

The DCSS interfaces with the ISTS top platform through the PDD, PJM and container, and with the back cover through the pilot chute attachment.

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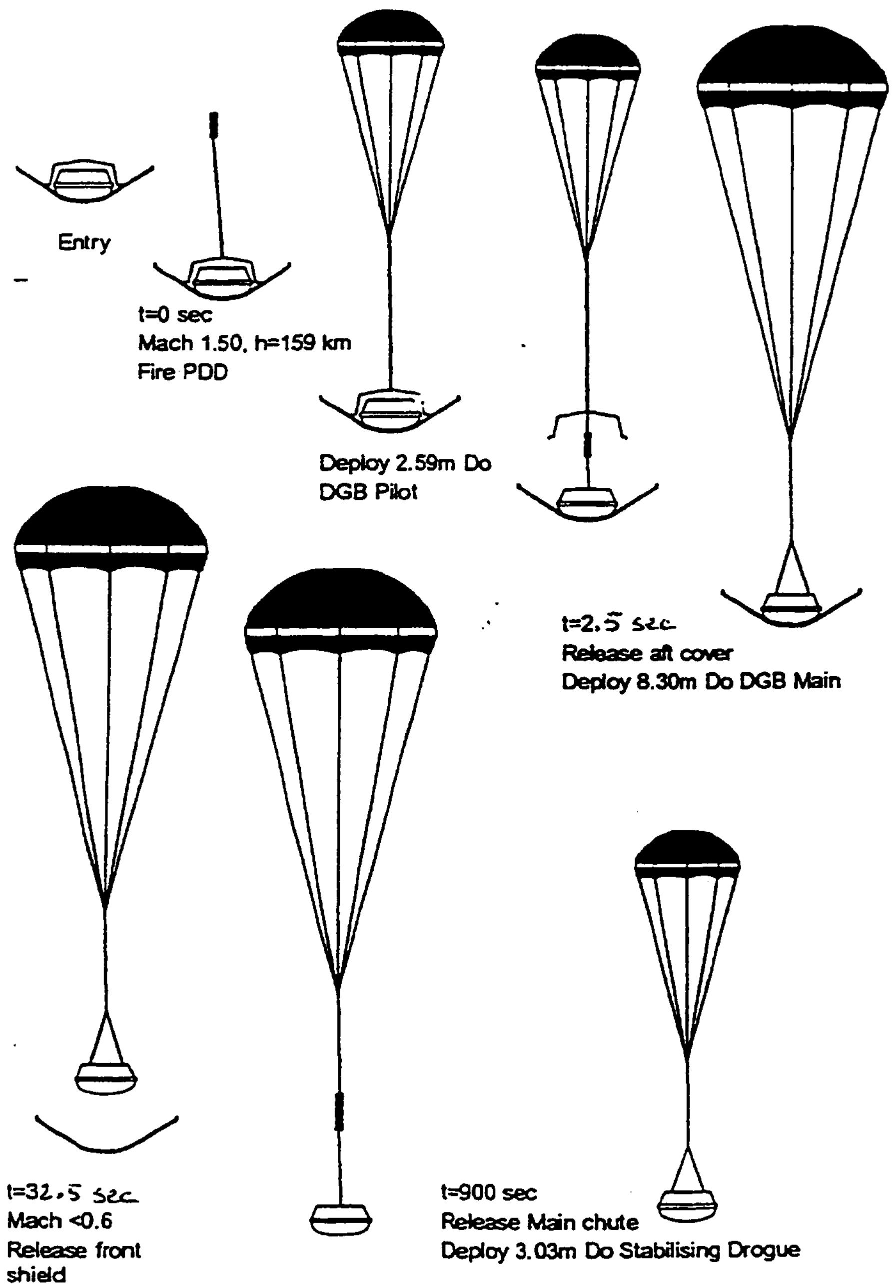

FIGURE 2.2-10 PARACHUTE DEPLOYMENT SEQUENCE

2.2.2-4 Separation Subsystem (SEPS)

SEPS mechanisms are necessary for two phases of the mission:

- mechanical and electrical separation from the Orbiter

- transition between Entry configuration ("cocoon") and Descent one (Descent Module under parachute) with the help of Pilot and Main Chutes. This transition is initiated by the Back Cover and Front Shield mechanisms, allowing Back Cover and Front Shield release, respectively.

All SEPS mechanisms are located on three fittings connected on one side to ISTS, on the other side to Orbiter struts. This configuration allows sufficient free field of view for DISR, large available angular sectors for spin vanes and HASI booms and stud and also an efficient structural load path.

On each fitting, the following pyro elements are implemented:

- one pyronut for SED

- one rod cutter for front shield

- one rod cutter for back cover.

The SEPS includes the following units:

- the Separation Device (SED) allowing mechanical separation from Orbiter which is constituted by:
  - 3 stainless steel springs giving separation force
  - 3 guiding devices with each 2 axial rollers rolling on a T-shaped helical track ensuring targeting even in degraded cases
  - one ring in carbon fiber to compensate the dissimetry of the Orbiter truss and to provide the necessary stiffness before and after separation
  - 3 pyronuts for mechanical link up to separation.

- the USM constituted by three 19 pin rack connectors mounted on the fittings which provides electrical connection between Orbiter and Probe up to separation and ensures very low extraction forces of the pins which are disconnected by the SED

- the Front Shield Mechanism (FSM) using three redundant AMD-BA rod cutters ensures the front shield release and gives an initial relative velocity between Probe and front shield through three spring devices

- the Back Cover Mechanism (BCM) using also redundant AMD-BA rod cutters ensures the release of the back cover

- three aluminium fittings supporting the four mechanisms and providing assembly interface with ISTS, Orbiter struts, back cover and front shield.

See the SEPS Baseline Overview in Figure 2.2-11.

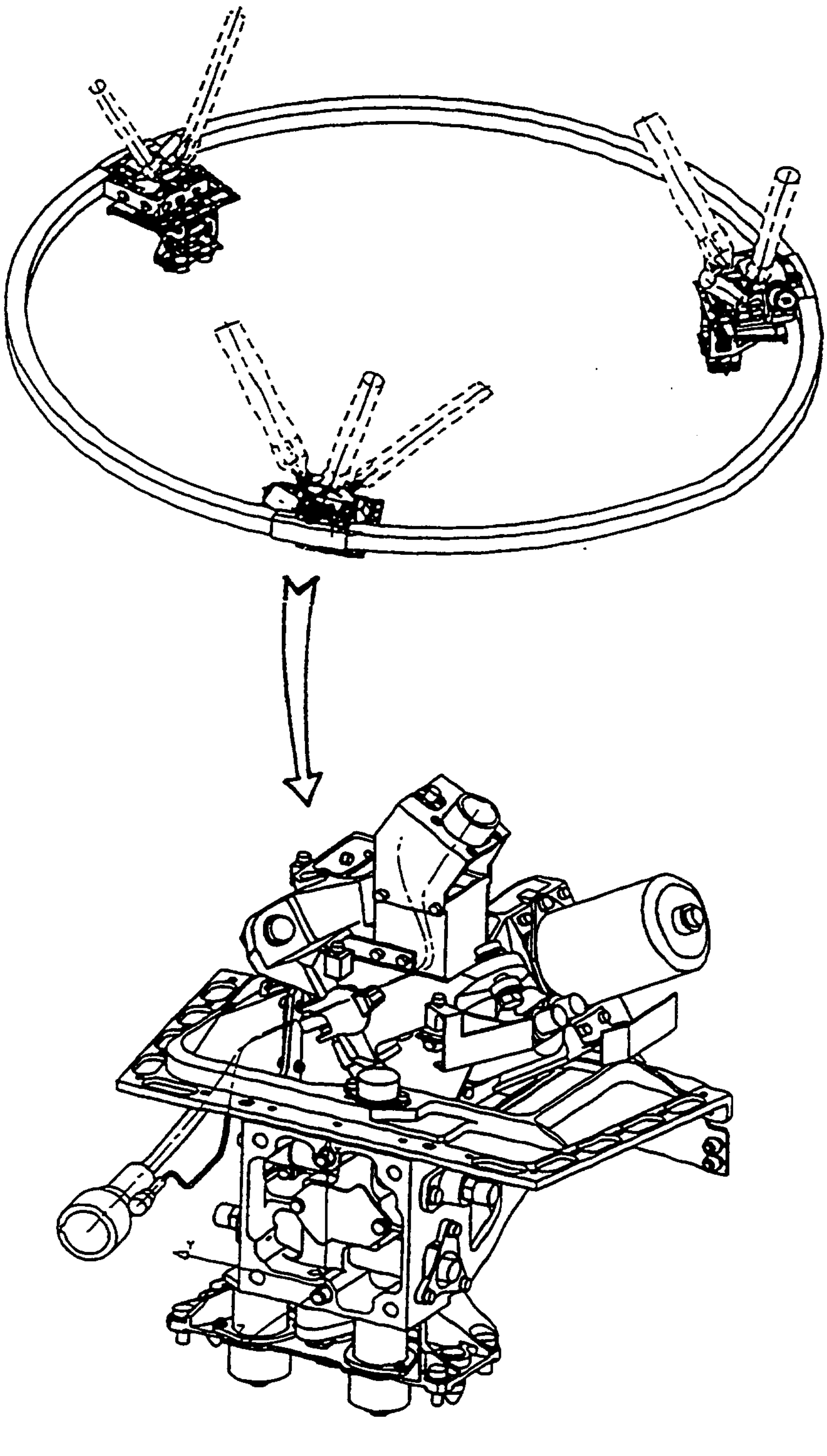

FIGURE 2.2-11 SEPS BASELINE OVERVIEW

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2.2.2-5 Inner Structure (ISTS)

The inner structure subsystem provides mounting support for the payload and the Probe subsystems necessary to ensure the proper functioning of the payload during the descent phase after the release of Entry Assembly (ENA).
The main elements of ISTS are:

- the 73 mm thick aluminium honeycomb sandwich called Experiment platform which supports the majority of the Experiments and S/S equipment units with associated harness

- the Top platform, an assembly of a 25 mm thick aluminium honeycomb sandwich which supports DCSS and Probe antennae

- two shells called "after cone" and "foredome" made in aluminium in order to form a Faraday cage precluding damage due to lightning during storms in Titan atmosphere

- one central ring ensuring junctions of after cone and dome and supporting radar antennae, HASI booms, USM connectors and dischargers

- titanium radial struts which provide interface with SEPS and ensure thermal decoupling

- titanium vertical columns which ensure link between the two platforms and transfer main parachute deployment loads

- spin vanes located on the dome for spin control during Descent

- a set of secondary structure for Experiments and equipment mounting in particular:

    • a DISR bracket
    • brackets for the interface with experiments sealing
    • titanium batteries brackets ensuring thermal decoupling
    • one access door in after cone for late access and Probe cooling during ground test
    • adjustable bracket for HASI accelerometer to ensure that the accelerometer is at the center of gravity of the Probe
    • top platform and ring feed throughs for harness

This structure is fully sealed excepted a venting hole of about 6 cm^2 on the top platform and Experiment hole in Central ring and Dome.

The ISTS allows for accommodation of GCMS, ACP, SSP inlet and outlet tubes and of DISR large field of view.

Figure 2.2-12 shows the ISTS main components.
Figures 2.2-13 and 2.2-14 show the experiment platform layout.
Figure 2.2-15 shows the top platform layout.

D5

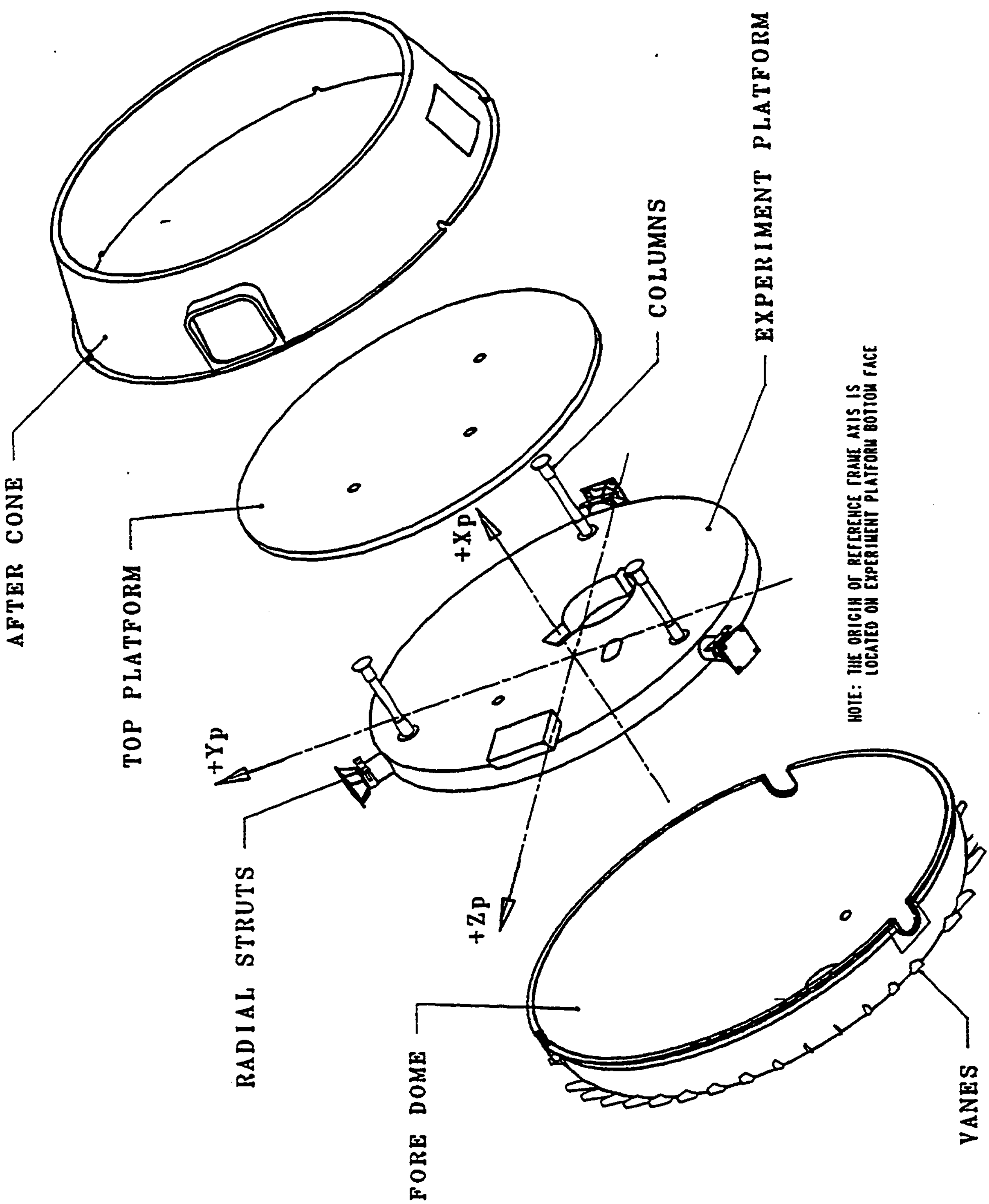

FIGURE 2.2-12 ISTS DESIGN

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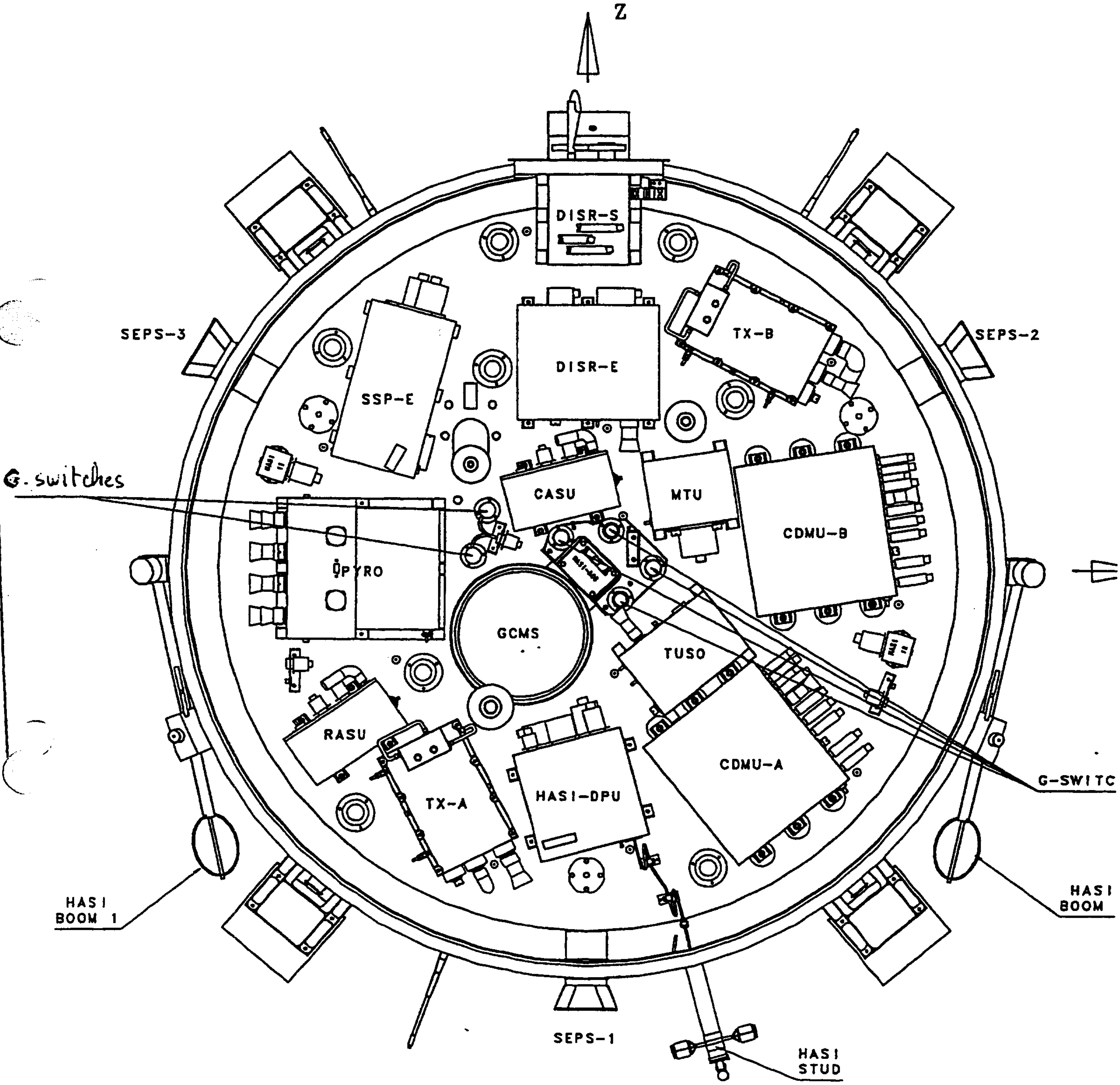

FIGURE 2.2-13 EXPERIMENT PLATFORM LAYOUT (TOP SIDE)

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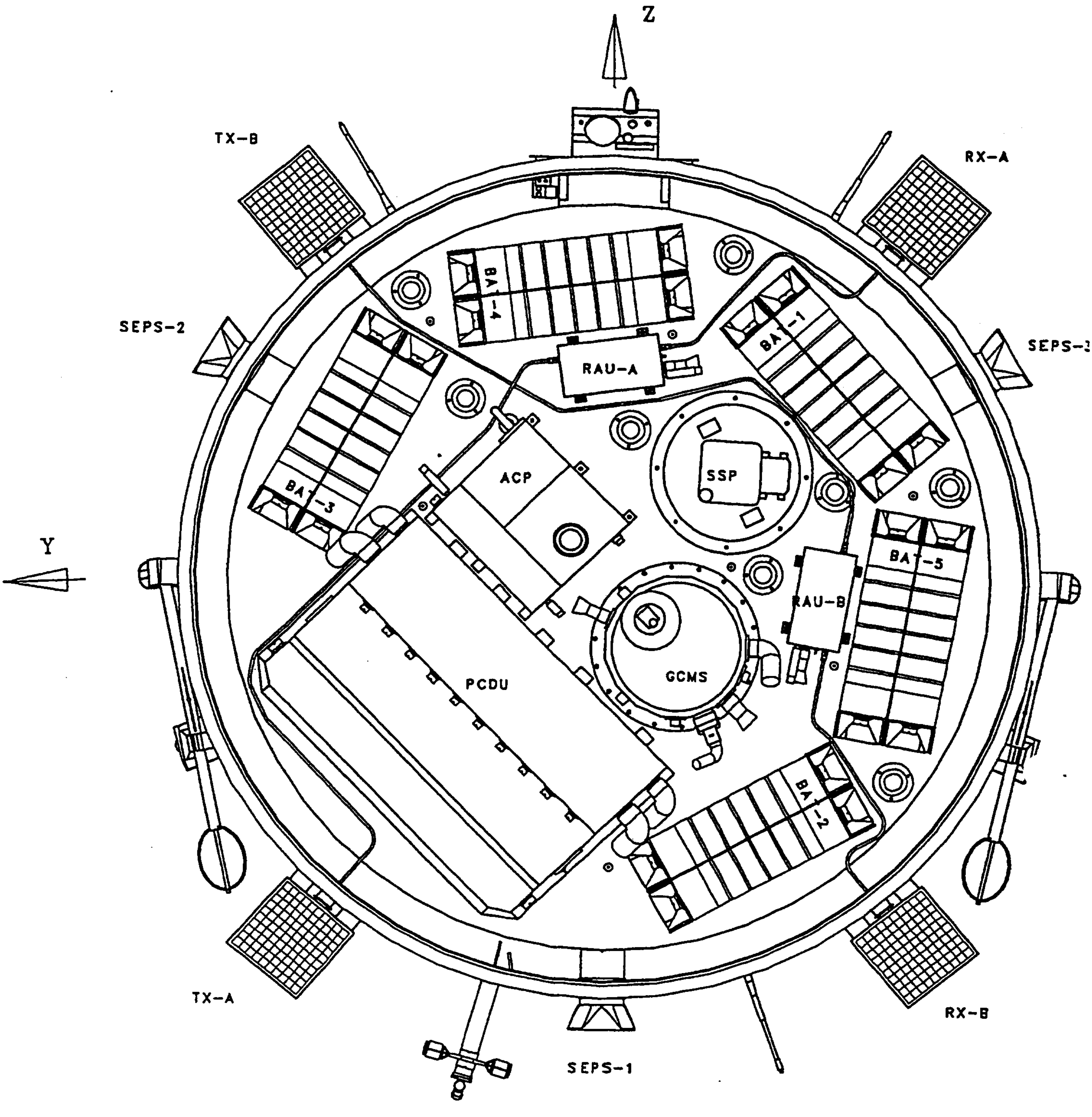

FIGURE 2.2-14 EXPERIMENT PLATFORM LAYOUT (BOTTOM SIDE)

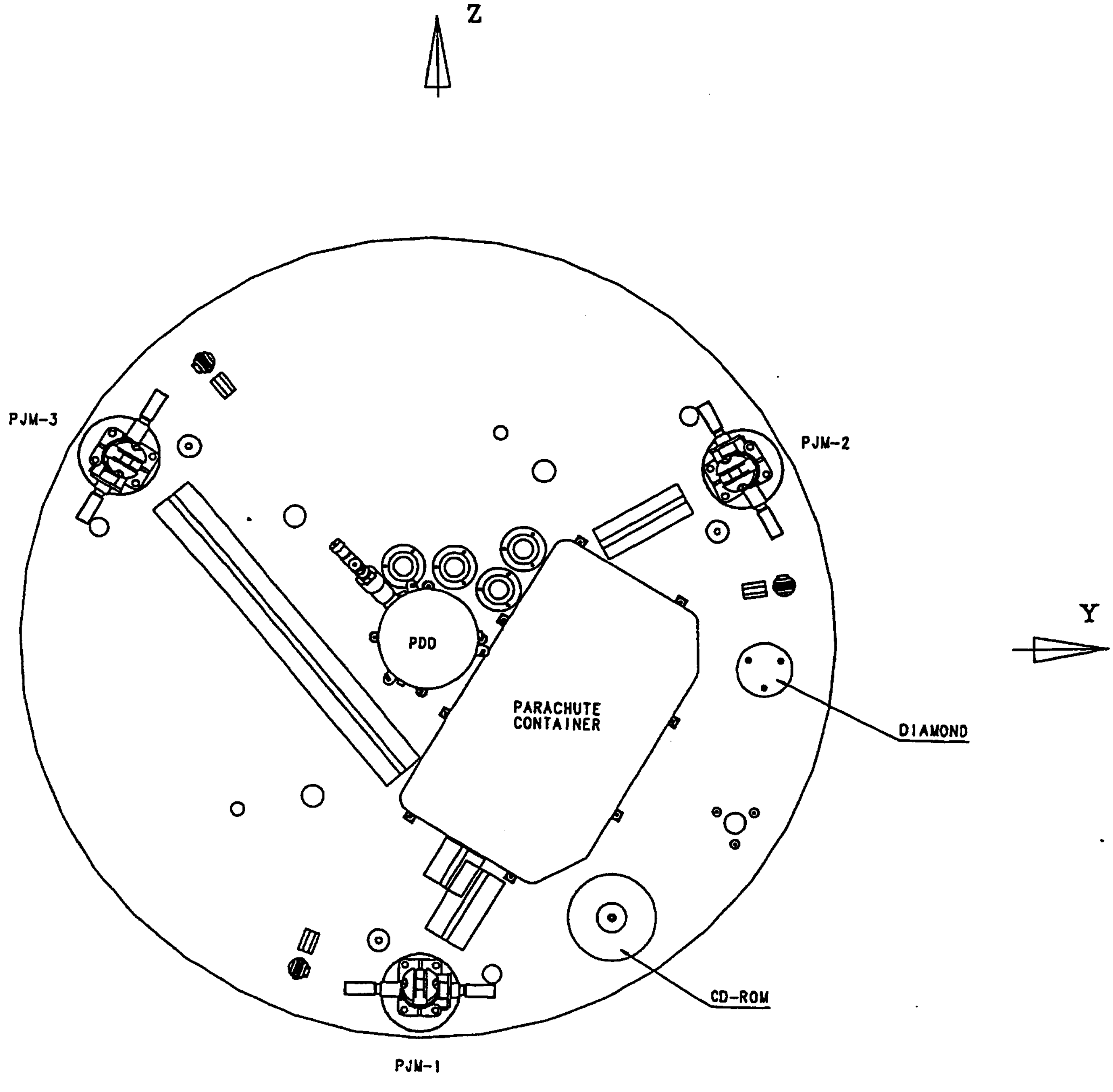

FIGURE 2.2-15 TOP PLATFORM ACCOMMODATION

2.2.2-6 DISR Cover

The DISR is one of the six scientific instruments of the payload. It main objective is to investigate the composition of Titan's atmosphere, clouds' structure as well as surface's nature.

During the Entry of the Probe into Titan's atmosphere, contaminent particules might pollute optics of the DISR instruments.

The DISR cover's basic mission is to protect the DISR against pollution during all the phases of the Mission till the end of Entry phase, where the cover is jettisoned on a command given by the Descent module.

The DISR cover is basically a stiffened aluminium shell equipped with 3 glass windows.

The cover is connected to the Descent module via an interface frame, bolted on to the after cone.

The mechanical link between the DISR cover and the interface frame is ensured by one 6mm diameter bolt whose main function is to transfer the loads from the cover to the Descent module across all Mission phases until the separation of the cover.

The release mechanism is one rod-cutter pyrotechnically and mechanically redundant, operated by the Descent module.

After jettison, the frame equipped with the rod-cutter remains on the Descent module whereas the 2 springs are ejected with the DISR cover.

Concerning thermal aspects, the inner and outer surfaces of the shell are alodine treated in order to minimize the emissivity towards the Descent module.

D5

2.2.3 Thermal architecture

While the PSE is controlled by the Orbiter thermal control, the Probe thermal control maintains experiments and units within allowed temperature range during all mission phases.

The main elements of the Probe thermal architecture are the following:

- a "space" thermal control which partially insulates the Probe from the Orbiter and allows a low variation of experiments and units temperature while incident solar flux varies from 3800 W/m^2 to 17 W/m^2 from launch till coast phase end:

  . MLI surrounding all external areas: the back cover, the SED, ring included and the front shield except a small part of the frontshield dedicated to the thermal window implementation

  . 35 Radioisotope Heater Units (RHUs) which provide heat during cruise, Saturn orbit and coast phases when the Probe is dormant avoiding too low temperature and located on experiment and top platforms in such a way that easy integration and cool down under fairing are provided

  . White painted thermal window on the front face of the front shield used to reduce sensitivity of thermal performances to MLI efficiency

- an "entry" thermal control with high temperature insulation material such as AQ60 on front shield front face, Prosial on front shield and back cover back faces avoiding to induce excessive temperatures on the internal aluminium structure when the Probe is submitted to large external thermal flux during the entry phase.

- a "descent" thermal control with:

  . a foam insulation made of light open cell Basotect foam covering the internal side of the descent module shells and top platform in order to avoid forced convection due to the Titan cold atmosphere and to decouple experiment platform and units from the cold aluminium shells. Indeed, the descent module is partially vacuum tight as a hole in the back side of the Probe allows launch venting and pressure equalisation between the Probe inner part and the atmosphere during the descent

  . sealing around payload cut-outs, harness and all elements protruding through descent module shell to suppress permanent gas flow in the Probe.

In addition, the key thermal features below complete the Probe thermal architecture.

Low emissivity coating and low conductive material are used on the bare zone of the SED to avoid temperature fluctuation within the Probe during coast phase after Orbiter/Probe separation and to guarantee start up unit temperature.

Mechanisms are thermally insulated from entry structure in order to avoid a too high temperature during entry phase and to allow a nominal functioning.

ISTS junctions between experiment platform and cold outer surface of descent module are in titanium in order to ensure high thermal decoupling.

All units except batteries are well linked conductively to the experiment platform. Batteries are thermally insulated in order to increase their temperature during descent.

The effects of thermoelastic stress during the entry and descent phases on the external aluminium shell and experiment platform are controlled by appropriate structural design and material choice.

All external surfaces are electrically conductive and are grounded.

Figure 2.2-16 summarises the main thermal components.

On Orbiter side, PSAs and RUSO are thermally controlled by radiation with the enclosure where they are located. RFE has a specific thermal control which uses:

- conductive insulation between RFE and the bus
- radiative insulation (MLI) all around RFE except radiator and around harness
- white painted thermal radiator shaded from the HGA main reflector
- 2 electrical heaters (prime + back-up) commanded via the CDS thermostatic control

D5

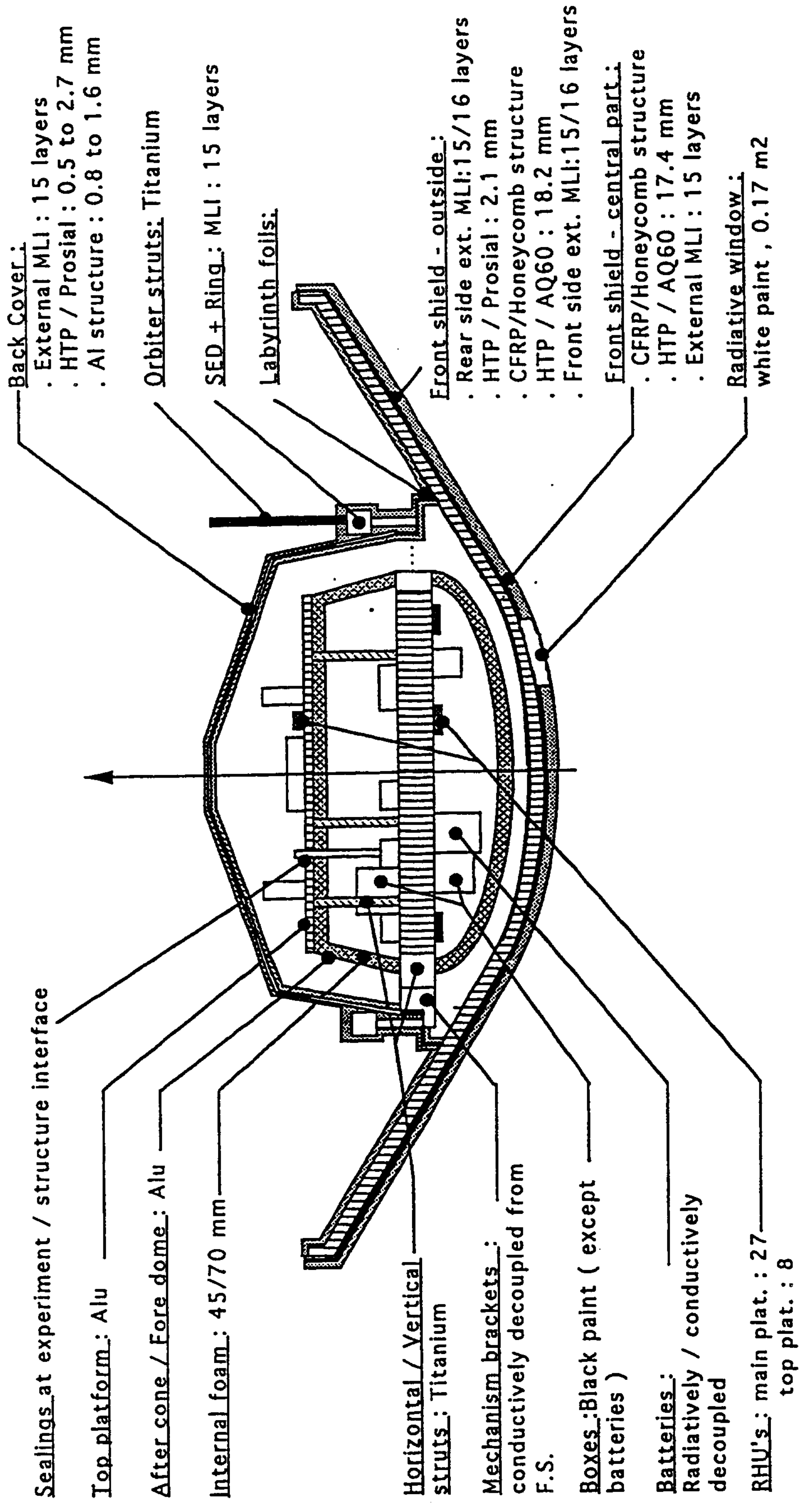

FIGURE 2.2-16 HUYGENS THERMAL ARCHITECTURE

2.2.4 Functional and electrical design summary

The data handling and processing functions are splitted between the Probe Support Avionics (PSA), part of PDRS, on the Orbiter and the Command Data Management Units (CDMUs), part of CDMS, on the Probe. See Block Diagram in Figure 4.2.1-1 in § 4.2.

The Probe Data Relay Subsystem (PDRS) combines the functions of RF link, data handling and communication with Cassini.

The PDRS transmits science and housekeeping data from the Probe to the PSE on the Orbiter. These data are then transmitted to the Orbiter CDS via a Bus Interface Unit (BIU).

During the cruise phase checkouts, the PDRS distributes telecommands to the Probe powered by Orbiter.

Electrical power is supplied to Probe units and experiments by five Li SO_2 batteries associated to a Power Conditionning and Distribution Unit (PCDU) after Probe separation. The Huygens mission can be successfully accomplished with the complete failure of one string (one battery or one BDR section).

To improve autonomy and fault-tolerance, CDMS and PDRS implement two identical separate sets of units each, through which separate data flows are channelized from Experiment outputs to Orbiter input.

Following TM exceptions are implemented:

- measurement of sensors within CASU and radar altimeters, are cross-strapped to both CDMUs
- MTU time values are cross strapped to both CDMUs
- the analog telemetries related to the PCDU BDR 3, voltage and current, are transmitted to both CDMUs while each CDMU monitors two of the four other BDRs
- timer power relay status and input relay status are monitored by only one CDMU to avoid useless grounding loop.
- the MTU power status is channelized: MTU1 to CDMU-A and MTU2 to CDMU-B, no TM on MTU3
- the RUSO (Receiver Ultra Stable Oscillator) parameters are only acquired by the PSA-A.

More, a delay is implemented between the two TM channels in order not to loose data if the redundant RF links are lost simultaneously for a short time.

Telecommands sent to two redundant functions are channelised ; telecommands sent to MTU are cross-strapped from both CDMUs.

Following exceptions to this TC channelisation rule concern:

- the pyro firing current limiters fired simultaneously by each CDMU

- the five PCDU input relays are switched ON by MTU (nominal & redundant) at Probe wake-up. They are switched ON by both CDMUs during the Battery Depassivation sequence and they are switched OFF by both CDMUs during the Battery Depassivation sequence and during the post-launch checkout

- the MTU power supply for coast timer 2 which can be switched ON and OFF by both CDMUs

- the commands related to TUSO transmitter A which are sent by the CDMU A only.

- additionally, the Processor Valid is only generated by the CDMU A and allows the Experiments to select informations coming from CDMU A or B.

2.2.4-1 Command and Data Management Subsystem (CDMS)

The CDMS has two primary functions:

- the autonomous control of the Probe operations after separation from the Orbiter

- the management of the data transfer from the equipments, subsystems and experiments to the Probe transmitter for relay to the Cassini Orbiter.

For all these functions, the CDMS is assisted by the Probe on board software, to which it provides the necessary processing, storage and interface capabilities.

Therefore, in order to perform the above tasks and to fulfil its mission during all the phases of the Huygens travel, the CDMS is comprised of the following (see Figure 2.2-17):

- 2 identical CMDU's

- 1 Mission Timer Unit (MTU)

- 2 mechanical G-switches for Mission Timer Unit Back-up

- 4 mechanical G-switches for Central Acceleration Sensor Unit Back-up

- 1 Central Acceleration Sensor Unit (CASU)

- 1 Radial Acceleration Sensor Unit (RASU)

- 1 Proximity sensor composed by 2 altimeters

D5

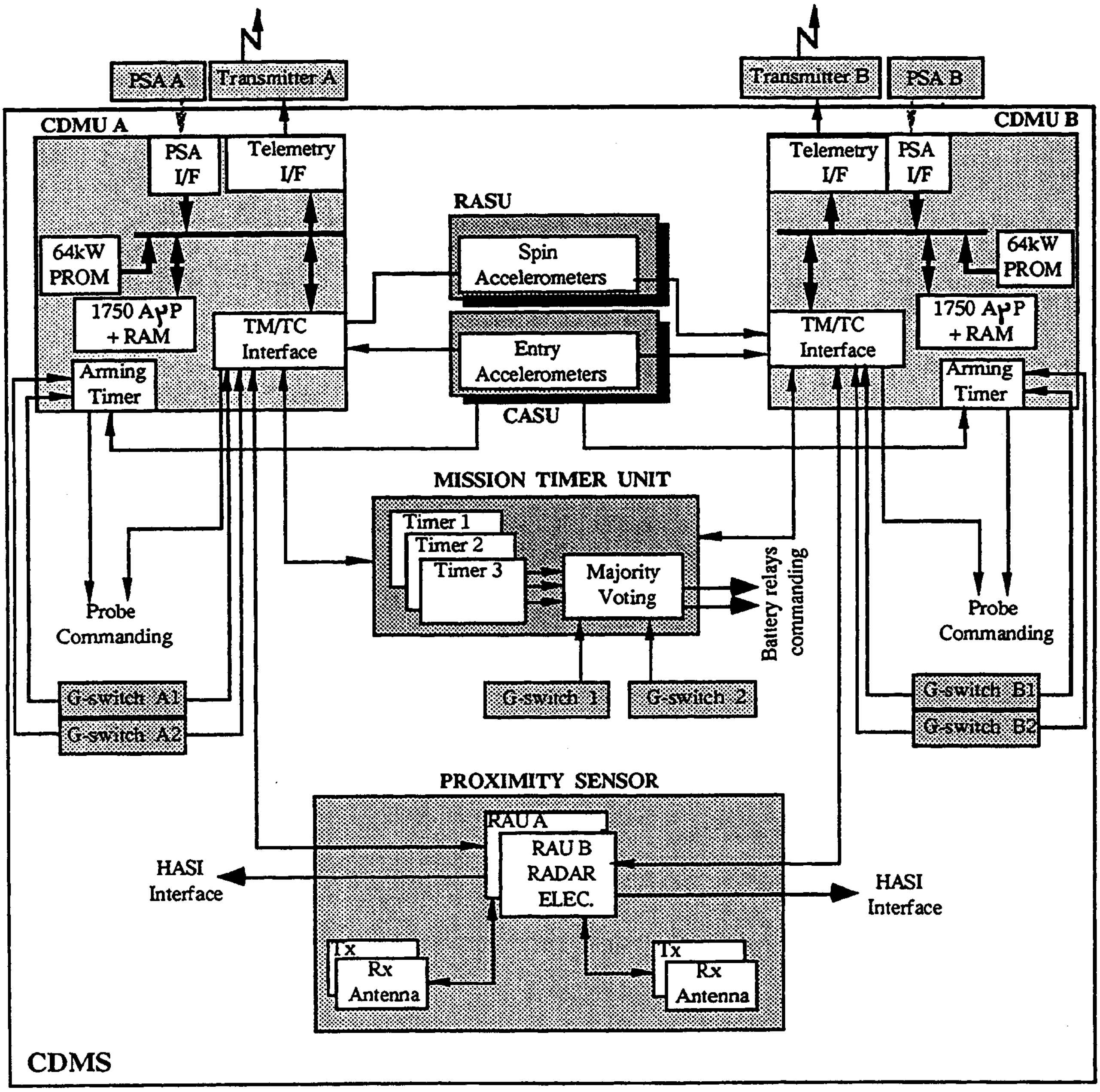

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FIGURE 2.2-17 CDMS ARCHITECTURE

a. CDMU

Each of the 2 CDMUs houses a MAS 281 16 bits 1750A processor running at 10 MHz, 64 kWords of Programmable Read Only Memory (PROM) for containing the POSW, and 64 kWords of Random Access Memory (RAM) for the storage of the POSW and of the dynamic data when the CDMU is on.

A Memory Management Unit is implemented to get memory management flexibility and provide some growth potential.

A Direct Memory Access (DMA) is available to facilitate the data transfer between the memory and the input/output registers thus off-loading the micro processor from repetitive Input/Output tasks such as the data transfer to and from the experiments, from the PSA when attached, and to the transmitter.

The program memory stored in RAM is protected against single error occurence by an Error Detection And Correction (EDAC) device which detects and corrects the single errors and detects the double errors reporting them as input for the Processor Valid function addressed hereunder.

The TM/TC management is based upon an internal OBDH bus which major benefit is to standardize the interfaces with the Probe On Board Software while making use of existing hardware.

The CDMUs perform DC/DC conversion for the sensor package and proximity sensor units.

Apart from the above classical features, the CDMUs implement some Huygens specific functions such as:

- the Arming Timer which role is to send pyro and protected lines arming commands following a specific hardware managed timelining, thus offering full decoupling from the POSW operation. The capability of this Arming Timer is actually 12 commands spread over 143mn with a 4.19 s of resolution.
  The Arming Timer is initiated upon analog detection of an acceleration threshold (Arming threshold, Tha), the acceleration data being acquired through CASU measurement. When enabled, the Arming Timer can also be started upon dedicated mechanical G-switches status change.

- the Processor Valid signal elaboration which purpose is to inform the Experiments about the health of the nominal CDMU in order to support them in their command reception process. This elaboration involves both the POSW (at initialization and during Mission execution) and the CDMS

- the reprogrammability implemented through the use of 16 kW of Electrically Erasable Programmed Read Only Memory (EEPROM) and allowing to patch the RAM content if necessary

- the EDAC single error count for reporting inside telemetry

- the capability, through specific 16 kW of RAM, to implement up to 32 frames software managed delay of one telemetry chain w.r.t. the other one. The delay implemented within the POSW is currently 6 frames.

CDMU architecture is shown on Figure 2.2-18.

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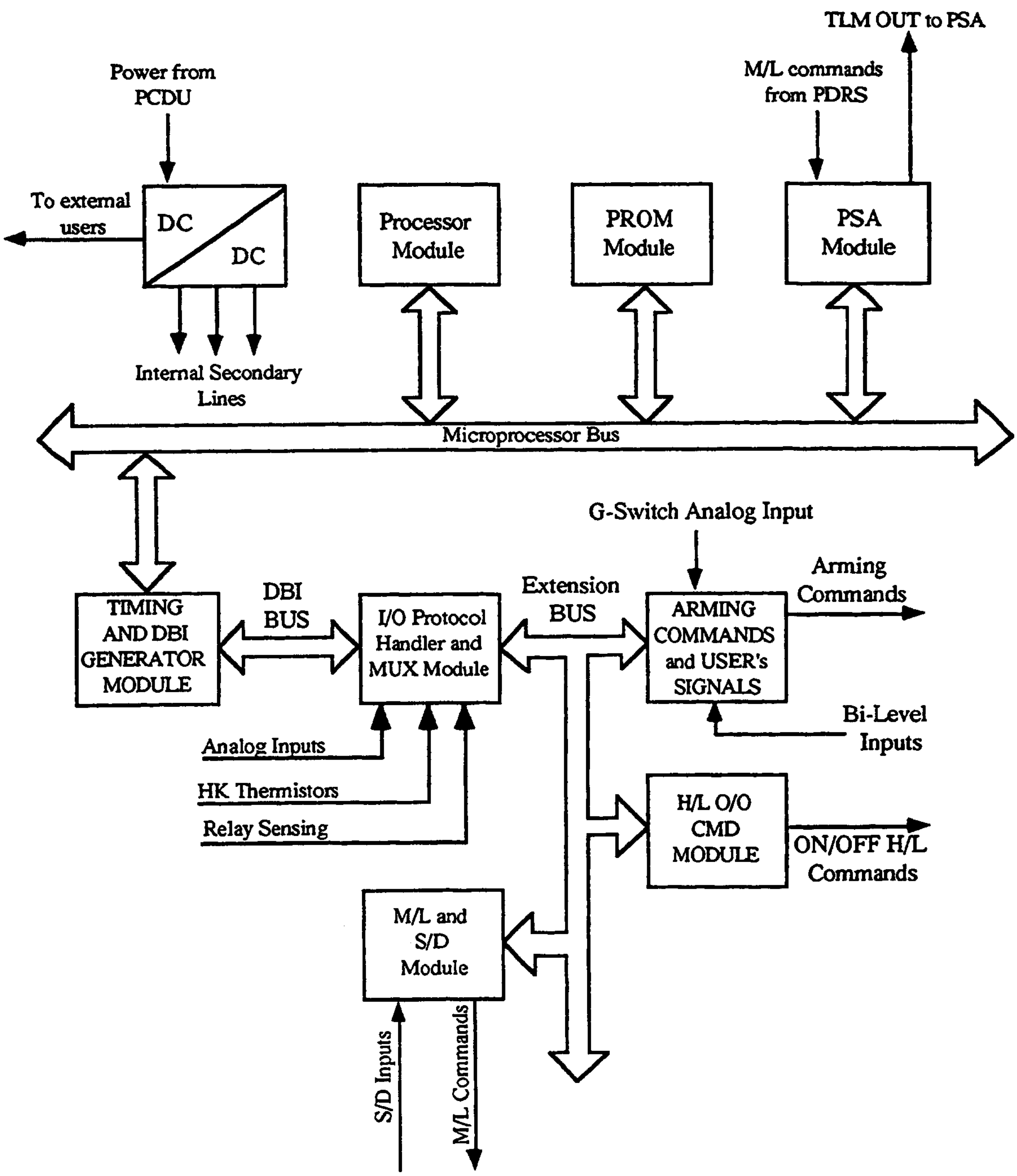

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FIGURE 2.2-18 CDMU ARCHITECTURE

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b. MTU and Associated G-switches

The MTU is an hardware programmable clock, which role is to wake-up the Probe after a preprogrammed duration corresponding nominally to 22 days after Probe separation.

As the Probe wake up is a critical mission operation, three active timer circuits are implemented in the MTU which makes a majority voting based on the "two-out-three" principle to activate the generation of 5 High Level Command (HLC) pulses in order to power up the Probe when the programmed delay time is reached. Each timer circuit can be programmed and verified by both CDMUs.

The coast timer resolution is 16 bit, corresponding to a time resolution of approximately 30 seconds.

Each of the three circuits has its own power supply and battery power source. This means that one single point failure can only inhibit the function of one timer. In the same way, a failure in short in one of the 3 timers can only lead to the loss of one battery.

The timers are followed by a hot redundant set of majority voting and High Level Command circuits. To save power during the coast phase, only the voting circuits are permanently powered.

When 2 out of the 3 timers have provided their time out signals, the power generation for the HLC drivers is enabled and the 5 HLC's are sent.

No single point failure can result in the total loss of the MTU function. Generally, all the cross-coupling between the three timer circuits in the two voting and command circuits are short circuit single point failure free to avoid any failure propagation between the redundant functions.

The majority voting principle of the MTU is implemented to protect the Probe against an early wake-up failure. To prevent from the late or non wake-up failure mode, the design makes use of 2 mechanical G-switches as additional inputs, short-circuiting the majority voting process. This allows, in case the 2 G-switches have passed a defined G threshold during the Entry phase, to activate the "ON" command sending to the battery relays.

To avoid any impact on the POSW, the G-switches set threshold is tuned to 6.2g on the rising edge of the Entry profile, which guarantees a POSW initialisation well before the T0 detection "G" area is reached.

Figure 2.2-19 shows the MTU architecture.

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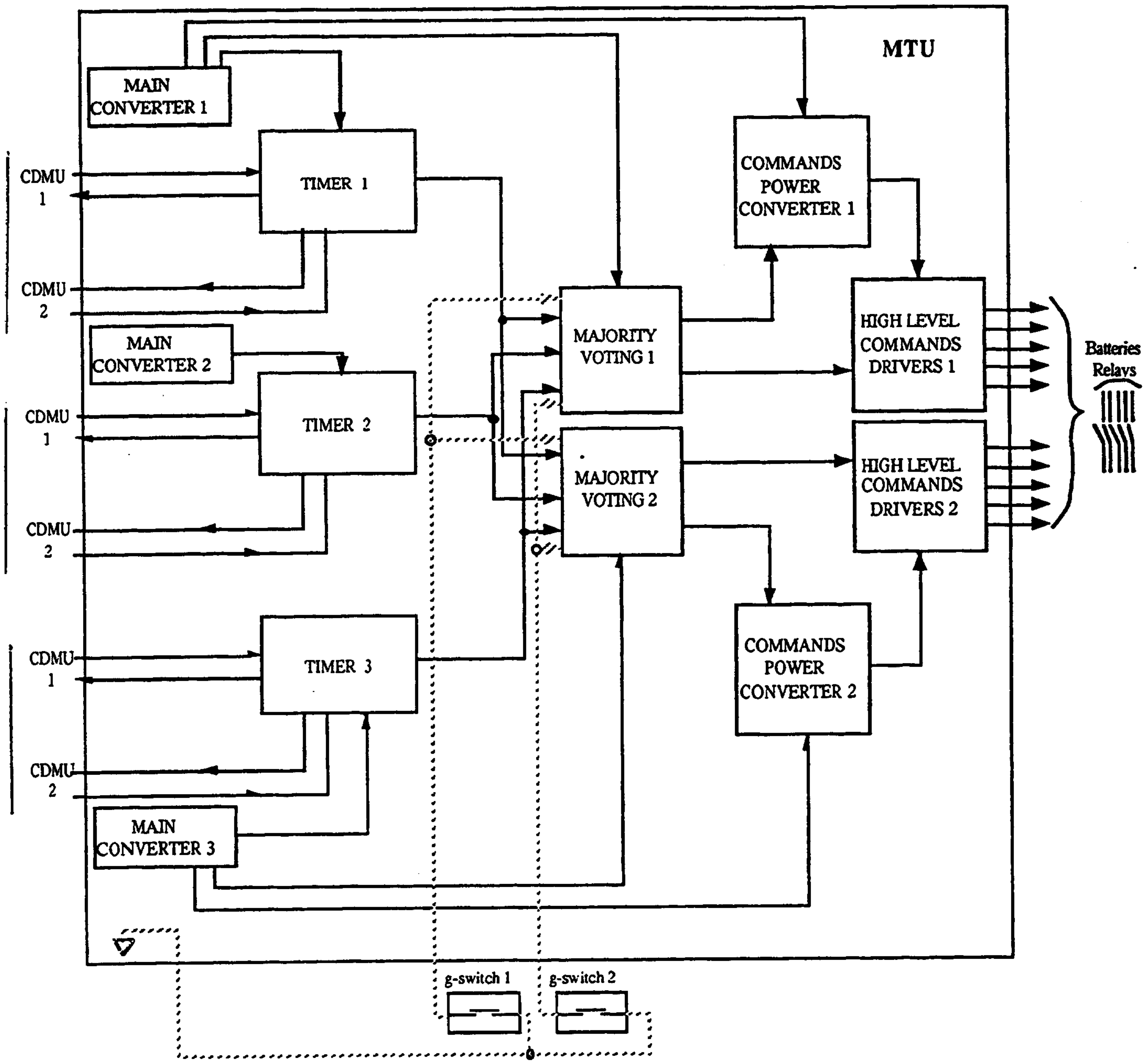

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FIGURE 2.2-19 MTU ARCHITECTURE

c. Acceleration sensors

The Entry phase detection is implemented through both a deceleration threshold analog detection function and a deceleration measurement software driven function.

CASU and RASU performing axial and radial acceleration measurements deliver analog signal to the CDMUs.

The CASU houses 3 accelerometers and associated measurement chains, all of them routed to both CDMUs, while the RASU houses only 2 accelerometers with the associated measurement chains channelized with the 2 CDMUs. Both units are independently powered by both CDMUs for reliability purpose.

The measurement chains are absolutely similar for CASU and RASU: conditioning electronics and anti-aliasing filter.

d. Proximity Sensor

It is in charge of the altitude measurement when approaching the Titan surface, ie from 25 km down to ground.

This measurement is mission critical for the Experiments operation, and as such the proximity sensor uses two totally redundant altimeters operating at different frequencies: 15.4 GHz and 15.8 GHz.

The transmitted signal frequency is swept over a range of 30 MHz with variable sweep rate dependent upon altitude. The received signal is amplified then mixed with a sample of the transmit signal. Ignoring any Doppler component, the received signal can be regarded as the transmit delayed by the propagation path delay.

Since the transmit frequency is swept, at any instant there will be a frequency difference between the received signal and the transmitted signal. This difference is directly related to the propagation path delay and thus altitude.

Both altimeter units interface with both CDMUs, providing 2 types of signal: digital serial 16 bits for the altitude information, analog signal for the returned signal amplitude (to be used in the frame of the scientific return improvement). The lock indication bit of the altimeter, utilized by the POSW, through the CDMUs, to validate the altitude data acquired is the LSB of the DS16 altitude information.

The altitude accuracy achieved over the whole range when in lock, is better than 10% of the actual altitude.

In order to improve the overall science return, a dedicated interface, comprising 2 signals, is established between the HASI and both altimeter units. It allows the sending of the returned Intermediate Frequency for further analysis by the experiment.

D5

e. CASU Back-up G-Switches

CASU operation is highly critical to the Huygens mission success. Further cautions are therefore taken through the implementation of a total CASU back-up.

It is based on 4 mechanical G-switches, 2 per CDMU chain, installed on a bracket close to the COG of the Probe. The G-switches principle of operation is the following: a calibrated seismic mass (about 42g) is hold in place by a magnet. When the selected G-threshold is passed (the G-threshold is basically given by the distance between the seismic mass and the magnet), the mass falls and presses an Honeywell microswitch which consequently indicates a status change. When the G-level becomes lower than the reset threshold of the G-switch, the seismic mass returns in its original position, letting the microswitch return to its original position too.

The status of 2 G-switches are acquired by each CDMU and its associated on-board software and are used under certain conditions to start the Descent operation.

The G-switches performances are:

- 2 G-switches with 6.2g as set threshold and 5.5g as reset threshold. Acuuracy on threshold detection is better than 2%.
- 2 G-switches with 2.5g as set threshold and $12 m/s^2$ as reset threshold. Acuuracy on threshold detection is better than 5%.

2.2.4-2 Probe Data Relay Subsystem (PDRS)

The PDRS is the Huygens telecommunication subsystem. The PDRS combines the functions of RF link, data handling and communication with Cassini.

The PDRS transmits science and housekeeping data from the Probe to the Probe Support Equipment (PSE) on the Orbiter. These data are then transmitted to the Orbiter CDS via a BIU.

The PDRS mission starts at To + 2 mn 30 and ends when the link is lost which can be up to 30mn after landing on Titan ground.

During the cruise phase checkouts, the PDRS is responsible of the TC distribution to the Probe powered by Orbiter.

As part of the DWE (Doppler Wind Experiment) in order to allow the accurate measurement of the doppler shift in the main RF carrier two ultra stable oscillators, the Transmitter Ultra Stable Oscillator (TUSO) on board the Probe and the Receiver Ultra Stable Oscillator (RUSO) on board the Orbiter, are used as reference signal sources.

The PDRS is constituted by the following:

- two hot redundant S-band Transmitters and two circular polarised Probe antennae on board the Probe,

- two low Noise Amplifiers with one diplexer within one box named the Receiver Front End (RFE) and two Probe Support Avionics.

The PDRS electrical architecture is fully channelised, except the TUSO and RUSO which are connected to only one chain.

D5

a. Probe Transmitting Terminal (PTT)

The PTT comprises the two transmitters and the two Probe antennae.

A PTT diagram is shown on Figure 2.2-20.

Each transmitter consists of three modules:

- the TCXO synthetiser and modulator module
- the 10 W Power Amplifier module
- the power supply module.

The reference oscillator is a Voltage Controlled Crystal Oscillator (VCXO) with a temperature compensating network (TCXO). The output signal (Fq) is sent to a priority switch which routes to the Phase Locked Loop (PLL) synthetiser either the internal TCXO reference signal or the external TUSO prioritary signal.

Then the signal coming from the synthetiser enters the phase modulator module. The modulating signal is a filtered BPSK modulated Non-Return to Zero (NRZ) data stream.

The modulated signal is upconverted in S-band (204 fq), filtered and finally sent to the 10 W power amplifier module of which last stage amplifier is the High Power Amplifier (HPA).

The nominal output power is 40 dBm (end of life, worst case including ageing).

The two transmitting antennae linked to the transmitters (two dual chains without cross-coupling) are quadrifilar helix antennae: the four spirals are fed at the bottom of the helix in phase quadrature.

The polarizations are circular, a Left Hand Circular Polarization (LHCP) for the signal transmission at fa = 2040 MHz and a Right Hand Circular Polarization (RHCP) for the signal transmission at 2098 MHz.

The minimum gain for the antennae mounted on the Probe is ≥ 0.9 dB for an elevation angle between +70° and +20° (reference: antenna mounting plane).

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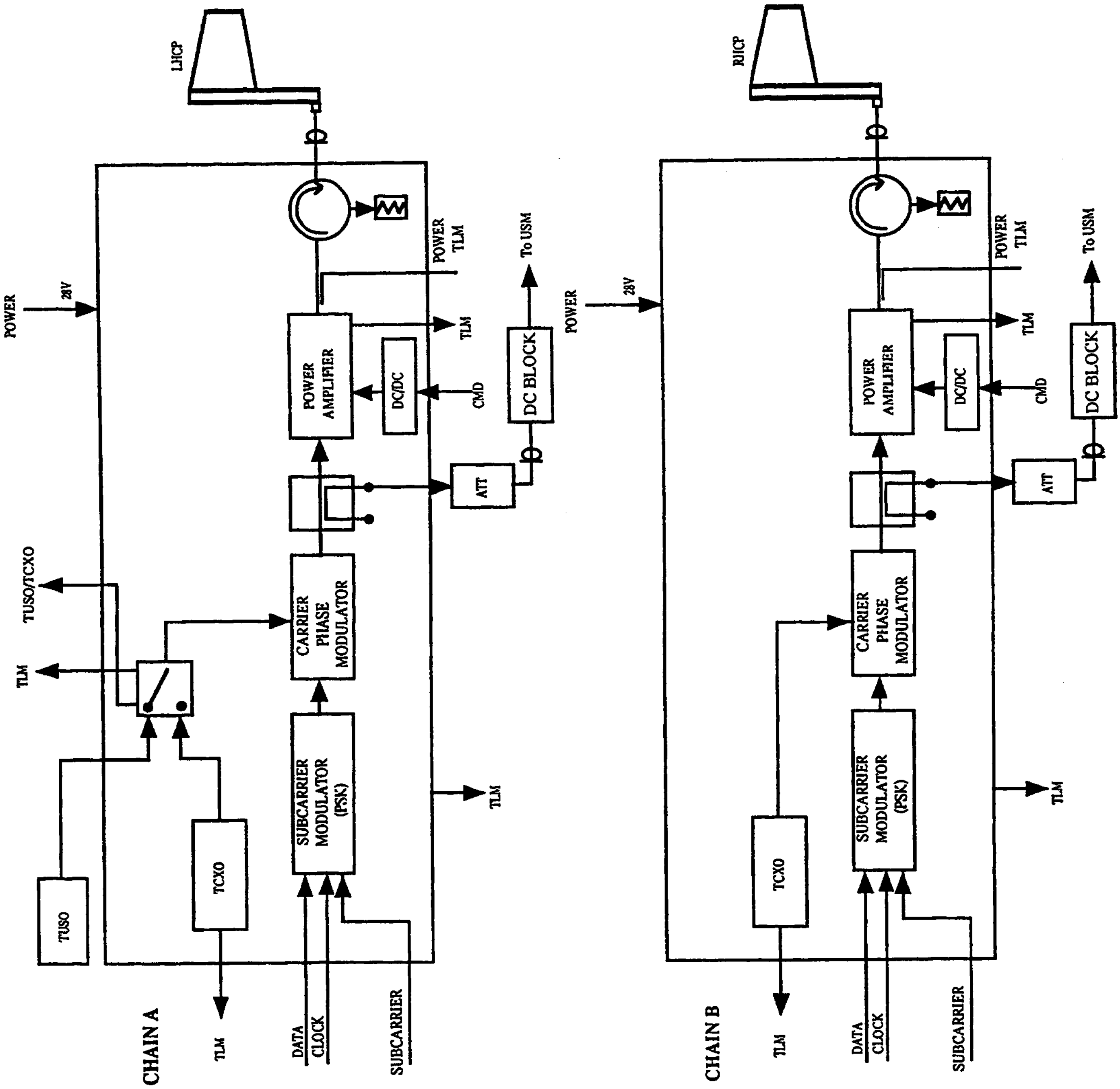

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FIGURE 2.2-20 PROBE TRANSMITTING TERMINAL FUNCTIONAL BLOCK DIAGRAM

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b. PSE

The PSE comprises the RFE, the PSAs and the RUSO.
In order to fulfill the DWE mission, a RUSO (Ultra Stable Oscillator) is connected to the PSA A.

A PSE diagram is shown on Figure 2.2-21.

The two LNAs linked to the Cassini High Gain Antenna (HGA) amplify by a factor of 20 dB the RF signal acquired by the HGA.

These LNAs are external to the PSA receiver section and assembled in the same unit: the RFE.
Each of the two redundant chains is composed of:

- . two RF inputs one linked to the HGA, the second one via a coupler and used during the check out period linking a dedicated transmitter output to the RFE
- . a preselection filter (coaxial cavity type with 6 poles)
- . an isolator
- . a low noise amplifier which consists of two cascaded FET stages
- . a gain setting attenuator.

The output are sent to the PSA's.

In addition, due to the shared used of the HGA with CASSINI a band pass filter (called Tx filter) in order to protect the LNA chain B in case of failure of the CASSINI transmitter and a circulator have been implemented (isolation between CASSINI S-Band transmission and HUYGENS S-Band reception: those two working modes are mutually exclusive).

The PSAs combine the reception function, the acquisition function based on a 256 points Fast Fourier Transform (FFT) algorithm, the signal demodulation, the data handling and the management functions.

These tasks are shared between the PSA hardware, the PSA Receiver Software (RSW) and the Support Avionics Software Subsystem (SASW).

The PSA architecture is shared in an analog section and a digital section.

The **analog section** is mainly devoted to the signal down conversion from the S-Band into the IF Frequency. After down conversion the IF signal is quantized and the samples processed by the digital section.

The main modules of the analog section are the RF/IF module, the local oscillator and synthetiser module, and the reference oscillator module.

The RF/IF section provides two frequency down conversion and gives the required in band selectivity to reject all the spurious spectral lines near to the second IF central frenquency.

The local oscillator provides signals for the first and second down conversion and the clock signals for the Analog/Digital (A/D) converter and the ASIC in the digital section.

The reference oscillator, driven by an external "direct digital synthetiser", generates signals for the local oscillator and the DWE.

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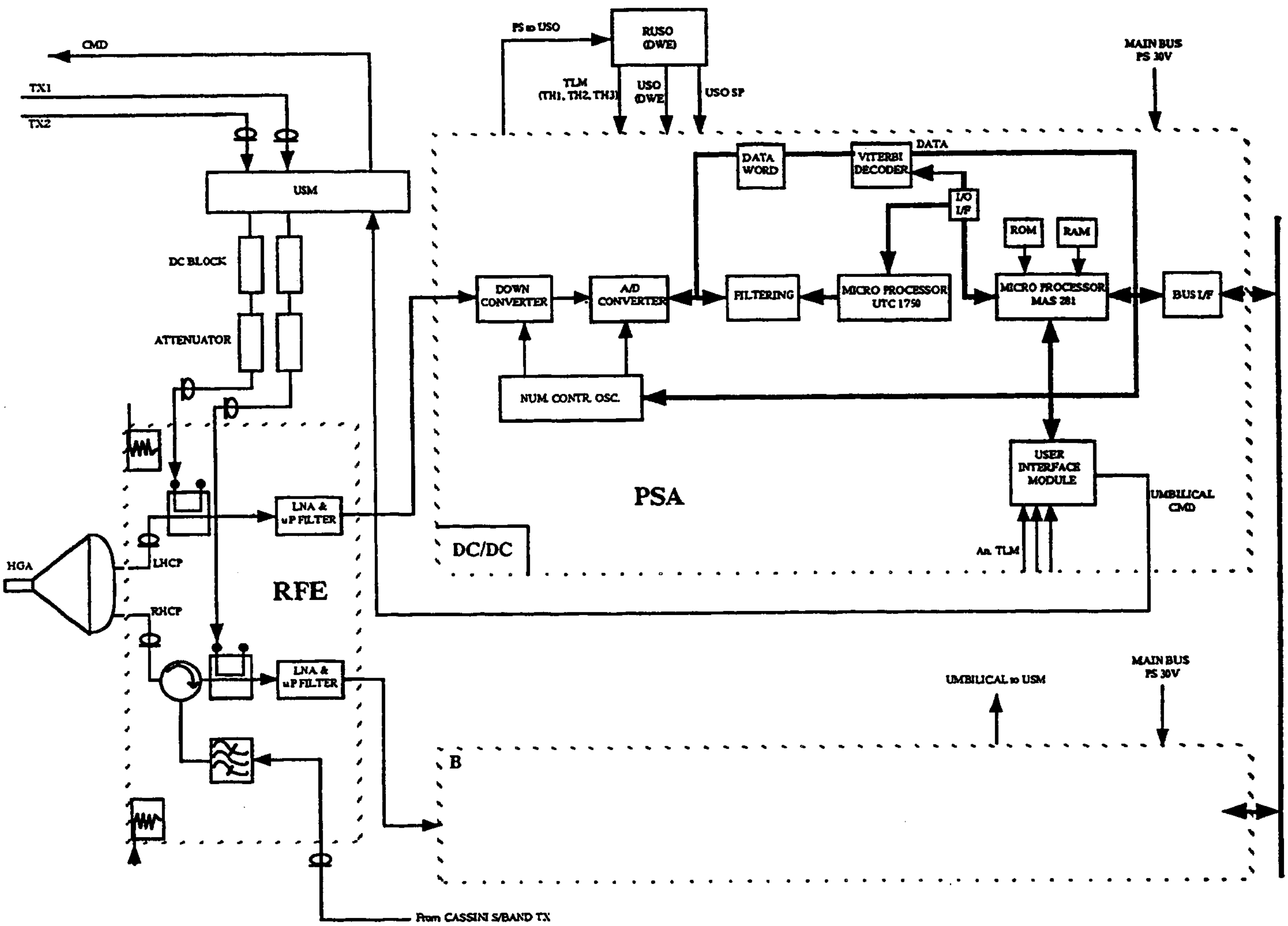

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FIGURE 2.2-21 ORBITER RECEIVING TERMINAL FUNCTIONAL BLOCK DIAGRAM

The **digital section** performs the following tasks:

- the signal acquisition and tracking task named Digital Signal Processing (DSP) function. After the FFT analysis and the frequency acquisition, the microprocessor enters the tracking state which output is a frequency synthesis for the local oscillator

- the data handling function which consists to:

  . transform the received transfer frame into a telemetry packet

  . generate PSA housekeeping data including the synthetized frequency information in a packet format

  . control and manage the communication with the Orbiter CDS via a Bus Interface Unit (BIU)

  . distribute the telecommand.

The digital section is composed of the following main modules:

- **the receiver digital module** constituted by the A/D converter and driver circuit, the UT1750 processor, 8 Kwords of RAM and 8 Kwords of PROM, the receiver signal processing ASIC

- **the interface digital module** which synthetises the receiver frequency using Ga As NCO and Ga As DAC devices

- **the support interface circuitry module** (SIC) which is composed by the Viterbi Decoder, the differential decoder, the transfer frame interface, the frame data interface, EEPROM (8 Kw) to memorise software patches, the PROM (32 Kw) containing the SASW, a serial interface USART used for testing, the analog telemetry interface, the receiver section telecommand interface and telemetry interface, the umbilical interface which has in charge to transmit the telecommand frame to the CDMS during the check out in cruise phase

- **the MAS 281 processor module**

- **the BIU module** which is the controller that allows communications between the PSA and the Orbiter 1553 bus.

In addition, the power supply module, made of 2 DC/DC converters, converts the +30 V primary bus voltage into the adequate secondary voltages.

2.2.4-3 Electrical Power Subsystem (EPSS)

The Electrical Power Subsystem controls and distributes power to experiments and equipments of the Probe.

It conditions, isolates and protects the Orbiter power supply until Probe separation.

After separation, the EPSS operates autonomously using primary batteries as the sole electrical energy source and performing similar functions for the Probe experiments and equipments.

The EPSS provides protection so that recovery from load malfunction or abnormal operating mode is possible. Depassivation of the primary batteries before separation is also performed by the EPSS.

The EPSS baseline design is summarised in Figures 2.2-22, 2.2-23 and 2.2-24.

The EPSS is constituted by the following:

- 5 primary batteries
- 1 Power Conditioning and Distribution Unit (PCDU) which conditions the available power at 28 V regulated on a main bus via 5 Battery Discharge Regulators (BDRs) controlled by a central triple redundant Main Error Amplifier (MEA) and distributes it to all experiments and equipments while providing all associated necessary protections.
  Prior to the separation, the EPSS performs the Depassivation of the batteries. During the coast phase and before batteries are connected to the main bus, dedicated specific lines provide power supply from 3 batteries to the CDMS Mission Timer Unit.
  A slight unbalance has been introduced in the power sharing between the 5 BDRs to compensate the depletion of 3 batteries during the coast phase
- 1 Pyro Unit which provides the arming and firing functions related to 2 redundant sets of pyro lines.

a. Battery

The Battery system consists of ten Galileo, 13 cells modules arranged in a configuration of 5 strings of two modules each. One of these strings (2 modules) is a completely redundant element. The G3108A3 cell used is a lithium/sulfur dioxide "D" type of 7Ah capacity.

b. PCDU

Each conditioning BDR section has an input power relay provided to completely disconnect the battery during all mission phases before Descent to avoid any loss of capacity by leakage current. Each one of the five PCDU input relays may be switch ON by MTU (nominal and redundant) for Probe wake-up, OFF by CDMUs during Cruise C/O2, and ON and OFF by CDMUs during the battery Depassivation sequence.

The 28V distribution function is performed by 28 distribution lines via 28 active current limiters. Current limiters are designed to be automatically switch OFF at powering-up except for the CDMU outputs (CDMU + accelerometers) that must be automatically switched ON.

Among the 28 distribution lines, 18 lines are main power lines (2 x 9 redundant) for users main power distribution, and 10 lines are energize lines to power protected devices (2 x 4 redundant for experiments + 1 proximity sensor A and 1 for proximity sensor B).

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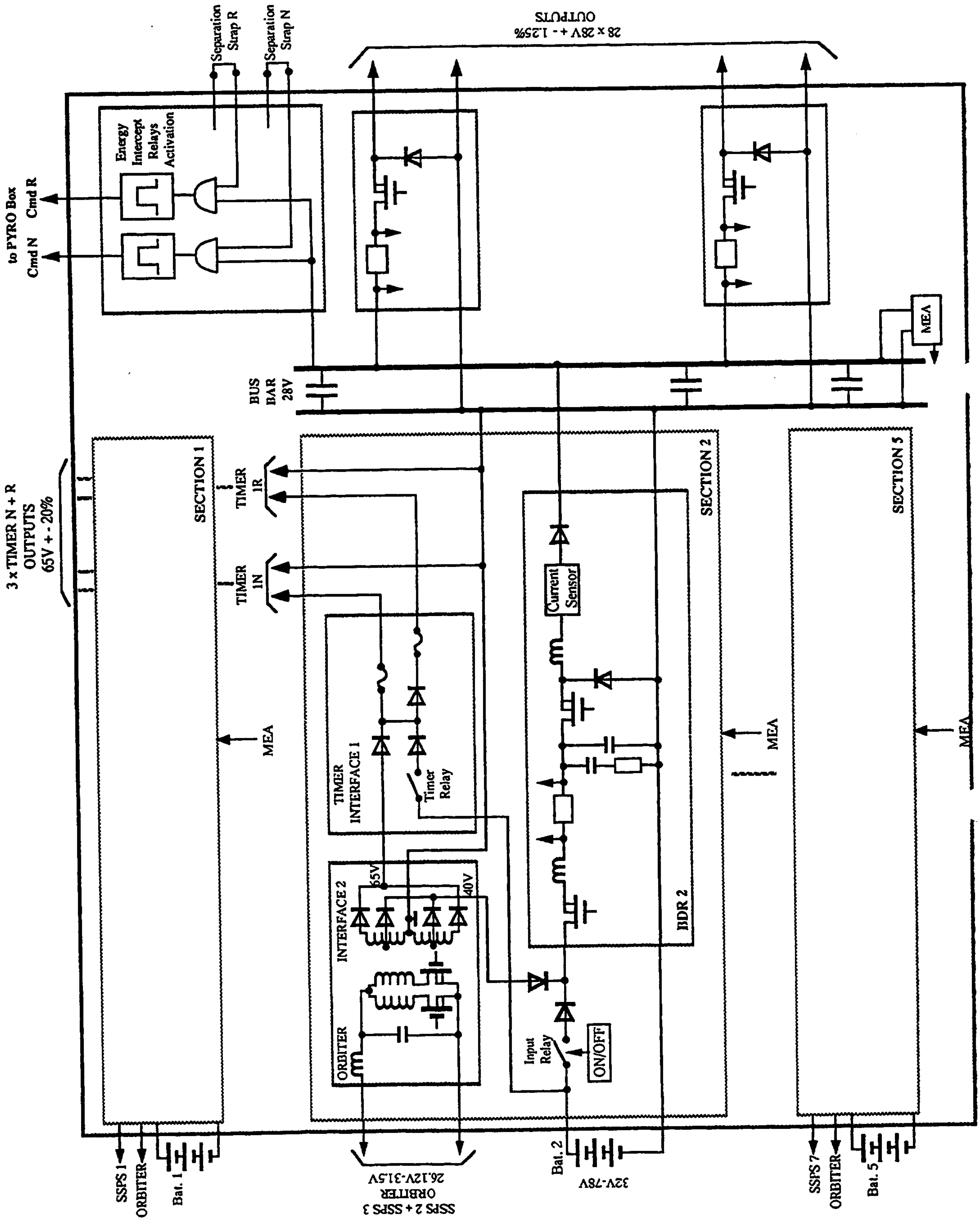

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FIGURE 2.2-22 PCDU BASELINE CONFIGURATION

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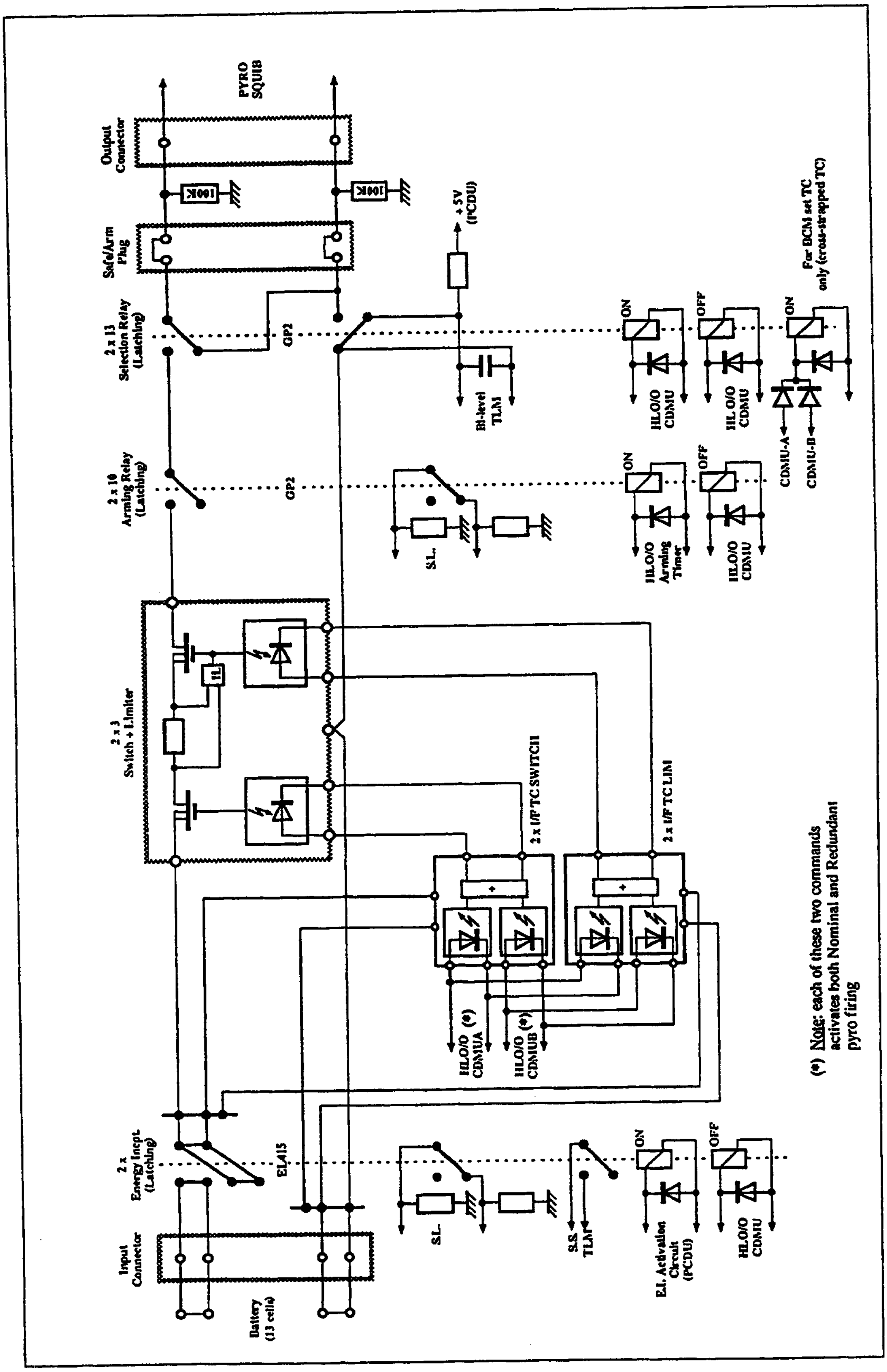

FIGURE 2.2-23 PYRO UNIT CONFIGURATION

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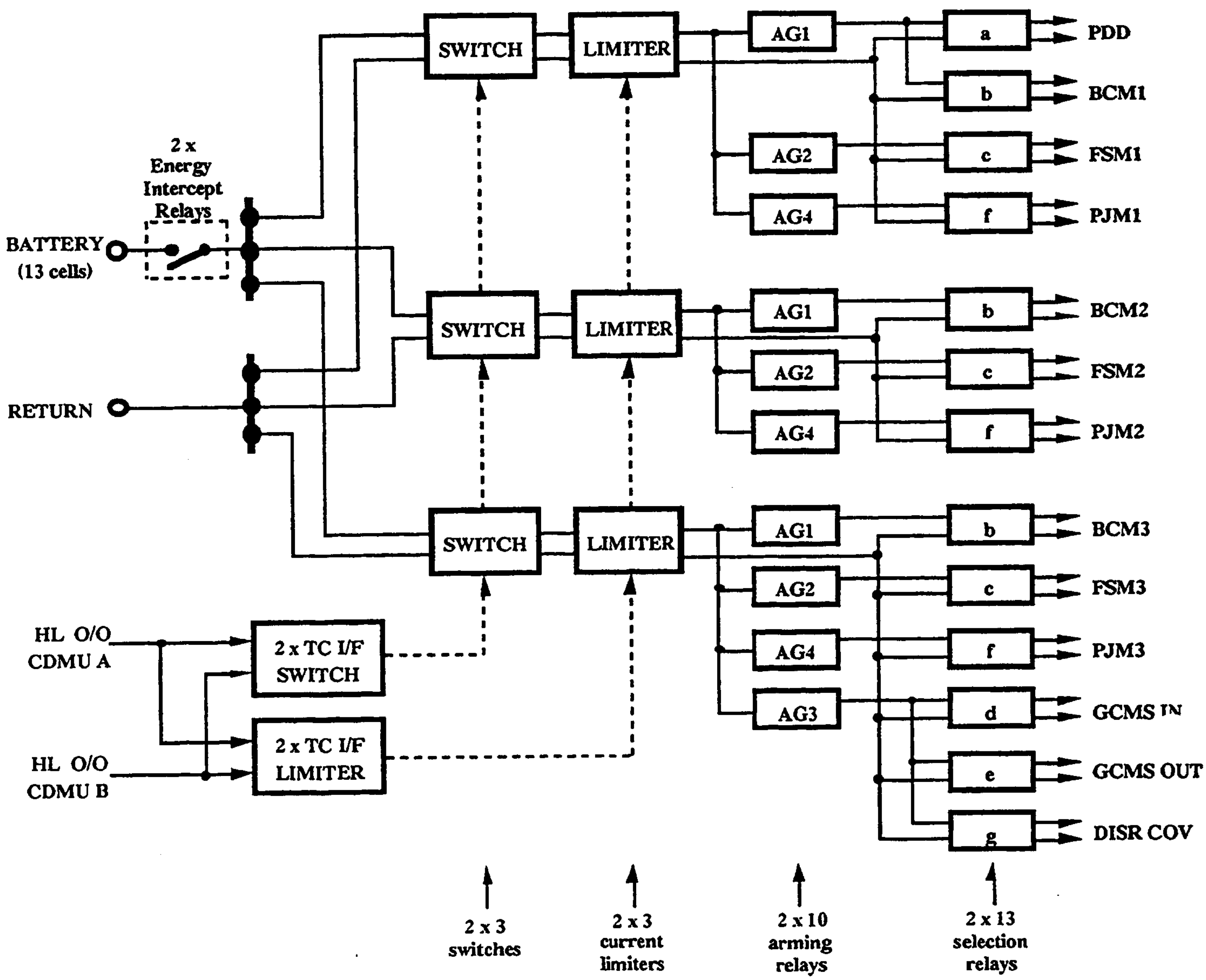


MD-P

FIGURE 2.2-24 PYRO LINES CONFIGURATION

Limiters on main power lines are switched ON and OFF by CDMUs through high level ON/OFF commands initiated by POSW or TC.

Limiters on energize lines are switched ON by the arming timers in CDMUs.

Some of them are switched OFF by arming timers (HASI, ACP). The others may be switched OFF by CDMUs (high level command initiated by POSW or TC).

Energize lines are implemented in the EPSS for energizing protected devices such as GCMS valves, ACP cap, HASI boom, Proximity sensor and DISR lamp. These devices are protected from being activated during checkouts and are activated only after separation of the Probe from the Orbiter, by the arming timer initiated by an axial deceleration measurement derived from the CASU. As not system critical, their activation remains under the experiment software responsibility.

In addition, arming timer switches ON the high power amplifier of the transmitter.

Transmitters HPA and proximity sensors need to be protected to remain unpowered during cruise phase checkout in order to avoid any RF disturbance at Orbiter level.

c. Pyrobox

The pyrobox contains 2 sets of 13 pyrolines split into 4 arming groups in order to prevent loss of the mission due to inverted firing commands, as presented in Table 2.2-1 hereafter.
The first set of PYROLINES is controlled by CDMU-A.
The second set of PYROLINES is controlled by CDMU-B with the following exceptions:

- Fire command and BCM selection relays set TCs which are cross-strapped: both CDMUs control each side of the PYRO box.
- Energy Intercept relays "closing" command is generated by the PCDU only.

In order to fulfil the safety requirements, 3 independent inhibits are implemented:

- 2 energy intercept relays (1 per set of pyrolines) switch ON by an activation circuit located in the PCDU inhibited by a separation strap through the Probe-Orbiter umbilical

- 20 arming relays (10 per set of pyrolines) switch ON by the CDMU arming timer which is a hardware device fully independent from CDMU software

- 26 selection relays (13 per set of pyrolines) switch ON by the Probe on board software.

Pyro firing is executed by activation of a solid-state switch plus current limiter (3 per redundant set of pyrolines) by a pulse command initiated by the Probe on board software according to the predefined timeline. To ensure simultaneity between nominal and redundant pyros for back cover release, front shield release and parachute jettison, each CDMU sends a single firing command for firing nominal and redundant initiators.

Prior each firing event, adequate selection relays are switched ON (ON commands by POSW). After firing event, selection relays are switched OFF (OFF commands by POSW).

FUNCTION	PYROS (redundancy not included)	ARMING GROUP	ENERGY INTERCEPT* RELAY ACTIVATION	ARMING RELAY * ACTIVATION	SELECTION ACTIVATION *	FIRING ACTIVATION **
PROBE DESCENT DEVICE	1	1	Separation strap + activation circuit in PCDU (H/W)	Arming timer (H/W) initiated by CASU = Ta	CDMU (POSW)	CDMUs at T0
BACK COVER MECHANISM	3				CDMU (POSW)	CDMUs at T0 + 2.5s
FRONT SHIELD MECHANISM	3	2		Arming timer (H/W) initiated by CASU = Ta + 25.17s delay	CDMU (POSW)	CDMUs at T0 + 32.5s
GCMS	2	3		Arming timer (H/W) initiated by CASU = Ta + 46.14s delay	CDMU (POSW)	CDMUs at T0 + 50s and T0 + 58.125s
DISR COVER	1				CDMU (POSW)	CDMUs at T0 + 1mn6.25s
PARACHUTE JETTISON MECHANISM	3	4		Arming timer (H/W) initiated by CASU = Ta + 5mn1.99s delay	CDMU (POSW)	CDMUs at T0 + 15 mn
TOTAL	13					

* no cross-strap of commands for nominal and redundant chains

** cross-strap of commands for nominal and redundant chains activation = switching ON

TABLE 2.2-1 PYROLINES ACTIVATION

D5

2.2.4-4 Probe Harness Subsystem (PHSS)

The overall mission requirements for the harness are to provide interconnections for distribution of power, signals, scientific data, pyro, umbilical.

It will interface between the different subsystems EPSS, CDMS, PDRS, SEPS, ISTS, and the experiment electronics.

The Probe harness is made of three main parts with separate routing:

- Power Distribution
- TM/TC distribution
- Pyro distribution up to pyro devices.

It is fixed on to the Probe experiment platform at the lower and upper faces, some bundles are fixed on struts for pyro and umbilical connections.

Metallic backshells are used for specific circuits such as pyro distribution up to pyro devices and for ESD shielding purpose.

The harness routing is given in Figures 2.2-13 to 2.2-15.

2.2.4-5 Umbilical (USM)

The main function of the umbilical is to transmit electrical power, informations and data and commands between Orbiter and Probe during the attached mode of the Mission up to the separation.

The USM ensures a clean electrical separation during Probe ejection (short circuits and other electrical anomalies to be avoided).

After separation, the USM is protected by a cover, on both Orbiter and Probe sides, to close the faraday cage and comply with insulation and grounding requirements.

The following table shows the affectation of power lines and signal lines on the 3 umbilical connectors.

Umbilical A	Umbilical B	Umbilical C
SEPS Temperature 1	Separation Strap 2	SEPS Temperature 3
SEPS Temperature 2	Orbiter Power 4	SEPS Temperature 4
Probe Temperature 1	Orbiter Power 5	Orbiter Power 1
Probe Temperature 2	MLC B Address	Orbiter Power 2
Orbiter Power 3	MLC B Data	MLC A Address
Energy Safety Loop	MLC B Clock	MLC A Data
Arming Safety Loop		MLC A Clock
Input Relays Loop	RF BITE B	
Timer Relays Loop		RF BITE A
Separation Strap 1		

2.2.5 Software design

The Huygens software is partitioned into two functionally independant parts, one resident within the Probe CDMU, the Probe on board software (POSW) and one resident within the PSA on board the Orbiter, the Support Avionics Software (SASW).

a. POSW

The POSW is in control of the following major functions:

- the Timing Management responsible of:
  - Providing a Real Time Counter (**RT Counter**) from the RTI
  - Providing a Mission Time Counter (**MT Counter**) from the RTI (synchronous with the RT Counter)

- the Telecommand Management responsible of:
  - collection and Validation of TCs
  - Execution of CDMS TCs
  - Forwarding of Experiment TCs

- the Telemetry Management responsible of:
  - Collection of Experiment Packets
  - Construction of CDMS HK Packets
  - Transmission of TM Transfer Frames

- the Probe Mission Management responsible of:
  - Detection of Titan atmosphere entry to determine the T0 event (initial "pilot" parachute deployment)
  - Execution of Mission Timeline Tables
  - Transmission of Descent Data Broadcast (DDB) to the Experiment at a regular cadence
  - Determination of the Spacecraft Dynamical State

POSW Architecture

The Probe on-board S/W is a hard real time embedded system which is written in ADA. The S/W is mission critical and completely deterministic. A hardware generated interrupt, a "heartbeat" is used to drive normal processing activities. This heartbeat is known as the Real Time Interrupt and occurs every 125ms. Once the heartbeat occurs POSW schedules execution of all functionality, namely Probe mission management, telecommand management and telemetry management in a simple iterative manner. POSW essentially uses a simple cyclic executive driven at 8 Hz.

Much of the POSW functionality is executed each 125ms period, or each computed unit of time as it is also known. However several sub-frequencies also exist. Activities such as Probe spin and altitude determination and DDB transmission are conducted at 0.5 Hz.

The transfer of telemetry transfer frames is performed by POSW each second. This transfer is initiated by the telemetry interrupt which is raised when the CDMU requires more data for transmission.

During nominal processing POSW only expects the RTI and TMI interrupts to occur. The raising of any other interrupt is due to an error condition and POSW will perform appropriate recovery actions. Ada exception handling is used throughout the S/W to detect and recover from unforeseen events. In addition a CUT overrun mechanism is incorporated into the S/W to allow recovery from processing overruns.

The POSW has two operational modes. One is Mission mode which is the absorbing state. This mode provides all the functionality required for software operations in all phases of the Mission. The other mode is a brief transitory mode used during startup. The initialisation mode lasts for 15 seconds afterpower ON and is essentially the configuration of the S/W for the Mission. Any software patches stored in EEPROM are applied to RAM during this mode. Unless otherwise stated, all descriptions heregiven are applicable to Mission Mode.

Mission reprogrammability is possible via an EEPROM. During the Cruise phase, software patching which contain the modified data are stored into EEPROM. These patches are subsequently applied by POSW when next energised, and POSW executes the modified mission.

b. SASW

The SASW is in control of the following major functions:

- the Timing Management responsible of:
  • Providing a Real Time Counter (**RT Counter**) from the RTI

- the Telecommand Management responsible of
  • Collection and Validation of TCs
  • Execution of PSA TCs
  • Forwarding of POSW and Experiment TCs

- the Telemetry Management responsible of:
  • Construction of SASW PSA HK Packets
  • Transmission of Super Packets/Dump Super Packets

- the BIU Management responsible of:
  • Receiving TCs
  • Sending TMs
  • Receiving Spacecraft Time and Telemetry Mode
  • Recovery from BIU Failures

SASW Architecture

The SASW is a hard real time embedded system which is written in ADA. The S/W is mission critical and completely deterministic. The RTI broadcast generated by the CDS on BIU Bus is used to drive normal CUT processing activities. The Real Time Interrupt (RTI) occurs every 125ms. Once the RTI occurs SASW schedules execution of all CUT level functionality, namely Probe telecommand management and telemetry management in a simple iterative manner. Superimposed on this cyclic scheduling is the interrupt level processing that is required to handle the arrival of the Probe Frame, the programming of the DMA to transfer the frame into BIU RAM and the handling of the subsequent completion of the DMA transfer.

Mission reprogrammability is possible via an EEPROM. During the Cruise phase, software patching which contain the modified data are stored into EEPROM and only applied to main RAM during the next initialisation sequence.

2.2.6 Budget summary

2.2.6-1 Mass

Hereafter is the system level mass breakdown.

	Weighted Mass (Kg)	
	PROBE	PSE
FRSS	78.75	
BCSS	16.13	
SEPS	11.40	10.29
DCSS	12.34	
ISTS	41.41	
THSS	19.61	1.30
EPSS	44.53	
PHSS	12.61	
CDMS	23.64	
PDRS	5.86	16.30
RUSO		1.90
TUSO	1.90	
EXPERIMENTS	43.27	
Mechanical Hardware	0.40	
DISR cover	3.92	
Balance Mass	2.85	
TOTAL	318.62	29.79
	348.41	

TABLE 2.2-2 SYSTEM MASS BUDGET

D5

2.2.6-2 MCI

Mass properties are measured ones, correlated during FM physical properties test and computed for the configurations occuring during Probe mission:

- Cruise Configuration (including SED part on Orbiter)
- Begin Entry Configuration
- End of Entry Configuration [front face - FRSS MLI - ablated (AQ60) FRSS]
- Descent under Main Parachute with FRSS
- Descent under Main Parachute without FRSS and without DISR Cover
- Descent under Drogue with Drogue
- Descent Configuration without mass of Drogue, (only Descent Module)

and are gathered in Table 2.2-3.

Phase	Mass (Kg)	CG Location (mm)			INERTIA (m^2 x kg)		
		Xsat	Ysat	Zsat	Ix	Iy	Iz
Cruise Phase	330.23	75.65	1.69	5.50	136.50	80.29	77.51
Begin. Entry Phase	318.62	75.44	1.75	5.38	126.17	74.63	71.57
End Entry Phase	309.72	82.54	2.48	5.13	126.11	74.30	71.30
Under Main with FRSS	287.60	65.19	2.64	5.46	113.20	66.00	63.19
Under Main without FRSS	206.91	81.33	3.67	1.17	38.60	25.62	23.61
Under Drogue with Drogue	201.51	71.83	-0.52	3.68	38.23	24.71	22.70
Descent Phase	200.48	69.22	-1.46	5.46	38.49	24.51	22.93

TABLE 2.2-3 PROBE MCI

2.2.6-3 Power and energy

Table 2.2-4 gives the Probe consumption and allocation for Coast and Descent phases.

Table 2.2-5 gives the PSE power budget during the Relay Link mode.

Tables 2.2-6 and 2.2-7 give the Probe system consumption and allocation during checkouts when the Probe is powered by the Orbiter.

Table 2.2-8 gives the nominal Probe energy budget.

Annex 1 provides the worst case budgets.

See 1-minute resolution of Power data in Doc HUY.AS/c.100.OP.0384:
Table 1.9-20 for Checkout 1
Table 1.9-21 for Checkout 2
Table 1.9-22 for Descent

D5

	COAST		PRE-ENTRY ENTRY		DESCENT without Proximity Sensor		DESCENT with Proximity Sensors	
	BUDGET	Allocation	BUDGET	Allocation	BUDGET	Allocation	BUDGET	Allocation
PDRS Probe	0.0		10.6	11.2	78.1	86.0	78.1	86.0
CDMS	0.31	0.5	19.6	30.0	19.3	30.0	29.8	45.0
Payload (max)	0.0		48.5	60.0	88.2	190.0	82.1	190.0
EPSS (Pyro)	0.0		1.7	1.7	1.7	1.7	1.7	1.7
PCDU losses	0.0		23.0	25.0	40.0	47.3	41.0	47.3
Sec. Power	**0.31**	**0.5**	**80**	**101**	**187**	**306.0**	**192**	**321.0**
Harness losses 0.5% of Sec. Power	0.0		0.40	< 1% on each power supply	0.94	< 1% on each power supply	0.96	< 1% on each power supply
TOTAL	**0.3**	**0.5**	**103.7**	**126.2**	**228.1**	**353.3**	**233.6**	**368.3**

Margin	84%		22%		55%		58%	

in Watts

Data from SFT3 (DSS report for FM Probe: HUY_MBB_520_TR_0117)

TABLE 2.2-4 PROBE MISSION PHASE POWER BUDGET

	(S0-45min up to S0-15min)			
	Average Budget	Peak Budget (*)	Allocation	Comments
PSAs + RFE	50.9	-	55	
RUSO	19.5	-		warm-up
TOTAL PSE	70.4	-	75	

Margin	6 %	-

(*) no peak identified

	(S0-15min up to S0+153min)		
	Average Budget	Allocation	Comments
PSAs + RFE	50.9	55	
RUSO	10.00		steady state
TOTAL PSE	60.9	75	

Margin	19 %

PSAs and RFE values are measured values SFT1 FM test report
RUSO values from ESA fax ref: PY/2.0/MV/6252/sp dated 30/09/96

TABLE 2.2-5 PSE POWER BUDGET DURING RELAY LINK MODE

	PSE ON (TCXO) PROBE ON (TCXO) GCMS1 ON (*)	HASI ON (*)	ACP1 ON DISR 1 ON SSP ON	ACP1 OFF	ACP 1/3 ON DISR OFF HASI OFF GCMS OFF
	S0 - 30 S0 - 11	S0 - 11 S0	S0 S0 + 110	S0 + 110 S0 + 140	S0 + 140 EOM
PSA A + RFE	25.3	25.3	25.3	25.3	25.3
PSA B + RFE	25.6	25.6	25.6	25.6	25.6
RUSO	0	0	0	0	0
Total	50.9	50.9	50.9	50.9	50.9
TRANSMITTER A	5.4	5.4	5.4	5.4	5.4
TRANSMITTER B	5.4	5.4	5.4	5.4	5.4
CDMS A and B	19.6	19.4	19.4	19.4	19.4
EPSS	39.4	40.3	43.1	42.4	44.1
Total	69.8	70.5	73.3	72.6	74.3
ACP	0	0	3.5	0	64.7
DISR	0	0	12.2	8.7	0
TUSO	0	0	0	0	0
GCMS	17.7	17.7	26.3	25	0
HASI	0	11.4	11.5	11.4	0
SSP	0	0	10.4	10	10.1
Total	17.7	29.1	63.9	55.1	74.8
TOTAL	**138**	**150**	**188**	**178**	**200**
Power Allocation	262	262	262	262	262
Margin (W)	124	112	74	84	62
Margin (%)	47%	43%	28%	32%	24%

(*) TUSO is switched ON for about 7 seconds during this phase (9w)

PSE data: from SPT1 on FM Probe (report HUY_MBB_520_TR_0095)
Probe System data: from SPT4 on FM Probe (report HUY_MBB_520_TR_0136)
EPSS dissipation: ETCA ADP for FM2/SN 03 PCDU
PAYLOAD data: from SPT4 on FM Probe (report HUY_MBB_520_TR_0136)
Warning: peaks shorter than 16s may not be sampled on TMs

in Watts

(From FAR RID ESA-SY-021)

TABLE 2.2-6 PROBE SYSTEM CHECK OUT POWER BUDGET DISR DESCENT SIMULATION MODE ESTIMATED VALUES C/O SCENARIO 1

D5

	PSE ON RUSO ON	PROBE ON TXs ON GCMS ON TUSO ON	HASI ON	ACP 1 ON DISR 1 ON SSP ON	DISR OFF	ACP 1 OFF	ACP 1/3 ON HASI OFF GCMS OFF
	S0 - 60 S0 - 36	S0 - 36 S0 - 18	S0 - 18 S0	S0 S0 + 75	S0 + 75 S0 + 110	S0 + 110 S0 + 140	S0 + 140 EOM
PSA A + RFE	25.3	25.3	25.3	25.3	25.3	25.3	25.3
PSA B + RFE	25.6	25.6	25.6	25.6	25.6	25.6	25.6
RUSO	19.5	11	10	10	10	10	10
Total	70.4	61.9	60.9	60.9	60.9	60.9	60.9
TRANSMITTER A		5.3	5.3	5.3	5.3	5.3	5.3
TRANSMITTER B		5.3	5.3	5.3	5.3	5.3	5.3
CDMS A and B		19.8	19.8	19.8	19.8	19.8	19.8
EPSS		40.7	41.5	43.9	43.4	42.5	41.3
Total		71.1	71.9	74.3	73.8	72.9	71.7
ACP	0	0	0	3.7	3.7	0	23.3
DISR	0	0	0	14	0	0	0
TUSO	0	17.4	17.4	9.4	8.8	8.8	8.8
GCMS	0	17.1	15.3	24	32.6	25.8	0
HASI	0	0	11.2	10.9	11.6	11.4	0
SSP	0	0	0	10.5	10.2	10.3	10
Total	0	34.5	43.9	72.5	66.9	56.3	42.1
TOTAL	70	167	176	207	201	190	174
Power Allocation	262	262	262	262	262	262	262
Margin (W)	192	95	86	55	61	72	88
Margin (%)	73%	36.2%	32.7%	20.8%	23.1%	27.5%	33.4%

PSE data: from SPT1 on FM Probe (report HUY_MBB_520_TR_0095)
Probe System data: from IST2 on FM Probe (rdirect readings on supplied curves)
Warning: short peaks as CDMU TC cannot be sampled on TMs: up to 12w shall be added to each CDMU peak power
EPSS dissipation: ETCA ADP for FM2/SN 03 PCDU
PAYLOAD data: from IST2 on FM Probe

in Watts

(From FAR RID ESA-SY-021)

TABLE 2.2-7 PROBE SYSTEM CHECK OUT POWER BUDGET
DISR HEALTH AND CALIBRATION MODE
ESTIMATED VALUES C/O SCENARIO 2

D5

Resources Budget	Nominal Case 0°C	Hot Case 10°C
Fresh energy per battery module (Wh)	206	227.6
Total energy (5 fresh batteries) (Wh)	2059	2276
Worst Case Capacity loss per string (Ah)	1.51	1.85
Total Worst Case Energy losses (Wh)	520	637
TOTAL AVAILABLE ENERGY (Wh) 5 batteries	1539	1638
with 1 string failure and 1 cell failure per string	1184	1260

Notes:
- Capacity (10°C) = 0.948 * Capacity (20°C)
- Capacity (0°C) = 0.858 * Capacity (20°C)
- Fresh energy for battery is computed with 7Ah at 20°C
  --> 2.65V * 7Ah * 13 = 240Wh per module
- 1260 = 1638 * 25/26 * 4/5

	Coast 22 days (W)	Pre-entry & Entry 28 min (W)	Descent without Prox. Sens. 32mn (W)	Descent with Prox. Sens. 2h05mn (W)	ENERGY (Wh)
PDRS PROBE		10.7	78	78	209
CDMS	0.31	19.3	19.3	30.1	261
EPSS (Pyro)		1.65	1.65	1.65	5
PAYLOAD (max) (system allocation)					325
Probe failure					0
Exp. failure					0
PCDU losses		26.5	34.5	37.2	99
Harness losses 0.5%		0.16	0.49	0.55	3
Power Total	0.31	58	134	147	
Pre. sep. checks					50
Energy Total					**952**
Energy Available:					
nominal T profile					1539
hot case					1638
Margin %					
nominal T profile					**61.64%**
hot case					**72.03%**

Computations take into account:
- a maximum duration for the descent phase of 2h37mn
- a maximum duration for the coast phase of 22 days + 2 days max between Mission Timer Unit loading and separation of the Probe from the Orbiter
- allocation for pre-separation checks of 50 Wh

(From FAR RID ESA-SY-022)

TABLE 2.2-8 NOMINAL PROBE ENERGY BUDGET (after Separation)

D5

2.2.6-4 RF link

Table 2.2-9 gives the RF link budget for an ODT value of 4 hours.

F = 2040 MHz

1 ST SATURN ORBIT (NOMINAL CASE)	MARGIN ON CARRIER RECOVERY	MARGIN ON DATA RECOVERY
Beginning of mission	8.5	7.5
End of mission	8.8	7.8

F = 2098 MHz

1 ST SATURN ORBIT (NOMINAL CASE)	MARGIN ON CARRIER RECOVERY	MARGIN ON DATA RECOVERY
Beginning of mission	7.8	7.1
End of mission	6.4	5.7

F = 2040 MHz

2 nd SATURN ORBIT (NOMINAL CASE)	MARGIN ON CARRIER RECOVERY	MARGIN ON DATA RECOVERY
Beginning of mission	8.5	7.5
End of mission	8.8	7.8

F = 2098 MHz

2 nd SATURN ORBIT (NOMINAL CASE)	MARGIN ON CARRIER RECOVERY	MARGIN ON DATA RECOVERY
Beginning of mission	7.8	7.1
End of mission	6.4	5.7

TABLE 2.2-9 RF LINK BUDGET

2.2.6-5 TM/TC

Tables 2.2-10 (a and b) and 2.2-11 give the TC/Commands and Telemetry budgets respectively.

Terminology:
- Command signal = transfer of information from a specific unit to an application which is not directly addressable from the ground.
- Telecommand = transfer of information between two units of the Probe which is accessible by the ground through the umbilical during checkout or by reprogrammation of the MTT prior to the separation.

	CHANNEL A		CHANNEL B	
destination	ON/OFF	ML16	ON/OFF	ML16
CDMU A				
CDMU B				
Prox. S A				
Prox. S B				
Temp				
MTU		3		3
CASU				
RASU				
GCMS		1		1
HASI		1		1
DISR		1		1
ACP		1		1
SSP		1		1
TUSO				
PYRO A	20		1	
PYRO B	1		20	
PCDU	33		33	
TX A	4			
TX B			3	
TOTAL CDMU	58	8	57	8
CDMU capability	72	14	72	14

CDMU A		1		
CDMU B				1
RUSO				
LNA A				
LNA B				
PSA A	4	1		
PSA B			1	1
TOTAL PSA	4	2	1	2

Source: HUY.AS/c.100.DB.0204

TABLE 2.2-10 (a) TC BUDGET

D5

Destination	ON/OFF
PYRO 1	
PYRO 2	
PCDU	10
TOTAL MTU	10
MTU Capability	10
TX A	1
PYRO 1	4
PYRO 2	
PCDU	7
TOTAL ARMING TIMER A	12
Arming Timer A Capability	16
TX B	1
PYRO 1	
PYRO 2	4
PCDU	7
TOTAL ARMING TIMER B	12
Arming Timer B Capability	16
PYRO 1	1
PYRO 2	1
TOTAL PCDU	2

TABLE 2.2-10 (b) COMMAND BUDGET

D5

	CHANNEL A						CHANNEL B					
	A	A°	S	S+D	B	R	A	A°	S	S+D	B	R
CDMU A/CDMU	4	2			4*	2						
CDMU B/CDMU							4	2			4*	2
Prox. S. A/CDMU	1		1						1			
Prox. S. B/CDMU			1				1		1			
Temp/CDMU		12						12				
MTU/CDMU			3		1				3		1	
CASU/CDMU	3						3					
RASU/CDMU	2						2					
GCMS/CDMU			1	1					1	1		
HASI/CDMU			1	1		1			1	1		1
DISR/CDMU			1	1					1	1		
ACP/CDMU			1	1					1	1		
SSP/CDMU			1	1					1	1		
TUSO/CDMU	3				1		3				1	
PYRO 1/CDMU					13	1						
PYRO 2/CDMU											13	1
PCDU/CDMU	21				14	5	21				14	3
TX A/CDMU	4				1	1						
TX B/CDMU							4				1	1
TOTAL CDMU	38	14	10	5	34	10	38	14	10	5	34	8
CDMU capability	48	14	10	5	40	16	48	14	10	5	40	16

RUSO/PSA	3				1							
LNA A/PSA	1											
LNA B/PSA							1					
PSA A/PSA	2	1	4		1	2						
PSA B/PSA							2	1	4		1	1
TOTAL PSA	6	1	4	0	2	2	3	1	4	0	1	1

Pyro/Launch						2
PCDU/Orb.						2
PSE/Orb.		8				
Probe/Orb.		2				

A° = analog temperature sensor

Source: HUY.AS/c.100.DB.0204

* only 3 are transmitted

TABLE 2.2-11 TM BUDGET

DS

2.2.6-6 Software Budgets

Table 2.2-12 gives CPU and memory load budgets.

MEMORY OCCUPANCY

	SPACE USED (Kwords)		MARGIN
POSW	PROM	32.5	49%
	RAM	48.8	23%
	TM RAM	4	75%
SASW	PROM	20.1	37%
	RAM	38.5	39%
	BIU RAM	6.2	22%

CPU WORK LOAD

Margins wrong

[redacted]

	PERIOD	WORST CASE	MARGIN
POSW	RTI	96ms	23%
SASW	RTI	45ms	62%
	DTSTART	3.2ms	28%

TABLE 2.2-12 SOFTWARE BUDGETS

D5

2.2.6-7 Descent Time error

The main contributions are listed in Table 2.2-13 and all errors are root-sum-squared.

ERROR SOURCES	UNCERTAINTY	CONTRIBUTIONS (mn) MIN	MAX
Atmospheric density		-7.4	6.6
Probe mass	1.5%	-1.0	0.7
All parachutes SCx + winds (1)	15%	-7.3	7.0
Titan topography	2.5 Km	-8.0	8.3
Icing (at 50 km)	5 Kg	-1.7	0.0
Entry module SCx	10%	-0.4	0.0
Entry angle	59° - 68°	-0.3	0.3
T0 deceleration uncertainty	6.7%	-0.3	0.0
Modelisation		-6.0	6.0
QUADRATIC SUM		-14.6	14.1
System margin		-0.4	0.9
TOTAL		-15.0	15.0

(1) Parachute oscillations induce drag change

TABLE 2.2-13 DESCENT DURATION ERROR BUDGET

2.2.6-8 Entry Attitude error

Table 2.2-14, extracted from CASSINI Orbiter/HUYGENS Probe separation dynamics ICD reminds the allowable Probe attitude error at entry, as well as different error sources allocation.

ERROR SOURCE	MAGNITUDE (Degrees)
Velocity direction at delivery to specified separation orientation	1.9
Orbiter pointing error at Probe separation SED X-axis to I/F mating plane	0.12
Probe interface to inertial space	2.0
Orbiter rotation during Probe release	0.05
Sum of SED inertia axis to kinetic momentum (tau) and kinetic momentum to principal inertia axes (epsilon) = Poinsot angle	9.0
Probe principal inertia axis to Probe geometric X-axis (alpha)	0.5
Probe geometric X-axis and front shield axis of symmetry	0.5
Kinetic momentum during coast phase	1.0
Total error (RSS)	9.5

TABLE 2.2-14 ENTRY ATTITUDE ERROR BUDGET

2.2.6-9 CDMS Delay Budget

The delay between the two data transmission chains (in order to recuperate on the delayed chain data that could have been lost earlier on the non-delayed chain because of RF link loss as a consequence of a wind gust for instance or of a lightning strike) is fixed at 6 seconds.

D5

2.2.6-10 Science Packets Budget

The Science Packet allocation is given in Table 2.2-15.

	EPT1	EPT2	EPT3
ACP	1	2	2
DISR	75	74	71
GCMS	15	15	15
HASI	14	9	9
SSP	3	8	11
Payload Allocation	**108**	**108**	**108**
Margin	0	0	0

EPT = Experiment Polling Table
Packet cycle time = 16 seconds

TABLE 2.2-15 SCIENCE PACKET ALLOCATION

D5

2.2.6-11 Thermal/Temperatures Predictions

Table 2.2-16 and Figures 2.2-25 to 2.2-30 give the predicted temperatures for the different phases.

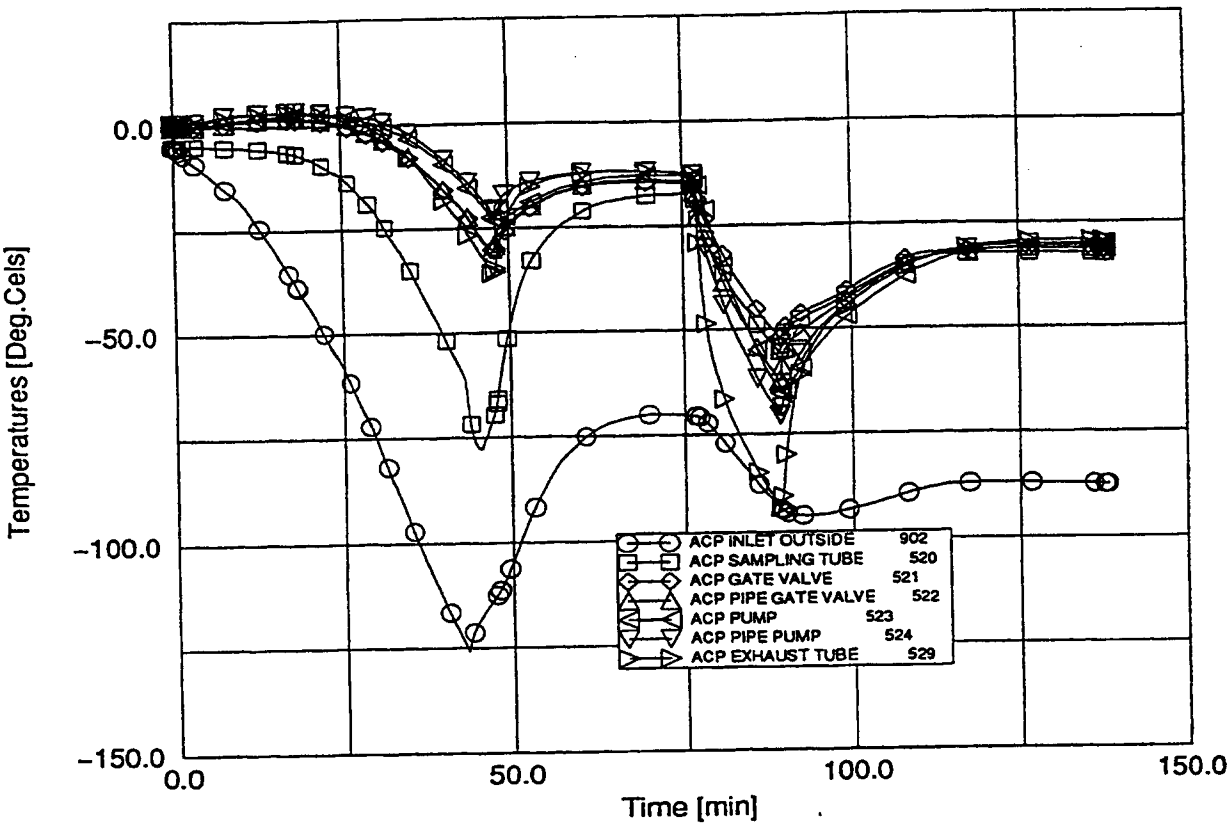
UNIT	DESIGN LIMITS OPER.	CRUISE 0.6AU	CRUISE 9AU	CHECK-OUT TMAX	COAST	ENTRY TMAX	DESCENT TMIN
ACP structure	-20/50	22	8	34	1	2	-45
ACP Elect.	-20/50	22	8	36	1	2	-28
GCMS housing	-20/50	23	9	43	1	3/8	-11/3
SSP Top Hat	-200/50	24	10	37	2	3	-199
SSP elect.	-20/50	24	10	45	2	3	1
HASI ACC.	-20/50	23	10	37	2	6	0
HASI DPU	-20/50	21	8	39	0	2	5
HASI I 1 & 2	-20/50	21/24	8/10	34/40	1/3	4	-8
HASI Booms	-200/40	-36	-51	-32	-62	-60	-198
HASI Stub	-200/40	-25	-39	-21	-49	-48	-190
DISR SH interior	-50/50	17	4	26	-4	-3	-74
DISR SH exterior	-200/40	4	-9	11	-16	-16	-155
DISR SH detector	-	-6	-20	1	-28	-28	-99
DISR Elect.	-20/50	24	11	35	4	4	-3
DISR Cover	-55/-25	-23	-36	-19	-45	-44	/
DWE (TUSO)	-20/50	22	8	42	1	6	2
Radar Antennas	-200/40	-27	-41	-23	-50	-49	-196
Probe Antennas	-200/40	-23/-18	-37/-31	-19/-14	-46/-40	-43/-38	-198

All temperatures are in °C.

For CDMS see § 4.1.1-4-3
For PDRS, see § 4.2.1-4-3
For EPSS, see § 4.3.1-4-3
For SEPS, see § 4.7.1-4-2
For DCSS, see § 4.8.1-4-4

TABLE 2.2-16 PREDICTED TEMPERATURES

D5



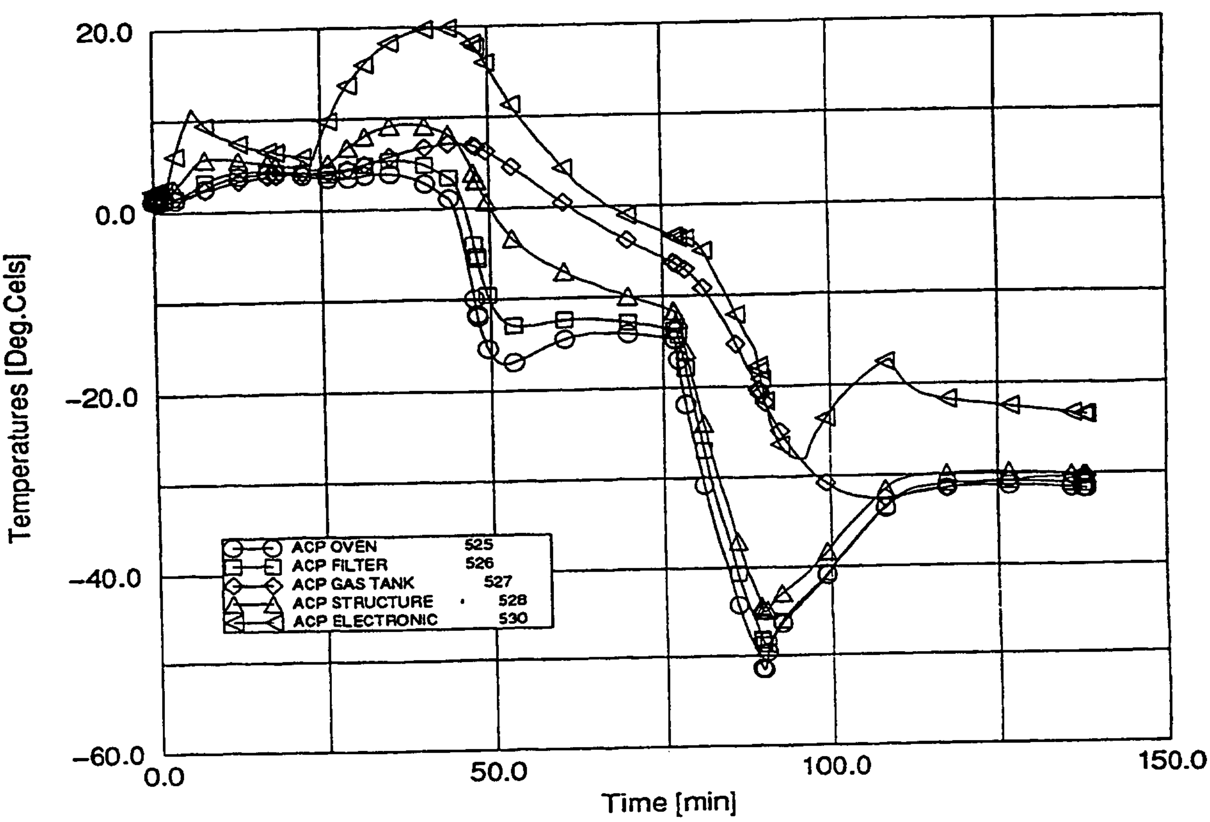
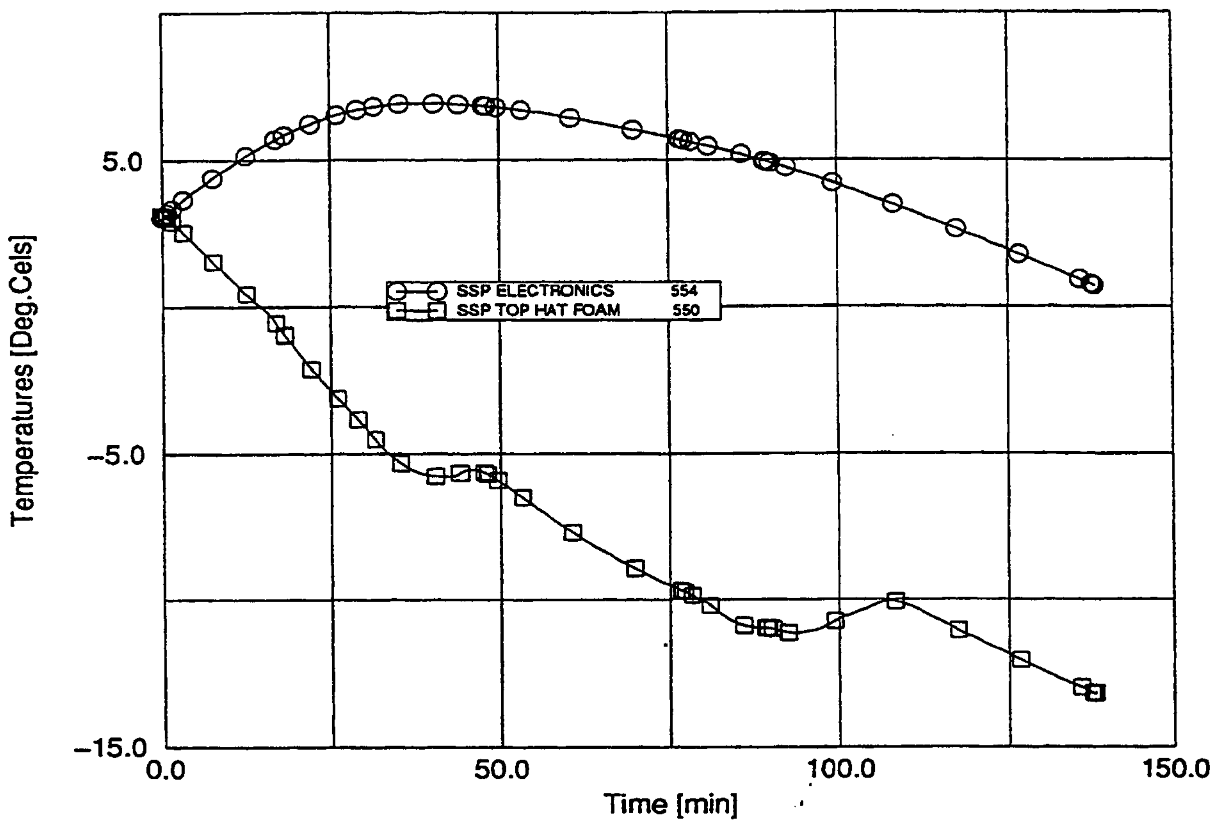


FIGURE 2.2-25 ACP TEMPERATURES DURING DESCENT



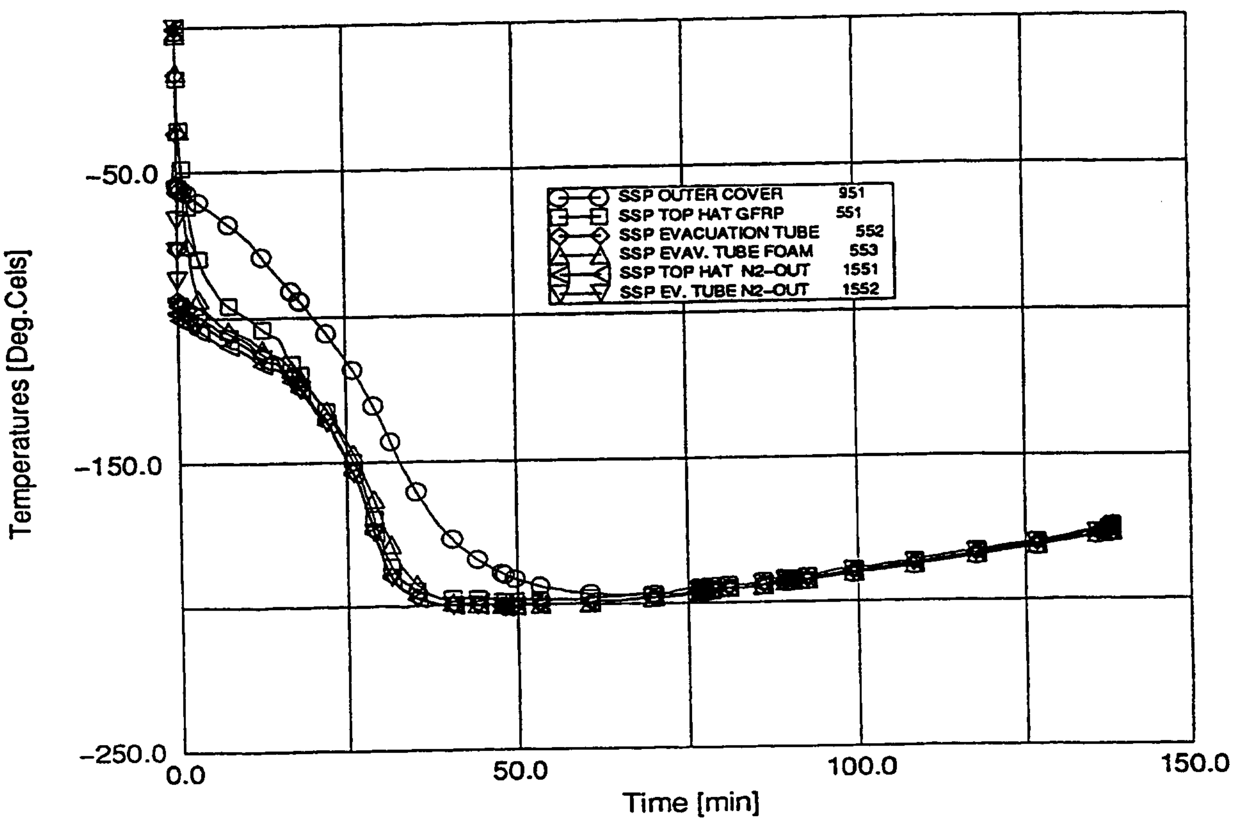


FIGURE 2.2-26 SSP TEMPERATURES DURING DESCENT

D5

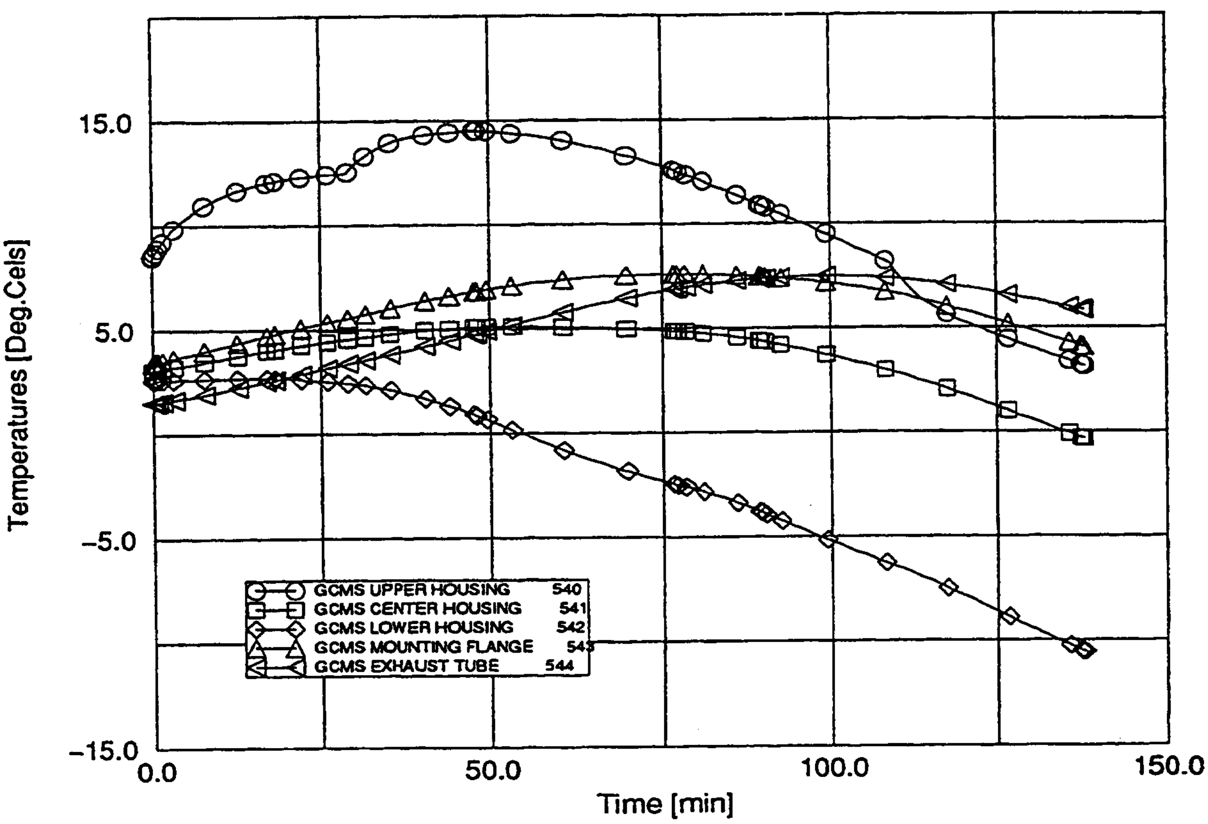
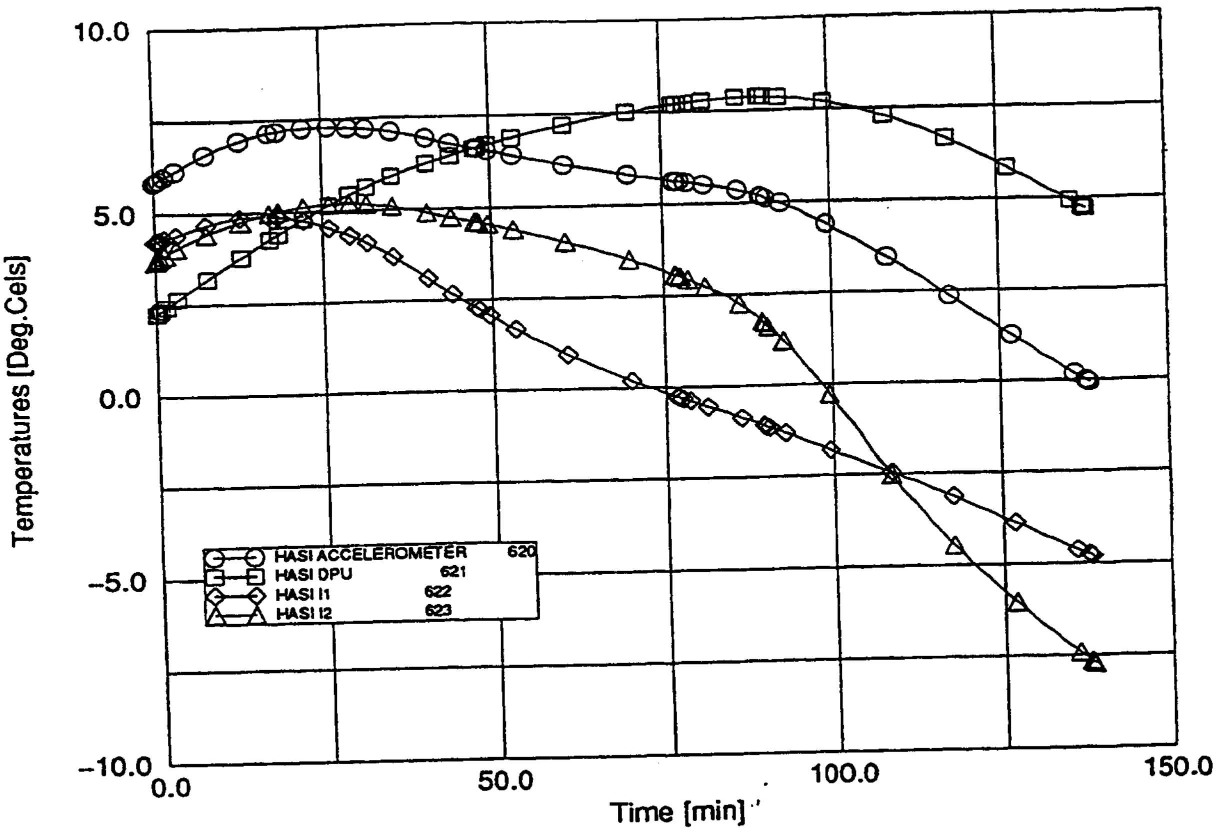


FIGURE 2.2-27 GCMS TEMPERATURES DURING DESCENT

D5



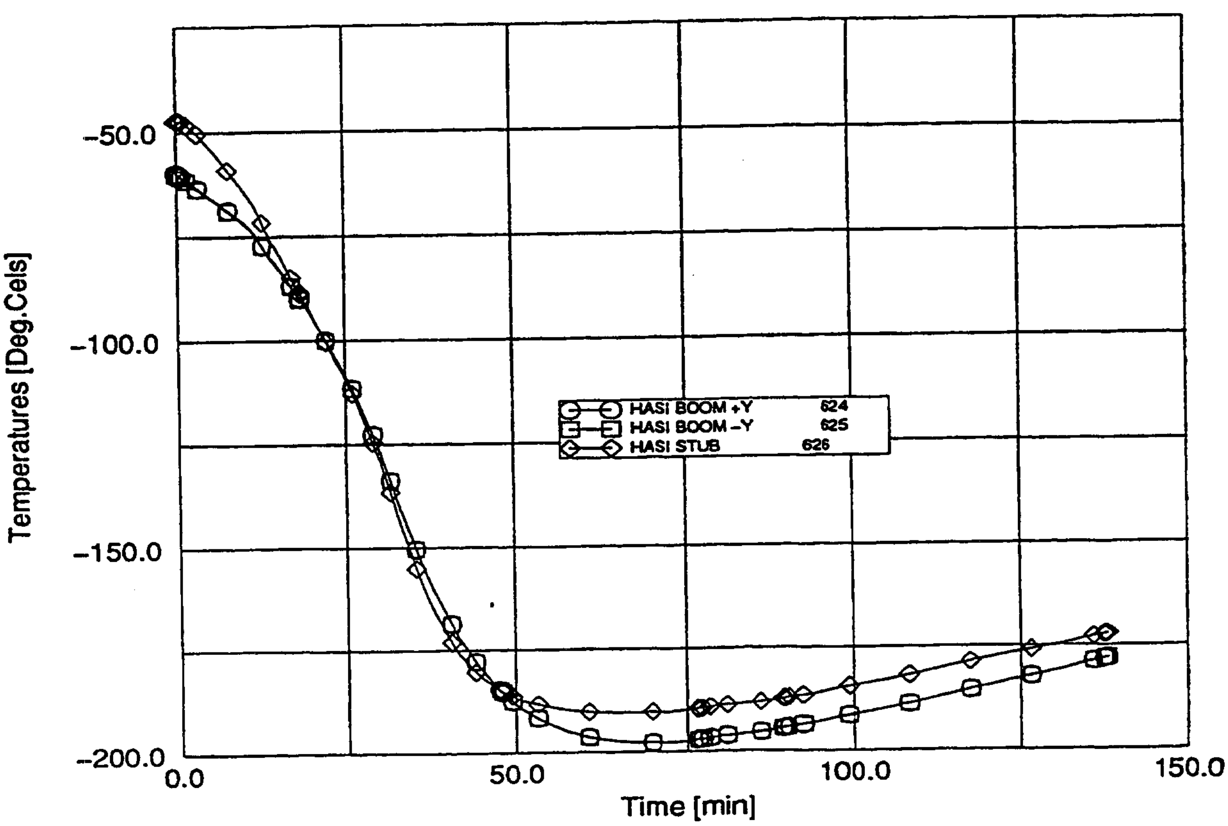


FIGURE 2.2-28 HASI TEMPERATURES DURING DESCENT

D5

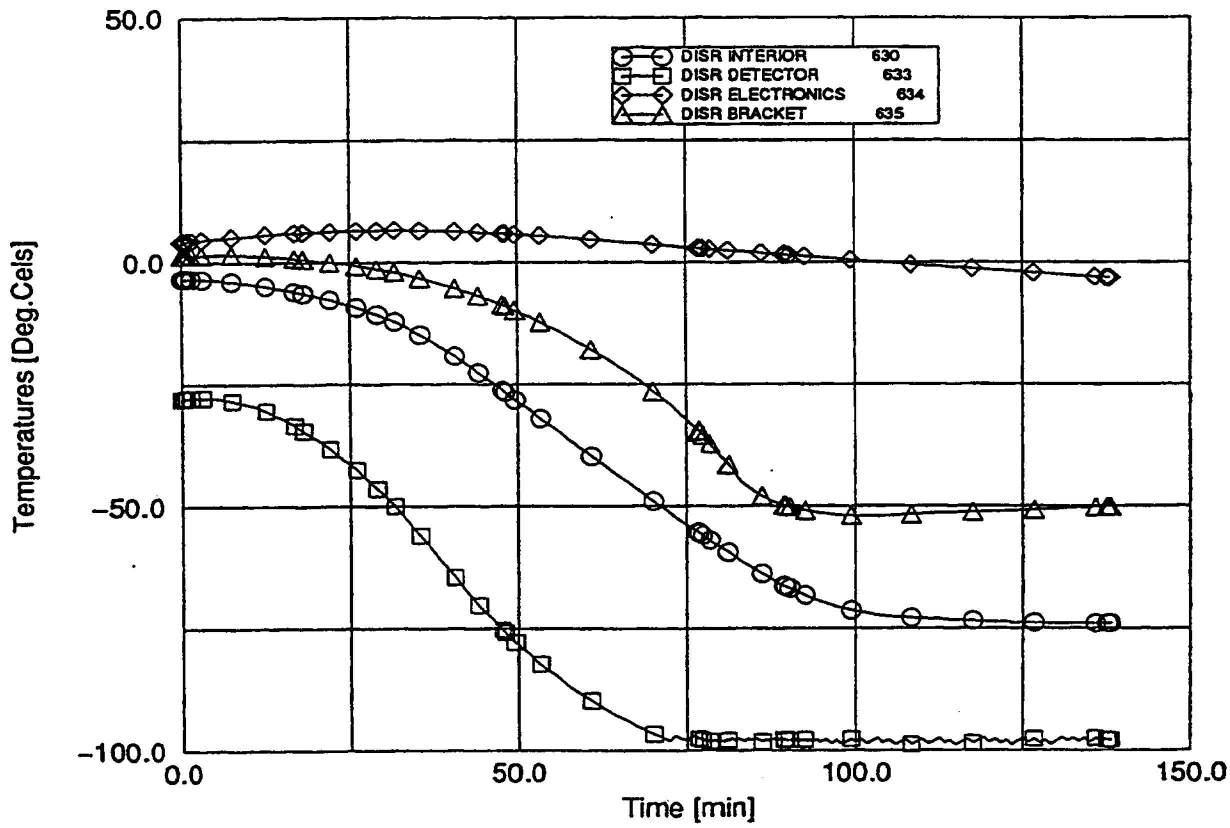


FIGURE 2.2-29 DISR TEMPERATURES DURING DESCENT

D5

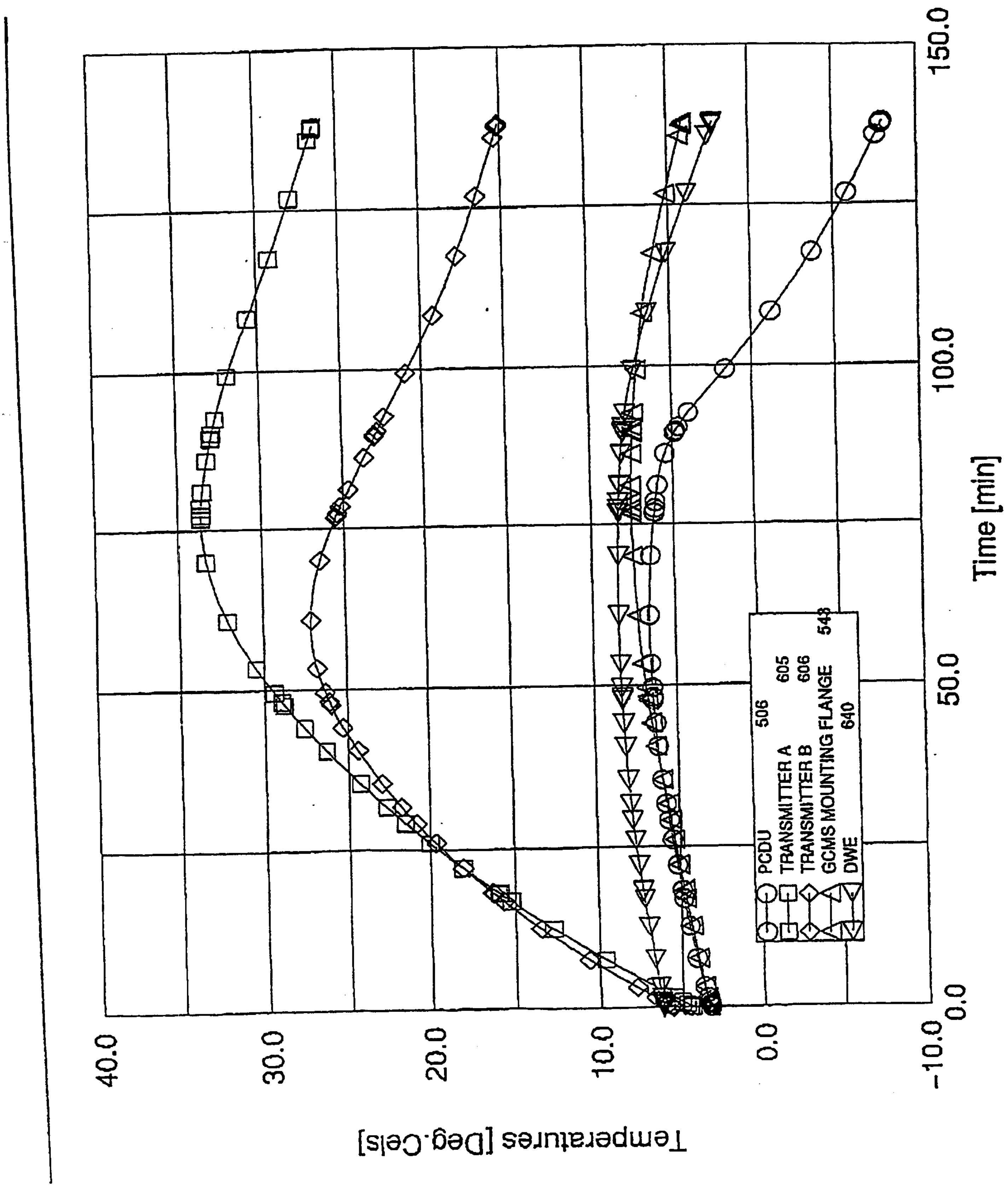


FIGURE 2.2-30 DWE TEMPERATURE DURING DESCENT

D6

3. PROBE SYSTEM OPERATIONS

In-flight operation of the Huygens Probe System will differ from that of conventional spacecraft because of three main features of its mission:

- the time taken to transmit telecommands from Earth to the spacecraft and to receive telemetry data in the reverse direction will be very long (of the order of one hour each way during Descent phase)

- there will be no telecommand link to the Probe after its separation from the Orbiter

- operations will be limited to the period of Coast, Entry and Descent through the Titan atmosphere plus in-orbit checkouts lasting about three hours which will be scheduled periodically during the Cruise phase and the Saturn orbit phase.

Therefore the operations concept is based on pre-programmed sequence controlled by timers.

This concept will also be adopted in the Cruise in-orbit checkouts, with the aim to follow as closely as possible the sequence of operations to be performed during the nominal Mission. A checkout is foreseen as soon as possible after launch to verify the integrity of mission-critical hardware following subjection to the launch environment. Special activities are foreseen during the Saturn orbit phase in preparation for the release of the Probe from the Orbiter.

As long as the Probe is attached to the Orbiter, Probe operations will be conducted from the Probe Operations Centre (POC) at ESOC in coordination with JPL, which is responsible for interactions with the Orbiter. All commands to the Probe will be routed from POC to the NASA Mission Operations System (MOS) located at JPL before uplink through the Orbiter Command and Data Subsystem (CDS).

During the whole mission, Science data and Housekeeping will be routed to POC for processing from the Orbiter CDS through the MOS.

After separation, operations will be controlled by the fully redundant Command and Data Management Subsystem (CDMS) issuing commands to the subsystems and limited commands to the experiments according to a programmed timeline.

For safety reasons, all potentially hazardous commands will require arming by a hardware timer, independent of the CDMS timer. This "Arming Timer" will be initiated by an axial deceleration measurement derived from CASU.

At appropriate times it will arm the various pyros in the pyrobox and energise certain devices in the PCDU. It will also control any other functions which need to be suppressed during the in-orbit checkouts. To ensure that all these functions are armed before activation, the CASU acceleration threshold is chosen to be greater than the threshold defining the start of the Descent phase.

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Once they have been turned ON by the CDMS, the experiments will control their own activities on the basis of time and altitude information provided to them in the Descent Data Broadcast (DDB).

Different phases timeline tables given hereafter refer to four main time events which are:

- Ts: time of Orbiter/Probe separation
- Tp: time of Probe activation
- S0: time of start of descent sequence
- Ta: arming time initiation

They refer also to five times:

- the Mission Timer Unit time as it is the MTU which provokes the Probe activation in Coast phase
- the Arming Time which corresponds to the operations controlled by the CDMU Arming Timer, such as PCDU protected devices energizing and pyrobox arming relays activation
- the POSW time which corresponds to the operations scheduled by the POSW through the CDMU
- the DDB time which corresponds to the payload operations controlled by themselves, only major payload operations are included for completeness in timeline tables
- the S0 related time which constitutes a common reference time and allows to date events resulting from operations.

Times depending on Entry/Descent profile are related to the nominal Entry/Descent profile.

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3.1 CRUISE PHASE

First, the Orbiter CDS will monitor the status of the Battery isolation relays and Timer relays after Launch.

The interval between subsequent checkouts in the Cruise phase will be nominally six months, but may vary between four and eight months, depending on any operational requirements of the Orbiter or its scientific payload. In addition, there will be some environmental conditions (e. g. Venus flyby, perihelion) under which it will not be desirable to activate the Probe. About two months after each checkout, by which time all acquired data should have been processed and analysed, a Checkout Review (COR) will be held to plan any special diagnostic or reconfiguration operations which have to be executed at the time of the next checkout.

The Cruise phase in-orbit checkouts will simulate as closely as possible the sequence of operations to be performed during the nominal mission of the Coast, Entry and Descent phases detailed in Tables 1.9-5 to 1.9-7 of HUM Operations Doc n° HUY.AS/.c.100.OP.0384.

The checkout sequences include 3 main times: the CDS time which is the time of TC issuing by the CDS, the S0 related time which is POSW time and the T0 related time which relates to the Descent Data Broadcast one.

This sequence comprises 4 timelines: the Coast Timer one, the Arming Timer one (H/W), the CDMS one (S/W) and the DDB one.

The powering up of the Probe by the Orbiter (through 7 SSPS) at the beginning of checkout simulates the Probe wake-up by the Coast timer and automatically starts the CDMS sequence.

The Arming Timer is responsible for activating arming relays in the pyrobox and energizing protected devices at PCDU distribution level. Due to the criticality of these activations, the Arming Timer (initiated by the CASU during the nominal sequence), is not simulated during checkout and consequently critical operations are suppressed.

Some Experiment switch ON excepted, the CDMS nominal sequence and DDB nominal sequence are performed as during the nominal mission, with simulation of the accelerometers signal by Suspend/Resume TC to enable to start the simulation of the Descent phase and by modification of the DDB by Alteration TC.

More, specific Experiment TCs are to be sent by the Orbiter CDS.

During checkouts, the Probe/PSE link is a low power RF link which enables to test the whole Transmitter, with the exception of High Power Amplifiers.

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3.1.1 Unit status

Two checkout sequences are foreseen.

The **Cruise checkout scenario 1** (run with the TCXOs only) called "DISR Descent simulation mode" is built according to the following ON/OFF sequence in which modification against previous step is indicated for each step:

- at S0 - 30 mn : (PSAs, RFE) ON
- at S0 - 29 mn : (PCDU, CDMUs, RASU, CASU, TXs, GCMS) ON, TUSO OFF
- at S0 - 11 mn : HASI ON
- at S0 : TUSO OFF, (ACP 1, DISR1, SSP) ON
- at S0 + 23 mn : GCMS disable valves
- at S0 + 110 mn : ACP 1 OFF
- at S0 + 140 mn : ACP 1/3 ON, (DISR, HASI, GCMS) OFF
- at S0 + 153 mn : (ACP 1/3, SSP) OFF

The **Cruise checkout scenario 2** (run with RUSO/TUSO only) called "DISR health and calibration mode" is built according to the following ON/OFF sequence:

- at S0 - 60 mn : (PSAs, RFE, RUSO) ON
- at S0 - 36 mn : (PCDU, CDMUs, RASU, CASU, TXs, TUSO, GCMS) ON
- at S0 - 18 mn : HASI ON
- at S0 : (ACP 1, DISR, SSP) ON
- at S0 + 20 mn : GCMS tholdscan
- at S0 + 35 mn : DISR internal calibration + GCMS lens scan 1
- at S0 + 75 mn : DISR OFF, GCMS high power mode
- at S0 + 82 mn : GCMS lens scan 2
- at S0 + 110 mn : ACP 1 OFF
- at S0 + 111 mn : GCMS calibrate
- at S0 + 140 mn : ACP 1/3 ON, (HASI, GCMS) OFF
- at S0 + 141 mn : ACP gate valve opening
- at S0 + 153 mn : (ACP 1/3, SSP, TUSO, RUSO) OFF

The corresponding power budget is given in paragraph 2.2.6.3.

3.1.2 Sequence of events

Tables 1.9-2 and 1.9-3 in HUM Operations Doc n° HUY.AS/.c.100.OP.0384 present the two checkout sequences of events. They take into account the following main constraints:

- one CDS telecommand at maximum per second, on each channel
- PSAs and TXs work on TCXO in checkout scenario 1. In checkout scenario 2, PSAs and TXs are in Mission Mode, RUSO/TUSO are selected.
- switch OFF of all 28V current limiters before Probe switch OFF (except TXs and TUSO).

The checkout scenario 2 implies about 2000 TCs, mainly due to GCMS operations. Specific telecommands such as software loading and patching, different spin values in DDB, final RUSO/TUSO selection are not included.

Checkout scenario 2 stands as L + 8 Days Checkout: it includes at Probe switch-ON, TCs for PCDU unit reset, i.e; TCs to open Battery input relays and Mission Timer unit relays. See Table 1.9-1 in HUM Operations Doc n° HUY.AS/.c.100.OP.0384.

3.1.3 System constraints and restrictions

In order to simulate the Mission sequence during the Cruise, special provisions will have to be made for these facilities which are peculiar to the Coast/Entry/Descent environments, namely coast timing and deceleration detection.

The methods of initiation/simulation, are as follows:

Tp: turning ON the power to the Probe from the Orbiter will automatically start the CDMS sequence as described above, thus simulating the Coast timer

Ta: the arming timer cannot be simulated to ensure that:

- no pyros will be armed, so firing commands issued from the CDMS will be ineffective
- no instrument booms or caps can be prematurely deployed
- the radar altimeter will not be activated inside the front shield
- the DISR lamp will not be tested

S0: will be simulated by sending a Suspend/Resume telecommand to the CDMS.

Additional telecommands will have to be available to the Probe during checkout for:

- telecommand insertion from the PSA such as units switch ON and OFF, TCXO/DWE selection, Experiment mode selection or specific commands
- telecommand to alter the DDB mission flag and the PSAs NCO frequency control word
- sequence suspension and resumption in order to introduce telecommands simulating accelerometers signal to start descent phase simulation and units switch ON and OFF different from the automatic ones
- loading and patching software
- inhibit TC to avoid CDMUs EEPROM/RAM transfer
- failure investigation
- sensor simulation:
    - linear accelerometer
    - spin measurement for the DDB by commanding different discrete values
    - in the absence of the radar altimeter the model-based information will continue to the simulated surface of Titan.

Checkout sequence must be restricted in order to be compatible with the power constraints, i.e. the power drawn from the Orbiter shall not exceed 262 W steady state.

Checkout sequence must be restricted in order to be compatible with the thermal constraints, in particular, Sun illumination of the Probe shall be avoided. See § 4.6.1-6 for Operational Constraints.

PSAs and TXs are in mission mode at switch ON i.e. default frequency includes doppler shift and RUSO/TUSO are selected, that means that frequency has to be changed at the beginning of checkout, TCXO is to be selected for PSA-A and TX-A in case DWE is switched OFF.

Two consecutive ON/OFF commands from MTT must be separated by at least 1 CUT i.e. 0.125 s.

All 28 V current limiters must be switched OFF before Probe switch OFF, the switching OFF of the current limiters is not mandatory but this lead to the overcurrent protection into the last connected SSPS when the total input power available decreases below the necessary value for the supplying of the output loads.

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Following constraints are devoted to Orbiter operations:

- as already mentionned, Sun illumination of the Probe must be avoided during checkout

- Cruise checkout must be scheduled following Flight Rule T2 in AD8

- telecommand cadence from CDS is limited to one per second

- the Orbiter shall not transmit any RF signal that will cause interference to the Probe system

- the BDR input relay must not be switched ON when the BDR section is already powered by the Orbiter. A delay of 30 seconds is required between switch OFF, either of SSPS "i" or Input Relay "i", and the new switch ON of BDR "i".

- the 7 SSPS have to be activated sequentially, in indifferent order, beginning with the two double SSPS (SSPS2 and SSPS3 then SSPS5 and SSPS6). The delay between the activation of the two switches of the double SSPS has to be lower than 495 ms. The delay for complete power ON shall be lower than 1370 ms. The delay between the last SSPS activation and switch ON of other 28 V limiters has to be greater than 2s in order to be sure that all the power is available at bus level

- following any powered ON Probe operation, including normal and aborted activity termination, the Probe activity restart time will be determined by considerations for the Probe and Orbiter systems, including but not limited to: electrical reset, transient thermal effects and payload sequence issues.

Specific TC operational constraints are given in § 6.1.4.

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3.1.4 Experiment special features

Experiments must be informed of the checkout phase through DDB, of the checkout suspension after a Suspend TC and also of the checkout de-activation before Probe switch OFF.

It is the intention that most Experiment operations which are specific to the checkout (e.g. sensor stimulation) will be preprogrammed in the instruments and activated by the experiments themselves on the basis of information contained in the DDB, including the checkout flag. Where this is not possible, telecommands can be sent from the PSA via the CDMS for such activities as mode control or power management.

Some specific operations cannot be operated such as GCMS injection valves opening. HASI accelerations will not be simulated. GCMS heaters can only operate for a short time.

ACP filter mechanism, pump electrovanes, oven and heaters can only run a limited time.

Following specific telecommands are identified:

- 2 x 6 TCs for DISR mode selection in Checkout 1 (DISR Simulated Descent)
- 2 x 30 TCs for GCMS Disable Valves in Checkout 1
- 2 x 6 TCs for DISR mode selection in Checkout 2 (DISR Health Check + Internal Calibration)
- 2 x (84 + 314 + 31 + 203 + 25) TCs for GCMS mode selection in Checkout 2 (GCMS tholdscan, lens scan 1, high power mode, lens scan 2, calibrate)
- 2 x 1 TCs for ACP Gate Valve Opening in Checkout 2

3.1.5 Diagnostic and reconfiguration activities

It is conceivable that analysis of data acquired during in-orbit checkout may reveal anomalies in the performance of an instrument or subsystem. Diagnosis of such problems may require the acquisition of specific data with the instrument in a configuration not foreseen in the nominal checkout sequence. Correction of faults may need a permanent reconfiguration, possible including an upload of (partially) modified software.

It is assumed that these activities will generally require specific telecommands to be inserted which are not part of the usual sequence. Since their specification will only be possible after completion of checkout data analysis they will normally performed at the next scheduled checkout This will give time for a proper validation of the required telecommand sequence before it is uploaded to the Orbiter.

Should a quick analysis of checkout data reveal that an instrument has a correctable fault which could prevent or seriously degrade the accomplishment of its scientific objectives, consideration will be given to requesting from JPL special facilities to carry out the necessary operations at the earliest opportunity.

D6

3.2 SATURN ORBIT PHASE

A full checkout will be performed as soon as possible after Saturn Orbit Injection, within approximately 7 days, to check the survival and performance of the Probe system after passage through Saturn's rings. This will also be the last opportunity to carry out any diagnostic tests.

It is intended that the final software load and reconfiguration if required, would take place as late as possible typically 5 weeks (TBC) before Orbiter/Probe separation, but allowing time for the data accumulated in the usual checkout sequence to be processed for verification. The final pre-separation checkout approximately 10 days (TBC) before separation will only permit a go/no-go decision for release as planned. No reconfiguration would be permitted then, since verification would not be possible. One exception is the TUSO switch ON command of the Mission Time Table which will be deleted through EEPROM and the TCXO selected in case previous check out evidenced a TUSO bad functioning. In this case, RUSO shall be OFF. Any anomaly detected that could jeopardise the Probe, or its mission as a whole, would imply postponement of separation to the second Saturn orbit.

Prior separation of the Probe from the Orbiter, the batteries will be depassivated and the MTU loaded with the appropriate value and initiated. The Depassivation operation will be performed eight days before separation while MTU loading is the last operation (max 2 days) before separation.

To check that both CDMUs are capable to load the MTU, an operation named "Redundant MTU Loading" will be performed in flight only once, must probably combined with the last checkout. It will allow to check that CDMU-A, which is the a-priori selected CDMU to load the MTU is still able to load in a proper way the MTU. In case, CDMU-A fails, it will be possible to modify the pre-separation MTU Loading sequence to perform MTU Loading via CDMU-B, without impacting the date of the Probe delivery.

Following paragraphs are limited to the final sequence as the previous ones on Cruise checkout are valid for Saturn orbit checkout.

3.2.1 Unit status

PSE is switched ON 20s before the Probe. Then, the PCDU, CDMUs, RASU, CASU will be switched ON through Orbiter SSPSs turn ON and the Transmitters low power part will be switched ON.

For Battery Depassivation, the adequate Experiments will be switched ON in order to set Probe load to 96W then switched OFF just before Probe and PSE will be switched OFF. For MTU Loading, only MTU will be switched ON.

3.2.2 Sequence of events

Table 1.9-4 (A) in HUM Operations Doc n° HUY.AS/c.100.OP.0384 gives the Depassivation operation which includes a reset of the pyro unit just after Probe switch-ON.
Table 1.9-4 (B) gives the MTU loading sequence timeline.
Table 1.9-4 (C) gives the Redundant MTU Loading sequence.
Table 2.9-16 gives the sequence to perform to load MTU via CDMU-B.
Table 2.9-17 gives the sequence to perform to select TCXO/RCXO.
Table 2.9-20 gives the Patch to apply to delete TUSO Switch ON in Pre-T0 MTT and in Post-T0 MTT.

3.2.3 System constraints and restrictions

Depassivation must be performed 8 days before separation and MTU Loading max 2 days before separation.

It is mandatory to perform Batteries Depassivation before activation of the MTU relays.

Telecommand cadence from CDS is limited to one per second.

Two consecutive ON/OFF commands from MTT must be separated by at least 1 CUT i.e. 0.125 s.

The 2 sequences will be performed with TCXOs. Experiments must be informed of the checkout suspension through DDB.

Experiments switch ON and OFF must be selected in order to satisfy a Probe load of 96 W.

Switch OFF of the Orbiter SSPS "i" is required before switch ON of the input relay "i", the delay between switch OFF of the SSPS and switch ON of the input relay must be greater than 30 seconds.

MTU loading must be performed with the best known Coast phase duration in order to ensure Probe wake-up at the most suitable date. This duration shall be provided with a resolution of 32 seconds.

Sequences have been defined in order to minimize the energy drawn from the batteries.

Orbiter failure during Depassivation would prevent the disconnection of the battery being depassivated, which could lead to loss of 1 battery. In order to protect against such a failure, a TC to patch into RAM a pre-T0 MTT comprising a sequence to disconnect all five batteries after 6 minutes has been implemented and is part of the sequence. These OFF commands will replace the Orbiter ones, if these have not been sent due to Orbiter failure, and will avoid energy consumption and battery depletion.

Downlink of the whole sequence, in particular, BDR currents, battery voltages and MTU values, is needed for the go/no go final decision.

The Orbiter must actuate the devices provoking the Probe separation; for 10 s before Probe separation and for 60 s hereafter, the Orbiter must not activate any thruster.

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3.2.4 Operations description

Depassivation

The PSE is switched ON, TCXO selected. The Probe is switched ON TCXO selected, the pre-To MTT is suspended just after CDMUs microprocessor initialisation end and experiment informed accordingly through DDB mission flag. Then the pyro unit is reset.

The Probe load is adjusted to 96W by switching ON Transmitters low power part and adequate Experiments in order SSPS do not trip OFF and to apply needed load (60W) on connected battery. Then the Battery Depassivation is performed in order to ensure suitable electrical characteristics of the 5 $LiSO_2$ batteries at beginning of mission by applying a load of at least 60W during 5 minutes sequentially on the 5 batteries.

The Probe is powered by the Orbiter double SSPS2-SSPS3 and one Battery which is Battery 1, 3, 4, 5 sequentially then by the Orbiter double SSPS5-SSPS6 and Battery 2.

Following last Battery Depassivation, all Probe loads except CDMUs, RASU, CASU and Transmitters are switched OFF just before PCDU OFF.

The PSE will be finally switched OFF.

The total duration of the Depassivation sequence is about 34 mn.

MTU Loading

The PSE is switched ON, TCXO selected. The Probe is switched ON TCXO selected, the pre-To MTT is suspended just after CDMUs microprocessor initialisation end and experiment informed accordingly through DDB mission flag. The Transmitters low power part are switched ON.

A first command from CDMU-A provokes the switch ON of the Timers 1 and 2 powered by the Batteries 2 and 3 respectively, a second command from CDMU-B provokes the switch ON of the Timers 2 and 3 powered by the Batteries 3 and 4 respectively. The 3 Timers are loaded sequentially in indifferent order by the CDMU-A.

Then, TUSO/RUSO are selected just before PCDU OFF.

The PSE will be finally switched OFF.

The total duration of the MTU Loading sequence is about 10 mn.

Redundant MTU Loading

The operation performs in sequence loading of the MTU by CDMU-A and beginning of count down, then loading of the MTU by CDMU-B and beginning of count down. During the whole sequence, the telemetry including MTU values is collected and sent to the Orbiter CDS for downlink and analysis in order to conclude on the CDMU to be used for the MTU Loading just before the separation.

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3.3 COAST PHASE

3.3.1 Unit status

Only the Mission Timer Unit (MTU) is running for a duration comprised between 21 and 22 days depending on the timing of visibility of the spacecraft from DSN ground station.

Then the PSE, i.e. PSAs, RFE and RUSO, will be turned ON to ensure that the receiver is ready before the start of data transmission and a sufficient RUSO warm-up for the adequate frequency stability.

Then the MTU will turn ON the Probe Battery Discharge Regulators (BDRs) according to the time values programmed within 2 days before the Orbiter/Probe separation. This will activate automatically the PCDU, the two CDMUs, the RASU, the CASU.

Considering Probe power constraint on one hand and necessity to warm-up the TUSO on the other hand, the wake-up of the Probe by the MTU is programmed 28 minutes before Entry detection S0.

When the 14.875s duration of CDMU microprocessor initialisation is elapsed, the TUSO and the two Transmitters will be switched ON. Then, the GCMS and HASI will be switched ON.

Note: In case previous C/O evidenced a TUSO or RUSO bad functioning, RUSO will not be switched ON and the TUSO Switch ON command of the MTTs will have been deleted through EEPROM just before separation.

3.3.2 Sequence of events

Table 1.9-5 in HUM Operations Doc n° HUY.AS/c.100.OP.0384 gives the Coast phase timeline.
Table 2.9-20 gives the Patch to apply to delete TUSO Switch ON in Pre-T0 MTT and in Post-T0 MTT.
Table 2.9-21 shows the Coast Phase without RUSO.

3.3.3 System constraints and restrictions

Seven commands are required from the Orbiter CDS: two SSPS switch ON for each of the two PSAs and one SSPS switch ON for each of the RFE heaters, the last one is the RUSO power ON through the PSA-A. The last command must be delayed by 1s w.r.t. the first six ones.

The 5 BDR input relays have to be activated sequentially, in indifferent order.

The delay between the last relay activation and switch ON of other 28 V limiters has to be greater than 2s (in order to be sure that all the power is available at bus level).

The CDMU 28 V limiters are automatically switched ON at 28 V bus power-up (i.e. just after first relay activation).

The total consumption on 28 V distribution outputs is limited to 400 W.

In case of failure of one section (battery, input relay or BDR) the nominal procedure is continued.

Two consecutive ON/OFF commands from MTT must be delayed by at least 1 CUT i.e. 0.125s.

Correct execution of Probe separation will be checked through attitude parameters, axial and angular accelerations recorded on-board the Orbiter and transmitted in auxiliary data.

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3.3.4 Operations description

The PSE activation will be made through time-tagged commands from the Orbiter Command and Data Subsystem (CDS).

The Probe activation will be made by the MTU, according to the time values programmed within the 2 days before the Orbiter/Probe separation.

The PCDU will detect the USM separation strap open status and automatically switch ON pyrobox energy intercept relays.

Then the CDMU microprocessor initialisation will start and last 14.875 s.

The TUSO, low power part of the two Transmitters, GCMS and HASI main power lines will be switched ON by the CDMU through the POSW pre-To Mission Timeline Table (MTT).

The CDMS will start the Descent Data Broadcast (DDB) and the data acquisition which will be passed to the Transmitter but lost as not stored, except the CASU measurements stored in such a manner than the last 6.4 mn values will be telemeasured when PRL is effective and tested by the POSW for the T0 detection process.

3.4 MISSION PHASE

3.4.1 Entry phase

3.4.1.1 Unit status

As at the end of the Coast phase, the following units are switched ON: MTU, PCDU, CDMUs, RASU, CASU, Transmitters low power part, PSAs, RFE, RUSO, TUSO (or RCXO-TCXO if bad functioning of RUSO or TUSO), GCMS and HASI.

Only GCMS1 will be switched ON before S0 if MTU is failed and Probe wake-up made by G-switches.

3.4.1.2 Sequence of events

Table 1.9-6 in HUM Operations Doc n° HUY.AS/c.100.OP.0384 gives the Entry phase timeline for nominal and back-up modes.

3.4.1.3 System constraints and restrictions

Constraints related to Coast phase are valid for the "Back-up" Entry phase.

It should be possible from auxiliary data to reconstructe time of Probe entry, ODT and target point coordinates according to actual Orbiter/Probe trajectories after Orbiter deflection manoeuvre including potential dispersions of separation and deflection manoeuvre.

3.4.1.4 Operations description

The only data acquisition stored during Entry will be the measurement of the HASI accelerometers which will be stored within the Experiment and the CASU measurement.

The Back-up Entry phase timeline corresponds to the case of MTU failure and Probe wake-up by the G-switch which occurs at about 3 mn after the beginning of Entry. In this degraded case, Coast phase timeline is delayed accordingly, the TUSO and GCMS warm-up duration is reduced by about 27 mn and HASI will be switched ON at T0+ 43s instead of T0-10mn i.e.during the Descent phase.

The Entry phase ends when the CASU detects the "S0" deceleration.

Note: In case previous C/O evidenced a TUSO or RUSO bad functioning, RUSO will have not been switched ON and the TUSO Switch ON command of the MTTs will have been deleted through EEPROM just before separation.

3.4.2 Descent phase

3.4.2.1 Unit status

The following units are switched ON: MTU, PCDU, CDMUs, RASU, CASU, Transmitters low power part, PSAs, RFE, RUSO-TUSO (or RCXO-TCXO if bad functioning of RUSO or TUSO), GCMS and HASI. The last instruments, ACP, DISR and SSP, the Transmitter High Power Amplifiers will be switched ON within the 2 first minutes of the Descent phase.

The radar altimeter electronics will be switched ON at about 32 mn after the start of the Descent phase.

3.4.2.2 Sequence of events

Table 1.9-7 in HUM Operations Doc n° HUY.AS/c.100.OP.0384 gives the Descent phase timeline.

3.4.2.3 System constraints and restrictions

Two consecutive ON/OFF commands from MTT must be delayed by at least 1 CUT i.e. 0.125s.

Only one "group" of pyro unit selection relays may be selected simultaneously, that means that the OFF command of the previous relays must be activated before the ON command of the next relays.

The delay between two successive firing commands must be greater than 500 ms.

As the CDMU Arming Timer step is of 4.194304 s, delay between two arming timer commands has to be of one time step minimum.

Delays between the pyro Set and Fire events and between the Fire and Reset events are adjusted to 4 seconds for all pyro events, except for PDD Fire - PDD Reset, and for BCM Set - BCM Fire due to aerodynamic stability constraints. For the BCM, the problem is solved by implementing the cross-strap of the BCM set commands 2 seconds after the PDD Reset. This ensures the following:

- the PDD is fired through both squibs by the early chain
- the late chain fires its own squib
- PDD and BCM pyro events are fully decoupled: in all cases the reset of the PDD occurs before the cross-strap setting of the BCM
- the cross-strap of the set commands of the BCM ensure that redundant and nominal squibs of the BCM are fired by the early chain
- the late chain tries again on all squibs
- for all other pyro events firing of both nominal and redundant squibs is performed by the early and the late chains with simultaneity ensured for multiple events (FSM, PJM).

The interleaving of events scheduled by altitude with those scheduled by time is determined on the basis of the current best knowledge of the nominal Descent profile. Once the atmospheric model is loaded in the Probe,changes in the sequence will only occur for those events related to altitudes below the level at which the radar altimeter begins measurement. Moreover, some events actuated by the Arming Timer must precede others which are altitude dependent, so the scheduling of the former must take account of all uncertainties in the model Descent profile.

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During the Descent phase, the Orbiter will be oriented to keep the axis of the HGA beam directed at the nominal point of touchdown of the Probe on the surface of Titan. Declination and right ascension of the nominal TITAN touch down point at the nominal Entry date plus 4.45mn nominal entry duration plus 138mn nominal Descent duration are (defined in the TITAN centered frame, i.e. TITAN equator and equinox of date):

- 18.4° and -52.3° respectively for the first Saturn orbit delivery
- 24.1° and -46.6° respectively the second Saturn orbit delivery.

During the PRL operation, the Orbiter must not transmit any RF signal and Probe data must be stored on-board the Orbiter for two later transmissions to ground. Appropriate restrictions will be placed on Orbiter science activities from 2 days before Probe data relay to 2 days afterwards.

3.4.2.4 Operations description

When the CASU detects the "S0" deceleration, each POSW will reset its timer at S0 time and go into the Descent sequence. When the CASU detects the Ta deceleration, the arming of the PDD pyroline relay and the BCM 3 pyroline relays will be performed.

At T0 (6.375s after S0), the PDD pyros will be fired, followed by the BCM pyros, provoking pilot chute deployment and Back Cover release.

The TUSO and the two Transmitters Low Power part will be switched ON again, in case their switch status were changed as a consequence of accelerations seen during Entry.

Then the Arming Timer will arm the 3 pyros of the Front Shield Mechanism (FSM), which are subsequently fired on command from the CDMUs.

The ACP will be switched ON. Following the release of the Front Shield, ACP valves and cap line will be energised for subsequent operations by the experiment themselves.

The GCMS pyros and DISR Cover pyros will be armed, the HPAs will be turned ON followed by the SSP. Then the GCMS pyros will be fired to open the inlet and exhaust tubes to the atmosphere.

The HASI booms dedicated line will be energised and booms deployed by the experiment itself then the line will be switched OFF.

The DISR Cover pyros will be fired inducing DISR cover jettison.
Then the DISR will be turned ON and Probe data transmission will start.

After that, most of experiments will be switched ON a second time in case either their switch status were changed as a consequence of accelerations seen during Entry, or in case the first ON TC would not have been executed - and their specific operations will be controlled by the Experiments themselves on the basis of their own timers or the information supplied to them in the DDB. Two exceptions are the energising of the DISR lamp and the energising of the GCMS heater line both under the Arming Timer control.

Other activities for the Arming Timer and the CDMS during the Descent will be the arming and firing of the pyros of the PJM to release the Main Parachute and deploy the stabiliser and the turn ON of the Proximity Sensor.

Finally, the ACP will be switched OFF.

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3.4.3 Surface phase

3.4.3.1 Unit status

All units except ACP are switched ON.

3.4.3.2 Sequence of events

There will be no specific Probe operations during this phase. The Probe power availability and PRL are sized for a 3 mn surface phase, but the link can be maintained up to 30mn after landing on the Titan ground.

It will be terminated by turning OFF the PSE which will be performed by the Orbiter after an interval chosen to be long enough to ensure the completion of data acquisition through the Probe Relay Link.

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4. SUBSYSTEM DESCRIPTION - OPERATIONS

4.1 CDMS

4.1.1 SUBSYSTEM DESCRIPTION

4.1.1-1 Subsystem Configuration

The CDMS is composed by the following units:

- Command and Data Management Unit: CDMU A
- Command and Data Management Unit: CDMU B
- Proximity Sensor:
  - # Radar Altimeter Unit: RAU A
  - # Transmit Antenna: TX A
  - # Receive Antenna: RX A
  - # Radar Altimeter Unit: RAU B
  - # Transmit Antenna: TX B
  - # Receive Antenna: RX B
- Central Accelerometer Sensor Unit: CASU
- CASU Back-up G-Switch A1
- CASU Back-up G-Switch A2
- CASU Back-up G-Switch B1
- CASU Back-up G-Switch B2
- Radial Accelerometer Sensor Unit: RASU
- Mission Timer Unit: MTU
- Wake-up G-Switch 1
- Wake-up G-Switch 2

The CDMS Architecture is shown in Figure 2.2-17 in § 2.2.
The CDMS block diagram showing internal and external connections is in Figure 4.1.1-1.

4.1.1-2 Functional Design and Operating Principles

4.1.1-2-1 Description of Subsystem Functions

CDMU A and B are the control processing unit. They manage TM/TC and control the Probe subsystems and Experiments; they are two absolutely similar entities, fully independent and operating in hot redundancy.
CDMU B sends similar telemetry as CDMU A, up to 30s after CDMU A, now fixed at 6 seconds. See the different TM parameters arranged by HK packets in § 4.4.4-3-7.

MTU is used to switch ON the Probe at the end of the Coast phase.
Two mechanical G-Switches are implemented as back-up of the MTU timers.

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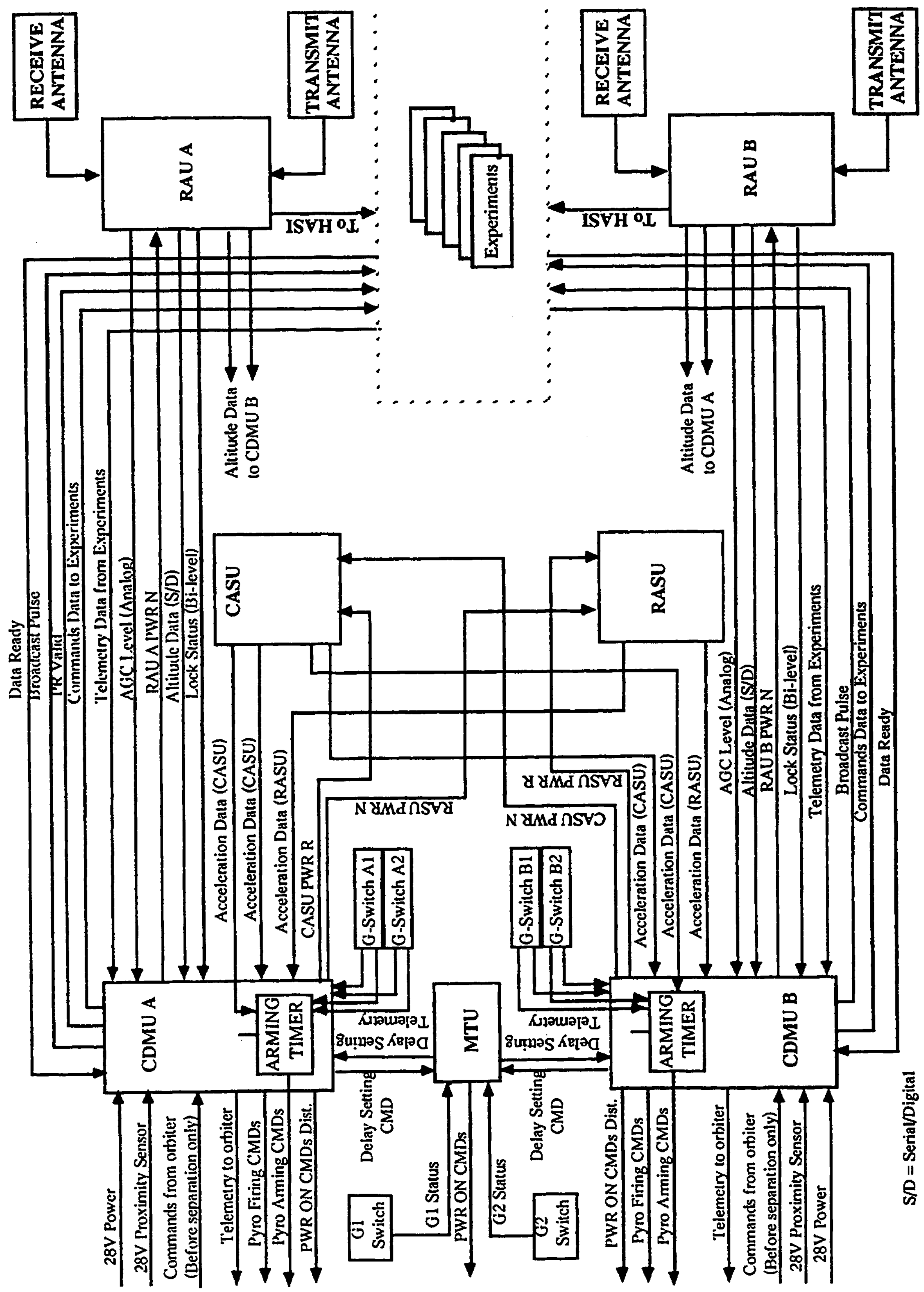

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FIGURE 4.1.1-1 CDMS BLOCK DIAGRAM

The Sensor Package is composed by two units: CASU and RASU. The CASU is used to sense entry acceleration and detect the impact with Titan atmosphere. The RASU is used to sense spin and pendulum motion during the Descent phase.
Two dedicated G-Switches per chain are implemented as back-up to CASU operation.

The Proximity Sensor is used to measure altitude from Titan surface. It is based on FMCW altimeter. It is composed by two redundant Radar Altimeter Units (RAU's) each one using one Transmit (TX) and one receive (RX) antenna.

With the exception of the MTU, the power is distributed to the CDMS units by the CDMU themselves.

Each CDMU is interfaced to two power buses:

- Main power bus
- Sensor power bus

The main power bus is used to supply CDMU itself plus both CASU and RASU.

The sensor power bus is used to supply only one Proximity sensor redundancy. In particular CDMU A supplies power to RAU A, CDMU B supplies power to RAU B.

CASU and RASU are powered once power is provided to the main power bus of at least one CDMU.

Normally, CASU is supplied by CDMU B and RASU by CDMU A.

In case of failure or in case one CDMU is OFF, both CASU and RASU are powered by the active CDMU, meanwhile the relevant connected RAU remains OFF.

4.1.1-2-2 Operational Modes during Mission Phases

Cruise Phase
During check-out sequence, the CDMS is switched ON, except RAUs which stay OFF.

Timer Loading
The CDMS is switched ON, except RAUs which stay OFF.

Coast Phase
Only MTU is switched ON.
CDMU (+ CASU + RASU) are switched ON at the Probe activation
RAUs are always OFF.

Entry and Descent Phase
The CDMU (+ CASU + RASU) and MTU are switched ON.
The RAUs are switched ON at Ta + 32mn (Ta = Arming Time of CDMU Arming Timer).

4.1.1-3 Units Description

4.1.1-3-1 CDMU Description

The Command and Data Management Units (CDMU's) are the intelligent cores of the Command and the Data Management Subsystem (CDMS).
Each CDMU includes the classic Central Terminal Unit (CTU) and Remote Terminal Unit (RTU) functions of a standard On Board Data Handling (OBDH) subsystem, providing the H/W necessary to manage and control the HUYGENS Probe.
The block diagram of the CDMU is provided in Figure 4.1.1-2.
The main CDMU components are the following:

- DC/DC Converter Module
- Processor Module
- PROM Module
- Probe Support Avionic (PSA) Module
- Arming Timer Command and User's Signals Module
- Timing and Data Bus Interface (DBI) Generator Module
- I/O Protocol Handler and Multiplexer Module
- M/L, S/D Module
- H/L O/O Commands Module

In the following, each constituent block is described.

The DC/DC converter provides secondary power lines to the subsystems units (CASU - RASU - RAU A - RAU B) including the CDMU itself.

The Processor Module is a general purpose microcomputer based on the MAS281 CPU.

The PROM Module houses 64 KWord of memory to store the on board software.

The PSA Module provides telemetry and telecommand interfaces with the Probe Support Avionics.

The Arming Timer sends pyro and protected lines arming commands following a specific hardware managed timeline, thus offering full decoupling from the POSW operation. It is initiated upon analog detection of an acceleration threshold, the acceleration data being acquired through CASU measurement. See Arming/energizing sequence in Table 4.1.1-1.

The processor valid signal elaboration informs the experiments about the health of the nominal CDMU in order to support them in their command reception process.

The Timing and DBI Generator Module is interfaced to the processor bus and is used to send commands and get telemetry data from I/O modules.

The I/O Protocol Handler and Multiplexer Module is interfaced to the Timing and DBI Generator. It decodes the DBI protocol and it sends commands/acquires data from the I/O modules.
In addition, it houses input multiplexers for analog thermistors and relay sensing input lines.

The M/L and S/D Module transfers M/L commands and get S/D data from the users.

The H/L O/O Command Module houses the drivers to route the H/L commands to the users.

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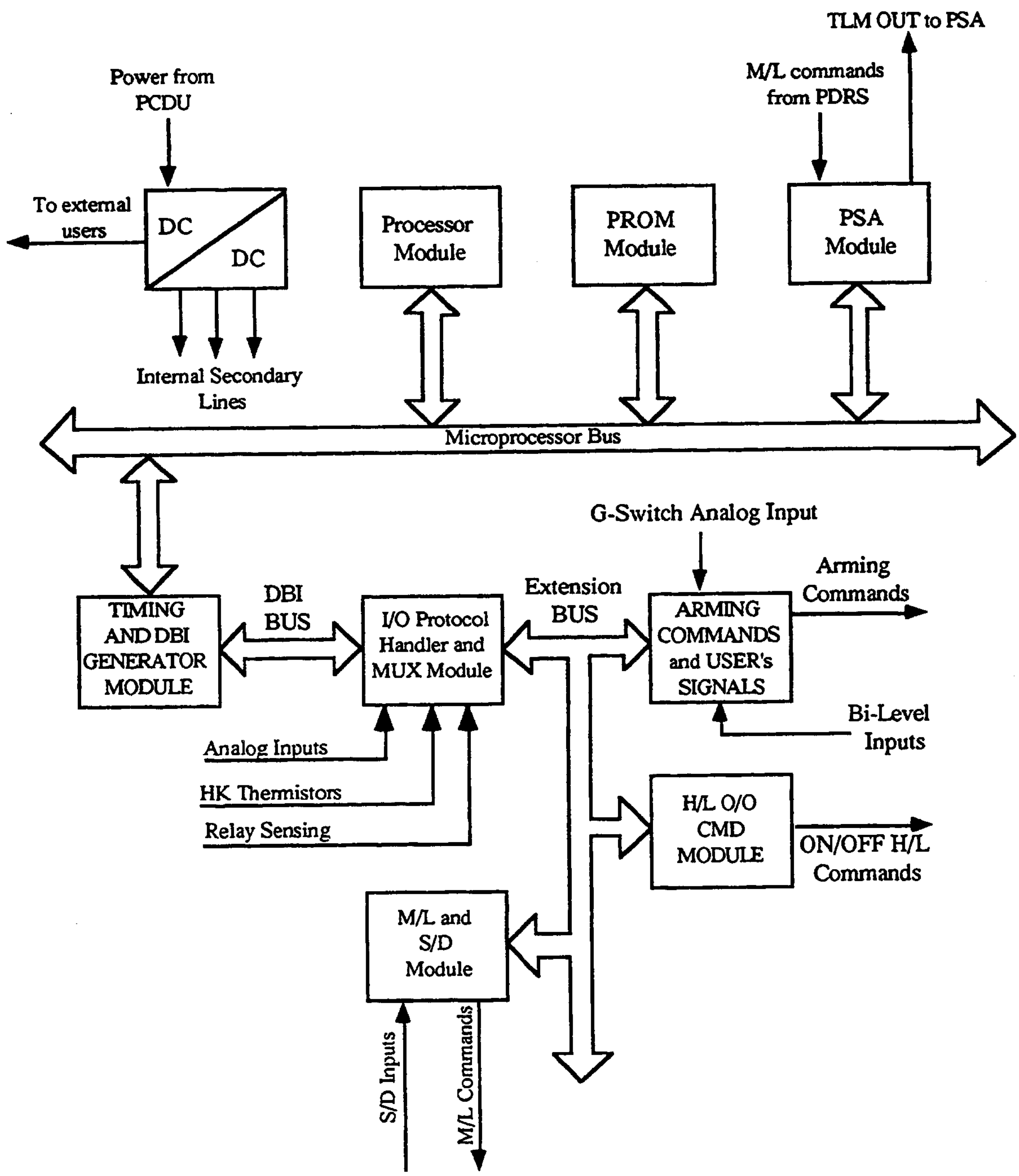

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FIGURE 4.1.1-2 CDMU BLOCK DIAGRAM

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Event Description	Arming Time	Destination
Arm Group 1: • Probe Descent device • Back Cover Mechanism	Ta	Pyro Unit
Arm Group 2: • Front Shield Separation Mechanism	Ta + 25.17s	Pyro Unit
ACP 2 ON	Ta + 37.75s	PCDU
Arm Group 3: • GCMS Pyros • DISR Cover	Ta + 46.14s	Pyro Unit
HPA ON	Ta + 50.33s	TX
HASI 2 ON	Ta + 54.53s	PCDU
HASI 2 OFF	Ta + 3mn25.52s	PCDU
Arm Group 4: • Parachute Release Mechanism	Ta + 5mn1.99s	Pyro Unit
ACP 2 OFF	Ta + 6mn0.71s	PCDU
GCMS 2 ON	Ta + 28mn56.44s	PCDU
RAU ON	Ta + 32mn0.99s	PCDU
DISR Lamp ON	Ta + 109mn57.63s	PCDU

Table 4.1.1-1 ARMING/ENERGIZING SEQUENCE/CDMU

4.1.1-3-2 Proximity Sensor Description

The Proximity Sensor radar altimeter system uses two totally redundant altimeters operating at different frequencies (15.4 GHz and 15.8 GHz).

The Frequency Modulated CW method implemented is commonly used for radar altimeter applications. A continuous transmitted signal is modulated, in frequency, with a rising and falling ramp waveform.

The received signal will be of a similar form. However, the received signal will be delayed by the signal propagation time, from transmitter, to target, to receiver and attenuated due to the atmospheric propagation loss.

The range to target is proportional to the propagation time and (with a linear frequency modulation ramp) also proportional to the instantaneous frequency shift between the transmitted and received signals.

The frequency shift is obtained by mixing the transmit and received signals, to generate a signal whose frequency is proportional to range.

Each redundant half of Proximity Sensor is implemented as a single unit with two antennas mounted externally to the HUYGENS Probe. Thus the total complement of units is:

• Radar Altimeter Unit A	RAU A (operating at 15.4 GHz)
• Transmit Antenna A	TXA A
• Receive Antenna A	RXA A
• Radar Altimeter Unit B	RAU B (operating at 15.8 GHz)
• Transmit Antenna B	TXA B
• Receive Antenna B	RXA B

A functional block diagram of one redundant half is shown in Figure 4.1.1-3.

Each RAU has two separate circuit types. Microwave microstrip circuits and the standard C-MOS and Analog circuits. These are essentially separate sections each forming half of the FMCW servo control loop. For reasons of isolation and ease of access, they are mounted either side of a central RAU case partition. The apportionment of the circuit functional blocks between the two compartments is also shown in Figure 4.1.1-3.

The microwave components are built on soft Teflon based substrates using microstrip technology. The overall function of this section is:

- to generate the transmit signal
- to amplify the received signal
- to mix the two signals and provide the frequency difference I.F. component output

The RAU electronics are shown in Figure 4.1.1-3. Due to the different nature of the circuits, they are implemented on three PCB assemblies:

- the I.F. Amplifier
- the main electronics control and measurement circuit which includes I/F to CDMU A and to CDMU B
- the varactor lineariser circuit

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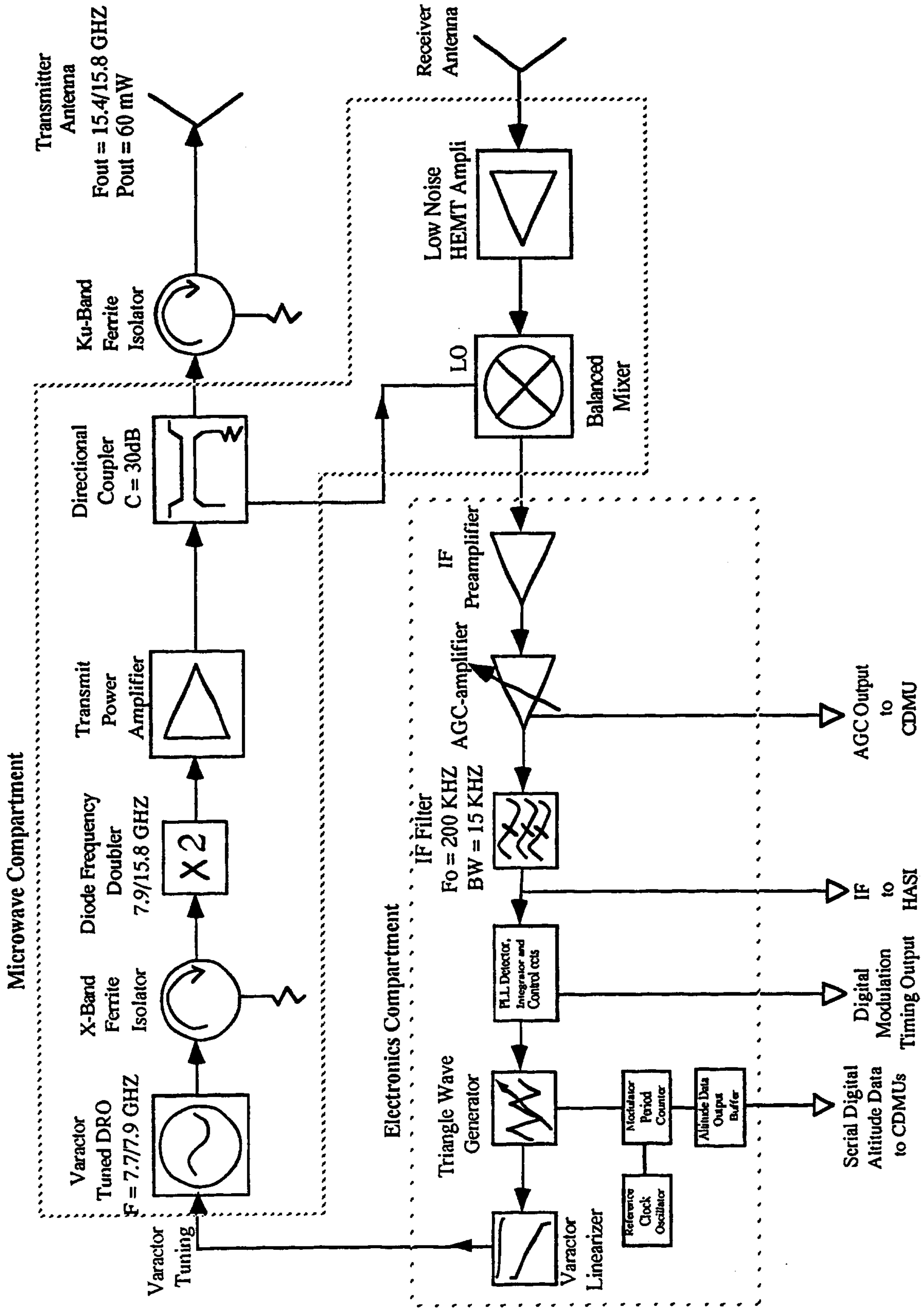

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FIGURE 4.1.1-3 PROXIMITY SENSOR FUNCTIONAL BLOCK DIAGRAM

In addition, the I.F. Filter, although being mounted within the microwave compartment, has its connections accessed within the electronics compartments and is regarded as being part of the electronics system.

The antenna structure is a planar slot radiator array with suspended stripline feed network. The body of the antenna is milled from aluminium alloy. This provides an antenna gain of 25 dB with a symmetrical beam of width of 7.9 deg.

4.1.1-3-3 CASU Description

CASU is used to measure axial acceleration in the range +0 to +10g; its full scale output is 5.12V at 10g with a scale factor of 0.512 V/g.

A block diagram of the CASU is shown in Figure 4.1.1-4.

The main building blocks are:

- Power Lines Oring Circuitry: this block provides the unit with proper power supply voltage starting from two hot-redundant input power lines. The circuit is designed in order to ensure that no single point failure for both nominal and redundant power lines can exist.
- Accelerometer conditioning blocks: these blocks contain the electronics dedicated to accelerometers analog output conditioning. The main building blocks, are an input buffer with its associated gain adjustment network; a low pass filter with a cutoff frequency of 2 Hz and finally an output stage consisting of two or three output buffers according to relevant pin function. The analog output are routed to both CDMU's.
  A dedicated current limiter is implemented at the supply input of each conditioning chain in order to avoid any failure propagation from any component of one conditioning chain to the remaining. Each current limiter withstands permanent short circuit conditions without any degradation; moreover, each current limiter circuit is designed to be single point failure free towards the input ored supply line.

4.1.1-3-4 RASU Description

RASU is used to measure spin acceleration in the range 0mg to 120mg. Its full scale output is 5.12V at 120mg with a scale factor of 42.66 V/g.

RASU design is based on CASU design. The only difference consists in the suppression of accelerometer 2 and relevant conditioning chain and in the suppression of arming output interface.

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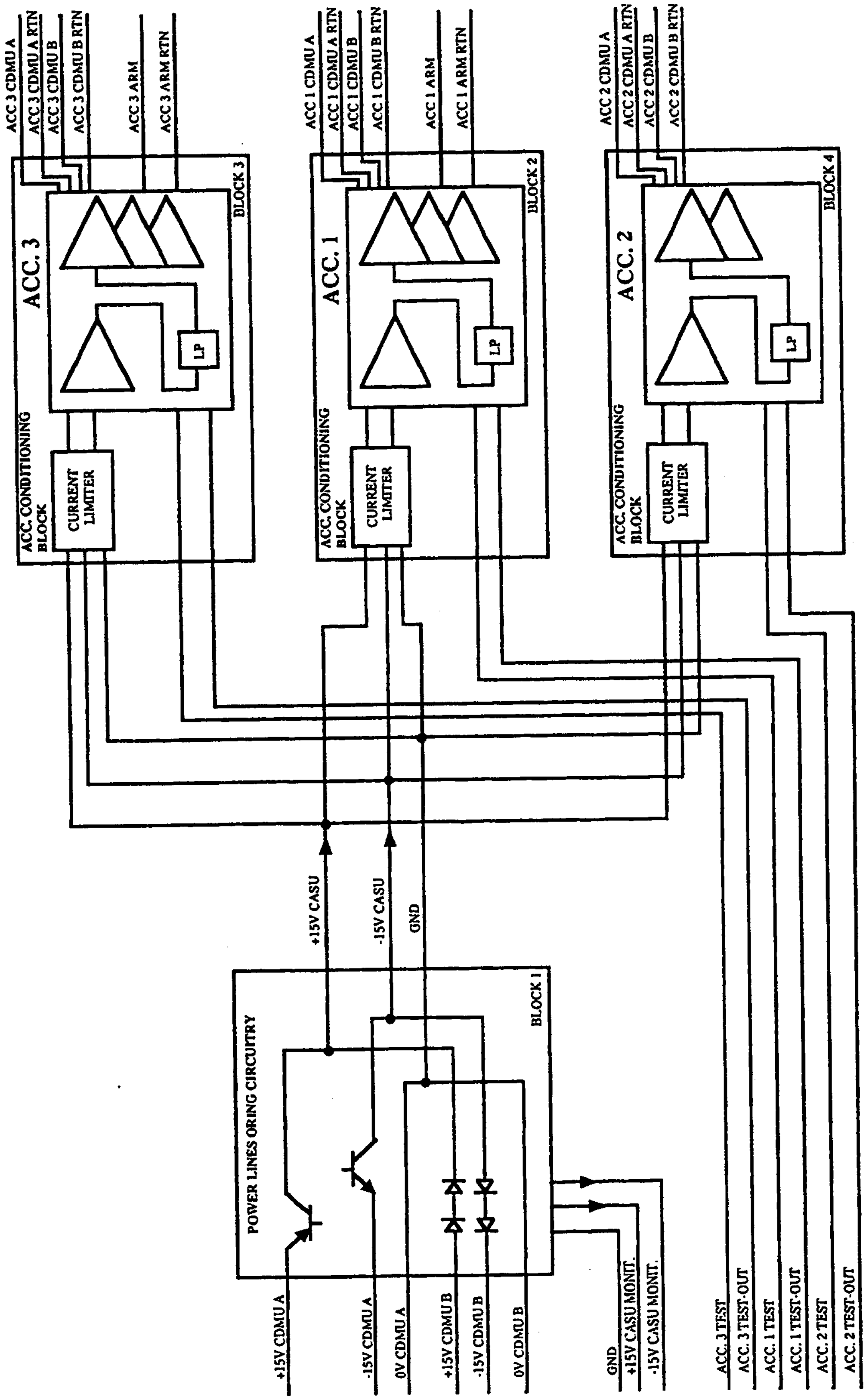

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FIGURE 4.1.1-4 CASU BLOCK DIAGRAM

4.1.1-3-5 MTU Description

The MTU is an hardware programmable clock, which role is to wake-up the Probe after a preprogrammed duration of nominally 22 days.

To obtain a single point failure free design, the MTU is based on three independent hot redundant Timer Circuits followed by two hot redundant Command Circuits.

Inside the MTU box the electrical circuits are organized on five independent printed circuits board, three identical boards each containing one complete Timer circuit and two identical boards each containing a complete Command circuit. The necessary board interconnection is obtained by standard wiring technic.

A MTU block functional schematic is shown in Figure 4.1.1-5. Each of the design blocks represents a separate Printed Circuit Board.

The outputs from each of the three Timer Boards are majority voted in parallel by the two Command Boards and, when at least two Timer Boards has issued the "Time_Out" signal or both G-Switches are active, both Command Boards will issue five independent High Level Commands (HLC's).

Two G-Switches are connected to the MTU to ensure start-up of the Huygens Probe in case of entering the atmosphere of Titan without time out of the Timer Boards.

The MTU operations can be grouped into three phases, a programming phase, a count down phase and a HLC firing phase.

During the programming phase, when the probe is still connected to the orbiter, all three Timers will be programmed via serial memory load interfaces from one of the two CDMU's with the exact value of the coast phase duration. The programmed values can be verified by the serial telemetry channels. When programming is finished, the CDMU's and all other probe systems except the MTU will be turned OFF and the Probe is "let go".

MTU count down starts immediately after valid programming, i.e. reading of 16 clock pulses inside one sample.
During the count down phase, the programmed Timer register is decremented by a very precise clock signal divided down to a period time of about 32 seconds. The expected count down phase (= coast phase) is about 22 days. During this period, the MTU will consume about 300 mW. To obtain this, logic is based on CMOS and only the needed circuits are powered during this phase. This is mainly the logic circuits on the Timer and Command Boards.

When the Command Board majority voting has detected either both G-Switches active or at least two of the three time out signals received, generation of supply voltage for the HLC output circuit is initiated. When this supply voltage is ready, five HLC's will be issued in sequential manner. After HLC sending, the generation of HLC sending voltage is stopped and the MTU will stay in a standby mode consuming only the "coast phase" power of about 300 mW.

For power saving during Coast phase, MTU line drivers are switched ON/OFF at the same time that CDMU is switched ON/OFF.

Each of the three Timer Boards can be loaded independently from either one of the two CDMU's before the Huygens Probe separation from the Cassini orbiter. The last received Memory Load value will be the value stored in the Timer register.

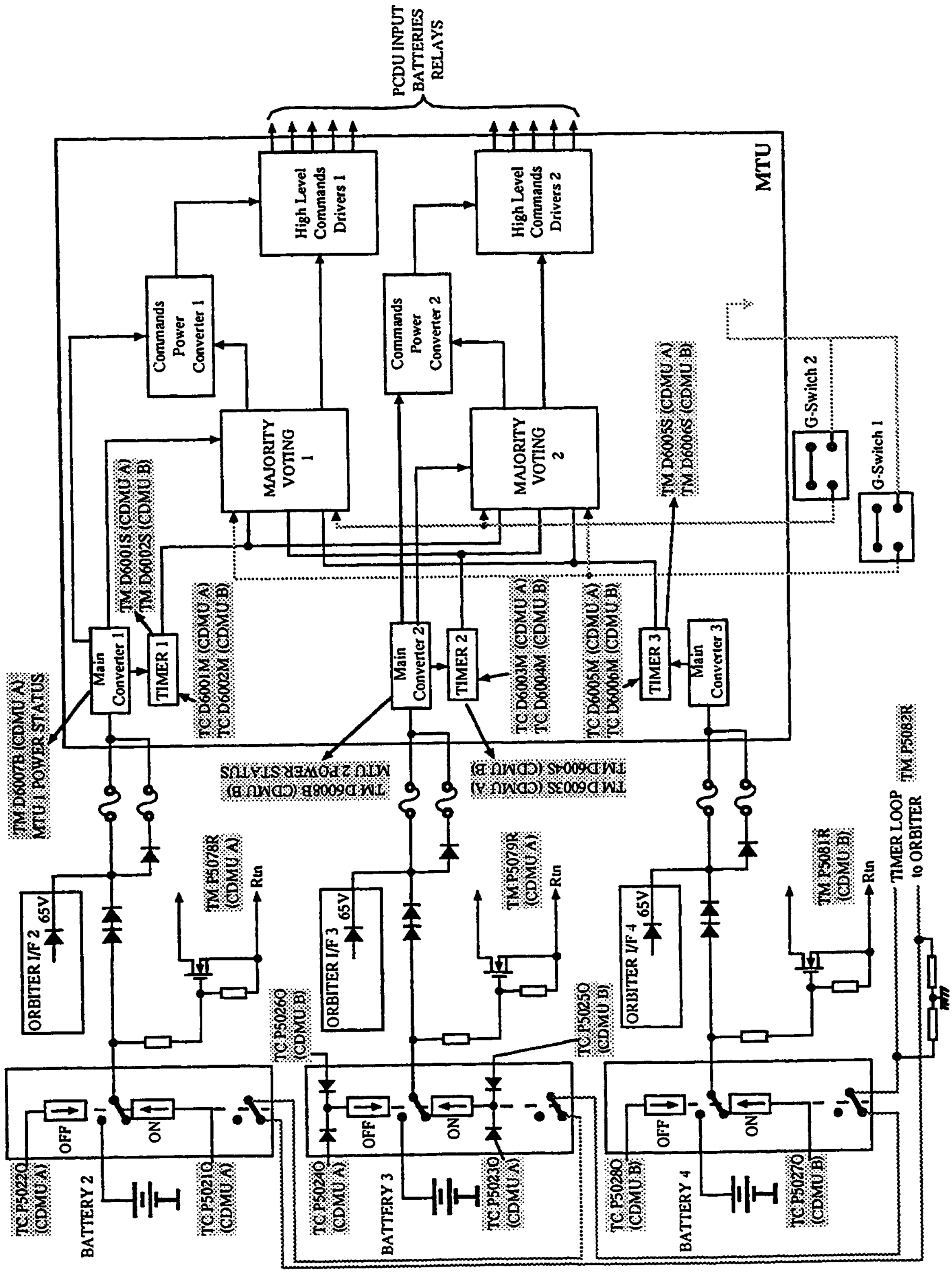

FIGURE 4.1.1-5 MTU BLOCK DIAGRAM

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The MTU is supplied directly from the Probe batteries with three 65 volt supply lines coming from independent batteries, one for each Timer Board.

Each of the Timer Boards generates its own internal supply voltage from the received 65 volt power line. In addition, Timer Board 1 also generates the needed voltage supply lines for the Command Board 1, while Timer Board 2 supplies the Command Board 2.

No single point failure can result in the total loss of the MTU function. Generally, all the cross coupling between the three Timer circuits in the two voting and Command circuits are short circuit single point free to avoid any failure propagation between the redundant functions.

4.1.1-3-6 WAKE-UP G-SWITCHES Description

To prevent from the late or non wake up failure mode of MTU, 2 mechanical G-Switches are used as additional inputs short circuiting the majority voting process. In case the 2 G-switches have passed a defined G threshold during the entry phase, this allows to activate the ON command sending to the batteries relays.

To avoid any impact on the software, the G-switches threshold is set to 6.2g on the rising edge of the entry profile, which guarantees a POSW initialisation well before the T0 detection "G" area is reached.

The G-switches principle of operation is the following: a calibrated seismic mass (about 42g) is hold in place by a magnet. When the selected G-threshold is passed (the G-threshold is basically given by the distance between the seismic mass and the magnet), the mass falls and presses an Honeywell microswitch which consequently indicates a status change. When the G-level becomes lower than the reset threshold of the G-switch, the seismic mass returns in its original position, letting the microswitch return to its original position too.

4.1.1-3-7 CASU BACK-UP G-SWITCHES Description

To cover partial or total CASU failure mode, 2 mechanical G-Switches per chain are needed:

- G-Switch 1 sets at 25 m/s^2 on the Entry profile rising edge and resets at 12 m/s^2 on the Entry profile falling edge
- G-Switch 2 sets at 62 m/s^2 on the rising edge and resets at 54 m/s^2 on the falling edge

If G-Switch 2 has set, then reset, and if CASU acceleration chain 1 (resp. 3) is found non operative, Arming timeline on CDMU-A (resp. CDMU-B) will be started upon G-Switch 1 reset.

If G-Switch 2 has set, then reset, a 20s timeout on T0 detection will be started upon G-Switch 1 reset. T0 will then be declared after these 20s have elapsed unless it has already been declared by the nominal CASU data processing.

4.1.1-4 Performance Characteristics

4.1.1-4-1 Power Consumption and Dissipation

	CDMU + CASU/RASU		MTU		RAU	
	Power Consumption	Heat Dissipation	Power Consumption	Heat Dissipation	Power Consumption	Heat Dissipation
Cruise Phase (Check-Out)	19.4W	19.4W	400mW	400 mW	0	0
Timer Loading	19.4W	19.4W	400mW	400 mW	0	0
Coast Phase	0	0	300mW; 6W during HLC sending (24ms);	300 mW	0	0
T0 - 18mn	19.4W (Probe Activation)	19.4W	400mW	400 mW		
Entry Descent Phase < T0+32mn	19.4W	19.4W	400mW	400 mW	0	0
Descent Phase > T0+32mn	19.4W	22.2W	400mW	400mW	11W	8.2W

4.1.1-4-2 Telemetry and Telecommand Budget

The following Telemetry lines are provided:

	Functions Capability	Internally Allocated	Used CDMU A/B
Analog	48	4	38/38
Thermistors	14	2	14/14
Digital Bi/Level	40	4	34/34
Relay Sense	16	0	10/8
Serial Digital	10	0	10/10
DS16 + Data ready	5	0	5/5

The following Telecommand lines are provided:

	Functions Capability	Internally Allocated	Used CDMU A/B
HL ON/OFF	72	0	57/56
HL ON/OFF Arming	16	0	12/12
M/L	14	0	8/8

The electrical characteristics of these interfaces are shown in the CDMU Interface Control Document Doc n° HUY-LABE-371-ID-00.

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4.1.1-4-3 Thermal Temperatures Prediction

UNIT	DESIGN LIMITS OPER.	CRUISE 0.6AU	CRUISE 9AU	CHECK-OUT TMAX	COAST	ENTRY TMAX	DESCENT TMIN
CDMU A/B	-20/50	22/24	8/12	36/40	3	5	2
RAU A/B	-20/50	24/25	10/11	35	3/4	4	-12
CASU	-20/50	24	10	34	3	5	5
RASU	-20/50	24	10	35	3	5	1
MTU	-20/50	24	10	35	3	5	2

All temperatures are in °C.

4.1.1-5 Interfaces

Refer to following documents for the interface characteristics (electrical, thermal or mechanical):

- CDMS ICD HUY-LABE-370-ID-0001
- CDMU ICD HUY-LABE-371-ID-0004
- RAU ICD HUY-LABE-371-ID-003
- CASU ICD HUY-LABE-3732-ID-0006
- RASU ICD HUY-LABE-3731-ID-007
- MTU ICD HUY-LABE-372-ID-005

CDMS/PROBE PDRS Telemetry Interfaces

The CDMS interfaces to the Probe PDRS transmitter to provide Telemetry data for transmission to the Orbiter via the PSA PDRS.
The CDMS and PDRS consist of two redundant halves. A channelized interface exists between each S/S on each side, with no cross-strapping.
The interface on each redundant side comprises three digital signal lines: Data line and the relevant Clock line and an high frequency Clock (Subcarrier).
The data line carries a serial bit stream representing transfer frames.
The bit rate is 8192 bps.
The data stream is Reed Solomon, NRZ-M convolutional encoded.
The Subcarrier frequency is 131072 Khz.

PSA PDRS/CDMS Telemetry, Telecommand Interfaces

Before separation, the transfer of commands and telemetry from the PSA PDRS to the CDMS, and the transfer of telemetry from CDMS to the PSA PDRS is performed via umbilical links.
Commanding of the Probe CDMS is through a Memory Load interface. Since the interface is used for the transfer of single Packets, it is organized so that data are loaded into single register (FIFO) before being transferred to the processor for further processing or redistribution to the user.
A telemetry link using a direct line between the CDMS and PSA Receiver carries the Reed Solomon, NRZ-M and convolutionally encoded transfer frames.

CDMS/Experiments Interfaces

The CDMU provides the 5 Experiments with the following:

- Broadcast pulses, one for each experiment, synchronous with HW Real Time Clock used by onboard software
- Processor Valid, one for each experiment, to indicate the status of the CDMU A only

4.1.1-6 TM/TC

See location of TM and TC in Annex 4 Drawings: HUY-1000-0002-3/7, 5/7, 6/7 and in Figure 4.1.1-5 for MTU.

4.1.1-6-1 Telecommand

CDMU

CMD REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	TM VERIF
D1 001 M	Umbilical memory load A	ML16	PSA A	CDMU A	UMBMLxxA	TC counter A
D2 001 M	Umbilical memory load B	ML16	PSA B	CDMU B	UMBMLxxB	TC counter B

CASU, RASU

None

RAU

CMD REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	TM VERIF
P5 047 O	RAU A Power OFF	O/O 13ms	CDMU A	PCDU	RAUAPWROFF	P5 049 B
P5 067 O	RAU B Power OFF	O/O 13ms	CDMU B	PCDU	RAUBPWROFF	P5 077 B

MTU

CMD REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	TM VERIF
P5 021 O	coast timer 1 power ON	O/O 13ms	CDMU A	PCDU	CTIMON1A	P5 078 R
P5 022 O	coast timer 1 power OFF	O/O 13ms	CDMU A	PCDU	CTIMOFF1A	D6 007 B
P5 023 O	coast timer 2 power ON	O/O 13ms	CDMU A	PCDU	CTIMON2A	
P5 024 O	coast timer 2 power OFF	O/O 13ms	CDMU A	PCDU	CTIMOFF2A	P5 079 R
P5 025 O	coast timer 2 power ON	O/O 13ms	CDMU B	PCDU	CTIMON2B	D6 008 B
P5 026 O	coast timer 2 power OFF	O/O 13ms	CDMU B	PCDU	CTIMOFF2B	
P5 027 O	coast timer 3 power ON	O/O 13ms	CDMU B	PCDU	CTIMON3B	P5 081 R
P5 028 O	coast timer 3 power OFF	O/O 13ms	CDMU B	PCDU	CTIMOFF3B	
D6 001 M	coast timer 1 load/init	ML16	CDMU A	TIMER 1	CTIMLOAD1A	D6 001 S
D6 002 M	coast timer 1 load/init	ML16	CDMU B	TIMER 1	CTIMLOAD1B	D6 002 S
D6 003 M	coast timer 2 load/init	ML16	CDMU A	TIMER 2	CTIMLOAD2A	D6 003 S
D6 004 M	coast timer 2 load/init	ML16	CDMU B	TIMER 2	CTIMLOAD2B	D6 004 S
D6 005 M	coast timer 3 load/init	ML16	CDMU A	TIMER 3	CTIMLOAD3A	D6 005 S
D6 006 M	coast timer 3 load/init	ML16	CDMU B	TIMER 3	CTIMLOAD3B	D6 006 S

4.1.1-6-2 Telemetry

CDMU

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
P5 022 A (HK2)	28V CDMU A Power Current	8 bit AN	PCDU	CDMU A	CDMUAPWR	/
P5 036 B (HK1)	28V CDMU A Limiter Status	DB	PCDU	CDMU B	CDMUASTAT	/
D1 002 A (HK2)	CDMU A supply voltage (5V)	8 bit AN	CDMU A	CDMU A	CDMUAANA1	/
D1 003 A (HK2)	CDMU A A/D calibration (4.54V)	8 bit AN	CDMU A	CDMU A	CDMUAANA2	/
D1 004 A (HK2)	CDMU A A/D calibration (0.3V)	8 bit AN	CDMU A	CDMU A	CDMUAANA3	/
D1 005 A (HK2)	CDMU A A/D calibration (0.5V)	8 bit AN	CDMU A	CDMU A	CDMUAANA4	/
D1 006 B (HK1)	CDMU A BL test (0V)	DB	CDMU A	CDMU A	CDMUABL1	/
D1 007 B (HK1)	CDMU A BL test (5V)	DB	CDMU A	CDMU A	CDMUABL2	/
D1 008 T (HK2)	DC/DC CONV temperature 1	Temp	CDMU A	CDMU A	CDMUATEMP1	/
D1 009 T (HK2)	DC/DC CONV temperature 2	Temp	CDMU A	CDMU A	CDMUATEMP2	/
D1 010 B (HK1)	Arming Timer A status	DB	CDMU A	CDMU A	GSWITCHA	/
P5 050 A (HK2)	28V CDMU B Power Current	8 bit AN	PCDU	CDMU B	CDMUBPWR	/
P5 064 B (HK1)	28V CDMU B Limiter Status	DB	PCDU	CDMU A	CDMUBSTAT	/
D2 002 A (HK2)	CDMU B supply voltage (5V)	8 bit AN	CDMU B	CDMU B	CDMUBANA1	/
D2 003 A (HK2)	CDMU B A/D calibration (4.54V)	8 bit AN	CDMU B	CDMU B	CDMUBANA2	/
D2 004 A (HK2)	CDMU B A/D calibration (0.3V)	8 bit AN	CDMU B	CDMU B	CDMUBANA3	/
D2 005 A (HK2)	CDMU B A/D calibration (0.5V)	8 bit AN	CDMU B	CDMU B	CDMUBANA4	/
D2 006 B (HK1)	CDMU B BL test (0V)	DB	CDMU B	CDMU B	CDMUBBL1	/
D2 007 B (HK1)	CDMU B BL test (5V)	DB	CDMU B	CDMU B	CDMUBBL2	/
D2 008 T (HK2)	DC/DC CONV temperature 1	Temp	CDMU B	CDMU B	CDMUBTEMP1	/
D2 009 T (HK2)	DC/DC CONV temperature 2	Temp	CDMU B	CDMU B	CDMUBTEMP2	/
D2 010 B (HK1)	Arming Timer B status	DB	CDMU B	CDMU B	GSWITCHB	/

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PROXIMITY SENSOR

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
P5 035 A (HK2)	28V RAU A Power Current	8 bit AN	PCDU	CDMU A	RAUAPWR	/
P5 049 B (HK1)	28V RAU A Limiter Status	DB	PCDU	CDMU A	RAUASTAT	P5 047 O
D3 001 S (HK3)	Pro. Sensor A monitoring N altitude data lock status	DS16 bit 15-1 bit 0	RAU A	CDMU A	 RAUAALTIN RAUALOCKN	/
D3 002 S (HK3)	Pro. Sensor A monitoring R altitude data lock status	DS16 bit 15-1 bit 0	RAU A	CDMU B	 RAUAALTIR RAUALOCKR	/
D3 005 A (HK1)	Pro. Sensor A AGC Voltage	8 bit AN	RAU A	CDMU A	RAUAAGC	/
P5 063 A (HK2)	28V RAU B Power Current	8 bit AN	PCDU	CDMU B	RAUBPWR	/
P5 077 B (HK1)	28V RAU B Limiter Status	DB	PCDU	CDMU B	RAUBSTAT	P5 067 O
D4 001 S (HK3)	Pro. Sensor B monitoring N altitude data lock status	DS16 bit 15-1 bit 0	RAU B	CDMU B	 RAUBALTIN RAUBLOCKN	/
D4 002 S (HK3)	Pro. Sensor B monitoring R altitude data lock status	DS16 bit 15-1 bit 0	RAU B	CDMU A	 RAUBALTIR RAUBLOCKR	/
D4 005 A (HK1)	Pro. Sensor B AGC Voltage	8 bit AN	RAU B	CDMU B	RAUBAGC	/

CASU

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
D7 001 A (HK4)	central accelero 1 value A	8 bit AN	CASU	CDMU A	CACC1VALA	/
D7 002 A (HK4)	central accelero 2 value A	8 bit AN	CASU	CDMU A	CACC2VALA	/
D7 003 A (HK4)	central accelero 3 value A	8 bit AN	CASU	CDMU A	CACC3VALA	/
D7 004 A (HK4)	central accelero 1 value B	8 bit AN	CASU	CDMU B	CACC1VALB	/
D7 005 A (HK4)	central accelero 2 value B	8 bit AN	CASU	CDMU B	CACC2VALB	/
D7 006 A (HK4)	central accelero 3 value B	8 bit AN	CASU	CDMU B	CACC3VALB	/

RASU

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
D8 001 A (HK2)	radial accelero 1 value A	8 bit AN	RASU	CDMU A	RACC1VALA	/
D8 002 A	radial accelero 3 value A (*)	8 bit AN	RASU	CDMU A	RACC2VALA (*)	/
D8 004 A	radial accelero 1 value B (*)	8 bit AN	RASU	CDMU B	RACC1VALB (*)	/
D8 005 A (HK2)	radial accelero 3 value B	8 bit AN	RASU	CDMU B	RACC2VALB	/

(*) These TMs are wired to CDMU, but are not processed nor transmitted by POSW/CDMU.

TEMPERATURE SENSORS

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
D5 001 T	Probe temp. 1 A (SEPS A)	Temp	TEMP	CDMU A	PTEMP1A	/
D5 002 T	Probe temp. 2 A (SEPS C)	Temp	TEMP	CDMU A	PTEMP2A	/
D5 003 T	Probe temp. 3 A (PJM A)	Temp	TEMP	CDMU A	PTEMP3A	/
D5 004 T	Probe temp. 4 A (PJM C)	Temp	TEMP	CDMU A	PTEMP4A	/
D5 005 T	Probe temp. 5 A (batt 1a)	Temp	TEMP	CDMU A	PTEMP5A	/
D5 006 T	Probe temp. 6 A (batt 3b)	Temp	TEMP	CDMU A	PTEMP6A	/
D5 007 T	Probe temp. 7 A (batt 5a)	Temp	TEMP	CDMU A	PTEMP7A	/
D5 008 T	Probe temp. 8 A (PCDU box)	Temp	TEMP	CDMU A	PTEMP8A	/
D5 009 T	Probe temp. 9 A (TX A box)	Temp	TEMP	CDMU A	PTEMP9A	/
D5 010 T	Probe temp. 10 A (GCMS flange)	Temp	TEMP	CDMU A	PTEMP10A	/
D5 011 T	Probe temp. 11 A (DISR SH ext.)	Temp	TEMP	CDMU A	PTEMP11A	/
D5 012 T	Probe temp. 12 A (foam inside)	Temp	TEMP	CDMU A	PTEMP12A	/
D5 013 T	Probe temp. 1 B (SEPS B)	Temp	TEMP	CDMU B	PTEMP1B	/
D5 014 T	Probe temp. 2 B (SEPS A)	Temp	TEMP	CDMU B	PTEMP2B	/
D5 015 T	Probe temp. 3 B (PJM B)	Temp	TEMP	CDMU B	PTEMP3B	/
D5 016 T	Probe temp. 4 B (PDD)	Temp	TEMP	CDMU B	PTEMP4B	/
D5 017 T	Probe temp. 5 B (batt 4b)	Temp	TEMP	CDMU B	PTEMP5B	/
D5 018 T	Probe temp. 6 B (batt 2a)	Temp	TEMP	CDMU B	PTEMP6B	/
D5 019 T	Probe temp. 7 B (batt 3a)	Temp	TEMP	CDMU B	PTEMP7B	/
D5 020 T	Probe temp. 8 B (batt 1b)	Temp	TEMP	CDMU B	PTEMP8B	/
D5 021 T	Probe temp. 9 B (TX B box)	Temp	TEMP	CDMU B	PTEMP9B	/
D5 022 T	Probe temp. 10 B (TUSO box)	Temp	TEMP	CDMU B	PTEMP10B	/
D5 023 T	Probe temp. 11 B (DISR DH ext.)	Temp	TEMP	CDMU B	PTEMP11B	/
D5 024 T	Probe temp. 12 B (after cone ins.)	Temp	TEMP	CDMU B	PTEMP12B	/

All these TMs are in HK2.

TIMER

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
P5 078 R (HK1)	coast timer 1 relay status A	rel. stat.	PCDU	CDMU A	CTIM1STATA	P5 021 O/P5 022 O
P5 079 R (HK1)	coast timer 2 relay status A	rel. stat.	PCDU	CDMU A	CTIM2STATA	P5 023 O/P5 024 O P5 025 O/P5 026 O
P5 081 R (HK1)	coast timer 3 relay status B	rel. stat.	PCDU	CDMU B	CTIM3STATB	P5 027 O/P5 028 O
P5 082 R	timer relay loop	rel. stat.	PCDU	Orbiter	CTIMLOOP	P5 021 O to P5 028 O
D6 001 S (HK3)	coast timer 1 value A	DS16	MTU	CDMU A	CTIM1VALA	D6 001 M/D6 002 M
D6 002 S (HK3)	coast timer 1 value B	DS16	MTU	CDMU B	CTIM1VALB	
D6 003 S (HK3)	coast timer 2 value A	DS16	MTU	CDMU A	CTIM2VALA	D6 003 M/D6 004 M
D6 004 S (HK3)	coast timer 2 value B	DS16	MTU	CDMU B	CTIM2VALB	
D6 005 S (HK3)	coast timer 3 value A	DS16	MTU	CDMU A	CTIM3VALA	D6 005 M/D6 006 M
D6 006 S (HK3)	coast timer 3 value B	DS16	MTU	CDMU B	CTIM3VALB	
D6 007 B (HK1)	MTU1 Power Status	DB	MTU	CDMU A	MTU1PWRSTATA	P5 021 O/P5 022 O + POW2 ON/OFF
D6 008 B (HK1)	MTU2 Power Status	DB	MTU	CDMU B	MTU2PWRSTATB	P5 023 O/P5 024 O P5 025 O/P5 026 O + POW3 ON/OFF

CASU BACK-UP G-SWITCHES

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
D1 011 R (HK1)	T0/Ta G-switch 1A status	rel.stat.	CDMU A	CDMU A	T0GSWITCH1A	/
D1 012 R (HK1)	T0/Ta G-switch 2A status	rel.stat.	CDMU A	CDMU A	T0GSWITCH2A	/
D2 011 R (HK1)	T0/Ta G-switch 1B status	rel.stat.	CDMU B	CDMU B	T0GSWITCH1B	/
D2 012 R (HK1)	T0/Ta G-switch 2B status	rel.stat.	CDMU B	CDMU B	T0GSWITCH2B	/

4.1.1-7 Operational Constraints

1- It is recommended to avoid to load MTU counters at the same time from both CDMU.

2- During normal check out, it is forbidden to load MTU counters. In case of failure investigation leading to loading of MTU counters, the loaded time value shall be preferably FFFF, in order to minimize the risk of automatic wake-up of the Probe.

3- During check out, it is requested to send Post-T0 Resume TC before 35mn are elapsed from Probe switch ON, otherwise Experiments would believe that CDMU A is in failure.

4- For specific constraints on Command sending, see § 4.4 POSW and § 4.5 SASW.

5- Warning: During TM acquisitions from other units when they are switched OFF, CDMU can acquire Hex value either "0000" or "FFFF" depending of the last bit condition of the previous reading.
This happens when the I/F of the unit in subject, when it is OFF, is in a high output impedence condition and is not able to condition the reading performed by the CDMU I/F.

6- After loading of Depassivation and MTU Loading sequence on-board the Orbiter and before sending it to the Probe, it is mandatory to get back the telemetry of the stored sequence, for example by dumping the CDS memory area in which the sequence is stored.

7- Warning: An important feature is that in checkout as well as in real Mission, Post-T0 mission timeline is **automatically started** from both CDMUs **38 minutes** after Probe switch ON.

4.1.2 NOMINAL OPERATIONS

4.1.2-1 CDMU's Operations

Each CDMU is able to:
- acquire analog voltages
- thermistors conditioning

The above input channels are converted by an 8 bit A/D converter.

TRANSFER FUNCTIONS FOR ANALOG CHANNELS and FOR THERMISTORS CHANNELS

They are given in Annex 2 TM/TC Data Tables.

The CDMU is able to acquire the following digital inputs:
- digital bi-level
- packet ready
- relay sense

The following rules apply:

TRANSFER FUNCTIONS FOR DIGITAL BI-LEVEL

The following applies when a digital bi-level channel is acquired:
- bit = 1 input voltage at CDMU level ≥ 2V
- bit = 0 input voltage at CDMU level < 1V

TRANSFER FUNCTIONS FOR PACKET READY SIGNALS

The following applies when acquiring Packet Ready Signals:
- bit = 1 Packet is ready
- bit = 0 Packet is not ready

TRANSFER FUNCTIONS FOR RELAY SENSE

The relay sense data are used to monitor the status of relay.
The following applies when relay sense data are acquired:
- bit = 1 relay status open
- bit = 0 relay status closed

CDMU A provides to each experiment one Processor Valid signal line to give an indication of the CDMU A health status.
The following will apply:

- Processor Valid = +5V   CDMU A health OK
- Processor Valid = 0V   CDMU A health KO

Only on-board software can raise up the Processor Valid line (5V).

After Unit power-on, the Processor Valid signal line is low (0V) until it is raised up (5V) by on-board software.
Once at +5V, the Processor Valid stays high until at least one of the following conditions happens:

- the CDMU internal trigger-go counter is not reset by on-board S/W
- an undervoltage is detected on the +5V power lines (V ≤ 4.54V)
- a double error on RAM is detected by EDAC

See Procedure DP01 CDMU Switch ON in § 1.1 of HUM OPERATIONS Doc n° HUY.AS/c.100.OP.0384.

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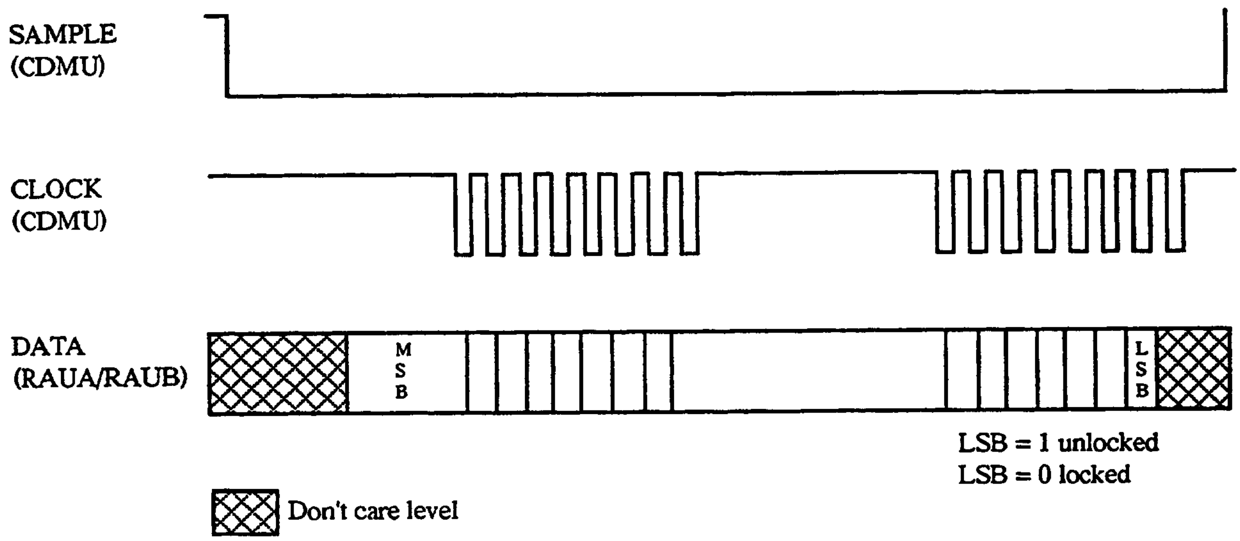
4.1.2-2 Proximity Sensor Operations

Each RAU is powered by one CDMU.
The RAU's have two operating modes:

- searching for lock mode when the unit is trying to acquire the lock, in this case data are not valid
- lock mode, when the unit is locked and data are valid

Each RAU provide to both CDMU's altitude data via 16 bit serial digital channels.
The interface to the two CDMU's is doubled so that both CDMU's can simultaneously acquire data from the same RAU.
The data format is shown in Figure 4.1.1-6.



C1

FIGURE 4.1.1-6 RAU DATA FORMAT

The altitude can be extracted with the following algorithm:

```
IF     LSB = 0
       RADAR STATUS = LOCKED
       ALTITUDE = DATA/2
ELSE   RADAR STATUS = UNLOCKED
       ALTITUDE NOT VALID
```

ALTITUDE value is in meters and LSB is 1 meter.

Switch ON of RAUs is automatically done by Arming Timers and therefore cannot be performed during checkout.
Switch OFF is not foreseen; in case of problem, switch OFF will be done with DP03 Part B.

4.1.2-3 CASU/RASU Operations

CASU/RASU provide an analog output proportional to applied acceleration as soon as power lines are applied, in particular:

- CASU measures 1g when its measuring arrow is directed vertically UP
- CASU measures 0g when its measuring arrow is placed parallel to horizontal surface
- RASU measures full scale with saturated output when its measuring arrow is placed vertically UP
- RASU measures 0g when its measuring arrow is placed parallel to horizontal surface

Units provide output voltages proportional to input *positive* accelerations; input negative accelerations are not measured and are reported as "0g":

- the output voltage is from 0V to 5.12V
- Scale factor: CASU: 0.512V/g
  RASU: 42.66V/g

No specific operations are foreseen.

4.1.2-4 MTU Operations

MTU Loading/Reading and count-down operations

Each of the three Timers can be loaded independently from either one of the two CDMU's before the Huygens probe separation from the Cassini orbiter
The programming is via M/L commands
The last received M/L value is the value stored in the time register
The content of each Timer can be read by both CDMU's via S/D interrogations
A data control mechanism exists so that M/L programming data is considered valid if and only if 16 clock pulses are detected in the active sample window. If this is not the case, the programming is rejected.
To save power when both CDMU's are detected OFF, the MTU switches OFF its M/L and S/D interfaces
The interface towards CDMU's is active if at least one CDMU is ON; in this case, it can be programmed and its content can be read back by both CDMU's.
The time registers can be programmed as often and as many times from both CDMU's as wanted, always the last value is loaded into the Timer
The 16 bit Clock/Sample Window function, in case of simultaneously programming from both CDMU channels, totally excludes the register programming, unless if the two sample windows show perfect overlapping with approximate synchronous clock signals. In this case, the correct received data of channel A is loaded into the registers.
At power ON the down counting function is not active and the data which are acquired via S/D are meaningless and random.
The down counting starts immediately after a correct programming
The exact Timer resolution is 31.99909 seconds per bit
Count down accuracy is better than ± 30 ppm.
Telemetry Read back reads the actual down counted Timer register content. Should reading occur at exactly the same time as the register updating occurs (few hundred nano seconds out of 32 seconds), the telemetry read value could theorically be wrong.
The Timer register content is decremented on one edge of the internal clock signal while the Time_Out signal is generated on the other. This means that the Telemetry read back value will always be one half clock period in advance to the actual time corresponding to 16 seconds. In other words, the first register decrement will take place already 16 seconds after programming, but Time_Out signal will not be issued before 16 seconds after register content is decremented to 0.

See Procedure DP02 MTU Loading/Reading in § 1.1 of HUM OPERATIONS Doc n° HUY.AS/c.100.OP.0384.

G-SWITCH Interface

The G-Switches are used as back-up devices to the MTU counters. The following applies:

- The two G-SWITCHES close at 6.2g and open at 5.5g.
- The H/L commands are delivered by MTU if the two G-Switches are closed at the same time for at least 20ms. (The closure expected time during Mission is ≈ 1 minute).
- Activation of the HLC, during countdown and until Time_Out has expired, can only be activated by G-SWITCH. Time_Out is when the timer has completed its programmed down counting.

MTU Powering

Each of the Timer boards generates its own internal supply voltage from the received input power bus lines.
Timer board 1 also generates the needed voltage supply lines for command board 1, while Timer board 2 supplies the command board 2.
A soft start is implemented so the MTU becomes active 50ms after its powering ON.

See PP04 Mission Timer Switch ON/OFF.

4.1.2-5 WAKE-UP G-SWITCHES/CASU BACK-UP G-SWITCHES Operations

None

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4.1.3 BACK-UP OPERATIONS

CDMUs are operating in hot redundancy. If one CDMU fails during a checkout, the next checkout will be implemented with the other CDMU only. See § 2.9.2 in § 1.9 of HUM OPERATIONS Doc n° HUY.AS/c.100.OP.0384.

As RAUs are operating in hot redundancy, there is no possibility of Back-up operations.

For RASU there is no redundancy, so no possibility of Back-up operation.

Wake-up G-Switches are implemented as Back-up operation for MTU timers; see Entry Phase Timeline Table 1.9.6 in § 1.9 of HUM OPERATIONS Doc n° HUY.AS/c.100.OP.0384.

CASU Back-up G-Switches are implemented as Back-up for overall CASU operations.

4.1.4 CONTINGENCY OPERATIONS

1- CDMU A or B in Failure

See Back-up operation.

2- CASU in Failure

If during Checkout period, Coast phase or Entry phase, 2 accelerometers fail, CASU operation will be covered by dedicated G-Switches (see Back-up Operations). If Accelerometer 1 or Accelerometer 3 fails, Back-up G-Switch will take over Arming timeline initiation task.

Contingency DC01 in Doc HUY.AS/c.100.OP.0384 presents the Patch to be applied when the CASU Back-up S0 detection must be inhibited, if for instance 1 of the 2 G-switches status associated to one chain is not as expected.

3- RASU in Failure

• Failure cannot be detected during checkout. A failure of RASU during Descent phase will lead to a degradation of the Mission.

• Radial Accelero value

CDMU A reads Accelero 1 value TM D8001A and CDMU B reads Accelero 3 value TM D8005A.
Accelero 1 value is wired to CDMU B, but not processed nor transmitted by POSW/CDMU B.
Accelero 3 value is wired to CDMU A, but not processed nor transmitted by POSW/CDMU A.

If necessary, Accelero 1 (3) value could be read by CDMU B (A) using Re-programmable Data. See Contingencies: DC02 RASU Accelero 3 on chain A
DC03 RASU Accelero 1 on chain B

4- RAU A or B in Failure

Failure cannot be detected during checkout. A failure of RAUs during Descent phase will le[illegible] degradation of the Mission.

If RAUs are found ON during Checkout, try to switch them OFF with Table 2.9-27 in Doc HUY.AS/c.100.OP.0384.

5- MTU in Failure

• If counters fail, G-Switches will awake the Probe.
• If command circuits fail, the Mission will be lost.
• If during C/O, it appears that P5078R and/or P5079R and/or P5081R (Coast Timer relay status) are closed (= 0), it is necessary to isolate Batteries by switching OFF the concerned MTU with Procedure PP04 Part B.
• If P5082R (Timer relay loop) = 1 (at least one relay closed), it is necessary to switch OFF the MTU(s), one after the other until P082R = 0.

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4.2 PDRS

4.2.1 SUBSYSTEM DESCRIPTION

4.2.1-1 Subsystem Configuration

The PDRS (Probe Data Relay Subsystem) transmits Housekeeping and Science data from the Probe to the PSE (Probe Support Equipment) on the Orbiter. These data are then transmitted to the Orbiter CDS via a BIU.

The PDRS mission starts between T0 + 1mn and T0 + 2mn30s and ends 3mn after the landing on TITAN ground.

The data are transmitted in S-Band on two redundant chains (A and B). The chain A is transmitted at 2040.0 MHz and the chain B at 2097.9 MHz.

The RF signal comprises a residual carrier signal, phase modulated by a subcarrier signal of frequency 131072 Hz and carrying the PCM encoded channel symbol stream.

The PDRS on Probe and on the PSE adapt a single data rate of 8192 bps.

The PDRS on board Probe and the PSE contain no single point failure. The PSE receiving part is capable of autonomously acquiring the carrier frequency within 3 s; the re-acquisition time is less than 3 sec, including ± 10° pendulum motion.

As part of the DWE, in order to allow the accurate measurement of the Doppler shift in the main RF carrier, two ultra stable oscillators are used as reference signal sources (one on the Probe side, the second one on the Orbiter side).

The PDRS consists of (see Figure 4.2.1-1):

- 2 S-Band transmitters on board the Probe, connected to the Probe Antenna via the RF harness.
- 1 RFE including 2 LNA's, each associated to 1 PSA.
- 2 S-Band receivers within the PSE, connected via the radio frequency harness to the CASSINI High Gain Antenna operating with circular polarizations.

Hot redundancy is achieved by two transmitters on the Probe, with circular polarization of opposite sense, and two corresponding receiving units (PSA) in the PSE, connected to the HGA antenna via two independent coaxial lines.

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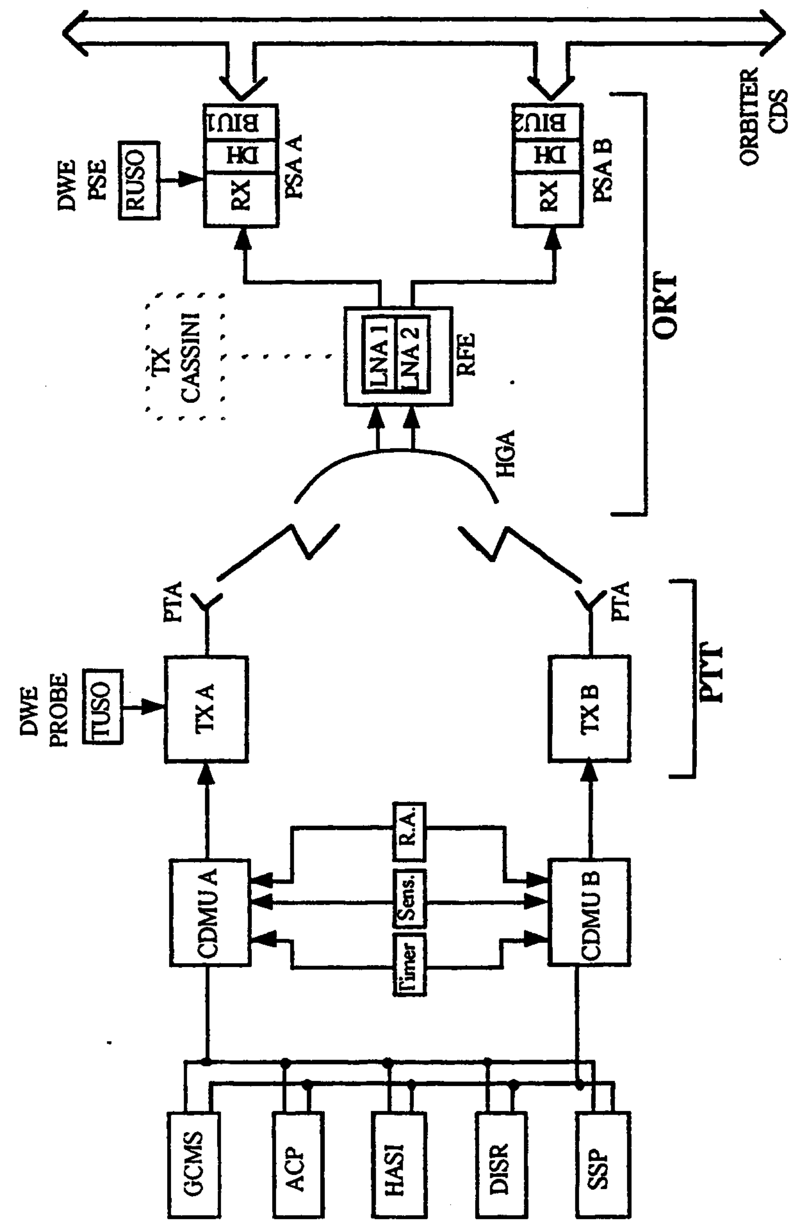

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FIGURE 4.2.1-1 PDRS BLOCK DIAGRAM

4.2.1-2 Functional Design and Operating Principles

4.2.1-2-1 Description of Subsystem Functions

The Probe Transmitter transmits the data gathered by the Probe to the Orbiter via 2 LNA's, included in RFE, and 2 PSA's which provide a "transparent" link during the various mission phases.

The PDRS link dimensioning takes into account a frame error rate of 10^{-5} at the earth station decoder output. The convolutional decoding is a function on the PDRS. The Reed Solomon decoding (outer decoding) is implemented at the earth station providing the required FER value.
The main communication service quality is BER = 4×10^{-3} at the receiving convolutional decoder output; this with a nominal system margin of 3 dB guaranteed during all mission phases.

In case of failure of the DWE-USO, the receiver is reconfigured via telecommand and uses as reference a standard stable oscillator (TCXO).

The PSA part of the PDRS performs Electrical Power Distribution for the PSA itself, the RFE and for the DWE USO, this last with and independently switchable line.

The PSA communicates with the Orbiter CDS via the BIU and Electrical Power Distribution. The following Data Handling main functions are implemented:
- Transform the received Transfer Frame into a Telemetry Packet in CCSDS format
- Collect local housekeepings, generate receiver housekeeping source Telemetry Packets in CCSDS format; sampling interval: 0.125 s for Digital Signal Processing variables, and for local analog variables (PSA and USO temperatures, PSA, RFE, USO unit voltage supply).
- Receive Telecommands Packets in CCSDS format from the Orbiter via the BIU
- Provide the telemetry (control word) of the reference NCO with a resolution of 48 mHz in order to measure carrier frequency changes due to Probe motion in the TITAN atmosphere; an external USO provides to one of two PSA units and to the relevant NCO a stable 10 MHz frequency reference.
- Distribute Telecommands locally within the PSE and verify execution of local PSE commands control of the S-Band receiver.
- Interface with the Probe before separation via umbilical links which allows Telecommand (via Video Umbilical) and Telemetry (via RF) exchange between PSA and Probe (regular monitoring of its health status) and full checkout of the PDRS periodically performed during the cruise phase.
After separation the interface is through the Radio Link and allows only Telemetry flow from Probe to the PSA.
- Maintain PSE time for telemetry datation, time-tagged commands and timeline driven operations (time transfer from Probe to PSA using synch marker detections).
- Provide indications of the lock status and of the AGC status.
- Control communication with the BIU for Telemetry and Telecommands.
- Handle a data bit rate of 8.192 Kbps, during the Probe descent on TITAN and check-out periods.
- Switch on the operational modes/states.

The PDRS is composed of two subassemblies:
- Probe Transmitting Terminal (PTT) and
- Orbiter Receiving Terminal (ORT)

The relevant functional block diagrams are shown respectively in Figures 4.2.1-2 and 4.2.1-3.

The block diagrams Figures 4.2.1-4 and 4.2.1-5 show the electrical interfaces.

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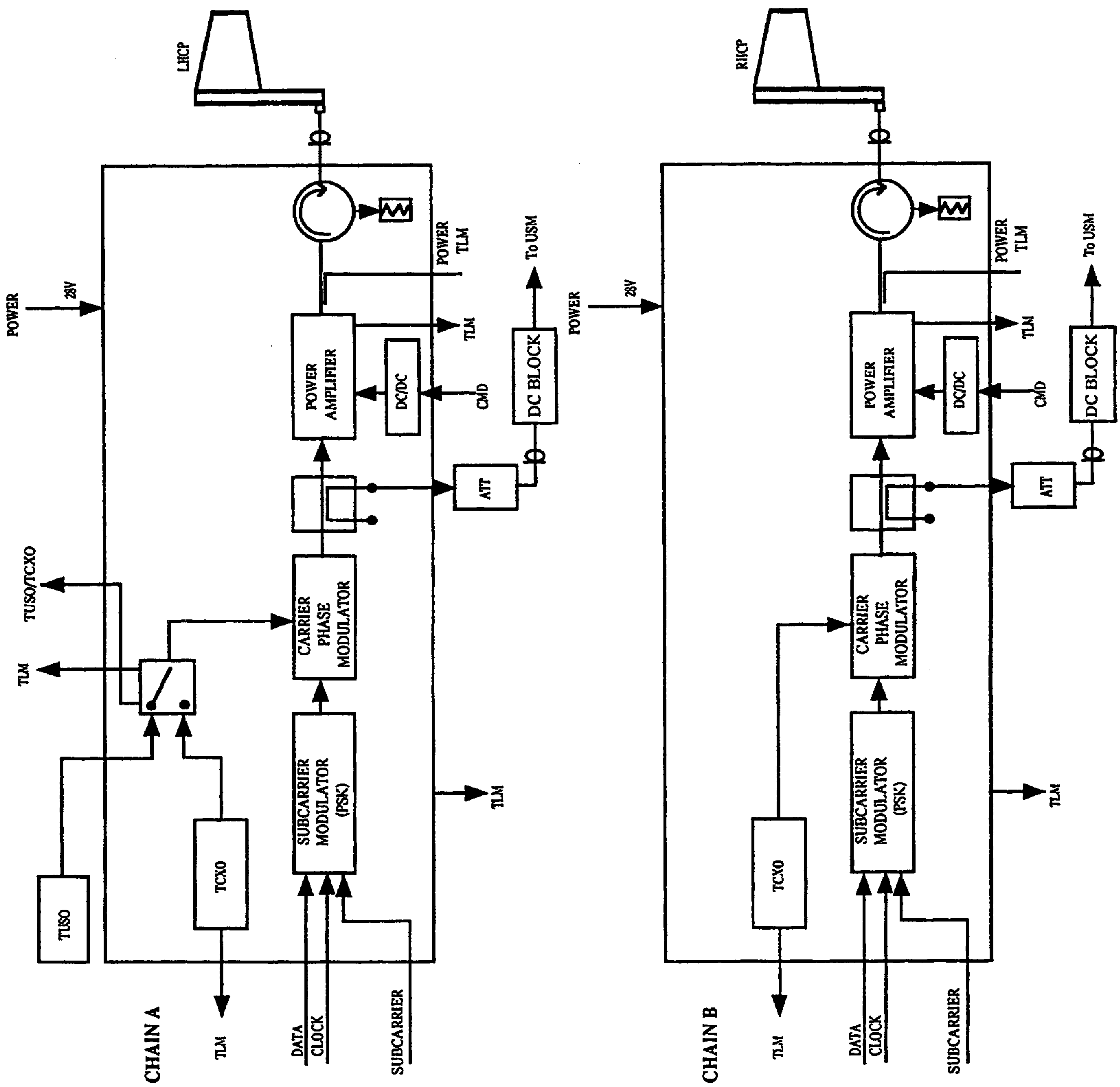

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FIGURE 4.2.1-2 PROBE TRANSMITTING TERMINAL FUNCTIONAL BLOCK DIAGRAM

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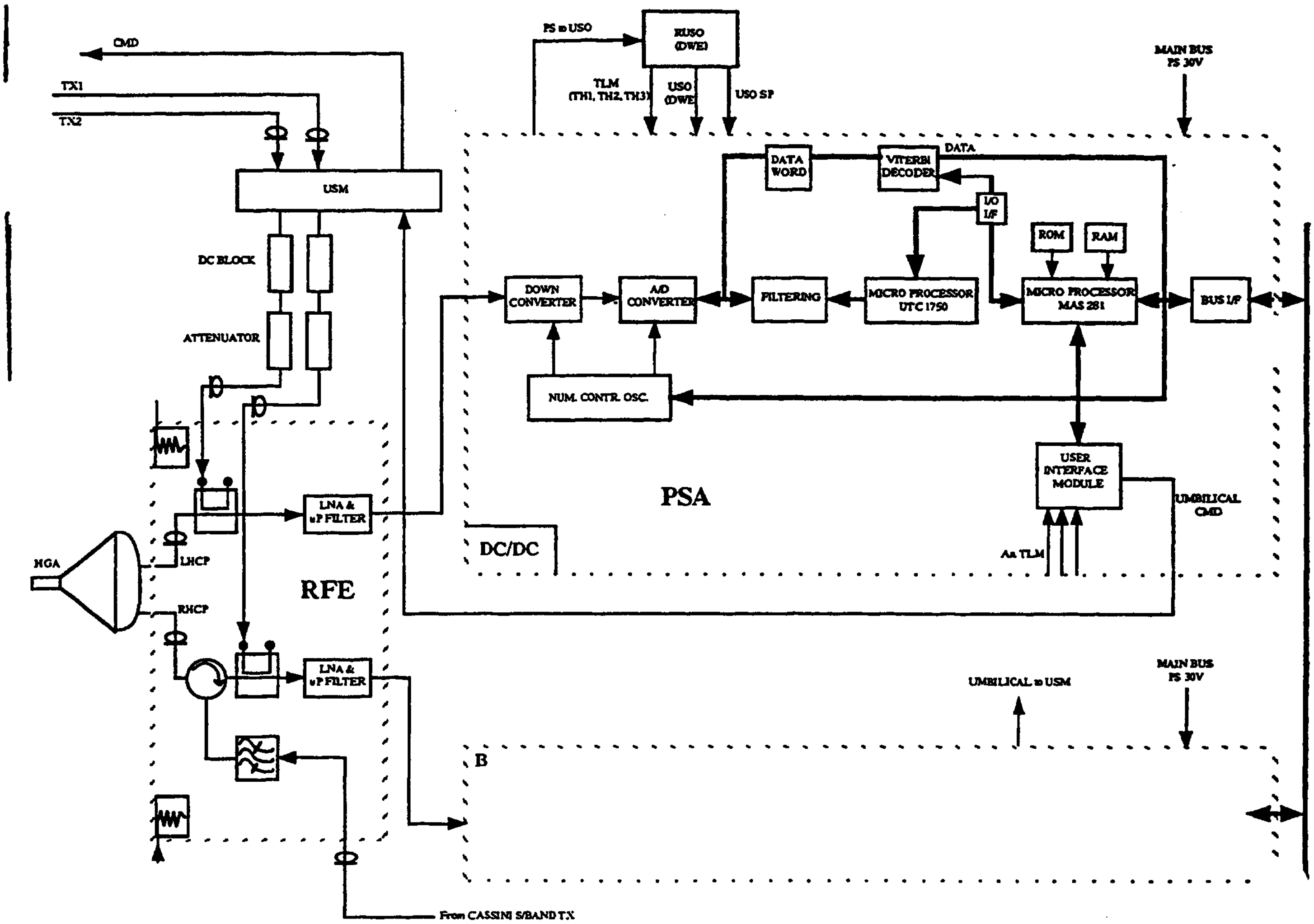

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FIGURE 4.2.1-3 ORBITER RECEIVING TERMINAL FUNCTIONAL BLOCK DIAGRAM

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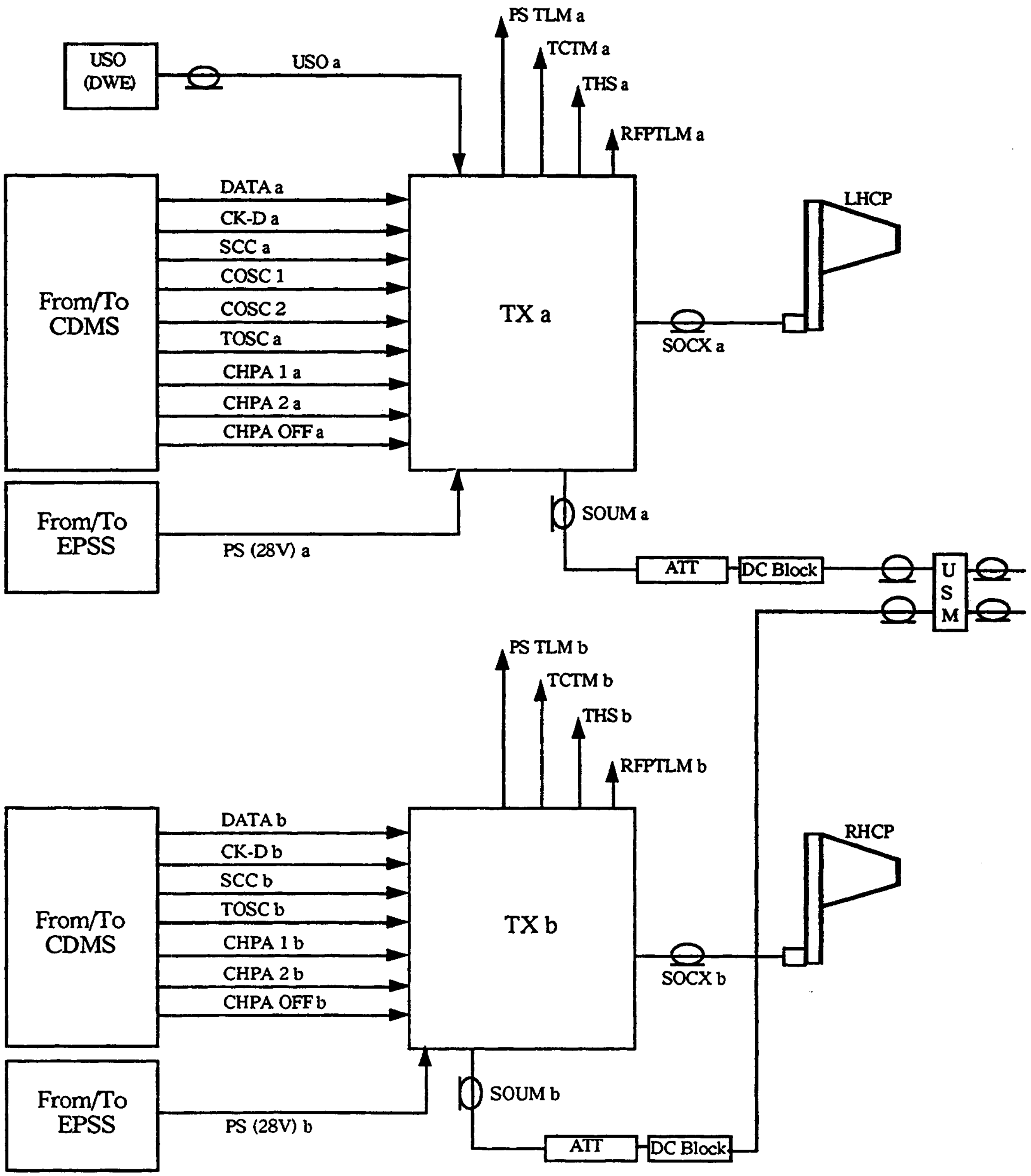

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FIGURE 4.2.1-4 PROBE TRANSMITTER INTERFACE OUTLINE

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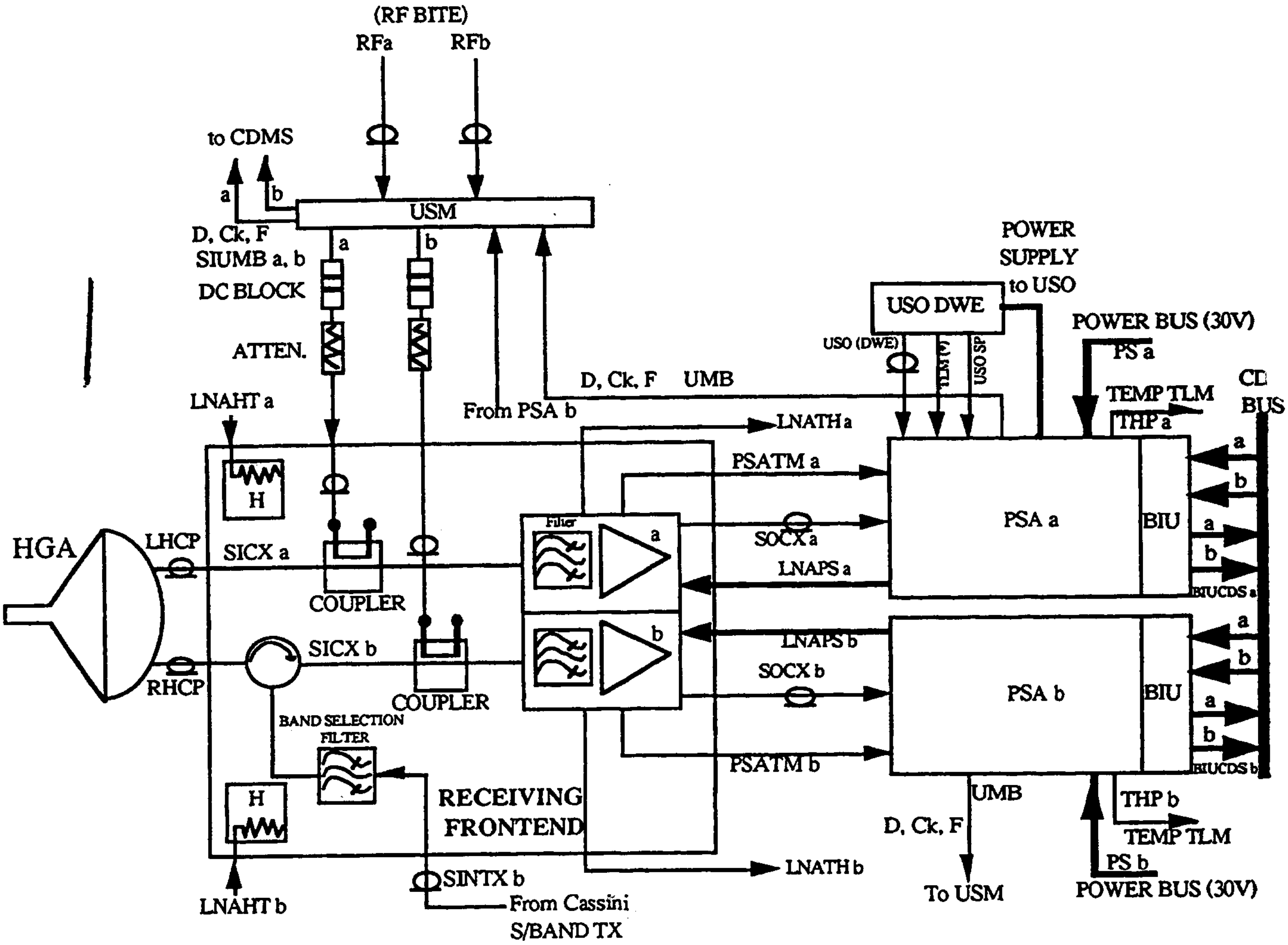

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FIGURE 4.2.1-5 ORBITER RECEIVING TERMINAL INTERFACE OUTLINE

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4.2.1-2-2 Operational Modes during HUYGENS/CASSINI Mission

HUYGENS/CASSINI spacecraft Mission is divided into six phases of which the last three ones are related to the Probe Mission itself.

Phase	Description	Environments	PDRS State
P1	Launch Phase	Launch	Dormant
P2	Cruise Phase from Earth Escape to Saturn orbit injection Duration: baseline: 6.7 years back-up: 11 years	Free Space	• Check-out sequences periodically (RF BITE) • Command distribution to PSA and Probe • Telemetry gathering
P3	Saturn Orbit Phase Duration: ≈ 4.5 months	Free Space	• At least one Check-out sequence • Depassivation sequence • MTU Loading sequence (RF BITE) • Command distribution to PSA and Probe • Telemetry gathering
P4	Coast Phase Duration: 22 days (max)	Free Space	• PSE side: - Timing - Warm up (40 mn before Entry Phase) - DSP - Autonomous control and management - Internal HK and dissemination to Orbiter • Probe side: - TX ON Low Power
P5	Entry Phase Duration: 5mn	PSE: Free Space PTT: Entry	• PSE side: - Timing - DSP - Autonomous control and management - Internal HK and dissemination to Orbiter • Probe side: - TX ON Low Power
P6	Descent Phase and Surface Phase Duration: 2.5 hours + 30mn	PSE: Free Space PTT: TITAN atmosphere	• PSE side: - Timing - DSP - Autonomous control and management - Internal HK and dissemination to Orbiter • Probe side: - Relay link transmission

4.2.1-3 Units Description

4.2.1-3-1 PTT Description

4.2.1-3-1-1 Probe Transmitter

The Probe Transmitter task is to transmit the data gathered by the Probe to the Orbiter. To accomplish this task a very reliable architecture is used based on a synthesized transmitter.

The synthesized output frequency is 204 Fq, where Fq can assume two values:
10.000 000 and 10.283 902 MHz.

Figure 4.2.1-3-1-1 shows the Transmitter block diagram.

The Probe Transmitter is an equipment composed by three mechanical modules:

- TCXO/Frequency Synthesizer & Modulator Module (double module)

- DC/DC Converter Module (double module)

- Power Amplifier Module (single module).

The TCXO/Frequency Synthesizer Circuit provides a very stable and clean signal. It uses a temperature controlled crystal oscillator as reference signal source and a PLL synthesizer. Further, it is possible to accept an external USO signal for the channel A. The internal TCXO/external USO switching is performed by a suitable external command.
The Modulator Circuit, basically, provides a linear phase modulation for the encoded telemetry data and performs a times eight multiplication and up-conversion of the incoming signal.

The Power Amplifier Module provides the required amplification to increase the input signal up to the required power level of 10 Watts minimum.

The Power Supply Module provides the secondary voltages for the unit.

The required power from main bus is around 43 Watts with a DC/DC converter efficiency of ≈ 84 %.

The Probe configuration comprises two S-Band transmitters, in hot redundancy.

Each of two transmitters receives the data, clock, subcarrier signal from the CDMU and power supply from EPSS. Each one is connected to the relevant Probe transmitting antenna (operating with circular polarization). The two transmitter chains operate with opposite circular polarizations and different frequencies.

Two outputs are available on each transmitter:
- one at 40 dBm for the RF link
- one at -40 dBm for the RF BITE link used during the checkout period and linked to the RFE through the umbilical

The unit interface outline is shown in Figure 4.2.1-3-1-2.

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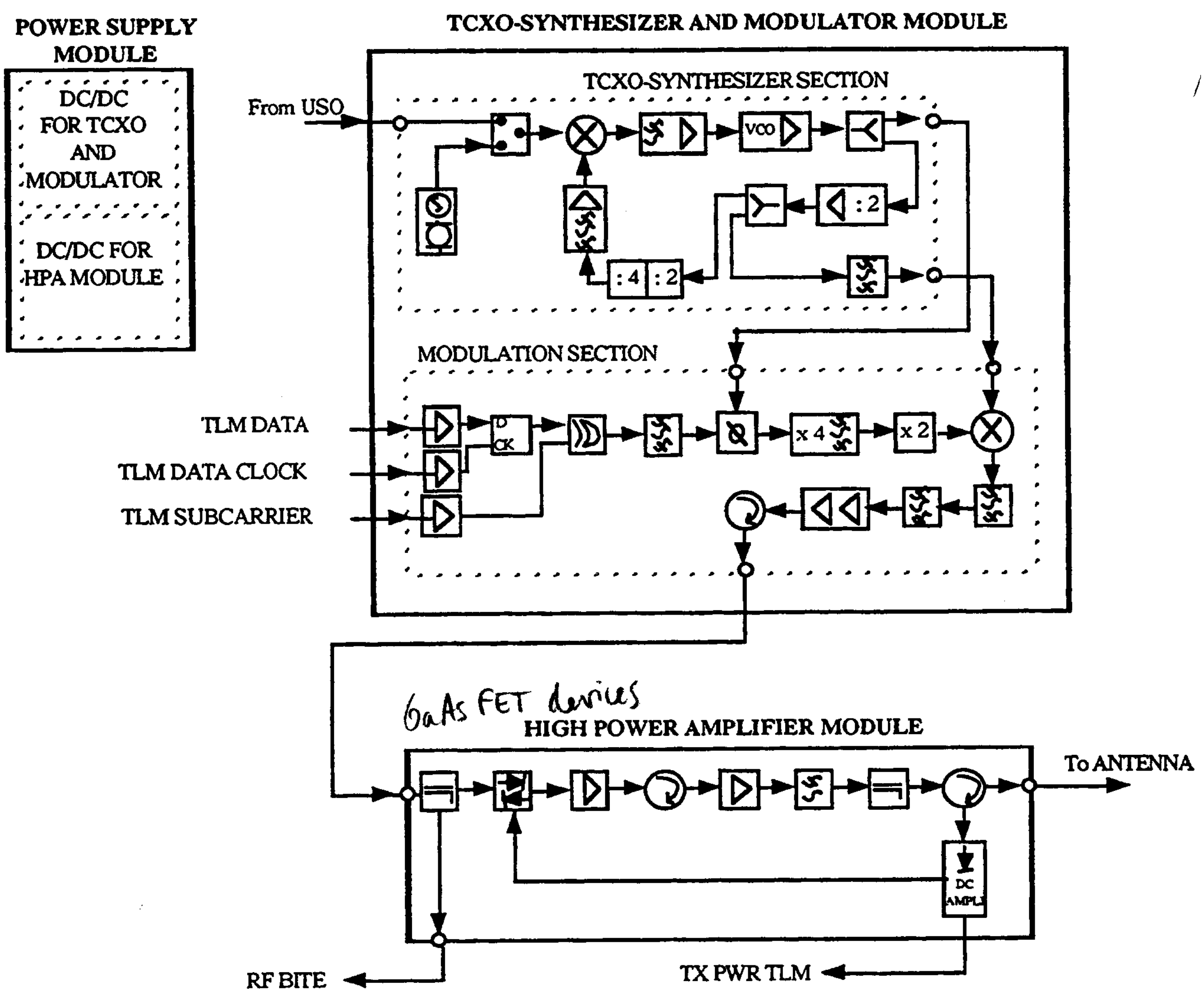

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FIGURE 4.2.1-3-1-1 TRANSMITTER BLOCK DIAGRAM

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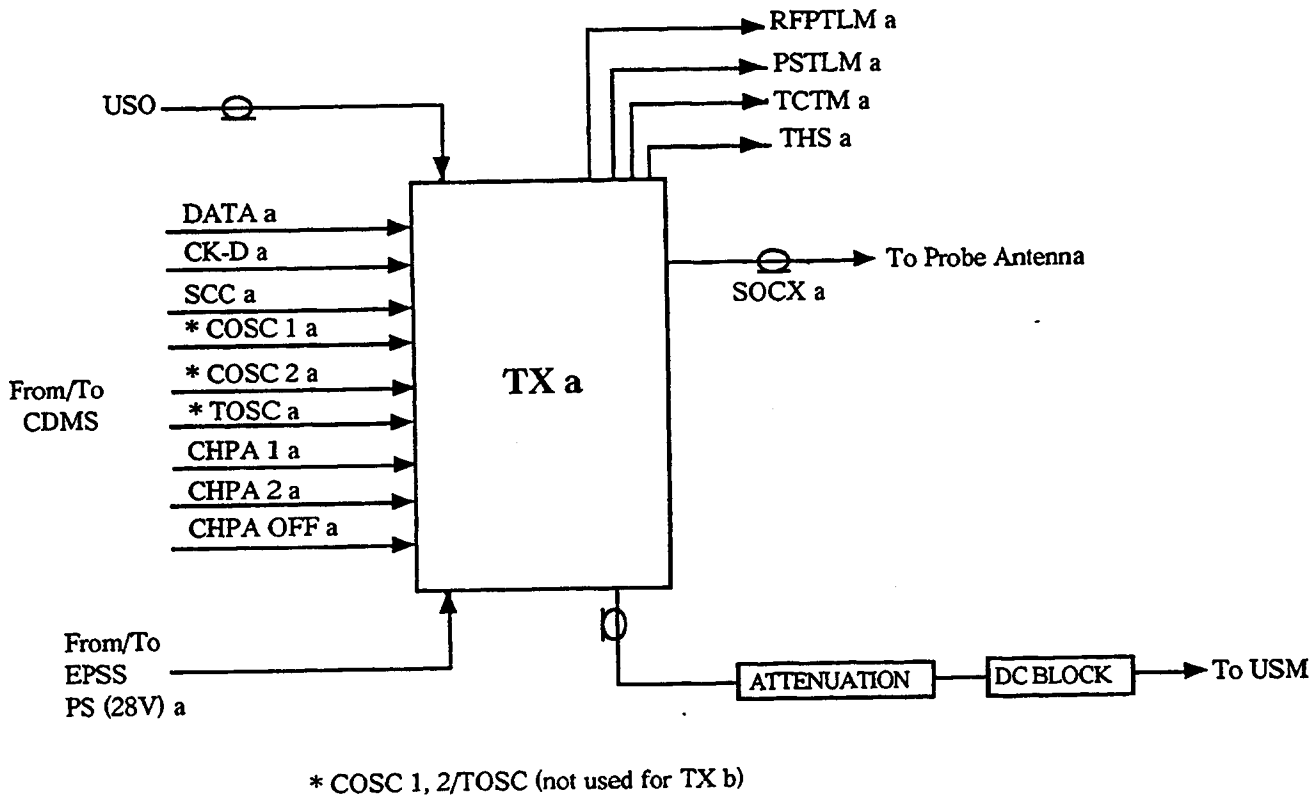

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FIGURE 4.2.1-3-1-2 PROBE TRANSMITTER UNIT INTERFACE OUTLINE

The modulated signal is sent to a times four multiplier, a bandpass filter selects the wanted harmonic spectral line. Then a times two multiplier provides a signal at a frequency of 192 Fq, a mixer and two bandpass filters (a comb filter, five poles Butterworth type and a four poles hairpin line filter) perform the up-conversion up to 204 Fq.

Finally, two amplifier stages provide the Power Amplifier Module with the suitable drive power level.

TCXO/Frequency Synthesizer and Modulator Module

The reference oscillator is a TCXO at a frequency of Fq. Mainly, the TCXO consists of two sections: a VCXO circuit and a temperature compensating network. The reference signal, TCXO or USO, is selected by Telecommand (for chain A).

The frequencies of the two quartz oscillators (two TCXO) differ of about:
57.916 MHz/204 = 283902 Hz
Fq A = 10.000 000 MHz, Fq B = 10.283902 MHz.

The TCXO relevant to the TX chain A operates at about same frequency than the USO for the Doppler Wind Experiment.

The BPSK signal coming from the synthesizer enters the Modulator Circuit to phase-modulate the carrier.

The linear carrier phase modulator consists of a quadrature hybrid with the -3 dB ports terminated in identical reactances, comprising series variable LC networks. Carrier modulation is achieved by varying the reactance of the LC networks, by changing the capacitance of two varicap diodes.

The 131072 Hz square wave subcarrier is BPSK modulated by square wave encoded data in an EXOR circuit. The modulation filter is a 4-pole low-pass Butterworth filter, having a -3 dB bandwidth of 170 KHz. This scheme, suppressing the frequency (also modulated by data) generates a sinusoidal subcarrier phase modulated by square wave NRZ data.

Power Amplifier Module

The power amplifier module consists of the following main blocks:

a. preamplifier
b. driver stage
c. output power stage.

Isolators are used to ensure good input VSWR, to isolate driver from final stage, to protect the output against mismatching.

A low-pass filter is inserted at the output in order to reduce the second harmonic level.

The amplifier design is based on GaAs FET devices.

DC/DC Converter Module

The DC/DC converter module acts as an electrical interface between the unit and the spacecraft (S/C) power bus. This module, using the S/C Bus as input voltage, provides the required output voltages for the transmitter modules. The BUS input voltage is 28 volts (+ 1.25, - 2.25 %) floating.

It is made of two DC/DC converters:

- DC/DC 1: supplies the FET amplifiers of the HPA module
- DC/DC 2: supplies the TCXO-SYNTH. and Modulator module.

DC/DC 1 can be turned ON/OFF by command while DC/DC 2 is always ON.

As soon as the + 28 V primary bus is present, DC/DC 1 turns OFF TCXO-SYNTH. and Modulator module. Afterwards, by execution of the dedicated ON command, DC/DC 1 delivers the secondary voltage. A block diagram is presented in Figure 4.2.1-3-1-3.

The converter design is based on PWM coupled inductor technique. The 140 KHz switching frequency is chosen to improve the control loop response, using small size passive components.

The use of PWM Push-Pull assures high performances in term of conversion efficiency. The regulation is based on the "current mode" control principle. By this design it is possible to obtain a very fast response to the load changes.

Load	Power (W)
DC/DC 1	37.5
DC/DC 2	5.5

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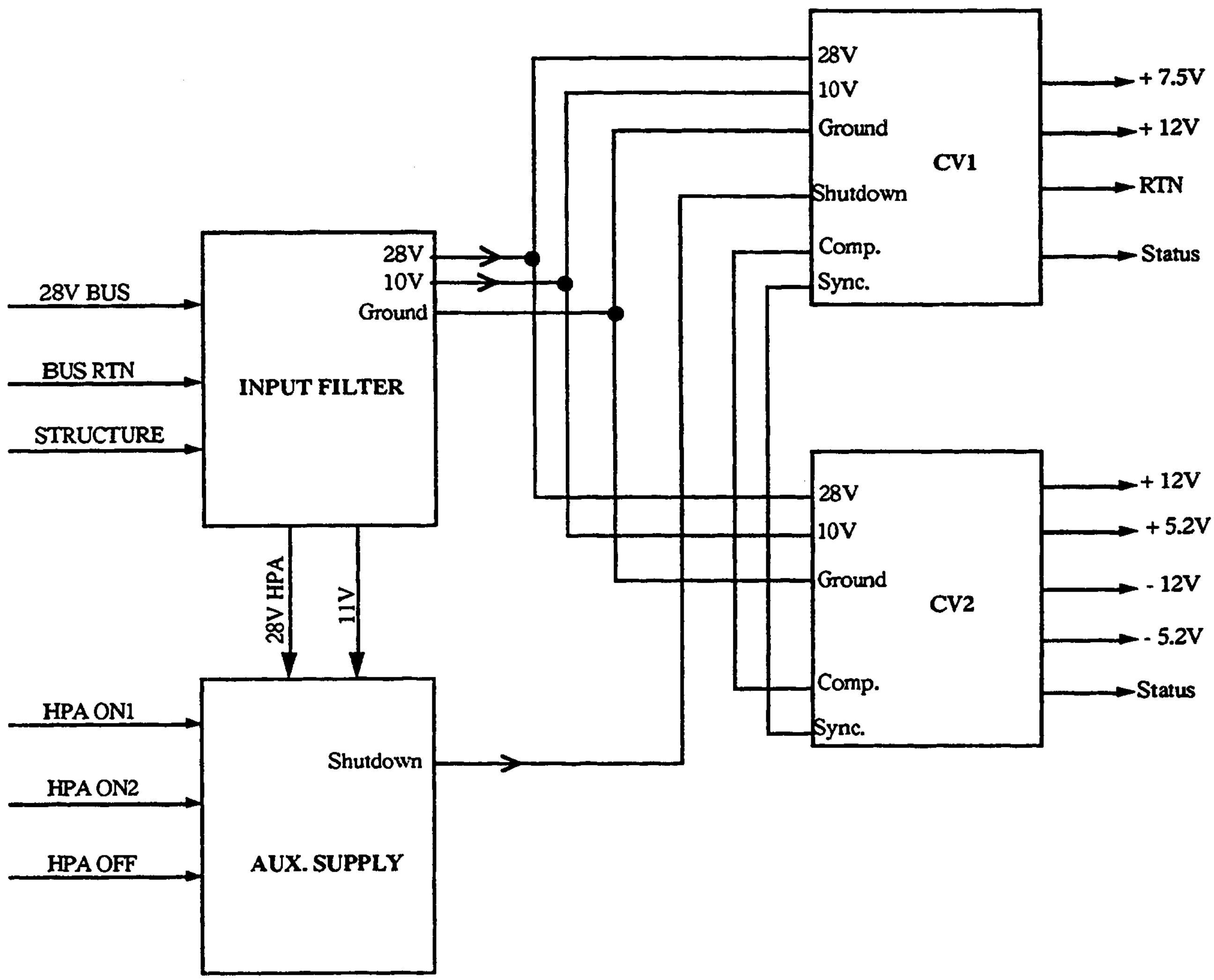

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FIGURE 4.2.1-3-1-3 DC/DC CONVERTER BLOCK DIAGRAM

4.2.1-3-1-2 PTA Probe Transmitter Antenna

The Probe Transmitting Antenna (PTA) is a resonant quadrifilar helix antenna. It consists of four metal strip elements shaped to a helix. The wires are supported by a thin dielectric tube, see Figure 4.2.1-3-1-4. The radiation characteristic is determinated mainly by the shape of the helices, i.e. the number of turns, the pitch distance, and the diameter of the antenna.

The four spirals are fed at the bottom in phase quadrature, i.e. with equal amplitude and with the phase relation 0°, 90°, 180° and 270°. The signals are summed in a stripline network consisting of a 180° hybrid and two 90° hybrid. The stripline network is placed in a separate box located below the spirals: it also contains a matching section that matches the radiating helices to 50 ohms.

The signal generated by the transmitter is radiated by the Probe Antenna as circularly polarised signal.

The Probe Antenna performance is compatible with the environment and with the physical constraints upon antenna size, location (see Figure 4.2.1-3-1-5).

The antenna provides gain and radiation pattern as implied by the overall link geometry and the Orbiter-Probe interface requirements.

The mechanical design is shown in Figure 4.2.1-3-1-6.

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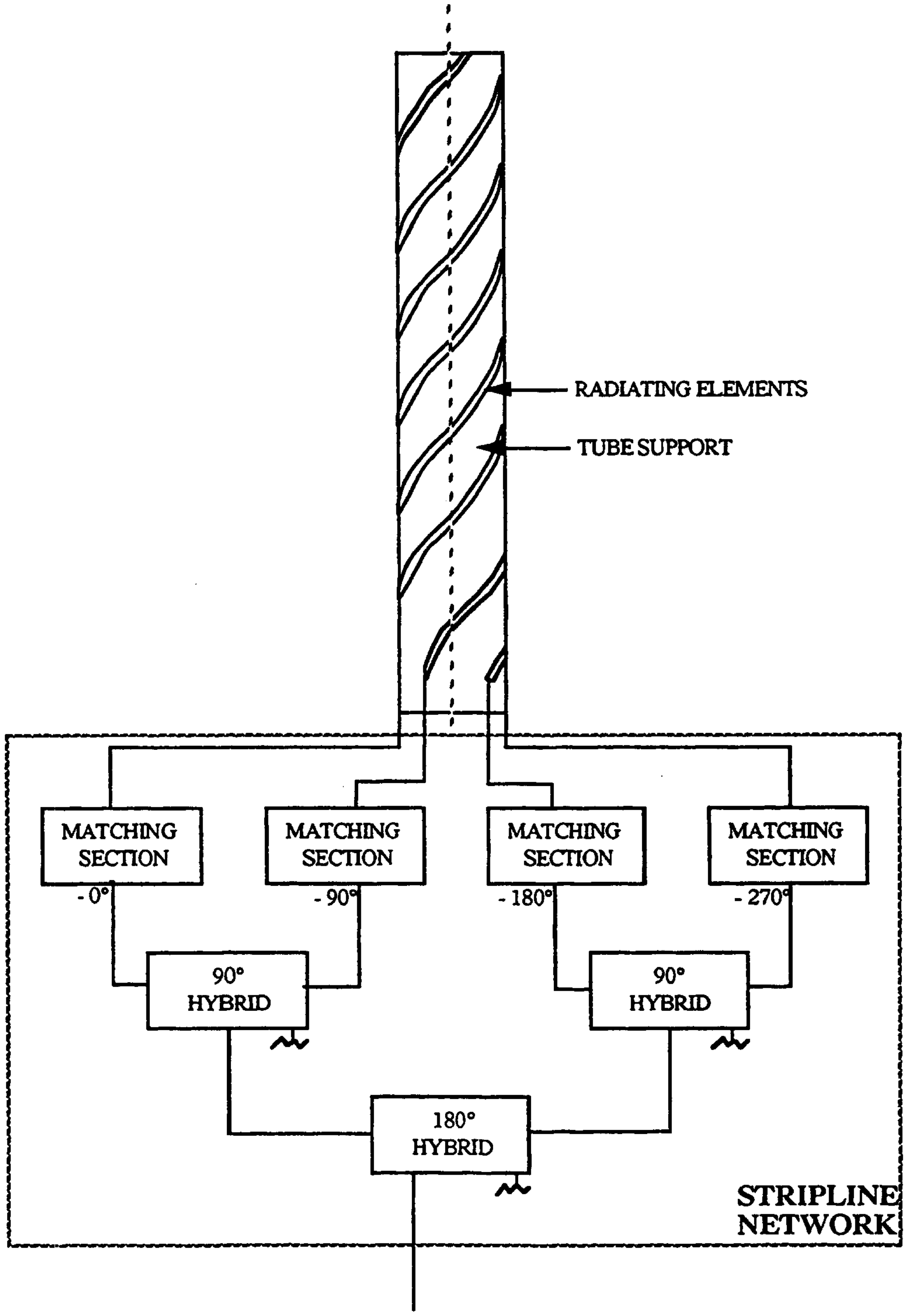

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FIGURE 4.2.1-3-1-4 PROBE ANTENNA BLOCK DIAGRAM

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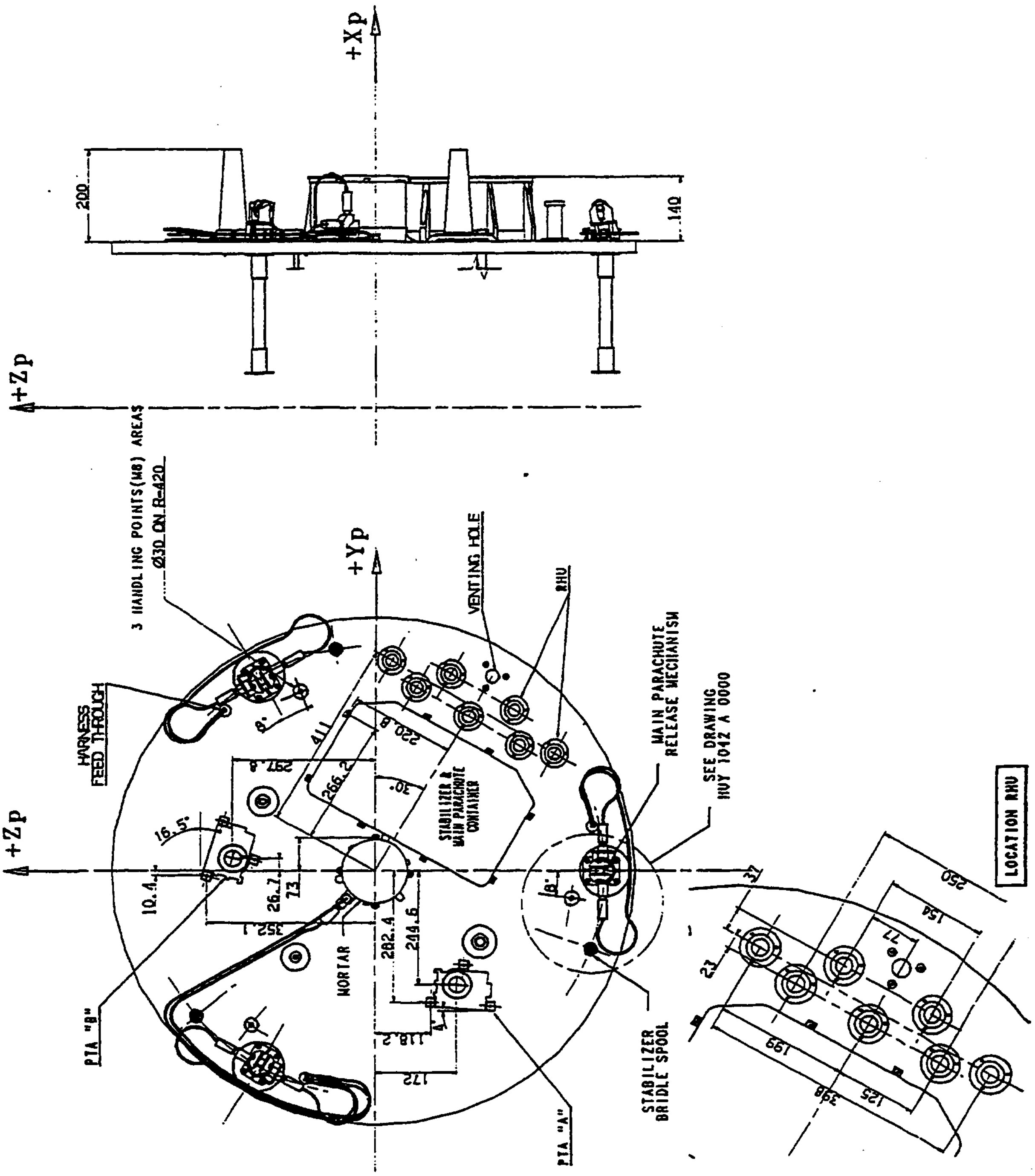

FIGURE 4.2.1-3-1-5 PTA LOCATION

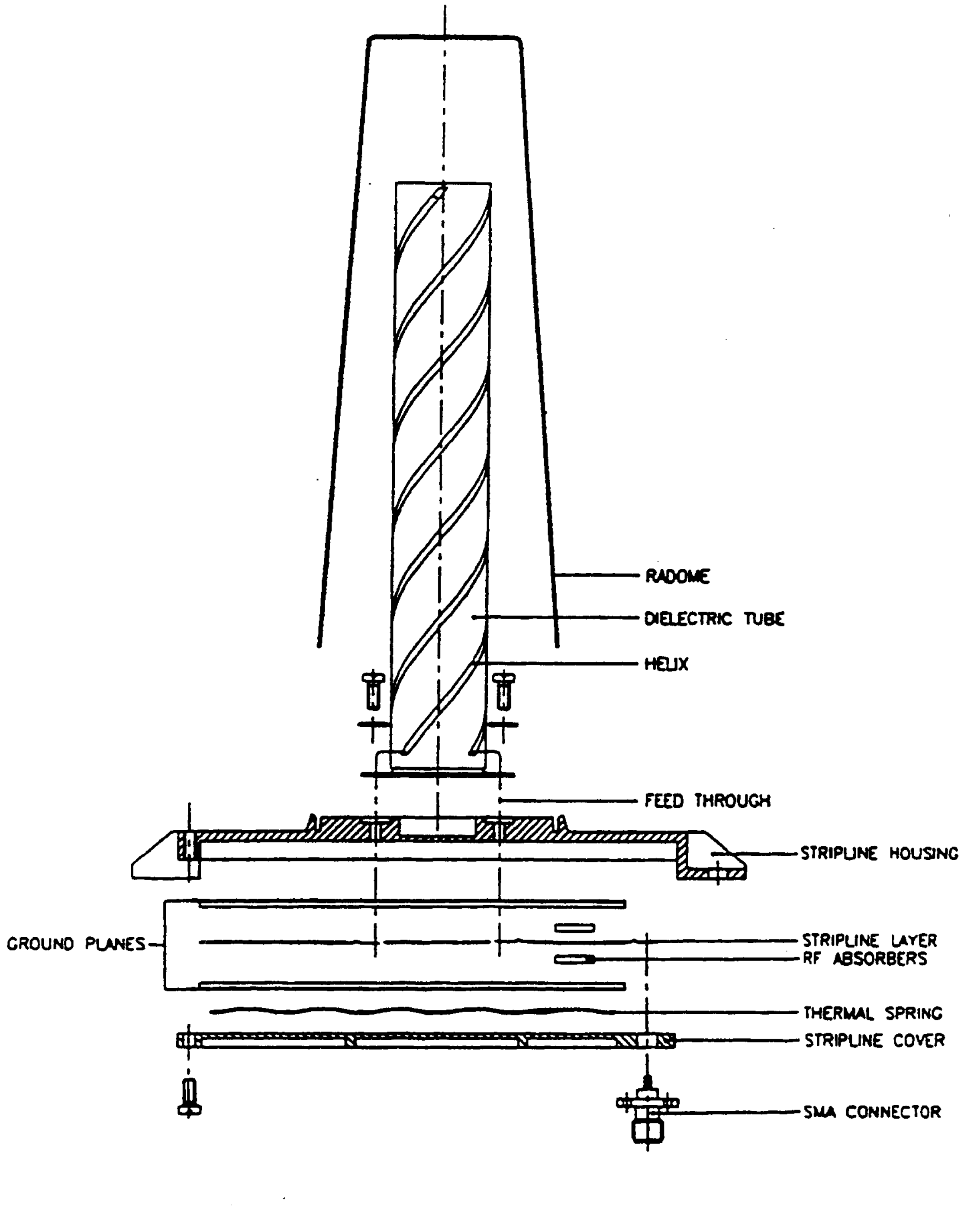

FIGURE 4.2.1-3-1-6 PROBE TRANSMITTING ANTENNA MECHANICAL LAYOUT

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4.2.1-3-2 ORT Description

4.2.1-3-2-1 HGA Antenna

The HGA antenna on board CASSINI Spacecraft provides the two signals as an input of the receiving front-end unit. The antenna is compatible with the environmental constraints and the accommodation envelope on board the orbiter.

4.2.1-3-2-2 Receiving Frontend

The unit (internally redundant) is linked to the CASSINI HGA and amplifies by a factor of 20 dB the RF signal acquired by the HGA.
The RFE is external to the PSA receiver section but assembled in the same unit. Each of the two redundant chains is composed of:

- two RF inputs, both linked to the HGA and to the USM, via a coupler, to be used during the checkout period.
- a preselection filter (coaxial cavity type with 6 poles)
- an isolator
- a low noise amplifier which consists of two cascaded FET stages
- a gain setting alternator

The outputs are sent to the PSAs.

It should be pointed out that the LNA's are not supplied when RF power is present at the S/Band interface with the CASSINI transmitter. Hence a band pass filter called Tx filter is used to avoid damaging the LNA due to spurious or unexpected large signals at the PDRS operating frequencies.

The unit block diagram is given in Figure 4.2.1-3-2-1.

An external power supply (provided by the PSA unit DC/DC converter) provides the proper secondary voltage for the unit.

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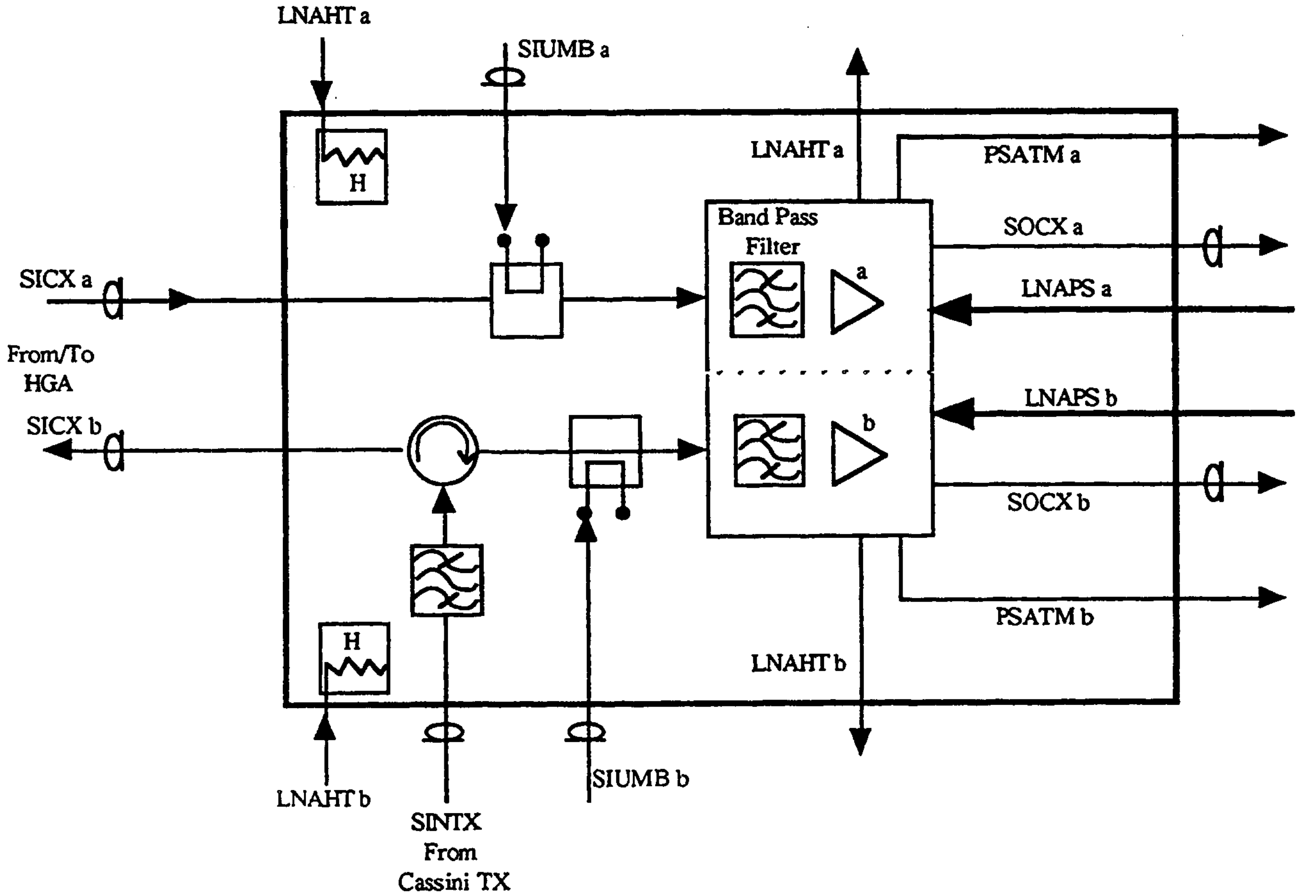

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FIGURE 4.2.1-3-2-1 RECEIVING FRONTEND UNIT BLOCK DIAGRAM

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4.2.1-3-2-3 PSA

Figure 4.2.1-3-2-2 shows the Probe Support Avionic (PSA) unit block diagram.

The PSA fulfills the following functions:

- the signal acquisition based on a 256 points FFT algorithm
- the signal demodulation
- the data handling

These functions are split into two sections:

- RF Receiver
- Data Handling

The characteristics of the link are:

- Two data streams, identical in terms of information content, but temporally delayed by 6s, are sent from Probe to the Orbiter on two different carriers at S/Band frequency
- The chosen data rate is 8192 bps at the CDMS convolutional encoder input and Orbiter PSA receiver convolutional decoder output
- The digital data are modulated on a 131072 Hz subcarrier, with BPSK modulation
- Nominal carrier phase modulation index is 1.4 rad (± 5 %)
- Due to demodulator symbol phase ambiguity (and also due to possible subcarrier cycle slippages) and according to ESA PSS-04-103 differential encoding and decoding are applied before and after the coding/decoding stages respectively, in such a way restoring unambiguous information.
  In fact a 180 degrees phase reversal can occur in the incoming symbols when operating with BPSK modulation scheme. This ambiguity is eliminated by differentially encoding the bit stream prior to convolutional encoding at the source (CDMS function). The Viterbi decoder output is then differentially decoded at the receiver post decoding.

In addition:

- the **power supply** module made of two DC/DC converters converts the +30V primary bus providing +5V, -5V, +12V, -12V, -5.2V, -2V to the RFE and the PSA modules.

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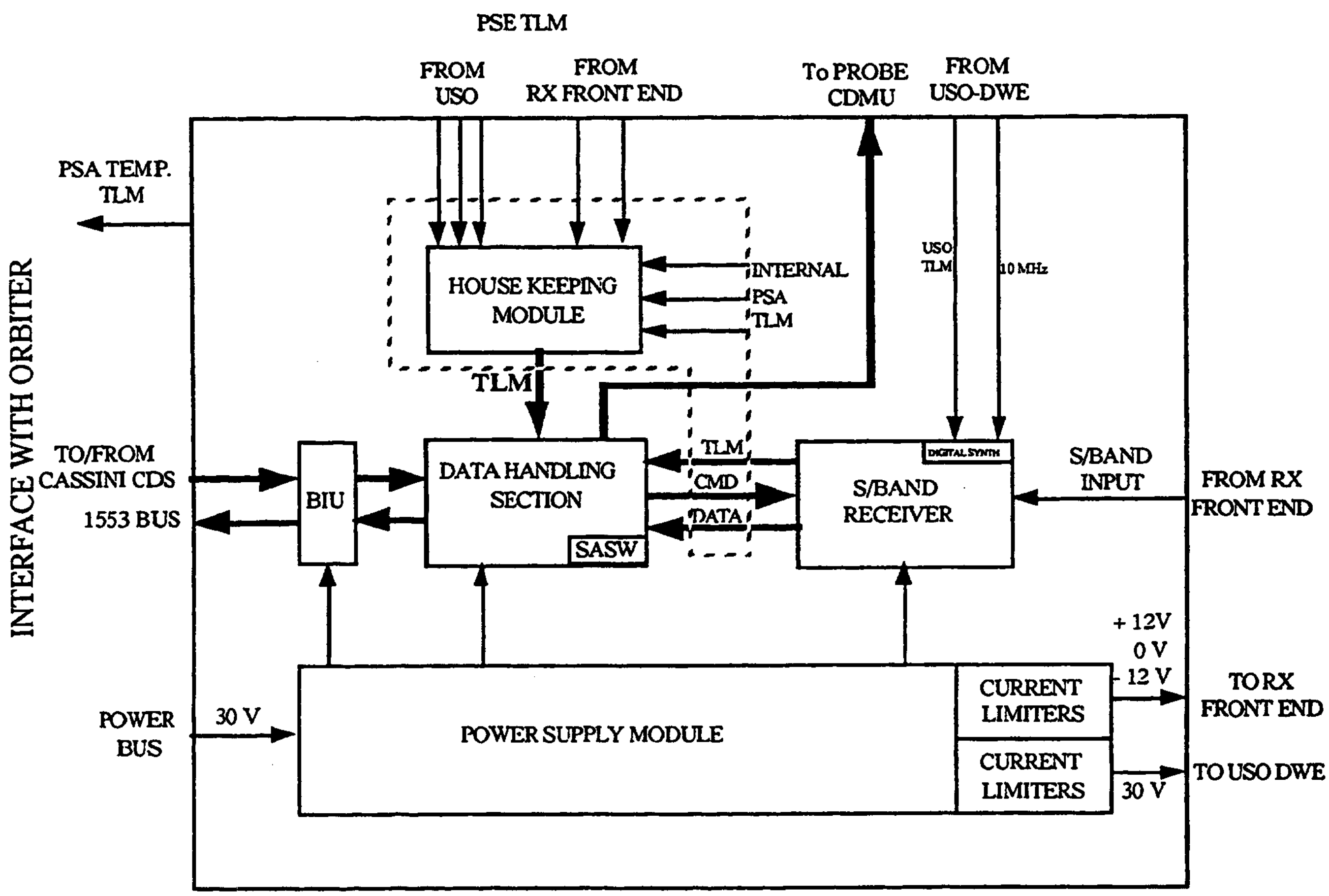

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FIGURE 4.2.1-3-2-2 PSA UNIT BLOCK DIAGRAM

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RF Receiver

The S-Band receiver is organized in an analog section and a digital section, as illustrated in Figure 4.2.1-3-2-3.

The analog section is devoted to:
- the **RF/IF** section which provides two frequency downconversions and gives the required in band selectivity to reject all the spurious spectral lines near the second IF central frequency.
- the **local oscillator and synthetiser** module which provides signals for the first and second downconversion and the clock signals for the A/D converter and the ASIC in the digital section.
- the **reference oscillator** module, driven by an external "direct digital synthetiser", which generates signals for the local oscillator and the DWE.

The digital section is constituted by:
- the **receiver digital** module constituted by the A/D conversion and driver circuit, the UT1750 processor which manages the receiver software called RSW (the software tasks are the DSP, Digital Signal Processing, the internal commands and housekeeping data management), 8 Kword RAM and 8 Kword PROM, the receiver signal processing ASIC.
- the **interface digital** module which synthetises the receiver frequency using Ga As NCO and Ga As DAC devices.

The loop filters for AGC, carrier and subcarrier and the lock status algorithms are digitally implemented via DSP microprocessor.

The carrier loop is closed at S-Band frequency (long loop closure) and the Doppler component is completely removed at the second IF, to extract a coherent reference signal for DWE.

One TCXO is provided: Rf = 10 MHz

The Fq TCXO/USO (10 MHz) generates the clock of the carrier NCO: the choice of the Fq frequency value takes into account the signal reconstruction to obtain a good spectral purity at S-Band level.

4 x F1 is the clock reference for the A/D converter, besides it fixes the second IF value (F1) simplifying the frequency plan and ASIC design.

The Direct Digital Synthesiser (DDS) output is derived from the reference USO (coherent reception), according to the DWE requirements (PSA unit A).

The Doppler Wind Experiment needs a very fine frequency resolution for the Doppler measurement of incoming signal.

The DDS architecture uses a 32 bit frequency resolution (NCO) and 12 bit amplitude quantization (DAC).

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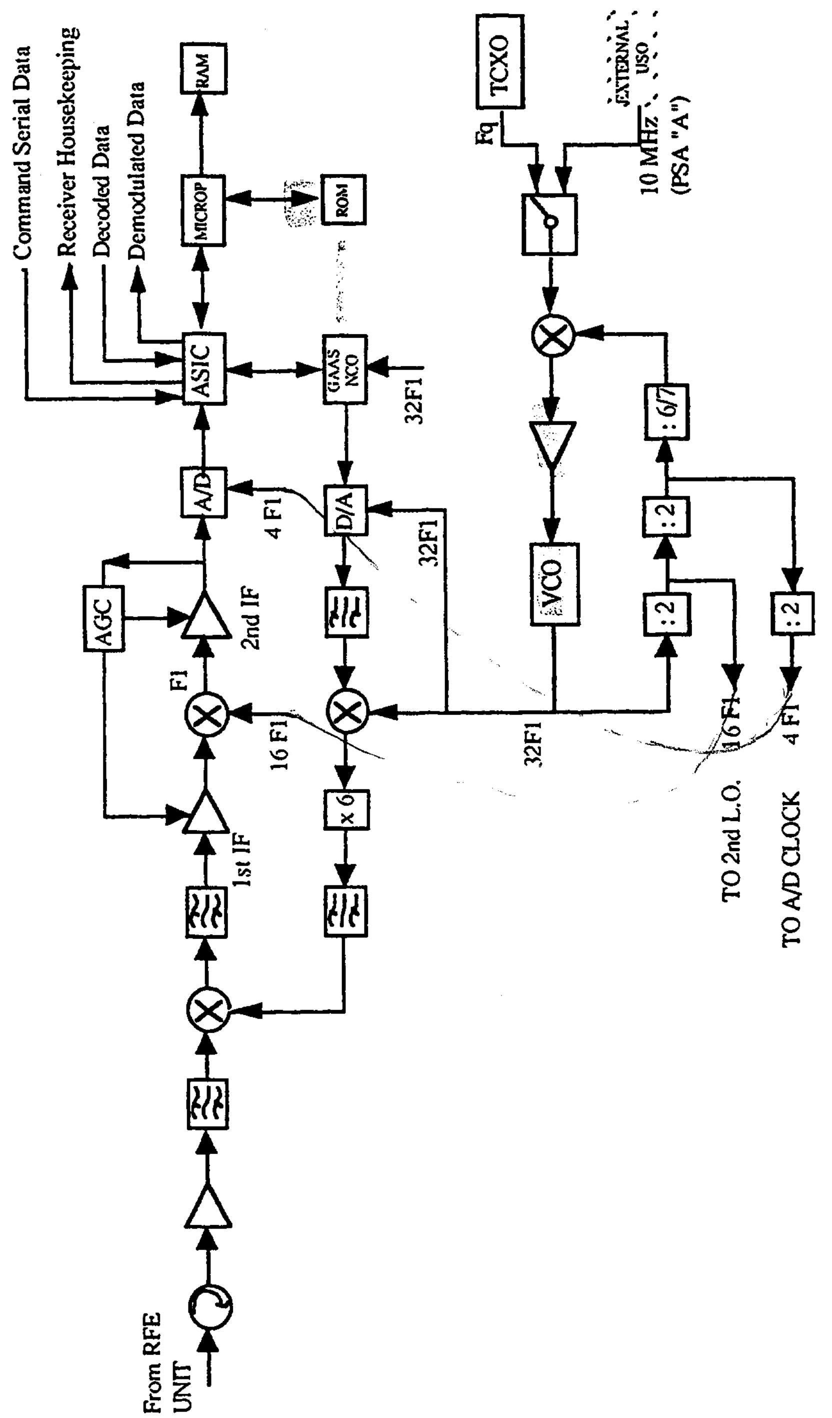

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FIGURE 4.2.1-3-2-3 S-BAND RECEIVER FUNCTIONAL DIAGRAM

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Data Handling

The Data Handling section is supported by software called SASW (Support Avionic Software) managed by the microprocessor MAS 281.
The main Data Handling (DH) performed functions are pointed out in the following:

- acquisition and tracking of the transfer frame synchronisation marker
- transform the received transfer frame into a TLM Packet CCSDS format
- generate PSA H/K data including the synthetized frequency information in CCSDS packet format
- control and manage the communication with the Orbiter CDS through the BIU (receive TCs, and TMs & HK frames)
- dispatch Telecommand to PSA and to Probe CDMS (via umbilical link)
- maintain PSA time for telemetry from dating and on-board PSA timer function.

The following modules are involved:
- the housekeeping circuitry housed in the Support Interface Circuitry module (SIC)
- the MAS 281 module
- the BIU module

Figure 4.2.1-3-2-4 shows the Data Handling Architecture.

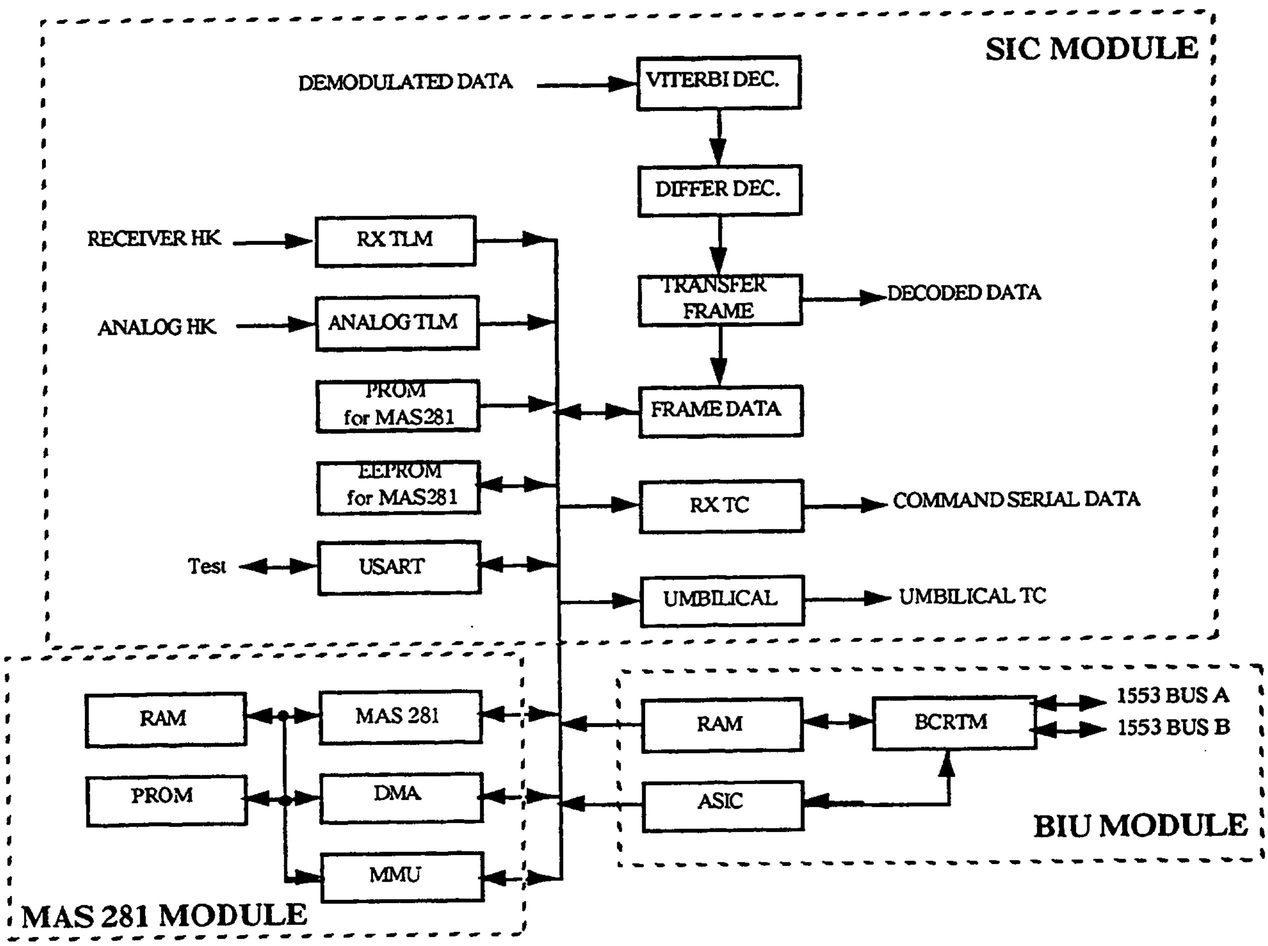

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FIGURE 4.2.1-3-2-4 DATA HANDLING ARCHITECTURE

Support Interface Circuitry module (SIC)

It is composed of:
- the Viterbi Decoder
- the differential decoder
- the transfer frame interface
- the frame data interface
- EEPROM (8 Kw) to memorise software patches
- the PROM (32 Kw) containing the SASW
- a serial interface USART used for testing
- the analog telemetry interface
- the receiver section telecommand interface and telemetry interface
- the umbilical interface which has in charge to transmit the telecommand frame to the CDMS during the checkout and cruise phase

Microprocessor Module

See § 4.5 SASW.

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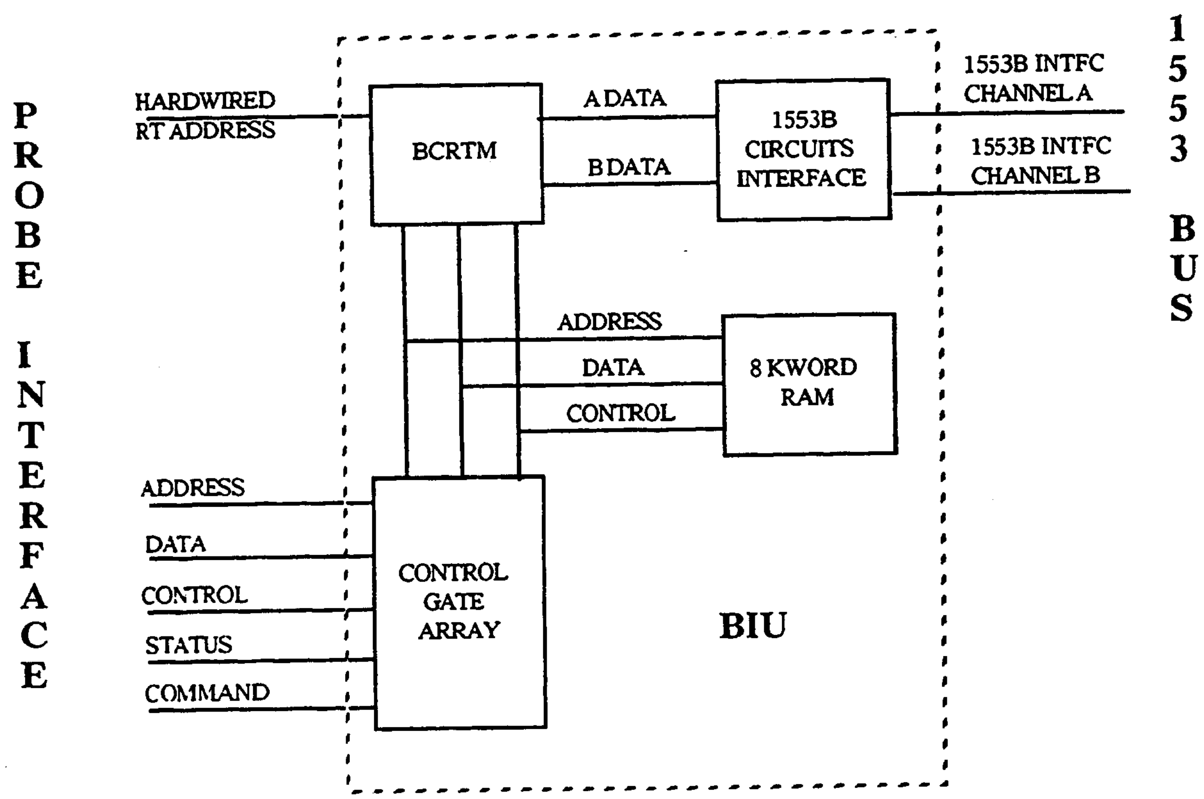
BIU Module

The BIU is an intelligent controller for the interface between PSA and Orbiter CDS.

The BIU contains control circuitry and buffer memory required to allow communications between the PSA and the Orbiter CDS via dual redundant MIL-STD 1553B Bus. Communications between PSA and CDS consists of commands from CDS to PSA or scientific data and telemetries from PSA to CDS.

The block diagram of the BIU and relevant interface is shown in Figure 4.2.1-3-2-5.



C1 FIGURE 4.2.1-3-2-5 BLOCK DIAGRAM OF THE BIU AND RELEVANT PSA INTERFACE

For more details, see § 4.5 SASW.

4.2.1-4 Performances Characteristics

4.2.1-4-1 Power Consumption and Dissipation

	TX		TUSO		PSA + RFE	RUSO
	Power Consumption	Heat Dissipation	Power Consumption	Heat Dissipation	Power Consumption	Power Consumption
Cruise Phase (Check-Out)	2 x 5.55 W or 1 x 5.55 W	2 x 5.55 W or 1 x 5.55 W	15 W or 0	15 W or 0	51.7 W	15 W
Coast Phase	0	0	0	0	51.7 W	15 W
T0 - 18mn	2 x 5.55 W	2 x 5.55 W	15 W	15 W	51.7 W	15 W
Entry Phase	2 x 5.55 W	2 x 5.55 W	9 W	9 W	51.7 W	9 W
Descent Phase	2 x 37.8 W	2 x 30.2 W	9 W	9 W	51.7 W	9 W

4.2.1-4-2 Telemetry and Telecommand Budget

The following Telemetry lines are provided:

	DESTINATION		
	CDMU A/B	PSA A/B	ORBITER
Analog	7/7	6/3	0
Thermistors	0	1/1	4
DB	2/2	2/1	0
Relay Status	1/1	2/1	0
DS16	0	4/4	0

The following Telecommand lines are provided:

	SOURCE	
	CDMU A/B	PSA A/B
O/O 13ms	4/3	0/0
ON/OFF	0/0	4/1
ML16	0/0	1/1

D6

4.2.1-4-3 Thermal Temperature Prediction

UNIT	DESIGN LIMITS OPER.	CRUISE 0.6AU	CRUISE 9AU	CHECK-OUT TMAX	COAST	ENTRY TMAX	DESCENT TMIN
Transmitters A/B	-20/50	22/24	9/10	36/37	2/3	4/6	15/26

Component	Tmin			Tmax operat		
	limit	calc.	Phase	limit	calc.	Phase
RFE	-20	-20	SC	50	31	CH
PSA	5	12	CC	50	40	SH
RUSO	-20	14	CC	50	41	SH

SC = Saturn Cold
SH = Saturn Hot
CC = Cruise Cold
CH = Checkout

All temperatures are in °C.

Note: For EMC reasons, thermistors which provided temperature telemetries of PSA A and B have been moved and implemented between PSA boxes.

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4.2.1-4-4 PTT Performances

a. Operating Frequencies

• Carrier Frequencies

Fa (External USO or Internal TCXO)	2040.000000 MHz
Fb (Internal TCXO only)	2097.916093 MHz.

• Stability

The frequency with the internal source (TCXO) is set within 0.5×10^{-6} of the assigned value (Fa or Fb) at a temperature of 24° ± 2°C.

• Short Term Stability

At any temperature within the operational range, the RMS fractional frequency deviation over a 3 minutes period, measured with a 1 second integration time, does not exceed 10^{-9}.

• Long Term Stability

The frequency does not vary by more than $\pm 3.0 \times 10^{-6}$ over all missions phases, all effects included (setting excluded).

b. Input Data

The data are convolutionally encoded and pulse coded modulated (PCM):

• signal type PCM-NRZ-M

• symbol rate 16384 symb/s (bit rate 8192 b/s)

• Data clock
 # frequency 16384 Hz
 # jitter < 1 %
 # asymmetry < 0.5 %

• Sub-carrier
 # waveform square wave
 # frequency 131072 Hz ± 7 Hz
 # jitter < 150 ns p.p
 # duty cycle < 0.5 ± 0.15 %
 # synchronization between Subcarrier and Data Clock, see Figure 4.2.1-4-1

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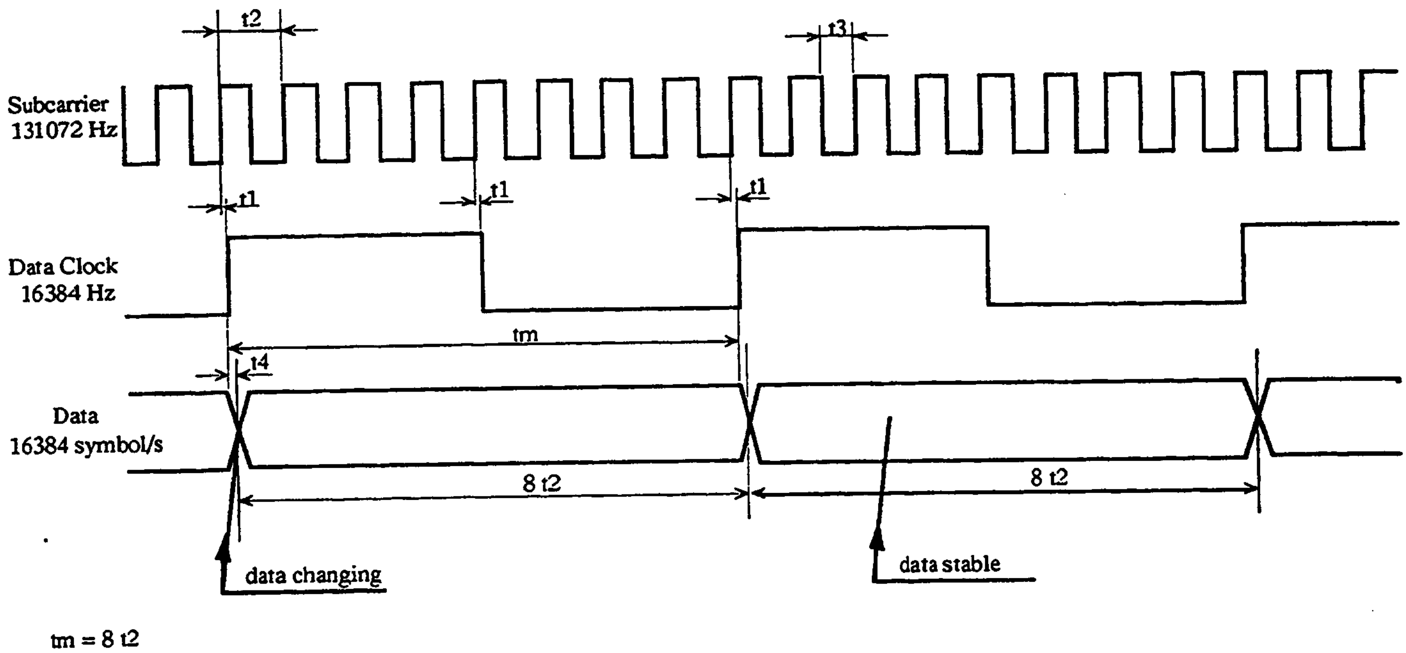

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t1	4 µs max
t2	7.629 µs
t3/t2	0.5 ± 0.15 %
t4	4 µs max
131072 Hz clock stability	± 7 Hz
clock jitter	150 ns peak to peak
rise time	2 µs max

FIGURE 4.2.1-4-1 WAVEFORM AND TIME DIAGRAM

• Short Term Stability
At any temperature within the operational range, the RMS fractional frequency deviation over a 3 minutes period, measured with a 1 second integration time does not exceed 1 Hz.

• Long Term Stability
The frequency does not vary by more than ± 0.125 Hz over 48 hours period at any temperature within the operational range.

c. Modulation

The carrier is phase modulated with a subcarrier modulated by the PCM-NRZ-M data convolutionally encoded.

• Phase modulation: PCM/BPSK/PM
The subcarrier is reversed in phase (180°) at each transition in the PCM waveform (differentially encoded)

• Index 1.4 rad pk

• Index stability ± 5 %

• Modulation Linearity:
The phase deviation as a function of the video voltage applied to the carrier phase modulator does not deviate from the ideal linear response by more than ± 3 % of the instantaneous value.

• Carrier Phase Noise:
The phase noise integrated between 10 Hz and 100 KHz is less than 2 degrees RMS.

• Phase Unbalance:
Every time, for more than 25 % of a subcarrier period after phase reversal, the phase of the modulated subcarrier is within ± 5° of the correct PSK signal.

• Amplitude Unbalance:
Every time the amplitude of the modulated subcarrier is within ± 5 % of the perfect PSK signal.

d. Output Section

• RF power level at 0/P connector: 10.0 W min
15.5 W max

• RF power level stability over 30s: 0.2 dB

• Output impedance: 50

• VSWR: 1.3 : 1

• Output Spectrum Symmetry: < 1 dB

• Spurious Emission: 60 dB below unmodulated signal

D8

4.2.1-4-5 PTA Performances

Polarization and Frequencies

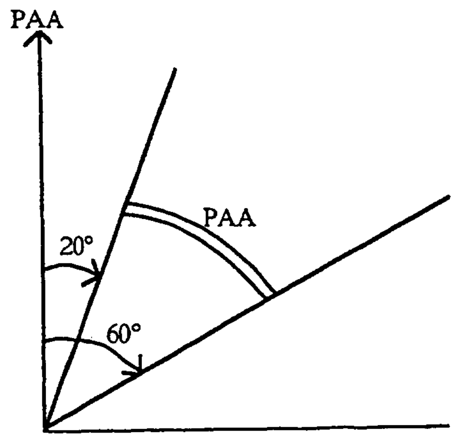
The antenna is implemented in double version:

- element a: radiation of a left hand circularly polarized signal at frequency
  fa = 2040.000 000 MHz ± 2 MHz
- element b: radiation of right hand circularly polarized signal at frequency
  fb = 2097.916 093 MHz ± 2 MHz.

Coverage

The coverage is defined by:

- 20° < PAA < 60° PAA = Probe Aspect Angle
- 0° < Phi < 360°



The back radiation (illumination at ± 90 degrees from the Probe axis) is sufficiently small in order to avoid any degradation of the receiver performance by re-radiation multipath from or via the Probe structure.

Polarization purity

The level of the cross polarized signal component is more than 5 dB below the level of the co-polarized component at any frequency in the operating frequency range towards any direction within the coverage.

Gain

The antenna gain, defined at the connector, within the specified coverage, is ≥ 0.9 dBi, taking into account the impact of the Probe structure and appendices.

Gain variation versus frequency

On the ± 2 MHz channel around the transmit frequency, the gain variation versus frequency is lower than 0.1 dB.

4.2.1-4-6 HGA Antenna Performances

Gain
The antenna gain, defined at the RFE input connectors (i.e. including the cable line losses), within the specified coverage, is not less than the values defined below, for each circular polarization.

Channel B: 2098 MHz ± 5 MHz:

≥ 35.3 dBic on axis (0 deg)
≥ 24.0 dBic at 2.0 deg off axis

Channel A: 2040 MHz ± 5 MHz:

≥ 34.7 dBic on axis (0 deg)
≥ 25.2 dBic at 2.0 deg off axis

Operating frequencies and polarizations
The HGA receives on two frequency ranges:

f1 = 2040.038 500 MHz ± 2 MHz with LHCP
f2 = 2097.954 593 MHz ± 2 MHz with RHCP

Polarization purity
The level of the cross polarized signal component is more than 5 dB below the level of the co-polarized component at any frequency in the operating frequency ranges, towards any direction within the required coverage.

Cassini/Huygens RF Constraint (Link Budget Aspect)
Noise temperature at RFE input: 113K

4.2.1-4-7 RFE Performances

Operating Frequencies

Two arms coming from the HGA antenna carry two different signals at different frequencies. The operating frequency ranges are:

a. ± 2 MHz centered at 2040.000 000 MHz input to SICX a I/F
b. ± 2 MHz centered at 2097.916 093 MHz input to SICX b I/F.

Input Signal Characteristics

The signal input level vary is according to the values given in table below.

	min dBm	max dBm
SIUMB I/F (Phase P2)	- (95 + 3)	- (95 - 3)
SICX I/F (Phase P6)	- 125	- 105

POWER LEVELS DURING THE PHASES P2 AND P6

Max Input Power for LNA no-damage

The maximum input level for no-damage is 16 dBm with RFE OFF. With RFE ON, about -30 dBm at S-Band and 0 dBm at other bands.

Gain

SICX I/F:

a. Nominal gain: 20 dB (< 15 dB for temperature range +10 +70°C)
b. Initial setting accuracy: +1., 0 dB
c. Gain variation (all environmental effects, included: < 1. dB.

SIUMB I/F:

a. Nominal gain: 0 dB
b. Initial setting accuracy: +3., 0 dB
c. Gain variation (all environmental included : < 2. dB.

Out of Band Rejection

At the SICX connector I/F (a, b)

FREQUENCY BAND	REJECTION
f < 1900 MHz	> 65 dBc
2296.7 MHz - 2300.7 MHz	> 65 dBc
8400 MHz - 8450 MHz	> 65 dBc
13700 MHz - 13900 MHz	> 30 dBc
31900 MHz - 32100 MHz	> 30 dBc

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Transmit Port Nominal Bandwidth
± 2 MHz centered at 2298.7 MHz input from CASSINI TX connector I/F

Attenuation at 2018MHz > -12dB
2040MHz > -19dB

Transmit Isolation
The transmit path, composed of the Bandpass filter and circulator provides 12 dB attenuation, at least on the input filter bandpass bandwidth, to avoid damage of the LNA in all impedance mismatch conditions on the ports SICX b and SINTX.

Insertion Loss Transmit Path
The insertion loss measured between SINTX and SICX b in the transmit band is not greater than 0.65 dB.

Phase Linearity - Transmit Path
The deviation from the ideal phase linearity does not exceed 0.5 deg across any 10 MHz within the transmit frequency band.

4.2.1-4-8 PSA Performances

Stability
The frequency of the internal reference source is set at the time of manufacture within $\pm$ 0.5 x 10^{-6} of the assigned value at a temperature of 24 $\pm$ 2°C.

Ageing
The frequency does not vary by more than $\pm$ 3. x 10^{-6} over the P1 to P6 mission phases all effects included (within exclusion of the initial setting).

Noise Figure
The noise figure at the PSA SOCX input connector, referenced to a 50Ω source impedance is ≤ 3 dB.

Carrier Acquisition Time
In presence of a signal at the SOCX interface connector within the operational range, the PSA receiver is phase locked to the residual carrier in a maximum time of 3 seconds, after the time of arrival of the signal, with probability > 0.99.

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4.2.1-5 Interfaces

PSA Interfaces

The following subsystems/units interface the PSA unit:

- SASW interfacing the PSA hardware
- Receiving Front End unit, part of the HUYGENS PDRS, interfacing the Orbiter S-Band High Gain Antenna
- CDS (Orbiter Level), interfacing the BIU module, internal to the PSA unit, through the dual redundant MIL-STD-1553 bus
- CDMU unit, part of the CDMS, on the HUYGENS Probe, via umbilical, before separation
- EPSS subsystem (Orbiter Level) which provides the 30 V bus supply to PSA unit
- REU unit (Orbiter Level), for PSA unit temperature monitoring when the PSA is off-powered
- USO unit, part of the HUYGENS PDRS, which interfaces the PSA (unit A only).

Figure 4.2.1-5-1 outlines the external interfaces.

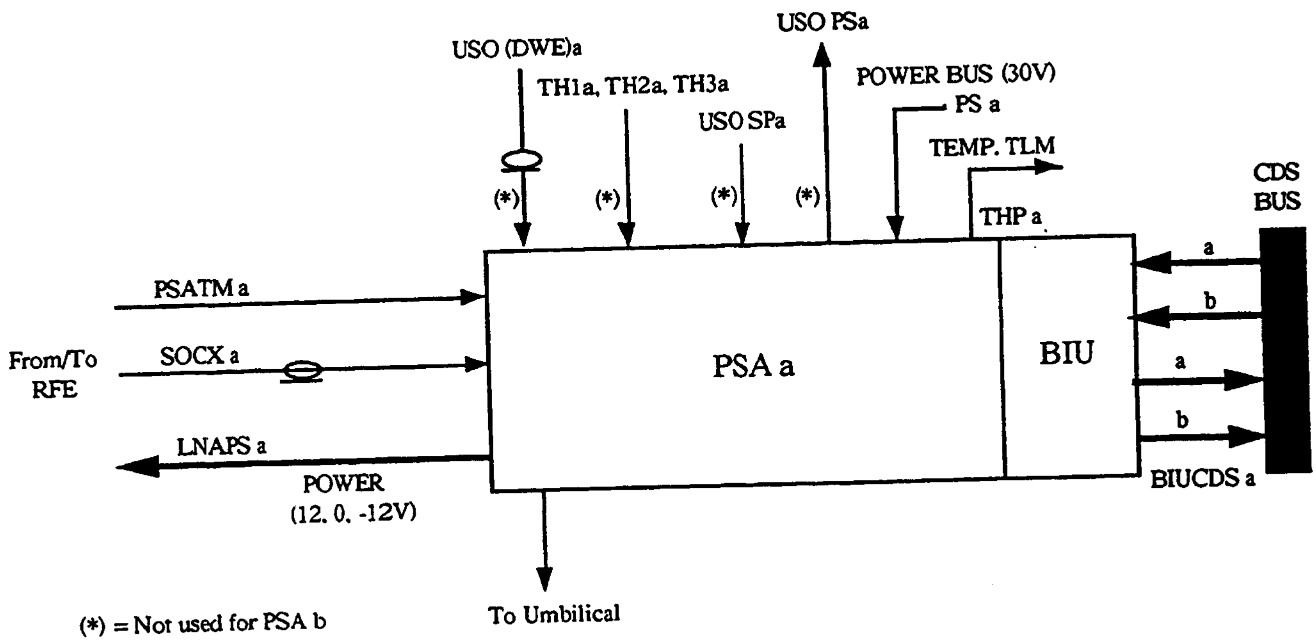

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FIGURE 4.2.1-5-1 PSA INTERFACE OUTLINE

LNA Interfaces

The following units interface the LNA:

- CASSINI High Gain Antenna
- PSA unit A
- PSA unit B
- CASSINI S/Band Transmitter (RFIS)
- Probe Transmitter unit A (via RF umbilical cable a)
- Probe Transmitter unit B (via RF umbilical cable b)
- REU (thermal sensors).

Umbilical Interface

The Umbilical Probe interface allows:

1- the telecommand frame transfer from the PSA to the Probe CDMS
2- the Probe RF telemetry (frame) transfer received from the RFE unit.

Telecommands

Memory Loads Command (MLC) type are used to transfer the telecommand frame toward the Probe CDMS.

The interface for MLC uses a double buffer. The data is loaded into the first register (16 bits) by the μP. The second one is a Parallel Input Serial Output (PISO) register. In this manner the μP or the DMA controller has a timing window of 128 μs to reload the first register with a new telecommand data in order to transmit at maximum speed all the telecommand frame. The 250 kHz clock required for serial synchronous data transmission (at 125 kbps) and the clock signal for timing interface management are generated by a dedicated oscillator followed by a dividing chain.

The timing controller generates a new DMA request to reload the emptied first input register when the new data is transferred from the register to the PISO.

In order to simplify the MLC I/F hardware it is possible to eliminate the double buffering. In this case when the transmission is completed the μP or the DMA controller will be enabled to load the PISO register with new data.
This introduces a pause in the transmission, which is probably negligible if a DMA transferring technique is used and probably not be acceptable if a μP interrupt technique is foreseen.

The telecommand umbilical cable is driven by a circuit that is compatible with the TTC-B-01 and capable of surviving to a short circuit for an indefinite time (for instance due to the cutting of the shielding twisted cables just before the Orbiter and Probe separation).

The architectural design is presented in Figure 4.2.1-5-2.

Telemetry (Data Transfer)

The RF telemetry is received at the S-Band input connector I/F.
It represents the differentially and convolutionally encoded data of the Probe telemetry frame generated by the CDMS.

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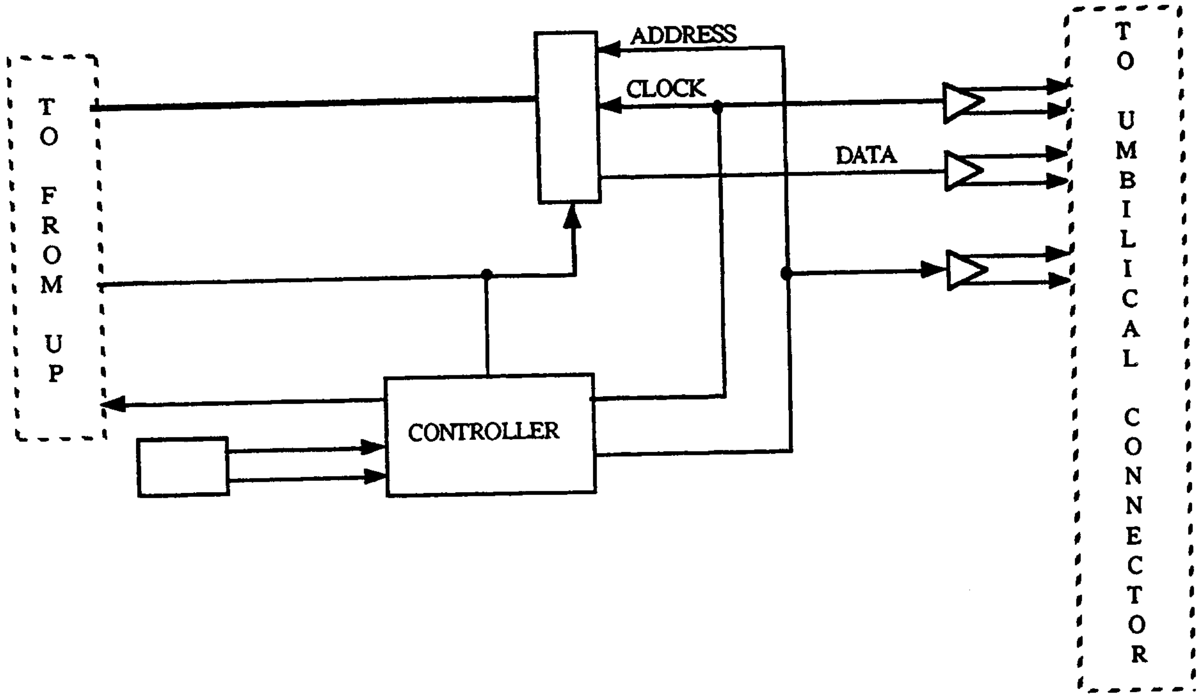

C1 FIGURE 4.2.1-5-2 TELECOMMAND PACKET CHANNEL (MEMORY LOAD COMMAND INTERFACE)

Refer to following documents for the interface characteristics (electrical, thermal or mechanical):

- Electrical Interfaces Control document HUY-AS/c-100-ID-0216
- Mechanical Thermal Interfaces Control document HUY-AS/c-100-ID-0208
- CASSINI HUYGENS Information System HW/SW ICD PD-699-086-1 155

Probe Transmitter Interfaces

The following units interface the Probe Transmitter unit:
- Probe transmitting antenna
- CDMS unit
- EPSS
- USO (DWE) unit (Channel A only)
- PSA (via RF umbilical cable) before separation.

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4.2.1-6 TM/TC

The following Data Handling main functions are implemented with the support of the SASW:

- transform the received Transfer Frame into a Telemetry Packet in CCSDS format

- collect local housekeeping generate source Telemetry Packets in CCSDS format to be sent to the Orbiter via the BIU

- receive Telecommands locally within the PSE and (during the cruise phase only) to the Probe CDMS via the umbilical and verify execution of local PSE commands

- control of the receiver

- maintain PSE time for Telemetry datation and time tagged command and timeline driven operations

- control communication with the BIU for telemetry and telecommands.

For more details see: Annex 2, HUYGENS TM/TC Data Tables and § 4.5 SASW.

See location of TM and TC in Annex 4 Drawings: HUY-1000-0002-1/7 and 2/7

4.2.1-6-1 Telecommand

CMD REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	TM VERIF
P5 029 O	TX A Power ON	O/O 13ms	CDMU A	PCDU	TXAPWRON	P5 037 B
P5 036 O	TX A Power OFF	O/O 13ms	CDMU A	PCDU	TXAPWROFF	
P5 049 O	TX B Power ON	O/O 13ms	CDMU B	PCDU	TXBPWRON	P5 065 B
P5 057 O	TX B Power OFF	O/O 13ms	CDMU B	PCDU	TXBPWROFF	
P5 033 O	TUSO N Power ON	O/O 13ms	CDMU A	PCDU	TUSONPWRON	P5 043 B
P5 042 O	TUSO N Power OFF	O/O 13ms	CDMU A	PCDU	TUSONPWROFF	
P5 054 O	TUSO R Power ON	O/O 13ms	CDMU B	PCDU	TUSORPWRON	P5 071 B
P5 063 O	TUSO R Power OFF	O/O 13ms	CDMU B	PCDU	TUSORPWROFF	
R1 004 O (*)	TXA HPA Power ON	O/O 13ms	CDMU A	TXA	HPAAPWRON	R1 002 A
R1 001 O	TXA HPA Power OFF	O/O 13ms	CDMU A	TXA	HPAAPWROFF	
R1 002 O	TCXO A Probe Selection	O/O 13ms	CDMU A	TXA	TCXOPRSELECT A	R1 005 R
R1 003 O	TUSO Selection	O/O 13ms	CDMU A	TXA	TUSOSELECT	
R2 002 O (*)	TXB HPA Power ON	O/O 13ms	CDMU B	TXB	HPABPWRON	R2 002 A
R2 001 O	TXB HPA Power OFF	O/O 13ms	CDMU B	TXB	HPABPWROFF	
R2 003 O	TCXO B Probe Selection	O/O 13ms	CDMU B	TXB	TCXOPRSELECTB	R2 005 R
R5 005 O	RUSO Power ON	ON/OFF	PSA-A	PSA-A	RUSOPWRON	R5 013 R
R5 006 O	RUSO Power OFF	ON/OFF	PSA-A	PSA-A	RUSOPWROFF	
R5 003 O	TCXO PSE Selection	ON/OFF	PSA-A	PSA-A	TCXOPSESELECT	R5 014 R
R5 004 O	RUSO Selection	ON/OFF	PSA-A	PSA-A	RUSOSELECT	
R6 004 O	TCXO PSB Selection	ON/OFF	PSA-B	PSA-B	TCXOPSBSELECT	R6 014 R
R5 007 M	NCO control word alt.	ML16	PSA-A	PSA-A	NCOCTRLA	R5 001 S/R5 002 S
R6 003 M	NCO control word alt.	ML16	PSA-B	PSA-B	NCOCTRLB	R6 001 S/R6 002 S

(*) Only for Ground testing. Never be used during Cruise Phase.

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4.2.1-6-2 Telemetry

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
E6 001 A (HK2)	TUSO A temp. 1 (lamp)	8 bit AN	TUSO	CDMU A	TUSOTEM1A	/
E6 002 A (HK2)	TUSO A temp. 2 (resonator)	8 bit AN	TUSO	CDMU A	TUSOTEM2A	/
E6 003 A (HK2)	TUSO A temp. 3 (crystal)	8 bit AN	TUSO	CDMU A	TUSOTEM3A	/
E6 004 B (HK1)	TUSO A status (lock)	DB	TUSO	CDMU A	TUSOSTATA	/
E6 005 A (HK2)	TUSO B temp. 1 (lamp)	8 bit AN	TUSO	CDMU B	TUSOTEM1B	/
E6 006 A (HK2)	TUSO B temp. 2 (resonator)	8 bit AN	TUSO	CDMU B	TUSOTEM2B	/
E6 007 A (HK2)	TUSO B temp. 3 (crystal)	8 bit AN	TUSO	CDMU B	TUSOTEM3B	/
E6 008 B (HK1)	TUSO B status (lock)	DB	TUSO	CDMU B	TUSOSTATB	/
E7 001 A (PSE)	RUSO A temp. 1 (lamp)	8 bit AN	RUSO	PSA-A	RUSOTEM1A	/
E7 002 A (PSE)	RUSO A temp. 2 (resonator)	8 bit AN	RUSO	PSA-A	RUSOTEM2A	/
E7 003 B (PSE)	RUSO A STATUS (lock)	8 bit AN	RUSO	PSA-A	RUSOSTATA	/
E7 004 A (PSE)	RUSO A temp. 3 (crystal)	8 bit AN	RUSO	PSA-A	RUSOTEM3A	/
P5 023 A (HK2)	28V TX A power current	8 bit AN	PCDU	CDMU A	TXAPWR	/
P5 029 A (HK2)	28V TUSO N power current	8 bit AN	PCDU	CDMU A	TUSONPWR	/
P5 051 A (HK2)	28V TX B power current	8 bit AN	PCDU	CDMU B	TXBPWR	/
P5 057 A (HK2)	28V TUSO R power current	8 bit AN	PCDU	CDMU B	TUSORPWR	/
P5 037B (HK1)	28V TX A limiter status	DB	PCDU	CDMU A	TXASTAT	P5 029 O P5 036 O
P5 043 B (HK1)	28V TUSO N limiter status	DB	PCDU	CDMU A	TUSONSTAT	P5 033 O P5 042 O
P5 065B (HK1)	28V TX B limiter status	DB	PCDU	CDMU B	TXBSTAT	P5 049 O P5 057 O
P5 071 B (HK1)	28V TUSO R limiter status	DB	PCDU	CDMU B	TUSORSTAT	P5 054 O P5 063 O

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TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
R1 002 A (HK2)	TX A output power	8 bit AN	TX A	CDMU A	TXARFPWR	R1 001 O R1 004 O
R1 003 A (HK2)	TX A power amp temp.	8 bit AN	TX A	CDMU A	TXATEMP	/
R1 004 A (HK2)	TX A secondary supply voltage	8 bit AN	TX A	CDMU A	TXAVOLTAGE	/
R1 005 R (HK1)	TX A selection status (TUSO/TCXO)	rel. stat.	TX A	CDMU A	TXASELECTST	R1 002 O R1 003 O
R1 006 B (HK1)	TCXO output level	DB	TX A	CDMU A	TCXOASTAT	/
R1 007 A (HK2)	HPA A power supply voltage	8 bit AN	TX A	CDMU A	HPAAVOLTAGE	/
R2 002 A (HK2)	TX B output power	8 bit AN	TX B	CDMU B	TXBRFPWR	R2 001 O R2 002 O
R2 003 A (HK2)	TX B power amp temp.	8 bit AN	TX B	CDMU B	TXBTEMP	/
R2 004 A (HK2)	TX B secondary supply voltage	8 bit AN	TX B	CDMU B	TXBVOLTAGE	/
R2 005 R (HK1)	TX B selection status	rel. stat.	TX B	CDMU B	TXBSELECTST	R2 003 O
R2 006 B (HK1)	TCXO output level	DB	TX B	CDMU B	TCXOBSTAT	/
R2 007 A (HK2)	HPA B power supply voltage	8 bit AN	TX B	CDMU B	HPABVOLTAGE	/

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TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
R3 002 A (PSE)	LNA A supply voltage	8 bit AN	LNA A	PSA-A	LNAAVOLT	/
R3 003 T	LNA A temp.	temp.	LNA A	Orbiter	LNAATEMPO	/
R4 002 A (PSE)	LNA B supply voltage	8 bit AN	LNA B	PSA-B	LNABVOLT	/
R4 003 T	LNA B temp.	temp.	LNA B	Orbiter	LNABTEMPO	/
R5 001 S (PSE)	PSA-A receiver HK word 1 *	DS16	PSA-A	PSA-A	RXADSPW1	/
R5 002 S (PSE)	PSA-A receiver HK word 2 *	DS16	PSA-A	PSA-A	RXADSPW2	/
R5 003 S (PSE)	PSA-A receiver HK word 3 *	DS16	PSA-A	PSA-A	RXADSPW3	/
R5 004 S (PSE)	PSA-A receiver HK word 4 *	DS16	PSA-A	PSA-A	RXADSPW4	/
R5 007 A (PSE)	PSA-A secondary supply voltage	8 bit AN	PSA-A	PSA-A	PSAASECVOLT	/
R5 008 A (PSE)	PSA-A RX supply voltage	8 bit AN	PSA-A	PSA-A	RXAVOLTAGE	/
R5 010 T (PSE)	PSA-A temperature	temp.	PSA-A	PSA-A	RXATEMP	/
R5 013 R (PSE)	RUSO power status	rel.stat.	PSA-A	PSA-A	RUSOPWRST	R5 005 O R5 006 O
R5 014 R (PSE)	PSA-A selection status (RUSO/TCXO)	rel.stat.	PSA-A	PSA-A	PSASELECTST	R5 003 O R5 004 O
R5 015 B (PSE)	PSA-A chain identifier	DB	PSA-A	PSA-A	PSAACHAINID	/
R6 001 S (PSE)	PSA-B receiver HK word 1 *	DS16	PSA-B	PSA-B	RXBDSPW1	/
R6 002 S (PSE)	PSA-B receiver HK word 2 *	DS16	PSA-B	PSA-B	RXBDSPW2	/
R6 003 S (PSE)	PSA-B receiver HK word 3 *	DS16	PSA-B	PSA-B	RXBDSPW3	/
R6 004 S (PSE)	PSA-B receiver HK word 4 *	DS16	PSA-B	PSA-B	RXBDSPW4	/
R6 007 A (PSE)	PSA-B secondary supply voltage	8 bit AN	PSA-B	PSA-B	PSABSECVOLT	/
R6 008 A (PSE)	PSA-B RX supply voltage	8 bit AN	PSA-B	PSA-B	RXBVOLTAGE	/
R6 010 T (PSE)	PSA-B temperature	temp.	PSA-B	PSA-B	RXBTEMP	/
R6 013 B (PSE)	PSA-B chain identifier	DB	PSA-B	PSA-B	PSABCHAINID	/
R6 014 R (PSE)	PSA-B selection status (TCXO)	rel.stat.	PSA-B	PSA-B	PSABSELECTST	R6 004 O

* See details of PSAs Receiver HK words 1 to 4 hereafter.

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PSA Receiver HK Word 1: R5001S/R6001S:

Bit	Description	Value
15 to 13	HK Word Identifier	Always 000
12	Subcarrier lock status	1 = locked
11	FFT result	1 = FFT threshold passed
10	Frequency channel selection	1 = Doppler frequency selected
9	Carrier lock status	1 = locked
8	Viterby data decoder status	0 = status not OK (*)
7 to 0	NCO control word LSB	Bits 7 to 0 LSB = 0.0484Hz

(*) This bit is meaningful only when RSW = 6 Signal Tracking State (in R5003S or R6003S); for the other RSW values, it shows "0" default value.

PSA Receiver HK Word 2: R5002S/R6002S:

Bit	Description	Value
15 to 13	HK Word Identifier	Always 001
12	Synchro Marker status	1 = locked
11	Background RAM test	1 = RAM test passed
10	Processor test	1 = Proecessor test passed
9	Receiver PROM test	1 = PROM test passed
8	Receiver RAM test	1 = RAM test passed
7 to 0	NCO control word Byte 2	Bits 15 to 8

PSA Receiver HK Word 3: R5003S/R6003S:

Bit	Description	Value
15 to 13	HK Word Identifier	Always 010
12	PSA Identifier	0 = PSA A 1 = PSA B
11	Software squelch status	1 = S/W squelch active
10 to 8	RSW status: RSW in Reset Operating Test AGC Normalisation Test Signal Detection State Carrier Frequency Acquisition State Carrier Phase Acquisition State Subcarrier Acquisition State Signal Tracking State	000 001 010 011 100 101 110
7 to 0	Digital AGC word LSB	

PSA Receiver HK Word 4: R5004S/R6004S:

Bit	Description	Value
15 to 13	HK Word Identifier	Always 011
12	Bit Synchroniser	1 = locked
11 to 8	NCO control word MSbits	Bits 19 to 16 (range +/- 25KHz) (**)
7 to 0	Digital AGC word MSB	

See "Evaluation of the NCO frequency from HK data" hereafter.
(**) The negative values of NCO control word are coded in 2's complement.

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Evaluation of the NCO Frequency from HK data

The HK data contain 20 bits (19 numerical bit plus a sign bit) representing a portion of the carrier error loop term, defined as the correction to the receiver nominal frequency (RF BITE or Mission Frequency).
The procedure to obtain the numerical value of the carrier loop error term is slightly different according to its sign, as follows:

- Positive sign (bit 11 of R5004S or R6004S is zero)
  1. Built a **32-bit word** with:

Bit 31	: bit 11 of R5004S/R6004S
Bits 30 to 25	: all zeroes
Bits 24 to 22	: bits 10 to 8 of R5004S/R6004S
Bits 21 to 14	: bits 7 to 0 of R5002S/R6002S
Bits 13 to 6	: bits 7 to 0 of R5001S/R6001S
Bits 5 to 0	: all zeroes

  2. Use the value (CV) obtained after step 1 in the following relationship:

$$F_{out} = \frac{CV \times F_1}{5 \times 2^{31}}$$

where $F_1 = 8.125$ MHz and F_{out} is the carrier loop error term in Hz.

- Negative sign (bit 11 of R5004S or R6004S is one)
  1. Built a **32-bit word** with:

Bit 31	: bit 11 of R5004S/R6004S
Bits 30 to 25	: all "1"
Bits 24 to 22	: bits 10 to 8 of R5004S/R6004S
Bits 21 to 14	: bits 7 to 0 of R5002S/R6002S
Bits 13 to 6	: bits 7 to 0 of R5001S/R6001S
Bits 5 to 0	: all zeroes

  2. Evaluate the 2's complement of the value obtained after step 1 (with the value in binary format, invert all bits and add 1);

  3. Use the value (CV) obtained after step 2 in the following relationship:

$$F_{out} = \frac{CV \times F_1}{5 \times 2^{31}}$$

where $F_1 = 8.125$ MHz and F_{out} is the (negative) carrier loop error term in Hz.

4.2.1-7 Operational Constraints

1• To ensure the Checkout sequence, a PSA Alteration TC shall be sent to switch PSA to Basic Frequency, just after TX ON.

2• During Checkout sequence, HPA must be OFF to avoid risk of RF radiations inside the Probe (pyro danger).

3• SASW will deliver TMs and will accept TCs only 15s after PSA powered ON (except Inhibit TC between 6.5 and 9.5s).

4• The configuration TUSO + RUSO or
TCXO A + TCXO PSE

must be verified, specially for Descent Phase and it is recommended for Checkout sequence.

5• PSA switches to Doppler frequency after 60s receiver unlocked, so when the Tx is switched ON, PSA is returned on Doppler frequency. Therefore, it has been decided that Alteration TC must be sent twice with a delta of 20 seconds between them, 1 minute after TX is switched ON.

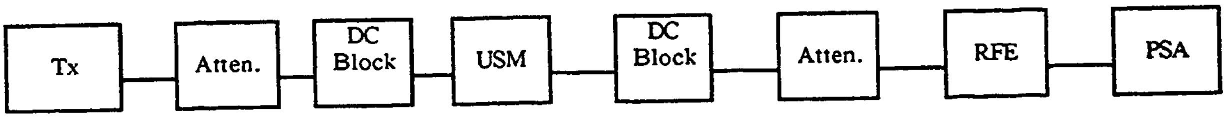
4.2.2 NOMINAL OPERATIONS

See Phase Description in § 4.2.1-2-2.

See Operations RP01 to RP06 in Doc n° HUY.AS/c.100.OP.0384.

Phases P2 and P3: before Probe separation:

- Command reception from BIU and execution in case the address indicates destination to PSA.
- Command routing to Probe CDMU
- PSA units housekeeping data collection and packetization and transmission to BIU.
- Checkout sequences (periodically), through the RF BITE:



The RF BITE procedure on the PSAs (including RFE also) and other equipments on board the Probe (involving Txs) is applied.
The proposed subsystem checkout is performed switching ON the Probe Transmitters, (receiving data from CDMS), RFE and PSA's and simulating the same operations/functions as during the Descent phase.
The PSA S/W running during Checkout is the same of the Descent Phase. It means that the same DSP and Data Handling functions are realised for both phases.

The only differences with respect to the Descent phase consist:

- Transmitter in Low Power mode (HPA OFF)

- Different NCO frequency control word (no Doppler Frequency shift present).

The PSA Software after the POWER ON, will operate following the operative modes where below presented:

OFF
POWER ON
↓
"INIT" Mode
↓
Initialization completed
↓
"MISSION" Mode

See § 4.5 for more details.

- Routing to BIU of the Probe sent telemetry after packet reorganization.
- Selection between Internal oscillators (TCXO) and TUSO/RUSO:
  Nominally the Mission is foreseen with DWE (TUSO and RUSO). So during the last C/O TUSO, and RUSO must be carefully verified: **Temperatures, elapsed time between switch-ON and LOCK**. If all is correct, the selection TUSO/RUSO must be kept at the end of MTU Loading sequence for the Descent. If a doubt exists on the health of TUSO or RUSO (for example potential parameters drift feared during Coast phase or Descent), then internal oscillator must be chosen on Probe side and on Orbiter side.
- Power supply distribution (to RFE, external DWE-USO, PSA unit A only).

Phases P4 and P5: after Probe separation:
- command reception from BIU and execution in case subaddress indicates destination to PSA
- PSA units housekeeping data collection and packet generation and transmission to BIU
- Radio Relay link signal acquisition (DSP tasks).
- Autonomous control and management.
- Default NCO frequency control word
- In order to measure carrier frequency changes due to the Probe motion in the TITAN atmosphere, the Probe Transmitter A and the PSA are capable to run coherently to external DWE USO (Doppler Wind Experiment).
- Power supply distribution (to RFE, external DWE-USO unit a only).

Phase P6:
- transmitter ON and set in High Power mode
- Radio Relay Link with signal acquisition and tracking (DPS Tasks)
- routing to BIU of the Probe sent telemetry after packet reorganisation
- PSA units housekeeping data collection and packet generation and transmission to BIU.

The warm up time relevant to the Descent phase is about 15 min.

4.2.2-1 Acquisition Tasks

The Digital S-Band Receiver (controlled by the DSP microprocessor) waits until a signal is detected (i.e. acquisition test threshold is passed).

The µP main tasks are:

a. Perform carrier, subcarrier, symbol clock and synch. marker acquisition for the S-Band signal.
b. Verify the carrier, subcarrier phase acquisition for coherent demodulation providing the relevant lock status detectors.
c. Verify the symbol clock acquisition providing the relevant lock status detector.
d. Perform signal tracking, data demodulation, synchronization marker detection/confirmation after successful completion of the functions **a., b., c.**

4.2.2-2 Signal Tracking Tasks

The DSP µP decides automatically to switch to tracking function if an RF signal is detected (observing the FFT threshold passing detector and to the lock status flags).

The DSP µP inside PSA unit main tasks are:

e. Perform carrier, subcarrier, symbol clock and synch. marker tracking for the S-Band signal
f. Verify the carrier, subcarrier phase tracking for coherent demodulation providing the relevant lock status detectors
g. Verify the symbol clock and synch. marker tracking providing the relevant lock status detector.

The algorithm realised by DSP µP in this tracking function are:

- CARRIER LOOP FILTER: second order loop filter
- CARRIER LOCK DETECTOR: verification of carrier phase acquisition and tracking for coherent demodulation
- SUBCARRIER LOOP FILTER: second order loop filter
- SUBCARRIER LOCK DETECTOR: verification of subcarrier phase acquisition and tracking for coherent demodulation
- COHERENT AGC: implementation of first order loop filter
- SQUELCH: verification of received signal Eb/No.

This tracking function is disabled when the residual carrier tracking is lost (CAR_LOCK = 0). In this case the acquisition function is re-activated.
h. Perform data demodulation.
i. Verify the received signal Eb/No value providing a squelch indicator.
j. Verify the tracking of the transfer frame synchronization marker after data convolutional and differential decoding.
k. Return to the acquisition function in case of persistent loss (500 ms) of the signal lock status indicators.

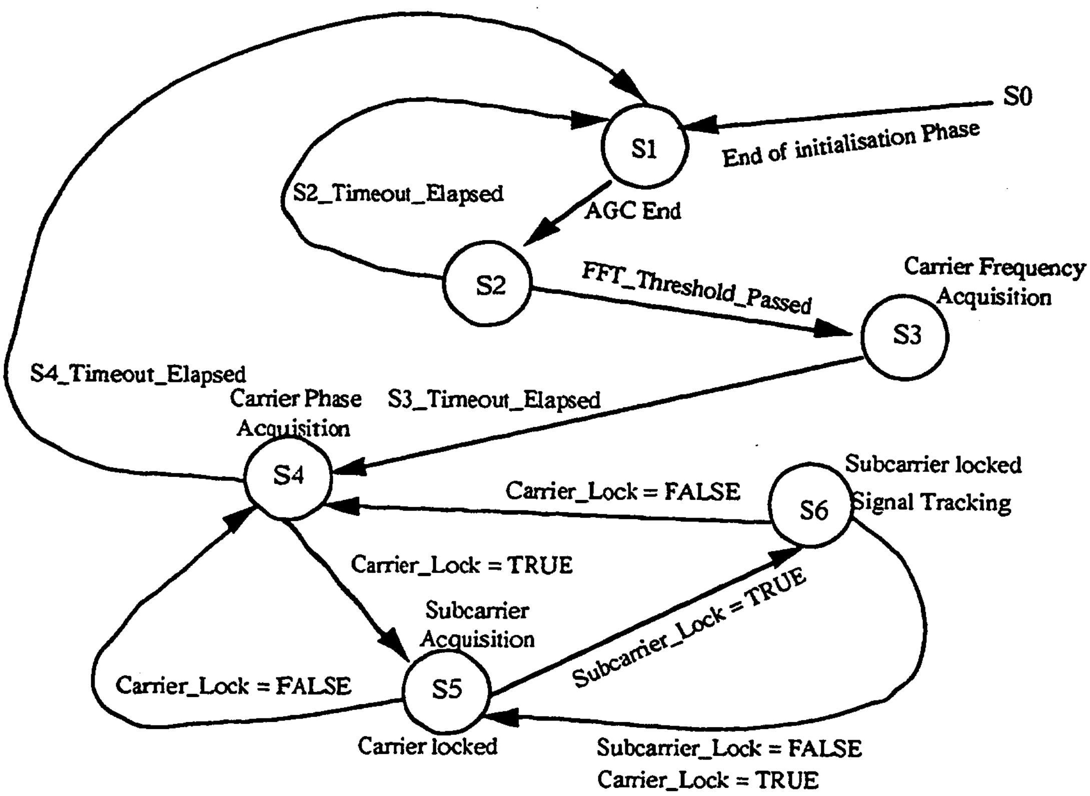
4.2.2-3 Data Handling Tasks

The µP main tasks are:

a. TCs acquisition from Orbiter via Bus 1553 by means of BIU.
b. TC routing to the Probe via umbilical interface.
c. TC decoding and execution relevant to PSA.
d. PSA Housekeeping Frame and Probe Transfer Frame routing to the Orbiter via Bus 1553 by means of BIU.

The PSA provides the power supply line to the RFE Unit and to USO (unit A only).

See Receiver States Diagram in Figure 4.2.2-1.



S0 70ms, fixed duration
S1 AGC calibration. Fixed duration 200ms
S2 Signal Detection; 300ms/FFT, 3 FFT executed
S3 Frequency acquisition; PLL closure; fixed duration 500ms
S4 Phase acquisition (Frequency Tracking due to Doppler effect)
Detector change from Frequency detector to Phase detector
Phase detector: permanently tracking of carrier; duration 500ms
Time-out 5s:
- carrier lock, go to S5
- carrier not locked, go to S1

S5 Tracking of sub-carrier; no time-out
S6 Signal Tracking:
Sub-carrier is locked
Tracking of Synchro marker
If Sub-carrier is lost, go to S5
If carrier is lost, go to S4

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FIGURE 4.2.2-1 RECEIVER STATES DIAGRAM

4.2.3 BACK-UP OPERATIONS

• During last checkout, before separation, ground operators must choose between internal oscillators and DWE and must ensure the configuration: TUSO + RUSO or
TCXO A + TCXO PSE

with following operations:
RP02: RUSO switch ON
RP04: TUSO switch ON
RP03: TUSO/TCXO A selection
RP06: RUSO/TCXO PSE selection

• If one PSA/SASW fails during checkout, for the next checkouts, use only the other one.

• If one TX fails during checkout, for the next checkouts, use only the other one.

4.2.4 CONTINGENCY OPERATIONS

As PDRS equipments are operating in hot redundancy, there is not really any possibility of Contingencies.

However, some equipments should always be in a same configuration during Checkout because they are not used during Cruise. If it appears they have changed, for example due to vibration, they must be replaced in their good configuration:

- HPAs should always be in OFF condition. If they are found ON during checkout, use Table 2.9-26 of HUY.AS/c.100.OP.0384 to switch them OFF.
- Internal TX B oscillator must always be selected. If not, use RC01 to select it again.
- Internal PSA B oscillator must always be selected. If not, use RC02 to select it again.

4.3 EPSS

4.3.1 SUBSYSTEM DESCRIPTION

4.3.1-1 Subsystem Configuration

As shown on Figure 4.3.1-1 the EPSS baseline configuration consists of:

a. Five Batteries

To provide the necessary energy for the Mission after separation from the Orbiter until a few minutes after impact of the Probe on the TITAN surface.

Each battery consists of two modules of 13 cells LiS02-7 Ah (nominal) in series.

b. One Power Conditioning and Distribution Unit (PCDU)

The PCDU provides the power conditioning and distribution to the Probe System equipments and users by means of a regulated main bus with adequate protections to ensure uninterrupted operations even in case of single failure inside or outside the PCDU.
During the cruise phase, the Probe is powered by the ORBITER and the PCDU provides the complete isolation of the batteries.
The conditioning of the power (from the ORBITER or from the batteries) is performed via 5 BDR (BDR) (Battery Discharge Regulator) sections that generate the 28 V bus, the distribution is performed by means of active current limiters.

The PCDU also provides Mission Timer supply during the Cruise Phase (Orbiter power) and during the Coast and the Descent Phases (Batteries).

c. One Pyro Unit (PYRO)

The PYRO unit provides 2 redundant sets of 13 pyro lines, directly connected to the center taps of 2 batteries through adequate protection devices for the activation of pyro devices.

To meet the safety requirements, three independent levels of relays are implemented in series in the PYRO units, as well as active switches and current limiters. Moreover, safe/arm plugs are also provided on the unit itself.

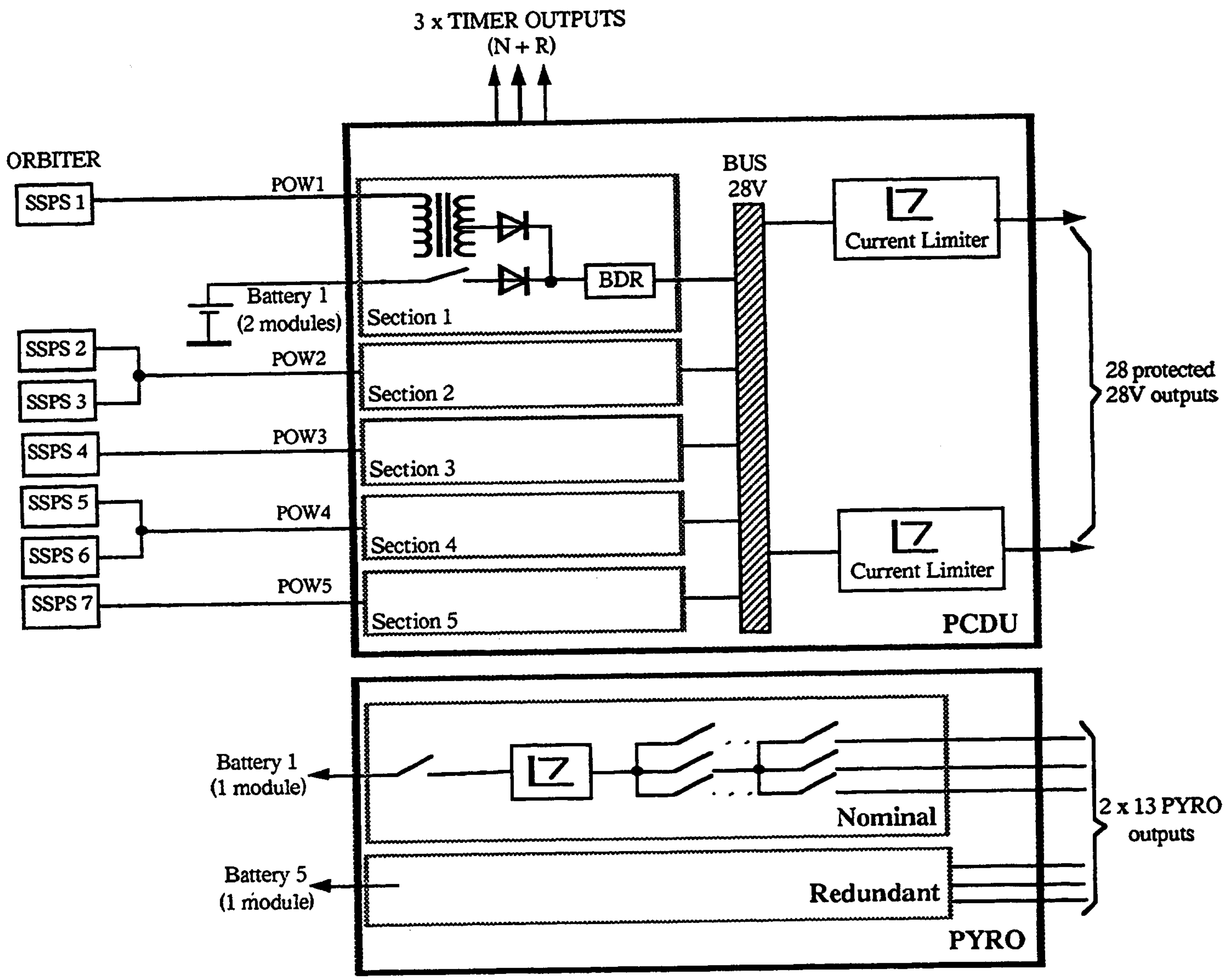
The EPSS is designed to meet the requirements of the mission, in terms of power capability with 4 sections (battery + BDR or ORBITER + BDR), consequently the 5 parallel sections of the EPSS are not designed to be single-point failure free.

The MEA (Main Error Amplifier) which controls the current delivered by the BDR sections and ensures the 28 V bus regulation is a centralized function fully reliable by means of 3 parallel circuits followed by output voters.

Concerning the 28 V distribution there is a total of 2 x 14 redundant current limiters (2 x 11 for experiments, 2 for CDMU, 2 for TX, 2 for RAU): either the 2 redundant current limiters supply the 2 redundant users or the 2 redundant current limiters supply one common user.

Concerning PYRO unit, there are 2 fully independent redundant sets of lines powered each by one battery module.

D2



DEFINITION: The power lines from Orbiter to BDR's sections are called:

SSPS 1	to BDR 1	= POW1
SSPS 2 + SSPS 3	to BDR 2	= POW2
SSPS 4	to BDR 3	= POW3
SSPS 5 + SSPS 6	to BDR 4	= POW4
SSPS 7	to BDR 5	= POW5

C1

FIGURE 4.3.1-1 EPSS BLOCK DIAGRAM

4.3.1-2 Functional Design and Operating Principles

4.3.1-2-1 Description of Subsystem Functions

a. PCDU (Figure 4.3.1-2-1)

The power conditioning is performed by means of 5 battery Discharge Regulators (BDR's) controlled by a centralized Main Error Amplifier (MEA). The BDR's are powered either directly by the batteries (one BDR for each battery) or by the ORBITER during the Cruise Phase by means of 5 ORBITER INTERFACE circuits connected to the SSPS of the ORBITER (2 double SSPS, 3 single SSPS); see Figure 4.3.1-1. Those interface circuits provide a galvanic insulation between the ORBITER and the PROBE and the voltage adaptation between the output of the SSPS and the input of the BDR.

The mission Timer supply is performed by means of three switchable battery voltage lines through series fuses or by means of the dedicated output voltage lines of the ORBITER interface circuits when the PCDU is powered by the ORBITER.

The PCDU provides complete isolation of the batteries by means of relays until separation of the PROBE from the ORBITER to avoid any loss of capacity by leakage currents (except for battery modules used for PYRO box powering: isolation is provided by PYRO itself).

The main bus voltage is distributed to subsystems and equipments (2 x 14 users) through current limiter devices assuming current limitation protection (the value of the current limitation is adapted for each user) and ON/OFF switching capability.

At PCDU/Probe powering up, all the limiters are automatically OFF except the two CDMU outputs that are automatically turned ON. A common current limitation (limitation of the total current delivered by two parallel current limiters with automatic switching OFF of the 2 lines in case of overcurrent detection) is also provided on 4 redundant outputs.

The PCDU also provides a protected + 5 V supply used by the PYRO to generate the bi-level status telemetries of the selection relays (there are two separate supplies, one for each half PYRO) and an energy intercept activation circuit that switches ON the energy intercept relay of the PYRO (there are two separate circuits, one for each half PYRO).

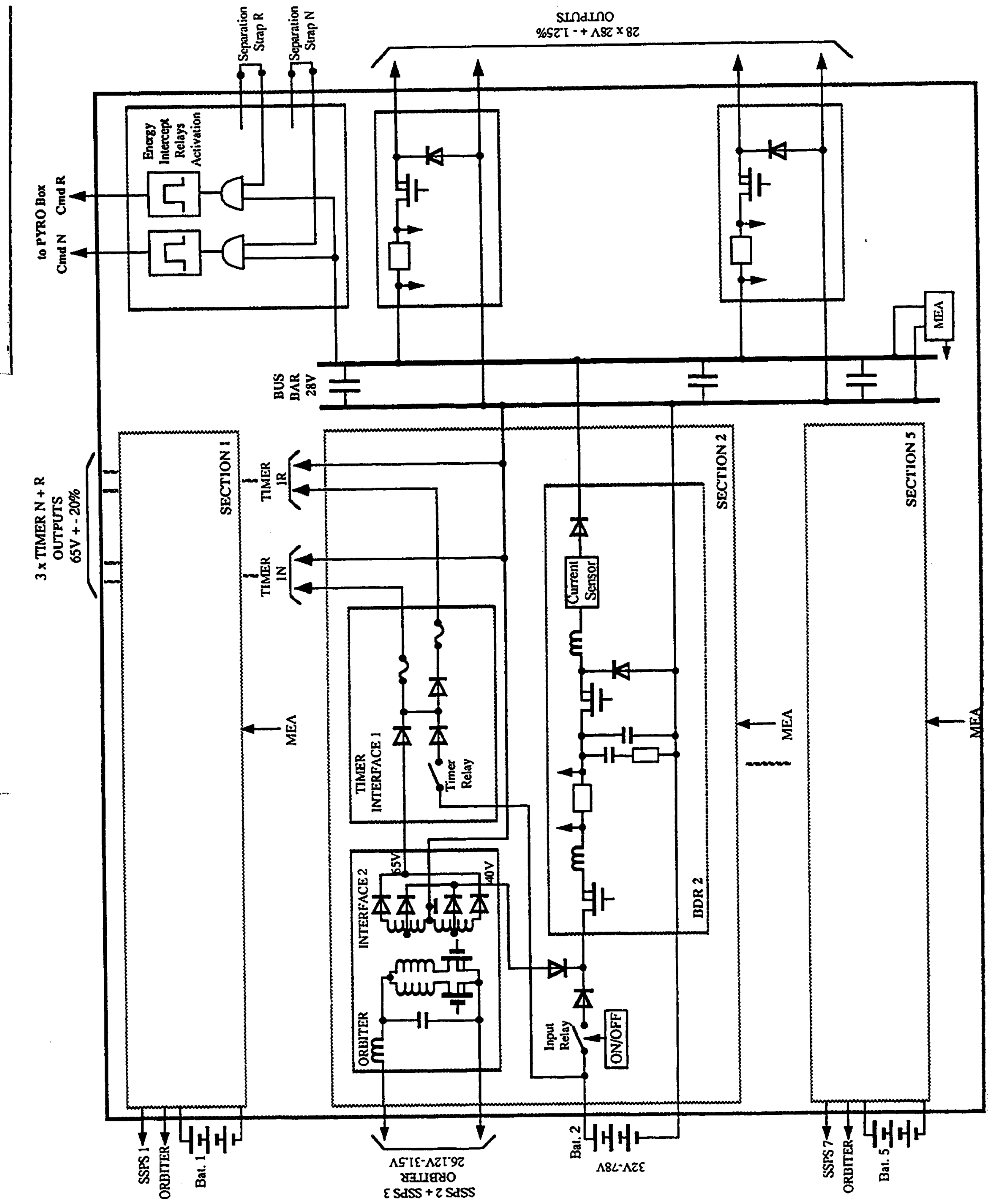
b. PYRO (Figures 4.3.1-2-2 and 4.3.1-2-3)

The PYRO unit provides 2 redundant sets of 13 pyro lines split into 2 x 4 arming groups:

- group 1: Back Cover (BCM) + Parachute Device Deployment (PDD)
- group 2: Front Shield (FSM)
- group 3: GCMS + DISR Cover
- group 4: Parachute Jettison (PJM).

In the cases of BCM, FSM and PJM three pyrotechnic devices associated with the same group of pyro lines are activated simultaneously.

D2



C1

FIGURE 4.3.1-2-1 PCDU BASELINE CONFIGURATION

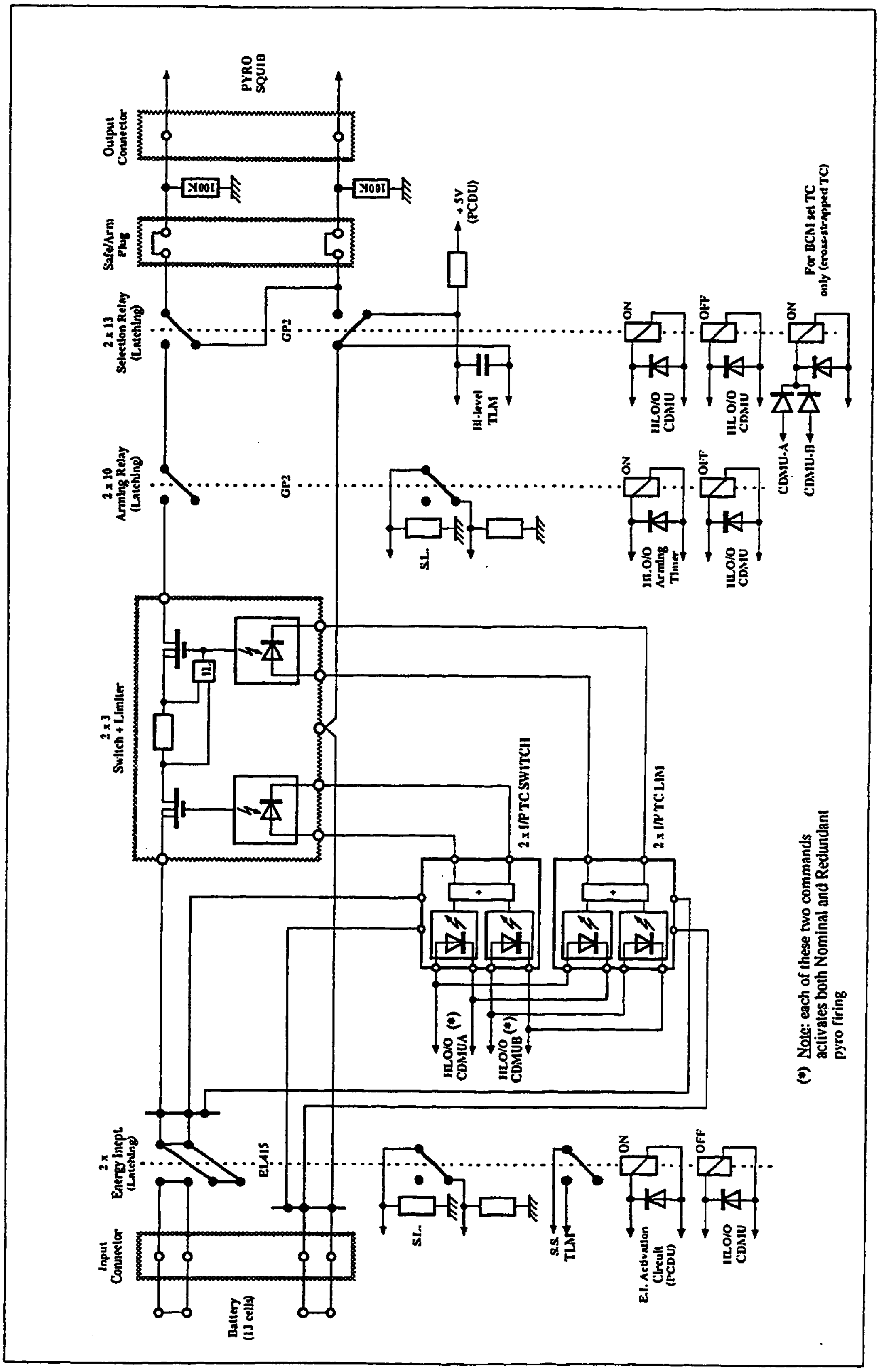


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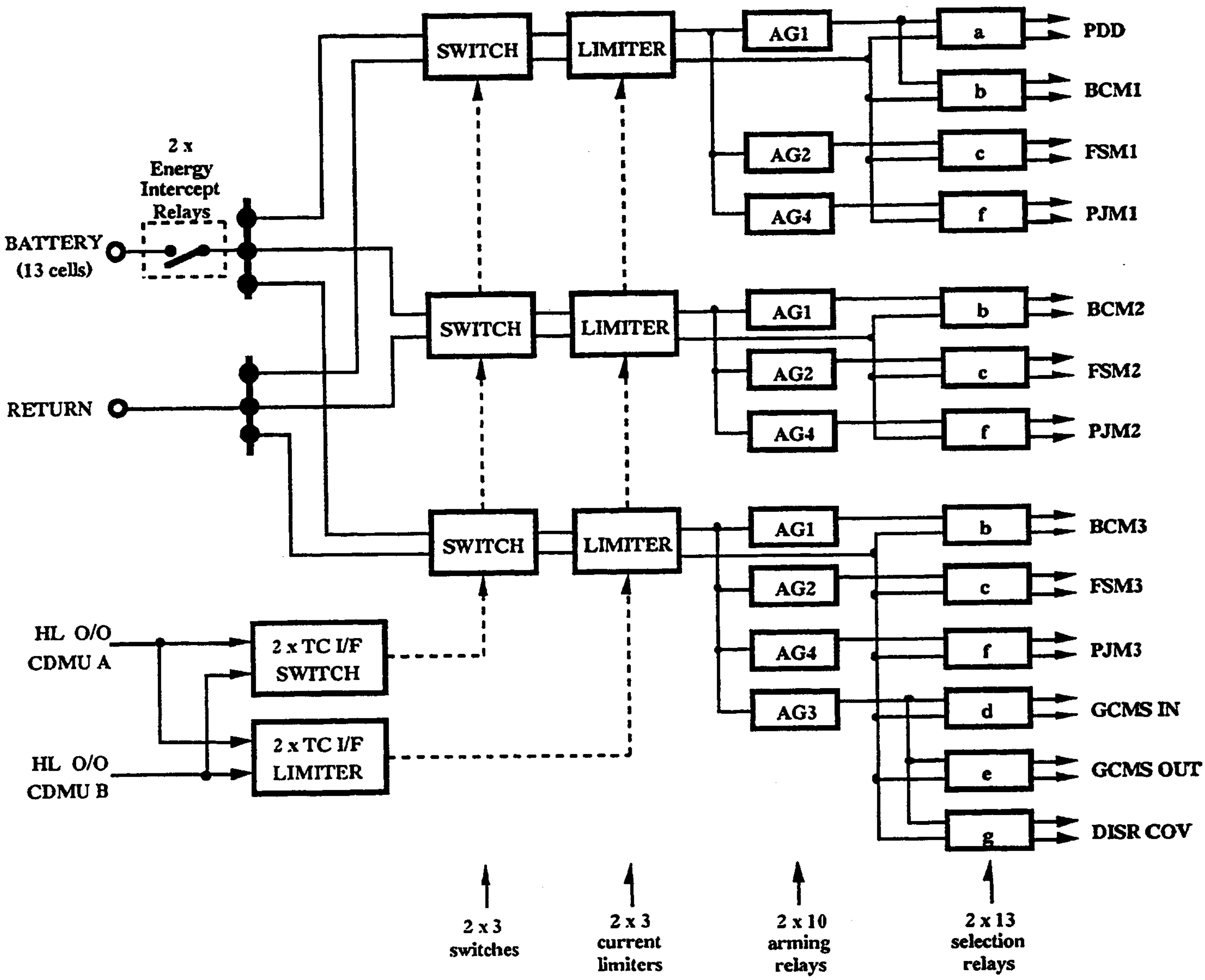
FIGURE 4.3.1-2-2 PYRO UNIT LINE CONFIGURATION



Note: each BCM selection relay can be set either by CDMU-A or CDMU-B.

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FIGURE 4.3.1-2-3 PYRO LINES GROUPING

Three levels of relays are implemented in series:

- energy intercept relay (activated by PCDU at the end of the coast phase)
- arming relays (activated by ARMING TIMER)
- selection relays (activated by CDMU).

Current limiters and active switches are also implemented in order to control the firing current. The relays provide only the selection of the squib that will fire. The firing of the squibs is controlled by the current limiters which are designed to limit the current at 5.5 A ± 10 % i.e. to ensure the nominal firing current of 5A. The active switches (activated by the same firing command as current limiter) provide a protection against a permanent ON of a current limiter combined with a short failure of the squib, they also allow to avoid a premature firing of a squib in case of short failure of the associated current limiter.

Note: the BCM selection relay set TC is cross-strapped,i.e, each BCM relay can be set either by CDMU-A or CDMU-B.

4.3.1-2-2 Operational Modes during Mission Phases

Cruise Phase - OFF

During all the cruise phase, except for periodic checkout operations, the EPSS is completely OFF: all relays opened - no power at ORBITER input. The monitoring loops allow to verify that all the relays are opened.

Cruise Phase - Checkout

During cruise phase, for checkout operations the EPSS is powered by ORBITER the regulation of the 28 V bus is performed by the BDR which are associated to the activated SSPS; the CDMU's current limiters are automatically ON, the total power available at bus level is equal to 200 W (for more details about power available, see § 4.3.1-4-4) all the relays are open.

Battery Depassivation

At the end of the cruise phase, the batteries are depassivated sequentially by applying a load of 55 W during a few minutes. The EPSS is powered both by ORBITER and by Batteries and a specific sequence of operations is foreseen (see Procedure PP03).

Timer Loading

Before the separation, after Battery Depassivation the timer relays are closed for the supply of the MISSION TIMER from the Batteries. The EPSS (28V Bus) is powered by ORBITER (input relays are opened).

Coast Phase

During all the Coast Phase, only the MISSION TIMER is supplied by batteries through specific Timer Relays. The EPSS is "OFF": input relays are opened, PYRO relays are open.

End Of Coast Phase - Awake Of Probe

At the end of the coast phase, the MISSION TIMER awakes the PROBE by activating the EPSS: input relays are closed and the CDMU's 28 V CURRENT LIMITERS are automatically switched ON as soon as the 28 V bus reaches its nominal value, the PYRO Energy Intercept Relay is also automatically switched ON (by a command sent by PCDU) the total power (400 W) is available on the 28 V DISTRIBUTION outputs.

Entry And Descent Phases

The EPSS ensures efficient distribution and conversion of the 5 Probe batteries energy to all subsystems and equipment of the Probe: PCDU relays are closed and the total power is available on the 28 V DISTRIBUTION outputs.

The PYRO ensures the selection and the firing of the squibs activated by CDMU commands.

4.3.1-3 Units Description

4.3.1-3-1 PCDU Description

a. BDR (Figure 4.3.1-3-1)

The main bus voltage regulation is ensured by means of the 5 parallel BDR's (PWM buck regulators), associated each with one battery or with one ORBITER I/F (when EPSS is powered by the ORBITER) and which can be considered as current sources controlled by the centralized MEA.

This configuration allows to control the current sharing at bus level and consequently the power sharing at batteries level.

It is important to note that the BDR transconductances values are adjusted to compensate the battery capacity unbalance resulting from the supply of the TIMER by the batteries 2, 3, 4 during the coast phase. That means that the current delivered by sections 1 and 5 is higher that the current delivered by sections 2, 3, 4 at main bus level. This is reflected by the BDR current telemetries as explained in § 4.3.1-6-2.

Input Relay

The input power relay completely disconnects the battery during all mission phases before Descent to avoid any loss of capacity by leakage current.
Four contacts are available on the relays:

- two are used in parallel for the power
- one is used for a switch status telemetry
- one is dedicated to a ground monitoring loop

Input Diode

The batteries being unprotected against reverse current, protection diodes are provided in the PCDU for safety reasons.

Input Current Protection

The input current protection ensures the following functions:

- protection of the battery against short failure or overload in case of single failure in the BDR section

- protection of the main bus against overvoltage in case of "short failure" of the buck

- automatic ON/OFF switching of the BDR versus the input voltage value

- soft start circuit to control in-rush current at powering up

- automatic switch off by the protection circuit in case of failure (under or overvoltage, overcurrent...).

D2

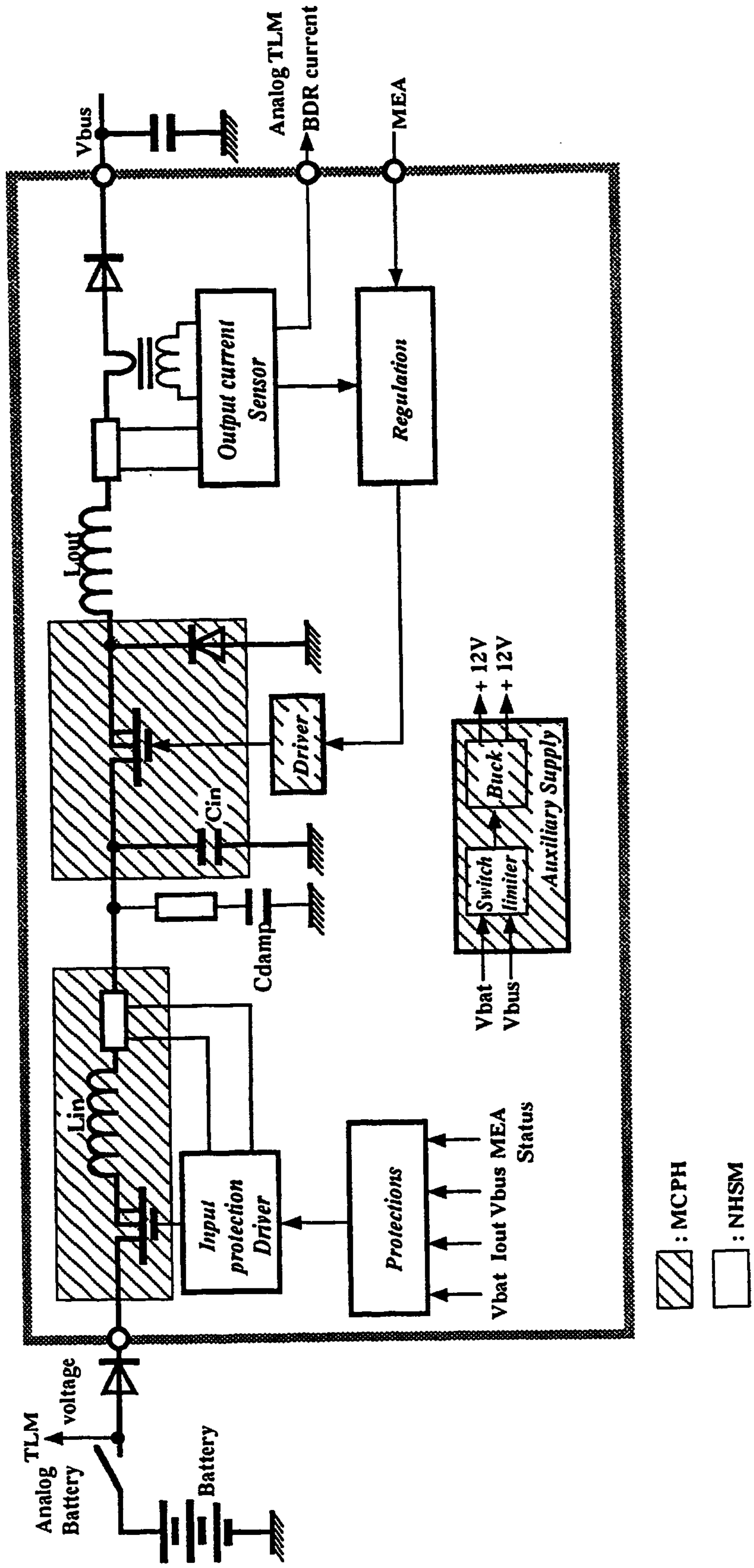

FIGURE 4.3.1-3-1 BDR

Input Filter

A conventional input filter is provided to meet the EMC requirement of conducted emissions between the PCDU and the batteries.
External MKU capacitors, with series resistors are provided, outside the hybrid, for the damping of the input filter.

PWM Buck Regulator

The output voltage of the MEA is presented to an error amplifier that integrates the difference between this voltage and the output voltage of a current sensor. The output of the error amplifier is transmitted to the buck transistors through a driver.

The Main Bus Voltage regulation is ensured by means of parallel PWM Buck regulators operating in a LC3 (Limit Cycle Conductance Control) mode, meaning that each BDR can be considered as a current source controlled by the MEA.

Each BDR is associated with one battery, which easily facilitates current sharing. It is important to note that this current sharing is ensured at Main Bus level and not at the level of the batteries. This means that, at battery level, it is a power sharing that is ensured.
Moreover, the individual BDR's gain are adjusted to compensate for the battery capacity unbalance resulting from the supply of the timer during coast phase (3 x 0.1W for 22 days). So:

$G1 = G5 = 1.14G$ and $G2 = G3 = G4 = G$

i.e. BDRs 1 and 5 are set to deliver a power greater than the one delivered by BDRs 2 to 4 in the rapport 1.14.

Output Summation Diode

This diode is necessary to protect the main bus against reverse current in one BDR section resulting from either a complete discharge of the battery or a short failure of the input filter capacitors. This diode also provides a protection against any potential short failure of a power element to the PCDU structure.

<u>b. MEA - BUSBAR</u> (Figure 4.3.1-3-2)

The MEA controls the current delivered by the BDR sections and ensures the accuracy of the bus voltage regulation better than ± 0.5% at main bus level.

This centralized function is made fully reliable by means of 3 parallel circuits followed by output majority voters.

The main function of the capacitor busbar is to ensure good performances in terms of output impedance and transients. In addition, it permits a reduction in the output voltage ripple.

For reliability reasons (protection against SPF), the bus bar consists of a number of MKU capacitors connected in parallel.

D2

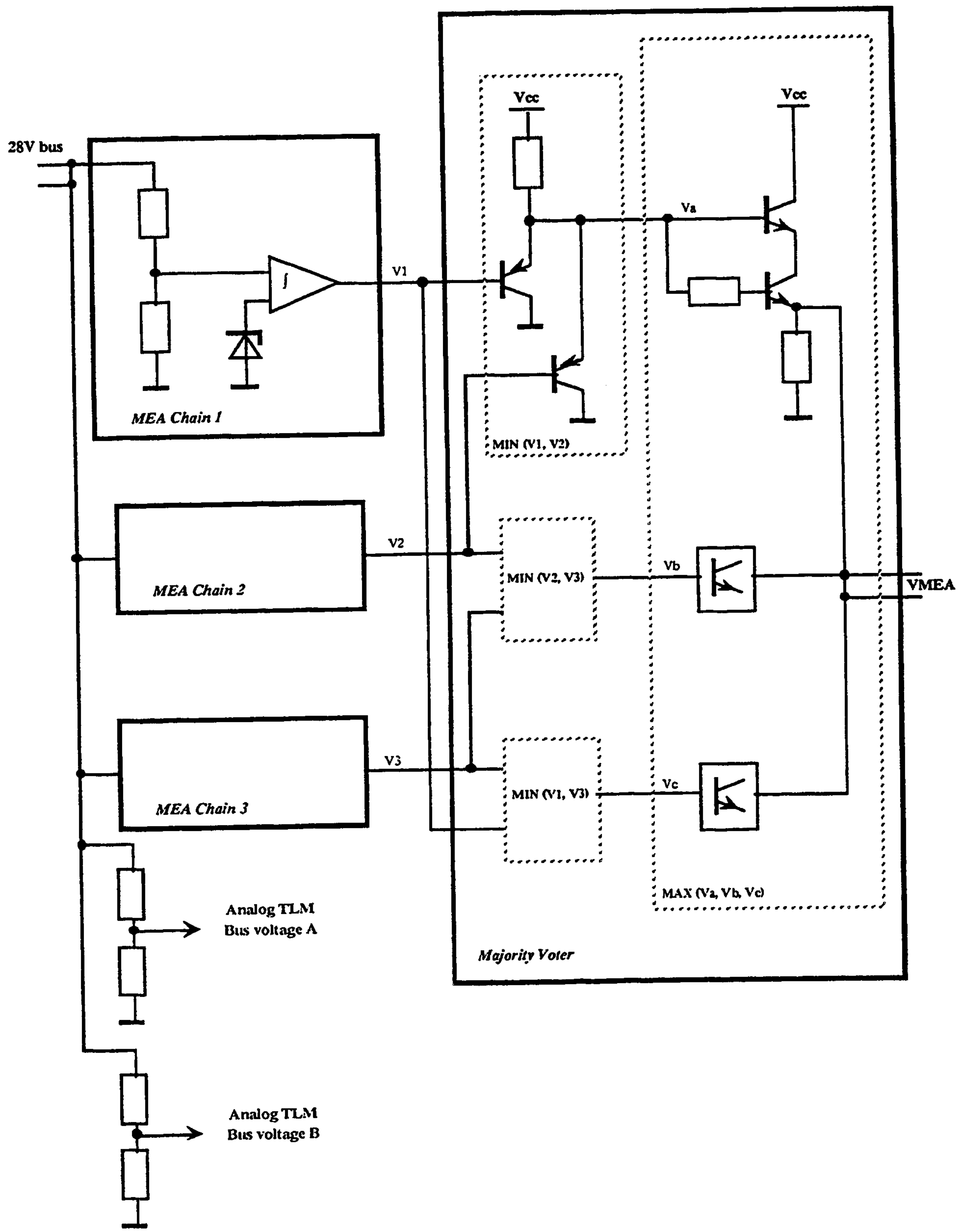

FIGURE 4.3.1-3-2 MEA FUNCTIONAL DIAGRAM

c. Current Limiter (Figure 4.3.1-3-3)

The 28 V main bus voltage is distributed to the different users through 28 active current limiters, that also provide the ON/OFF switching function as well as a current monitoring.

The current limiters are designed to be automatically switched OFF at powering up, except for the CDMU outputs that must be automatically switched ON. ON or OFF switching at powering up is imposed by a strap on each current limiter device.

The ON command also acts as a reset command in case of automatic switch OFF following an overload detection.

If the maximum current demanded by a given load is I_{MAX} then, taking a maximum precision of ± 5% on the current limitation value (including initial tolerance, temperature, radiation and ageing effects) and a further 10% to overcome the effects of MOSFET desaturation, the overall current limitation value range is given by:

$$1.1\, I_{MAX} \leq I_{LIM} \leq 1.22\, I_{MAX}$$

with a nominal value of $I_{LIM} = 1.16\, I_{MAX}$

The value of I_{MAX} varies, naturally, on a case by case basis.

The trip-off time in the case of current limitation is fixed, the period being determined by the thermal dissipation allowable. For these limiters up to 10 ms in limitation are guaranteed, whether this be at start-up or during normal operations.

The limiter also provides an analogue current telemetry and a bi-level status telemetry.

Each current limiter has its own associated electronics (auxiliary supply, control circuits, monitoring), fully independent of the rest of the unit to avoid any potential single point failure.

D2

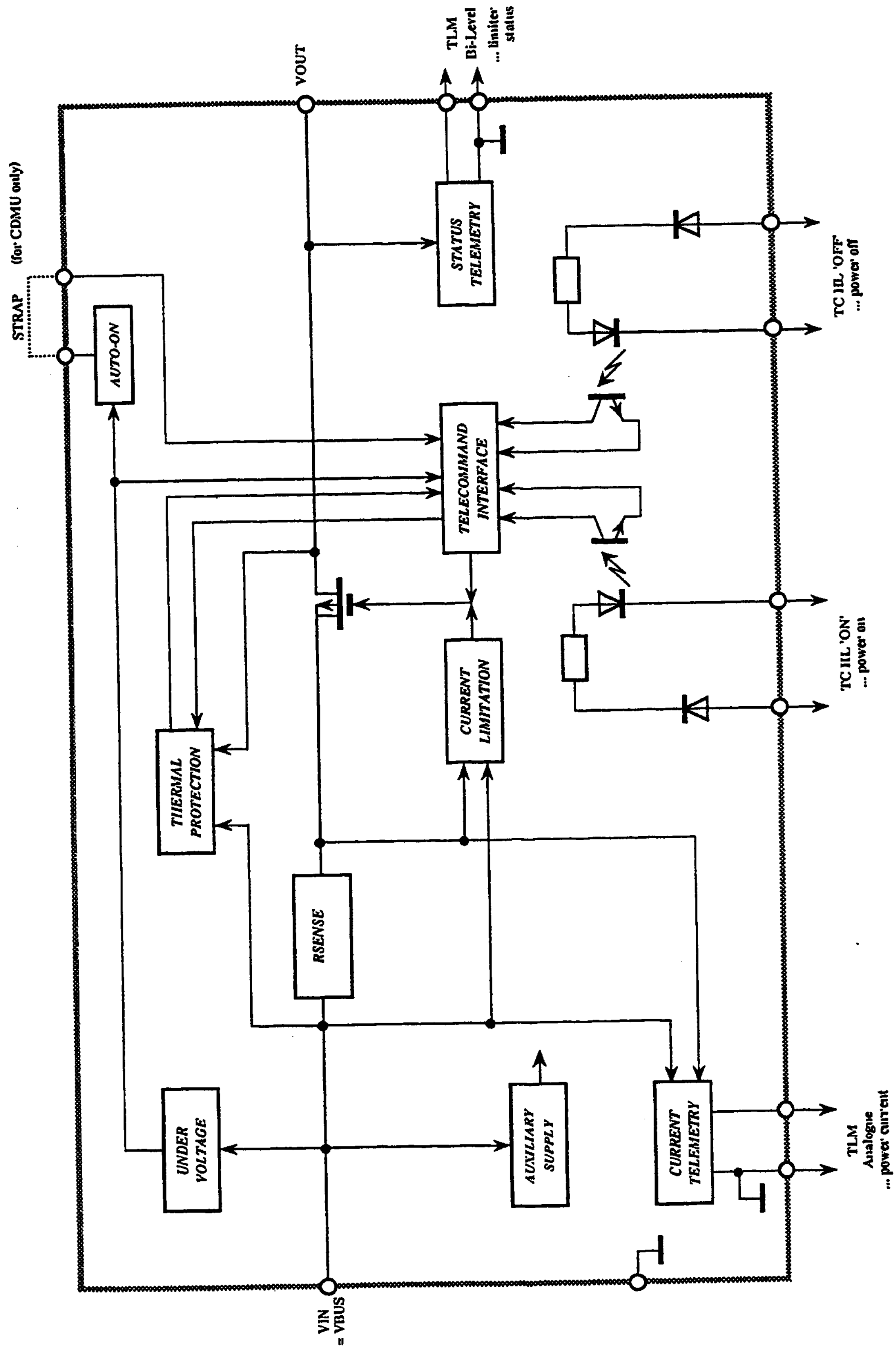

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FIGURE 4.3.1-3-3 CURRENT LIMITER

d. Common Current Limiter (Figures 4.3.1-3-4a and b)

For the 28 V distribution outputs, ACP3, GCMS1, GCMS2 and DISR1 which have a high I_{MAX} value, and to avoid a too high power consumption in case of failure user (up to 2 times $1.14 I_{MAX}$), a Common Current Limiter has been implemented. This Common Current Limiter will trip off the Redundant and the Nominal lines when the total Redundant and the Nominal current is > $1.1\ I_{MAX}$.

For ACP3, GCMS1 and DISR1 outputs, this function detects when a certain current threshold has been exceeded and sends an OFF command to the associated current limiter.

This OFF command is in fact logically 'ored' to the external OFF command (from CDMU) before to be sent to the associated current limiter.

A sensing resistor is implemented in the common line of the 2 limiters and there are 2 common current limitation circuits associated each with one of the 2 limiters. The threshold value of the common current limitation is below the current limiter's one, but a delay is implemented longer than the dissipation time allowed by the current limiter and so, the common current function does not act at turn-on.

For GCMS2 a simplified common current limitation is used: the nominal limiter is "activated" by the total (nominal + redundant) current (the current to Redundant Current Limiter is taken downstream the current sensing resistor of the Nominal Limiter).

e. Protected + 5 V Supply (Figure 4.3.1-3-5)

This supply is implemented to generate the bi-level status telemetries of the selection relays of the PYRO unit, it is produced simply by a series voltage regulator.

For the purposes of redundancy, two separate supplies are used, one for each half of the PYRO unit.

Protections are implemented to protect the main bus against failure.

There is not any telecommand or telemetry for this function.

f. Energy Intercept Relay Activation (Figure 4.3.1-3-6)

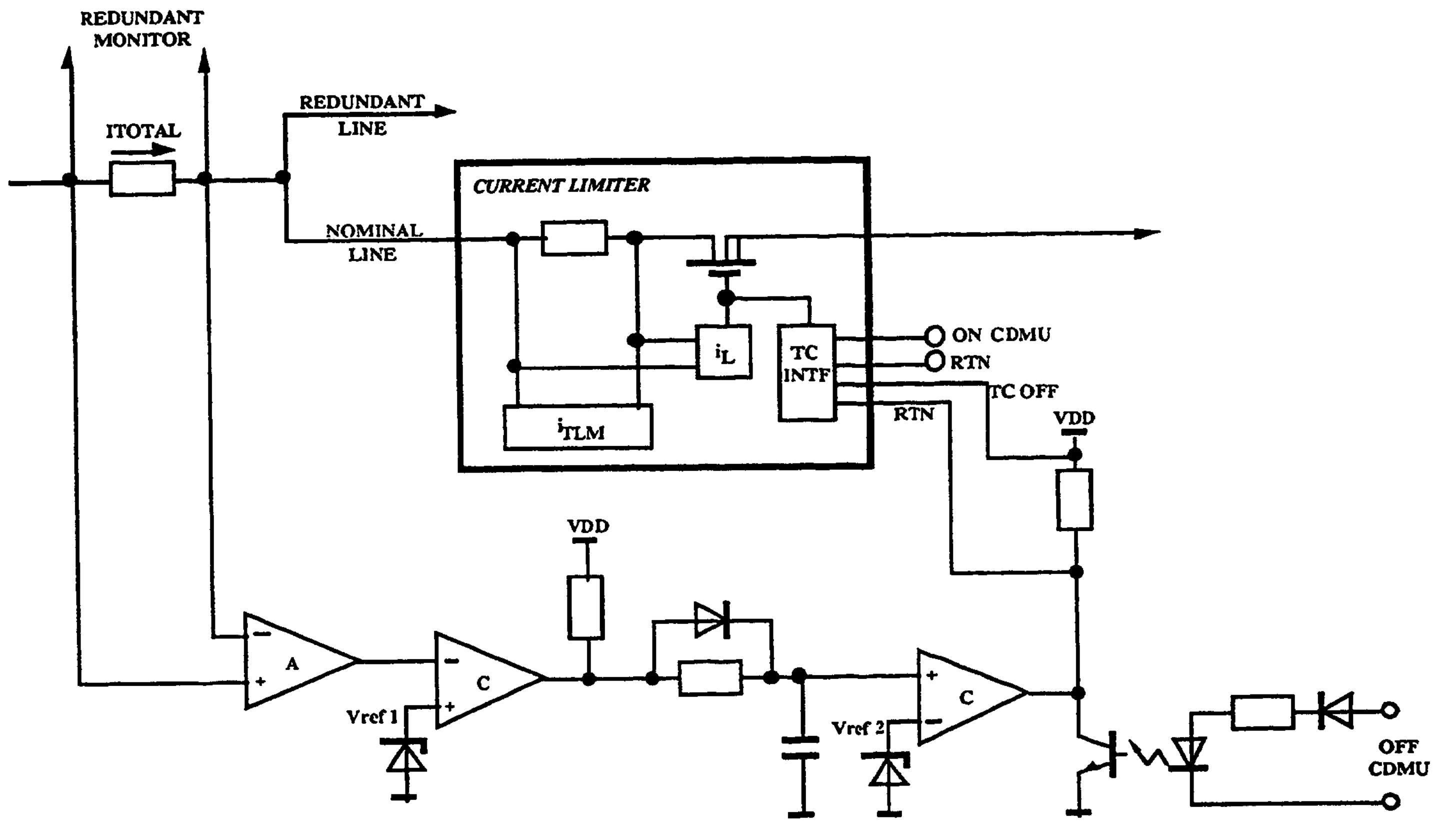
This function allows to activate the Energy Intercept Relay of the PYRO unit at the end of the Coast phase: the circuit detects the separation of the Orbiter and Probe by means of a separation strap in the umbilical connector and activation of the relay occurs as soon as the Main Bus is powered. Nominally after separation, this happens when Input Relays are switched ON in the PCDU by Timers, but this activation also occurs whatever the power source is - Battery or Orbiter.
The activation command pulse lasts about 100ms.

There are, in fact. two of these circuits each one dedicated to one of the Energy Intercept Relays (one for each half of the PYRO unit).

Each circuit is protected to avoid a permanent ON command of the relay.

There is not any telecommand or telemetry for this function at PCDU level; the telemetries of the relays are performed at PYRO level.

D2



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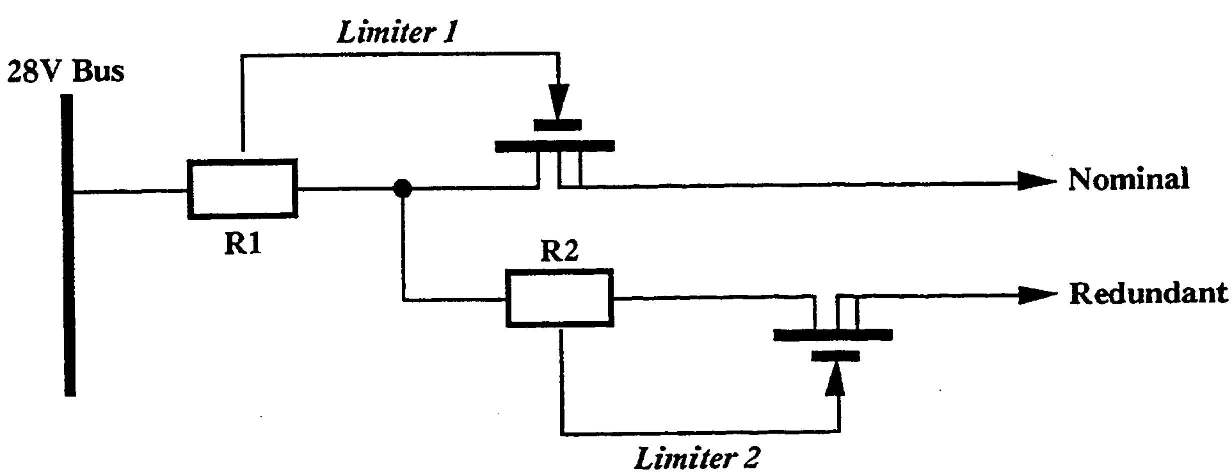
4.3.1-3-4a COMMON CURRENT LIMITATION (ACP3, GCMS1, DISR 1)



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4.3.1-3-4b COMMON CURRENT LIMITATION - GCMS2

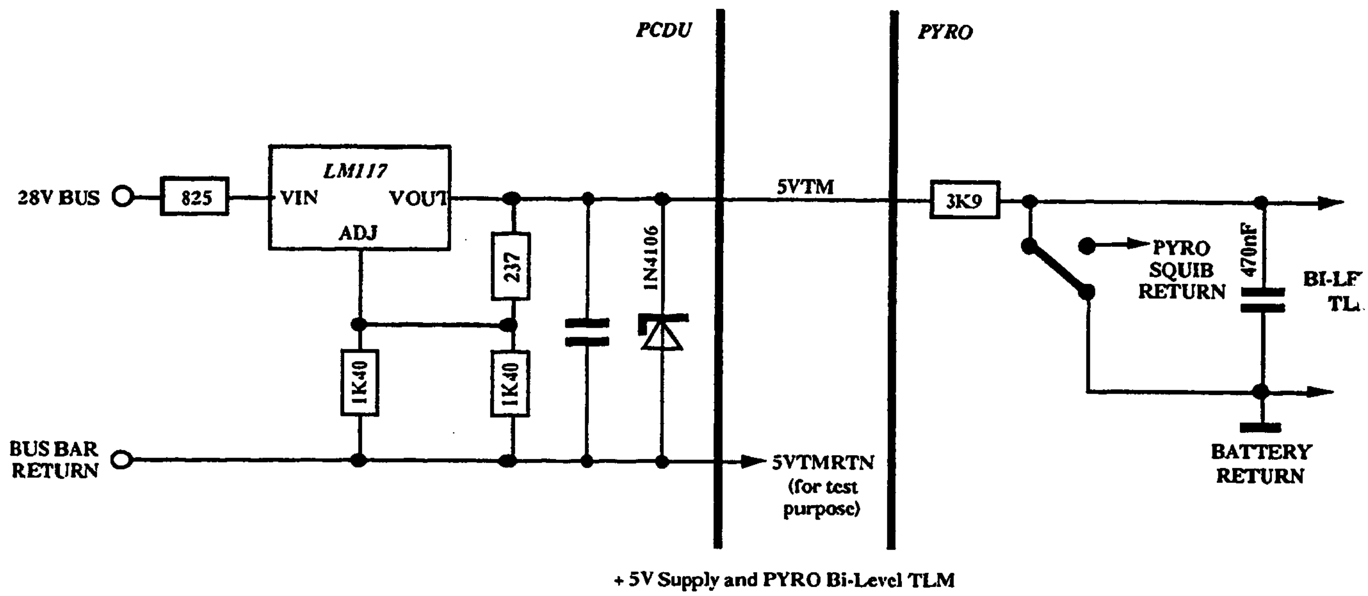

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FIGURE 4.3.1-3-5 + 5 V SUPPLY

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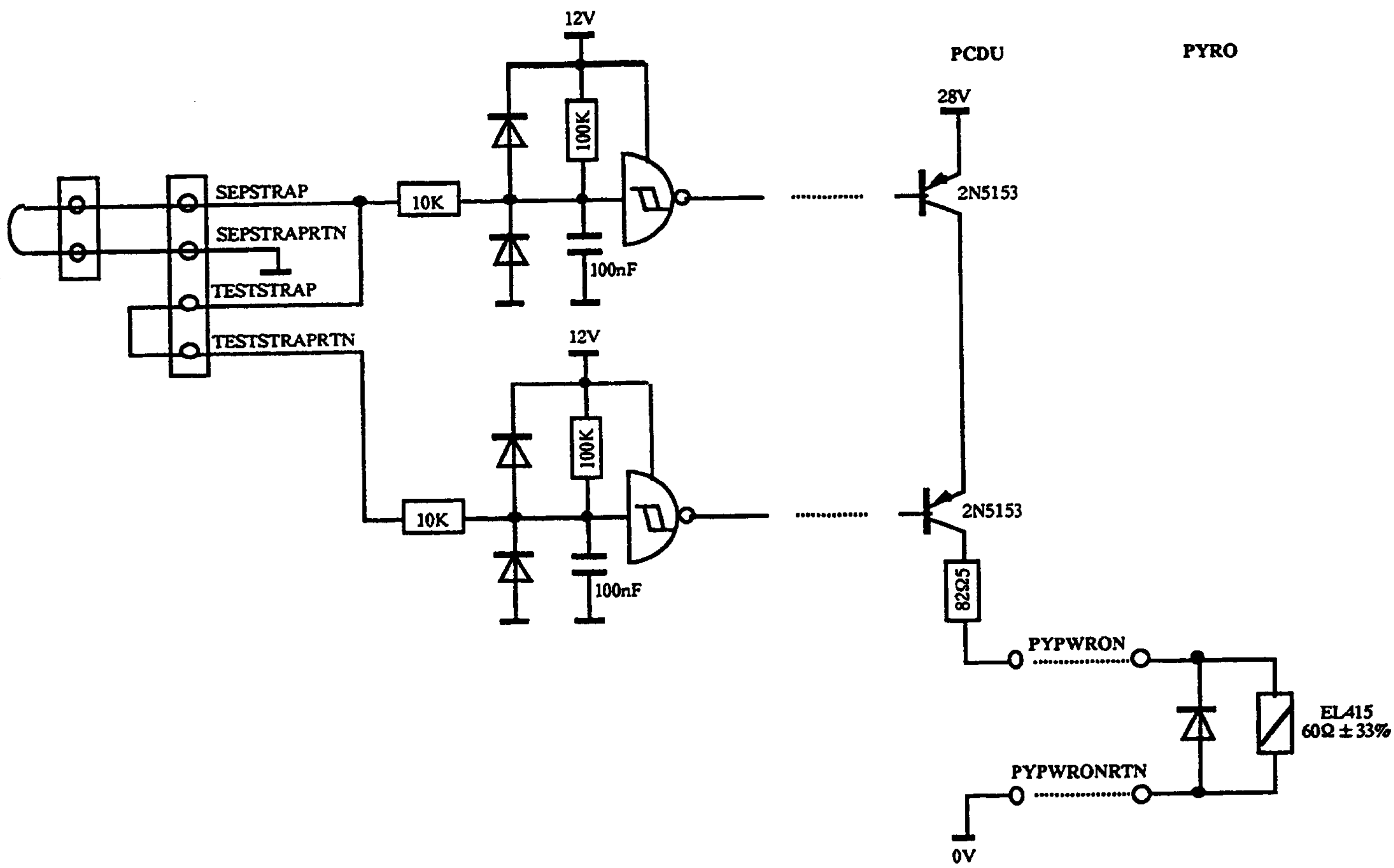

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FIGURE 4.3.1-3-6 ENERGY INTERCEPT RELAY ACTIVATION CIRCUITRY

4.3.1-3-2 PYRO Description

NOTE: The PYRO unit is constituted of 2 identical redundant chains fully independent:
PYRO 1 is associated with CDMU A, ARMING TIMER N and with "nominal" squibs
PYRO 2 is associated with CDMU B, ARMING TIMER R and with "redundant" squibs

The firing commands are cross strapped: CDMU A **and** CDMU B activate PYRO 1 **and** PYRO 2. Only one chain is described in this chapter.

The BCM selection relays **Set** TC are also cross-strapped.

a. Energy Intercept Relay

This relay is directly connected to the center-tap of its corresponding battery and performs both the energy intercept function and the battery isolation function during the Cruise phase.

The relay is activated by a dedicated circuitry in the PCDU (see § 4.3.1-3-1 f); the switch ON is performed at the end of the Coast phase when the input relays of the PCDU are switched ON.

Switch OFF of the relay can be performed by HL O/O command from the CDMU, while the Probe is still attached to the Orbiter.

The latching ON command is generated only one time by the PCDU: that means that the switch OFF of the relay is possible (by CDMU command), but in this case it will be IMPOSSIBLE to switch ON again the relay. A switch status telemetry is provided.

Two safety loops are provided for the Energy Intercept Relays and Arming Relays (PYRO 1 + PYRO 2). They are directly monitored at Launcher level.

b. Switches (Figure 4.3.1-3-7)

These are provided to protect against a permanent ON of the current limiters combined with a short failure of a squib.

They also allow to avoid a premature firing of a squib in case of short failure of the associated current limiter.

These active switches (three per half PYRO) are implemented upstream the current limiters and are activated by the same firing commands from both CDMU via a dedicated TC interfaces (see § d).

Not any telemetry is foreseen.

c. Current Limiters (Figure 4.3.1-3-8)

These are designed to guarantee a minimum current of 5 A during 50 ms. The command function is non-latching, i.e. the limiter is ON during the duration of the HL O/O command from the CDMU. For the grouping shown in Figure 4.3.1-2-3 a total of 3 limiters is required (for each half PYRO).

Because of dissipation limitation, the design has been based on a current limiter made of three current limiter sections (each capable of carrying 2 A max).

A resistor R has been added in the circuit in order to relieve the power to be dissipated by the limiting transistor and to limit the current delivery by the battery in case of short failure of a current limiting transistor.

The limiters are activated by the same firing commands from both CDMU via a dedicated TC interface (see § d).

In case of three Pyro squibs, the simultaneity for igniting the selected squibs is better than 1 ms.

Not any telemetry is foreseen.

d. TC Interface (Figures 4.3.1-3-9a and b)

It receives the HL O/O firing commands coming from the CDMUs and transfer them to the switches and current limiters. It has also in charge to filter them (immunity against short duration pulses), to shape them and to limit the pulse duration in case of a permanent ON command from CDMUs.

As it is shown in the timing diagram (Fig 4.3.1-3-9b), the different delays are implemented:

1. To be sure that it is the limiter that switches ON/OFF the current into the squib (and not the switch):

$\Delta t2$ ON > $\Delta t1$ ON

$\Delta t2$ OFF > $\Delta t1$ OFF.

$\Delta t1 = 328\mu s$ $\Delta t2 = 655\mu s$

2. To protect against a permanent ON command from CDMU:

$\Delta t3$ and $\Delta t4$ ($\Delta t3 = 106$ ms, $\Delta t4 = 69$ ms).

In case of non simultaneity of the two firing commands from CDMU A and CDMU B, two cases may occur: either only one pulse is generated, in case of overlap between the 2 commands and the duration is limited to $\Delta t4$, either two successive pulses are generated, first one corresponding to the first command and second one to the second command (this second pulse has no effect because the selected squibs have already been fired by the first pulse).

There is one TC interface in each half PYRO that receives firing commands from both CDMUs and that active the three switches and the three current limiters.

A delay of 500 ms is required between two successive firing commands from the same CDMU, otherwise the value of the current pulse (min 5 A) is not guaranteed.

D2

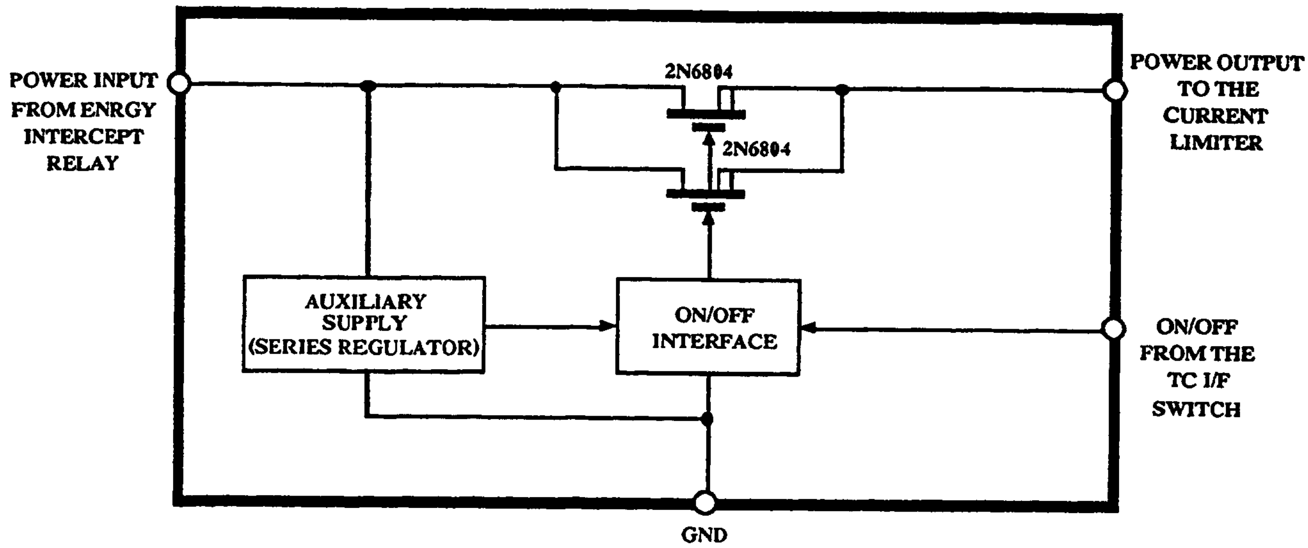

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FIGURE 4.3.1-3-7 BLOCK DIAGRAM OF THE SWITCH FUNCTION

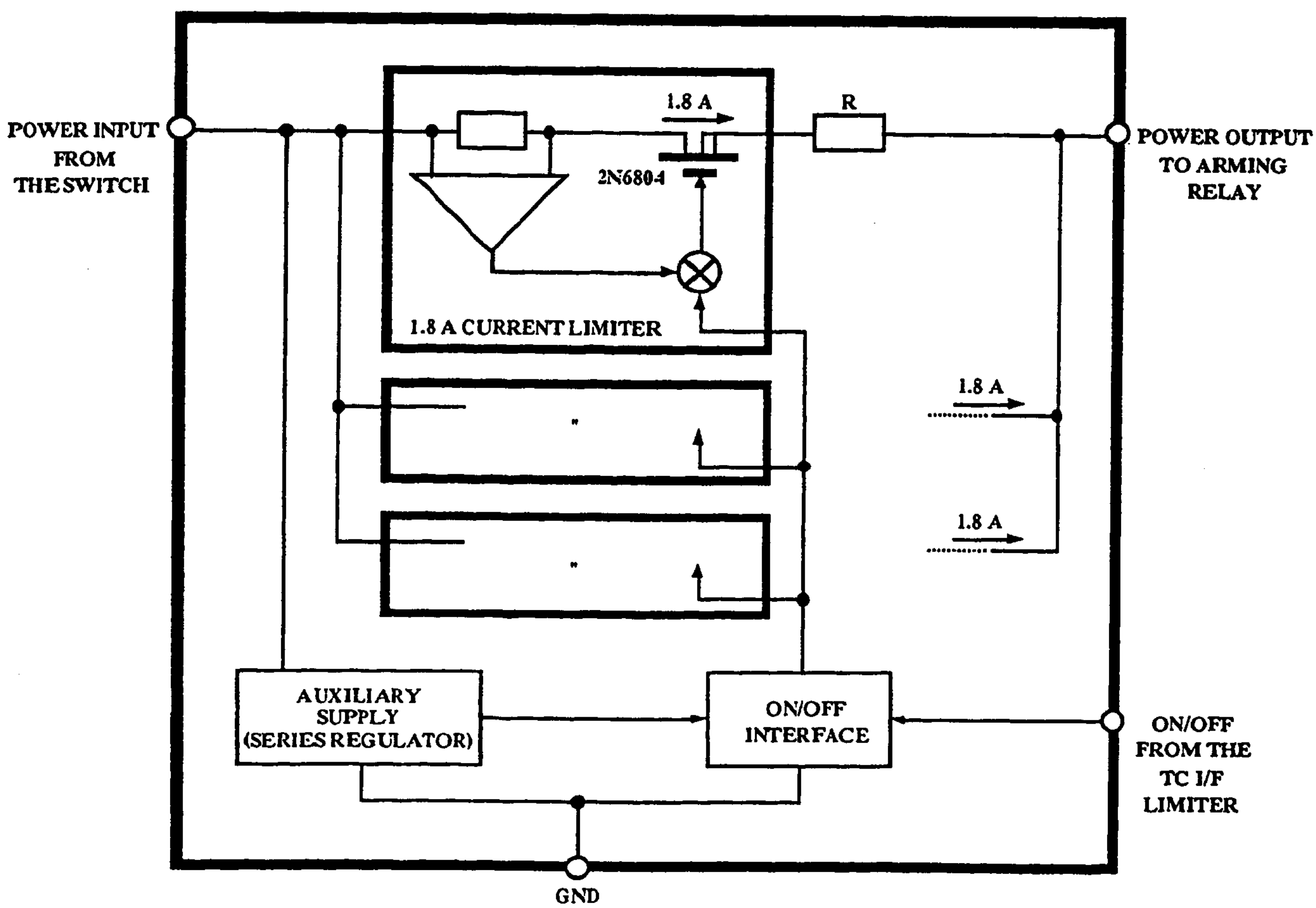

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FIGURE 4.3.1-3-8 BLOCK DIAGRAM OF THE LIMITER FUNCTION

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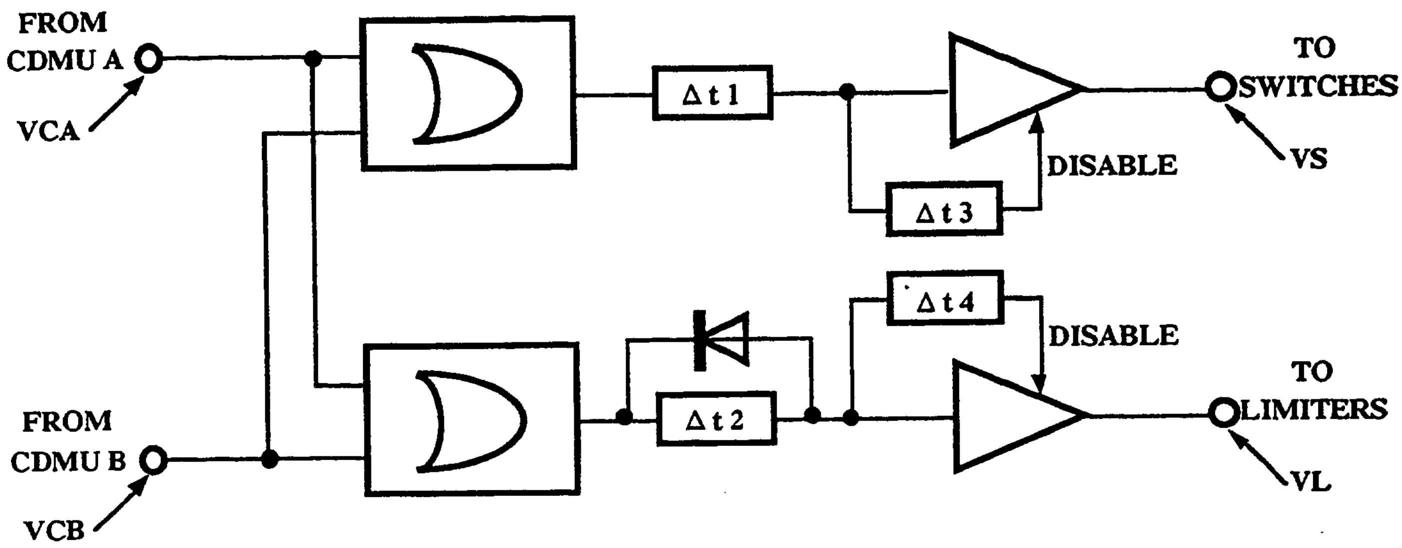

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FIGURE 4.3.1-3-9a FUNCTIONAL DIAGRAM OF THE TC I/F

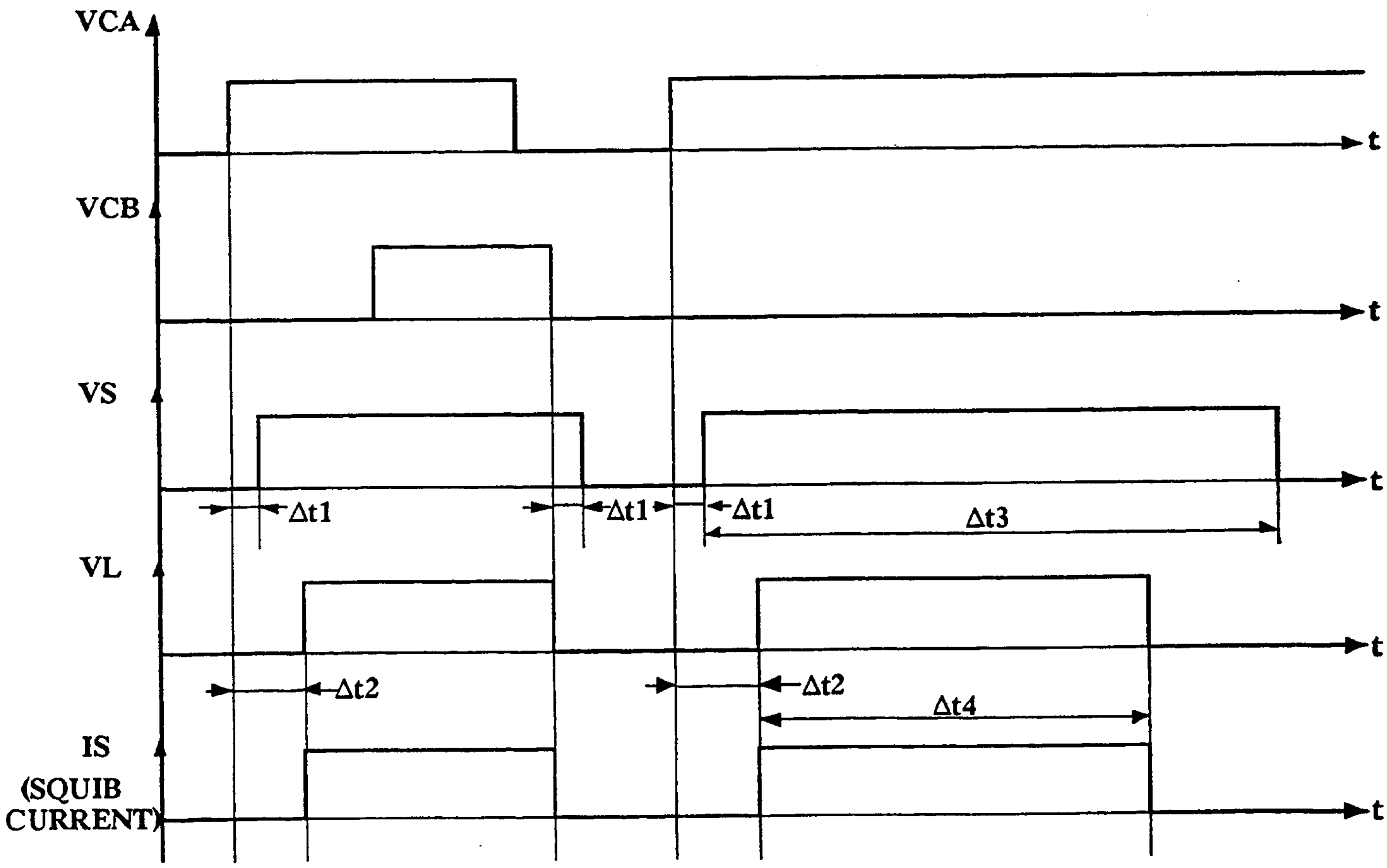

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FIGURE 4.3.1-3-9b TC I/F TIMING DIAGRAM

e. Arming Relays

These latching relays are grouped to allow to select which squibs will fire. The actual grouping requires a total of 10 relays (for each half PYRO). See Figure 4.3.1-2-3.

These relays are activated by HL O/O commands from ARMING TIMER and may be switched OFF by HL O/O commands from the CDMU: one command switches ON (or OFF) all the relays of the same group.

Not any telemetry is foreseen for these relays but a global safety loop is provided for the 20 relays (two half PYRO):
This Arming Safety Loop is directly monitored at Launcher level.

NOTE: Arming relay switch off is not mandatory during nominal operations it is useful only for ground tests.

f. Selection Relays

These latching relays provide a selection function for the squibs that are to fire, relays identified by a same letter in Figure 4.3.1-2-3. They select, in one TC, the squibs associated to a same mechanism which are activated simultaneously.

When not selected, the selection relay ensures that the squibs are short-circuited.

The relays are activated both ON and OFF by HL O/O commands from the CDMU.

A deselection command (named "RESET" command) have to be sent after the squibs firing, before the selection of the following squibs.

A bi-level status telemetry is provided for each relay by means of the protected + 5 V supply from the PCDU and a pull up resistor.

g. Safe/Arm Plug (Figures 4.3.1-3-10a and b)

A Safe/Arm plug (for each half PYRO) provides an additional level of safety during integration and ground handling, the Safe plug ensures that the squibs are short-circuited.

It is positioned so as to be accessible after integration has been completed.

h. Electrostatic Protection

Resistors of 100 KΩ are connected between the positive lines and the chassis, and the return lines and the chassis, to protect the squibs against any possible electrostatic charging.

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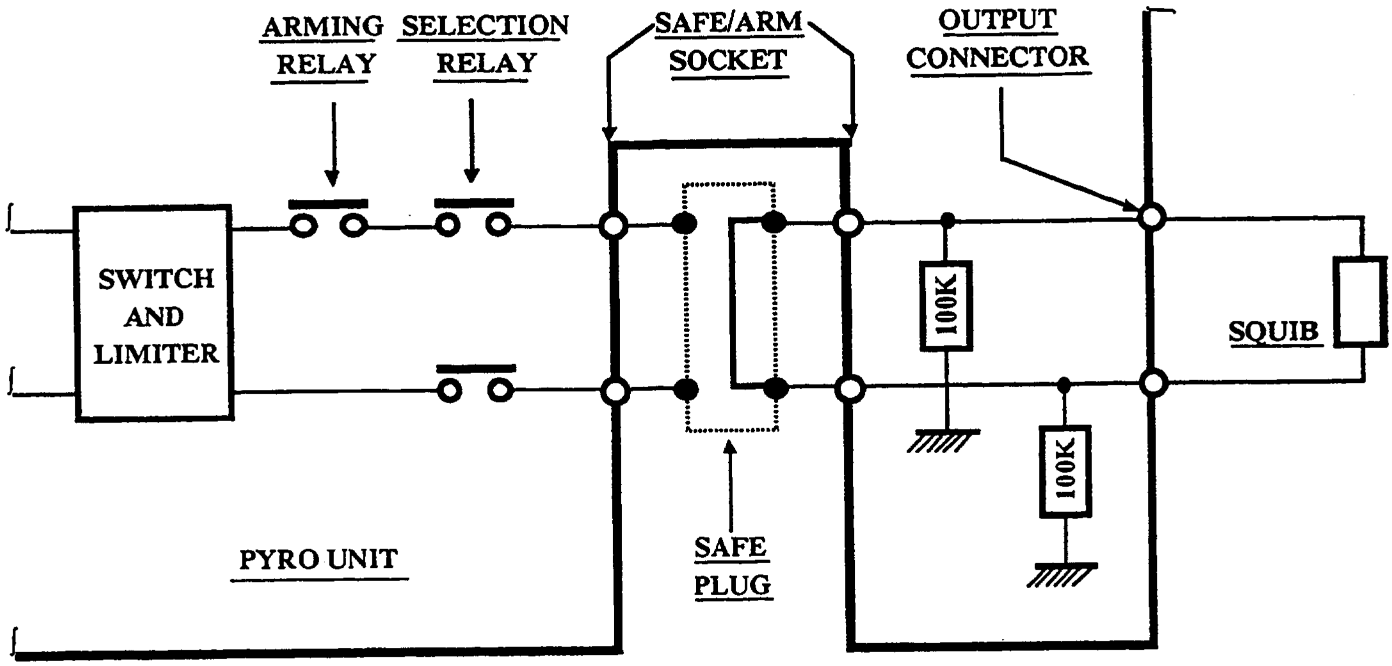

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FIGURE 4.3.1-3-10a ELECTRICAL CONNECTIONS PRINCIPLE REALIZED BY THE SAFE PLUGS

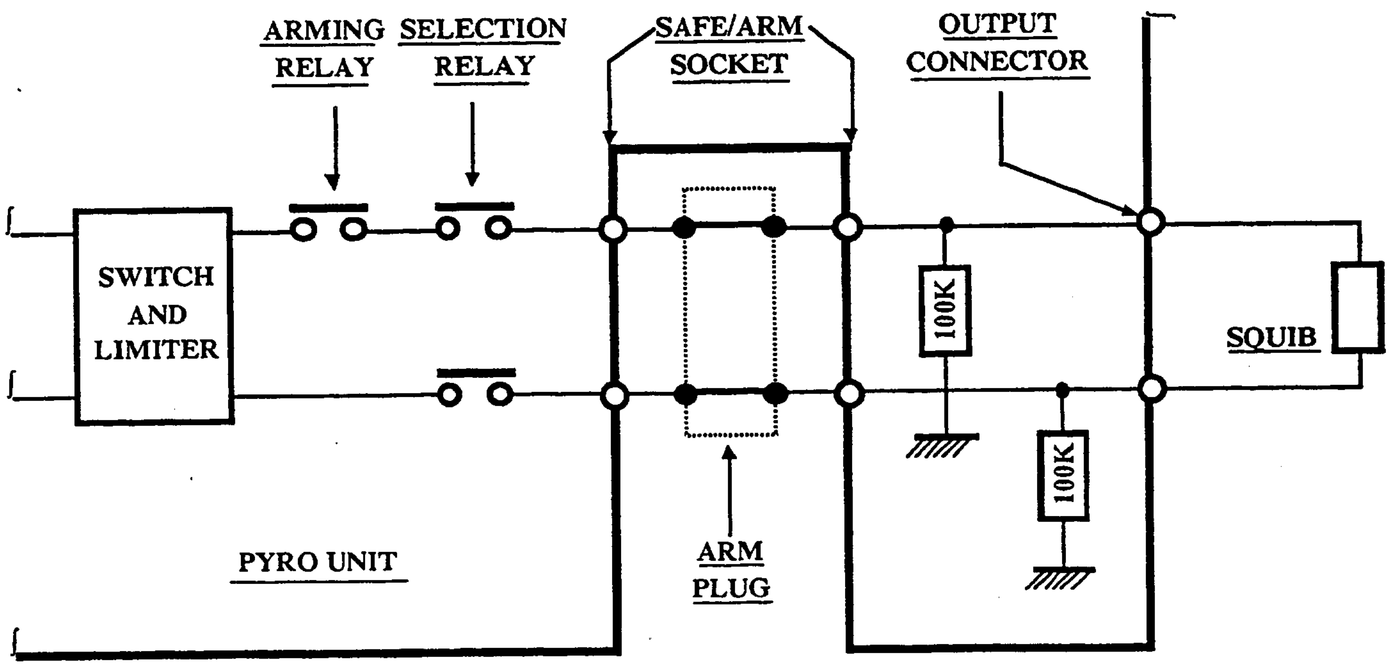

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FIGURE 4.3.1-3-10b ELECTRICAL CONNECTIONS PRINCIPLE REALIZED BY THE ARM PLUGS

4.3.1-3-3 BATTERY Description

The Battery system consists of ten Galileo, 13 cells modules arranged in a configuration of 5 strings of two modules each. One of these strings (2 modules) is a completely redundant element.
The G3108A3 cell used is a lithium/sulfur dioxide "D" type.

a. Battery Voltage Value

A typical cell voltage of 2.75V is expected during the mission, which corresponds to a battery voltage of 72V, for a discharge current of a few amperes.

However, during the application of pyro pulses (21A max), the total battery voltage value could be as low as 18V, which fully covers the requirement to have a minimum PYRO input voltage value of 15V.

b. Depassivation

The application of a load of 55W for a few minutes is sufficient to ensure a correct depassivation.
See Procedure PP03.

c. Battery Unbalance

The transconductance value of BDR's 1 and 5 (batteries not connected to the Timer) has been increased by a few percents to ensure that, in nominal conditions, all batteries will be fully discharged at the same time.
In order to get the total power available on main bus up to the end of discharge, the BDR's transconductances values are:

G2 = G3 = G4 = G [A/V]
G1 = G5 = 1.14 G [A/V]

4.3.1-4 Performance Characteristics

4.3.1-4-1 Power Consumption and Dissipation

a. PCDU

PHASE - CONFIGURATION		POWER DISSIPATION
CHECK OUT	P_{BUS} = 180 W ORBITER/5 SECTIONS	56 W + 2 W/- 5 W
BATTERY DEPASSIVATION	P_{BUS} = 90 W 1 ORBITER + 1 BATTERY	25 W + 3 W/- 6 W
TIMER LOADING	P_{BUS} = 60 W ORBITER/5 SECTIONS	46 W + 2 W/- 5 W
ENTRY PHASE	P_{BUS} = 120 W BATTERY/5 SECTIONS	30 W + 2 W/- 5 W
DESCENT PHASE	P_{BUS} = 300 W BATTERY/5 SECTIONS	47 W + 2 W/- 5 W

b. PYRO

PHASE - CONFIGURATION		POWER DISSIPATION
CRUISE-COAST PHASES	Relays open PCDU OFF	0 W
CHECK OUT	Relays open PCDU ON	0.15 W +/- 0.05 W
DESCENT PHASE	Relays closed PCDU ON	1.65 W +/- 0.35 W

c. BATTERY

PHASE - CONFIGURATION		POWER DISSIPATION	
COAST/ENTRY PHASE	P_{BUS} = 120 W	BAT 1, 5 BAT 2, 3, 4	3.2 W 2.8 W
DESCENT PHASE	P_{BUS} = 300 W	BAT 1, 5 BAT 2, 3, 4	11.9 W 10.2 W

4.3.1-4-2 Telemetry and Telecommand Budget

TM Budget

The following telemetries are provided:

	CDMU A/B			Orbiter	Launcher
	Analog	Relay Status	DB	Relay Status	Relay Status
PCDU	21/21	5/3	14/14	2	0
PYRO	/	1/1	13/13	0	2

TC Budget

The following telecommands are requested from each CDMU or Arming Timer. Moreover, 5 HL O/O commands are requested from each Mission Timer to activate the battery relays at the end of the coast phase.

	HL O/O "ON" from CDMU	HL O/O "OFF" from CDMU	HL O/O "ON" from Arming Timer	HL O/O "OFF" from Arming Timer
PCDU	15	18	5	2
PYRO	9	12	4	0

4.3.1-4-3 Thermal Temperatures Prediction

UNIT	DESIGN LIMITS OPER.	CRUISE 0.6AU	CRUISE 9AU	CHECK-OUT TMAX	COAST	ENTRY TMAX	DESCENT TMIN
PCDU	-20/50	21	8	42	1	3	-8
PYRO	-30/-10	24	10	35	3	4	-2
BATTERIES	-10/30	23/25	9/11	35	2/4	3/5	6

All temperatures are in °C.

4.3.1-4-4 PCDU Performances Characteristics

a. Main Bus Voltage

The PCDU provides a regulated bus voltage of 28 V +/- 1.25 % at the outputs.

Ripple and spikes do not exceed 300 mVpp (scope 50 MHz bandwidth) and 75 mV RMS (True RMS voltmeter 10 MHz bandwidth).

Voltage transients on the main bus do not exceed ± 200mV (±0.7%) for load steps of ±4 A. The duration of the transient directly depends on the MEA voltage control loop bandwidth (5 Khz i.e. 200μs), so steady state main bus voltage is recovered within 2ms.

b. Output Impedance

The Main Bus impedance is specified in Figure 4.3.1-4-1.

This figure also specifies the max impedance at PCDU outputs taking into account the resistance and the inductance of the series current limiter function.

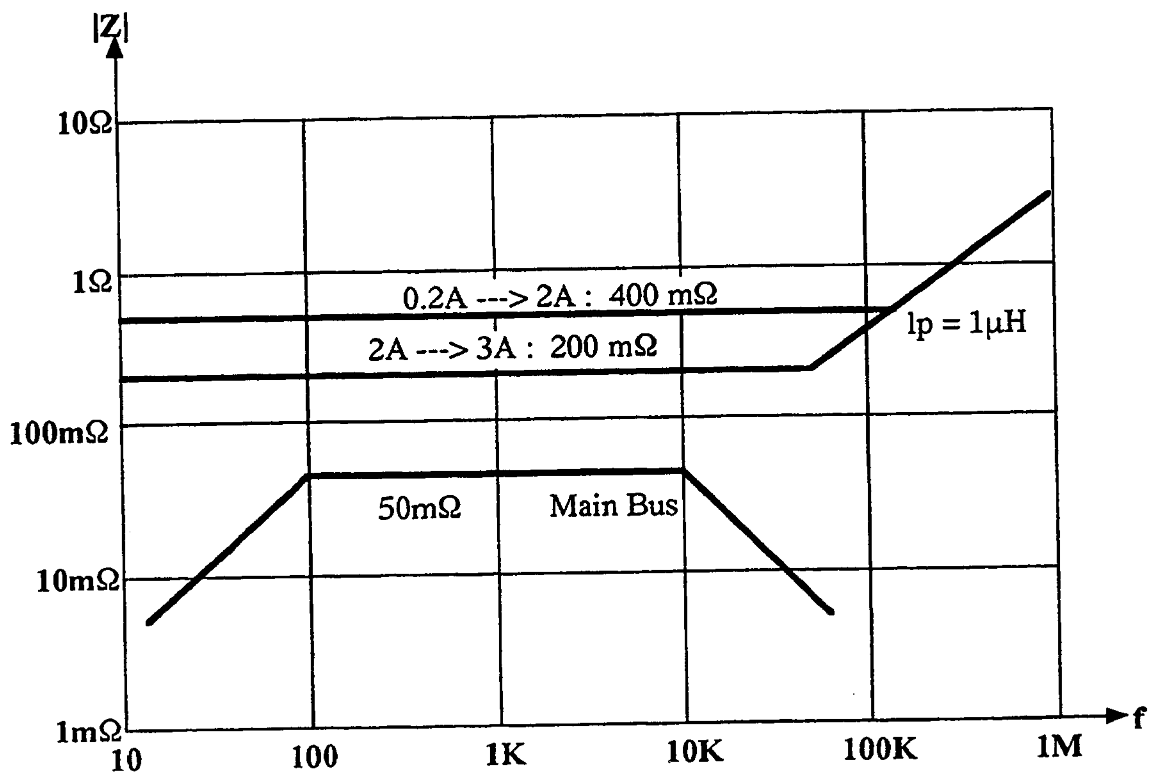

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FIGURE 4.3.1-4-1 OUTPUT IMPEDANCE

c. Power

The PCDU is sized for an average power demand of 300W with a maximum power demand of 400W at bus level (when powered by batteries).
Each BDR is able to deliver one fourth of this power, taking into account the total number of BDR's (5) minus one (possible failure).
When powered by Orbiter, the PCDU is able to deliver a maximum power of 200W at PCDU output level.

The value of the maximum power available at PCDU output level when **PCDU is powered by Orbiter** depends on the number and the type of connected SSPS; taking into account single or double SSPS and the different transconductances of the BDR (battery capacity unbalance)

• Power available, at BDR's output, from a SSPS in worst case conditions; see POWi definition in Figure 4.3.1-1:

• POW (1, 3, 5) 26V * 3A = 78W $* \eta_{orbiter\ I/F} * \eta_{BDR} =$ 66W
• POW (2, 4) 25.5V * 4.8A = 122W $* \eta_{orbiter\ I/F} * \eta_{BDR} =$ 100W

• Corresponding Power available at output level (typical value), taking into account the ≈10W of auxiliaries consumption:

• POW (1, 3, 5) $Pout_{MAX}$ PCDU = 56W
• POW (2, 4) $Pout_{MAX}$ PCDU = 90W

When the PCDU is powered by at least POW1 or POW5, the following formula is applicable (typical values):

$$Pout_{MAX}\ PCDU = N_{1,5} \times 66W + N_{2,3,4} \times \frac{66W}{1.14} - 10W$$

Where: $N_{1,5}$ = number of activated POW 1 or 5 = 1 or 2
$N_{2,3,4}$ = number of activated POW 2, 3 or 4 = 0, 1, 2 or 3

This formula takes into account:
• the maximum power available at bus level with a POW for I_{IN} = 3A/26V
• the BDR's transconductance unbalance configuration
• the consumption of the auxiliaries (≈ 10W typical value)

Examples:
1• If POW1 and/or POW5 are energised

$N_{1,5}$	$N_{2,3,4}$	$P_{available}$ W
1	0	56
1	1	114
1	2	172
1	3	230
2	0	122
2	1	180
2	2	238
2	3	295

2• If POW1 and POW5 are not energised and if POW3 is energised, the formula becomes:

$Pout_{MAX}$ PCDU = ($N_{2,3,4}$ x 66W) - 10W

$N_{2,3,4}$	$P_{available}$ W
1	56
2	122
3	188

3• If POW1, POW3 and POW5 are not energised, the formula becomes (I_{INMAX} = 4.8A):

$Pout_{MAX}$ PCDU = ($N_{2,4}$ x 100W) - 10W

$N_{2,4}$	$P_{available}$ W
1	90
2	190

The value of the maximum power available at PCDU output level, when **PCDU is powered by batteries** is:

$Pout_{MAX}$ PCDU = n * 130W (*)

Where: n = number of activated section.

But the total power at bus level, when powered by batteries, is limited to 400 W whatever the number of activated section, for dissipation reasons.

(*) The BDR's are designed to deliver a maximum power of 110W but their output current limitation has been set to 1.35 times this maximum value. Taking into account a possible drift of the current limitation value, the power capability will be at least 110W x 1.2 = 130W per section.

d. Power Dissipation

The table below summarizes the typical EPSS power dissipation vs P_{OUT}, the number of BDR's and the mission phase:

Pdissipation	5 BDR's	4 BDR's
P_{BUS} = 300 W/on Batteries	47 W	46 W
P_{BUS} = 400 W/on Batteries	57 W	57 W
P_{BUS} = 180 W/on Orbiter	56 W	52 W

e. BDR's Power Sharing

The 5 BDR's ensure a correct sharing of the power delivered by the Orbiter or by the Batteries.

At input level, the BDR's power sharing is better than:

10 W between 2 BDR's with Pout = 120 W/BDR

7 W between 2 BDR's with Pout = 60 W/BDR

6 W between 2 BDR's with Pout = 0 W/BDR

Moreover, the BDR's gain transconductance values are adjusted to compensate for the battery capacity unbalance resulting from the supply of the Mission Timer by only 3 batteries during coast phase.

f. Orbiter Interface - Timer Interface

The input filter is designed to meet the Orbiter interface EMC requirements of 10 mApp max.

A dedicated output voltage is provided to supply the Mission Timer during Cruise phase with a voltage of 65 V ± 20 % representative of the battery voltage.

Ripple and spikes on Timer outputs don't exceed 1 Vpp in the frequency range 30 Hz to 50 MHz.

g. Distribution

The PCDU provide the 28 V distribution lines to the different users with current limitation protection and ON/OFF switching capability. The power demand of each line is defined in Table 4.3.1-4-1, but does not exceed 84 W (3 A).

If the maximum current demanded by a given user is I_M, the current limitation I_L is given by:

$$1.1\ I_M \leq I_L \leq 1.22\ I_M.$$

A common current limitation is also provided on some output: the common current limitation value is given by:

$$I_M \leq I_L \leq 1.12\ I_M.$$

(Except for GCMS2 where $1.1\ I_M \leq I_L \leq 1.22\ I_M$).

The trip-off time in the case of current limitation is fixed: up to 10 ms in limitation is guaranteed whether this be at start-up or during normal operations.

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DESIGNATION	I_{MAX} (A)	REMARKS
TX OUTPUTS		
TX A	1.9	
TX B	1.9	
CDMS OUTPUTS		
CDMU A	1.25	
CDMU B	1.25	
RAU OUTPUTS		
RAU A	0.42	
RAU B	0.42	
EXP. OUTPUTS		
HASI 1 (N)	0.85	
HASI 1 (R)	0.85	
HASI 2 (N)	2.7	Pulse operation
HASI 2 (R)	2.7	Pulse operation
ACP 1 (N)	0.5	
ACP 1 (R)	0.5	
ACP 2 (N)	2	
ACP 2 (R)	2	
ACP 3 (N)	2.7	Common current limitation
ACP 3 (R)	2.7	Common current limitation
DISR 1 (N)	1.5	Common current limitation
DISR 1 (R)	1.5	Common current limitation
DISR 2 (N)	1.2	
DISR 2 (R)	1.2	
GCMS 1 (N)	1.68	Common current limitation
GCMS 1 (R)	1.68	Common current limitation
GCMS 2 (N)	1.32	Simplified Common current limitation
GCMS 2 (R)	1.32	Simplified Common current limitation
SSP (N)	0.65	
SSP (R)	0.65	
TUSO (N)	0.7	
TUSO (R)	0.7	

TABLE 4.3.1-4-1 28 V DISTRIBUTION

4.3.1-4-5 PYRO Performances Characteristics

The PYRO unit provides 2 redundant sets of 13 pyro lines split into 2 x 4 arming groups.

To meet safety requirements, the PYRO provides a minimum of three independent inhibits in series.

Power pulses of 5 A min. - 50 ms are delivered to the squibs.

In the case of the Back cover, Front shield and Parachute Jettison, the three pyrotechnic devices associated with the same group of pyro lines are activated simultaneously.

4.3.1-5 Interfaces

Refer to following documents for the interface characteristics (electrical, thermal or mechanical):

- PCDU IDS HUY.ETCA.352.ID.0012
- PCDU ICD HUY.ETCA.352.IS.0037
- PYRO IDS HUY.ETCA.353.ID.0013
- PYRO ICD HUY.ETCA.353.ID.0038
- BATTERY MODULE IDS HUY.ETCA.351.ID.0073
- BATTERY MODULE IDC HUY.ETCA.351.ID.0001.

a. Orbiter/PCDU Interfaces (Figure 4.3.1-5-1)

Five ORBITER INTERFACES circuits are provided in the PCDU (one per BDR) for the powering of the Probe by the ORBITER during cruise phase.

The INTERFACE provides voltage adaptation from SSPS (1 to 5) output voltage to BDR input voltage and to TIMER supply output voltage, it also provides isolation between PROBE and ORBITER. This is simply performed by a push pull transformer with an input filter designed to meet the Orbiter Interface EMC requirements. No series protection is provided this being already included in the SSPS function.

The push-pull delivers to the input of the BDR section a typical voltage of 45V, to achieve a correct operation of the BDR's with a suitable margin over the complete Orbiter Bus voltage range (26.1V --> 31.5V), and with a limited impact on the efficiency (estimated at 90% for the push-pull circuit).

Maximum admissible load current from Orbiter:	3 A	on POW1, POW3, POW5
	4.8 A	on POW2, POW4

The circuit delivers a maximum power of 110W at main bus level, with one single Orbiter I/F on double SSPS, which corresponds to the power requested during Depassivation sequences.

In nominal operation (PBUS ≤ 200W and 5 Orbiter Interfaces ON), the power delivered by one Interface whould not exceed 40W at 28V bus level.

A separate output voltage of 65V (± 20% to take into account the precision of the Orbiter Bus regulation and the voltage drop in the Orbiter Interface circuit) is also provided to supply the Timer during Cruise Phase with a voltage representative of the batteries.

There is not any Telecommand at EPSS level for the activation of these interfaces, the activation is automatically performed by the switch ON/OFF of the SSPS supplying the ORBITER INTERFACE.

Not any Telemetry is foreseen for the monitoring of the ORBITER I/F but the telemetries at BDR or Bus level (BDR current, Bus voltage) allow to monitor the behaviour of a complete Section (ORBITER + BDR).

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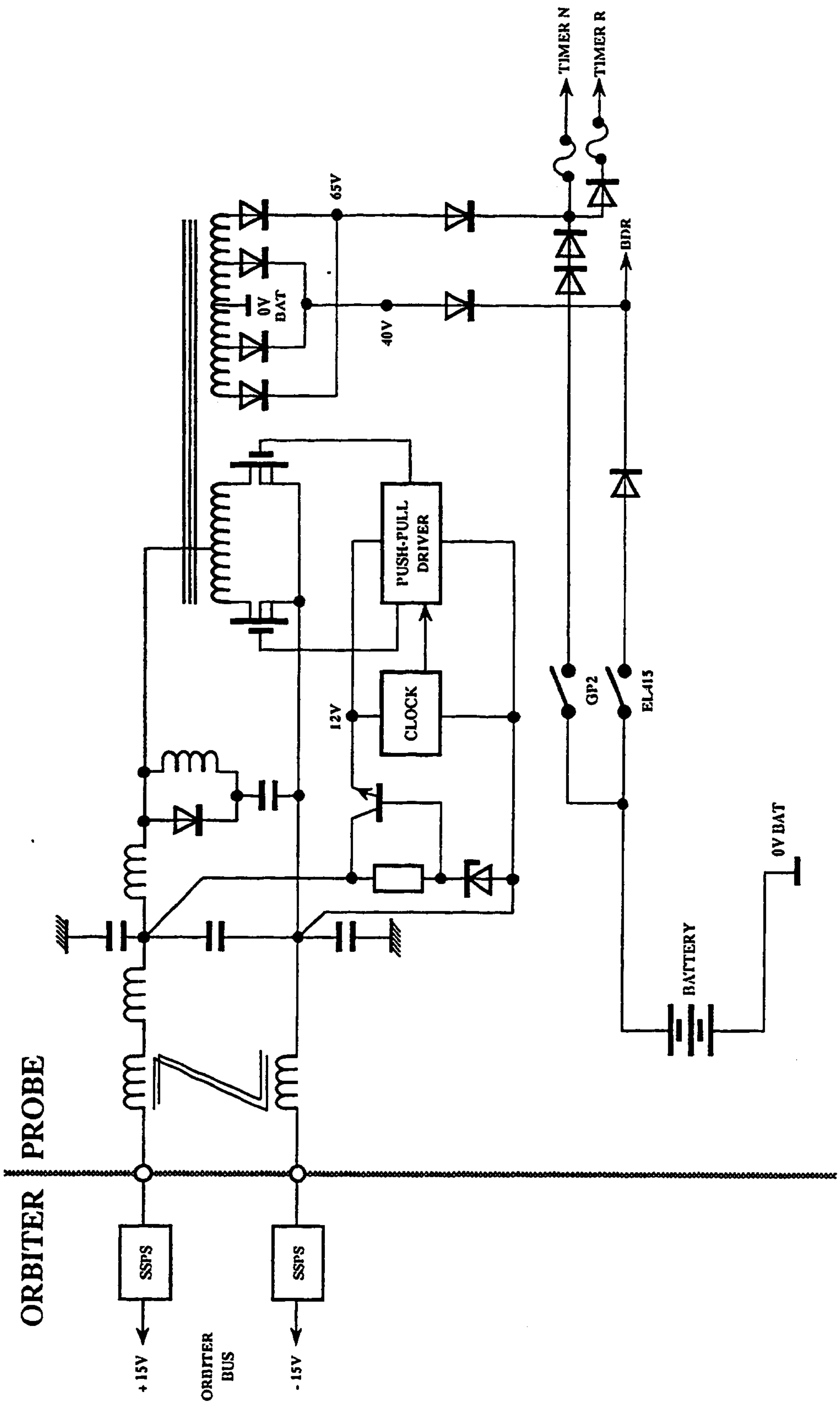

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FIGURE 4.3.1-5-1 ORBITER INTERFACE

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b. Battery/PCDU Interface (Figure 4.3.1-5-2)

The BDR's meet their full performances over a Battery voltage range from 32V (minimum input voltage requested to obtain 28V at the output of the BDR) up to 78V (maximum battery voltage corresponding to 3V/cell). A typical battery voltage of 70V (2.7V/cell) is expected during the mission.
As explained in the BDR description (§4.3.1-3-1 a), it is a power sharing that is ensured by the BDR's at battery level, and not a current sharing. This, however, does not have a significant impact on the batteries current sharing due to the expected very low dispersion of the batteries voltage values, also versus temperature and DOD.
Moreover, it is worth noting that even in case of full discharge of 2 out of the 5 batteries, the 3 remaining sections are still sufficient to provide the nominal power demand of 300W at bus level.

The isolation of the 5 batteries are performed by means of relays during the cruise and coast phases to avoid any loss of capacity by leakage current.
The batteries being unprotected against reverse current, protection diodes are provided in PCDU for safety reasons.

The latching relays are activated by redundant telecommands. For each relay we have a total of 6 telecommands:

ON : 2 commands (one from CDMU A and other from CDMU B) switch on the relay for the depassivation of the battery at the end of the cruise phase.
2 commands (one from Mission Timer N and other from Mission Timer R) switch ON the relay at the end of the coast phase.

OFF : 2 commands (one from CDMU A and other from CDMU B) switch off the relay during the battery depassivation sequence.

For each relay, a switch status telemetry is provided.
A global monitoring loop is also provided for the 5 relays directly at Orbiter level.

c. Timer/PCDU Interface (Figure 4.3.1-5-3)

The supply of the MISSION TIMER (3 redundant lines) is provided through series protection devices (fuses).

During cruise phase when the EPSS is powered by ORBITER a dedicated output of the ORBITER I/F transformer is used for the supply of the MISSION TIMER (TIMER 1 N/R are associated with ORBITER 2, TIMER 2 N/R with ORBITER 3, TIMER 3 N/R with ORBITER 4); see § 4.3.1-5 **a.**
Not any telecommand or telemetry is foreseen at EPSS level in this configuration mode (EPSS powered by ORBITER).

At the end of the cruise phase after battery depassivation and before PROBE separation, the 3 specific Timer relays (latching relays) are closed in order to supply the MISSION TIMER directly by the batteries (TIMER 1 N/R are associated with BATTERY 2, TIMER 2 N/R with BATTERY 3, TIMER 3 N/R with BATTERY 4).

The use of dedicated relays for the ON/OFF of the timer on the batteries enables the main power relays to remain open during the coast phase. This is mandatory to avoid a significant loss of the energy stored in the batteries resulting from leakage current in the BDR's.

A ON/OFF status telemetry and a monitoring loop are provided for the 3 relays.
The Timer relay loop is directly monitored at ORBITER level.

D2

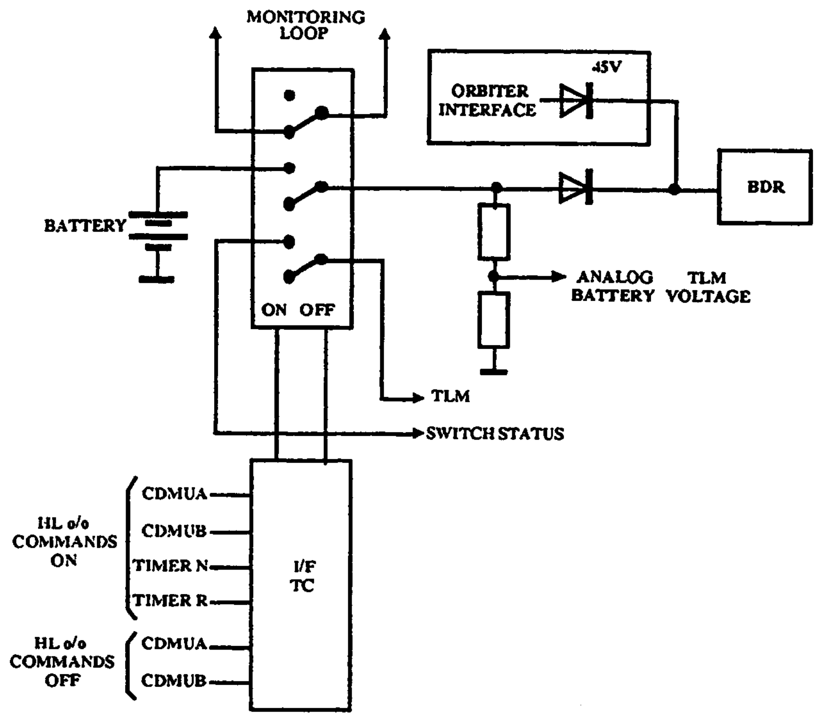

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FIGURE 4.3.1-5-2 BATTERY INTERFACE

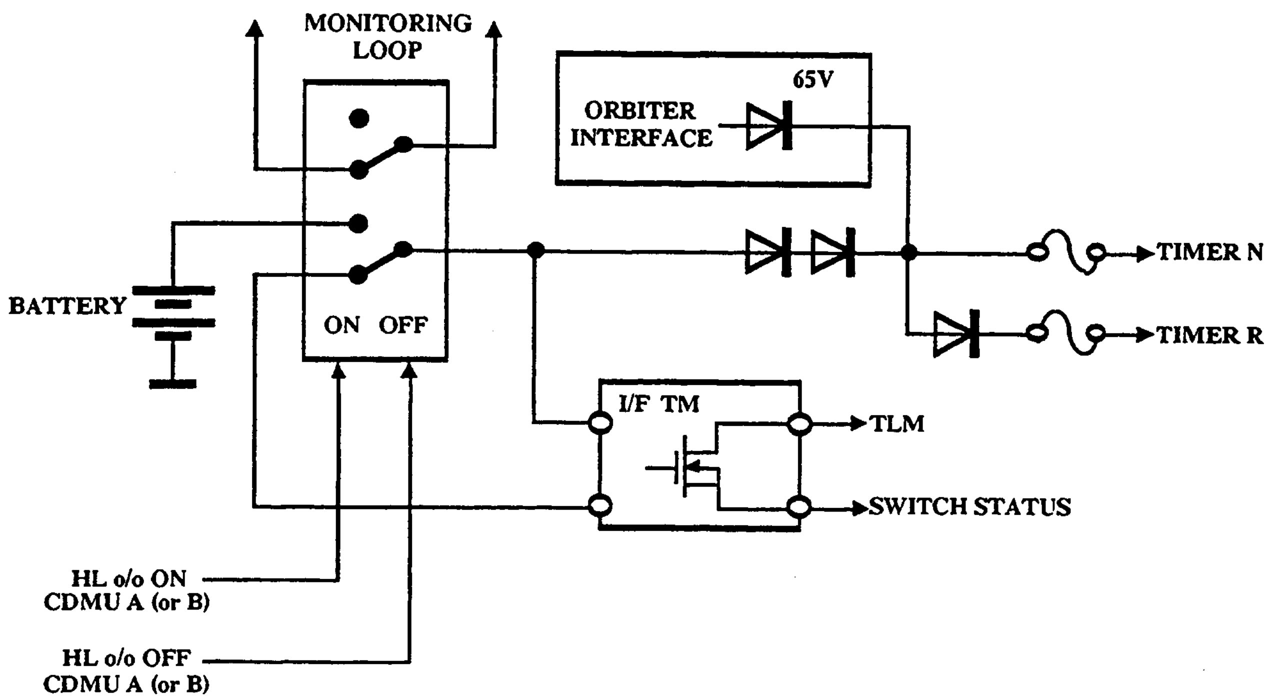

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FIGURE 4.3.1-5-3 TIMER INTERFACE

4.3.1-6 TM/TC

See location of TM and TC in Annex 4 Drawings: HUY-1000-0002-3/7 and HUY-1000-0002-4/7

4.3.1-6-1 Telecommand

PCDU

a. Input relay commands

Use:

Those latching commands activate (ON/OFF) the input relays of the PCDU in order to connect/disconnect the battery to the BDR section.

Operational constraints:

Switch OFF of the SSPS "i" is required before switch ON of the input relay "i" when the BDR section "i" is powered by ORBITER.

The delay between the switch OFF of a BDR (switch OFF of the associated SSPS or switch OFF of the Input Relay) and the switch ON shall be greater than 30 seconds.

Verification telemetry:

Input relay status: open or closed.

Battery voltage: gives the value of the battery voltage when the relay is closed. Equal to 0 V when the relay is open.

BDR current: gives the value of the current delivered by the BDR powered by battery or by ORBITER. This TLM is a "indirect" verification telemetry.

TELECOMMAND			TELEMETRY		
NAME/FUNCTION	CODE	SOURCE	EXPECTED TELEMETRY		CODE
PCDU section 1 ON	/	TIMER N	Section 1 input relay status A = closed	= 0	P5014 R
PCDU section 1 ON	/	TIMER R	Section 1 input relay status A = closed	= 0	
Section 1 input relay ON	P5001 O	CDMU A	Section 1 input relay status A = closed	= 0	
Section 1 input relay ON	P5011 O	CDMU B	Section 1 input relay status A = closed	= 0	
Section 1 input relay OFF	P5006 O	CDMU A	Section 1 input relay status A = open	= 1	
Section 1 input relay OFF	P5016 O	CDMU B	Section 1 input relay status A = open	= 1	
PCDU section 2 ON	/	TIMER N	Section 2 input relay status A = closed	= 0	P5015 R
PCDU section 2 ON	/	TIMER R	Section 2 input relay status A = closed	= 0	
Section 2 input relay ON	P5002 O	CDMU A	Section 2 input relay status A = closed	= 0	
Section 2 input relay ON	P5012 O	CDMU B	Section 2 input relay status A = closed	= 0	
Section 2 input relay OFF	P5007 O	CDMU A	Section 2 input relay status A = open	= 1	
Section 2 input relay OFF	P5017 O	CDMU B	Section 2 input relay status A = open	= 1	
PCDU section 3 ON	/	TIMER N	Section 3 input relay status A = closed	= 0	P5016 R
PCDU section 3 ON	/	TIMER R	Section 3 input relay status A = closed	= 0	
Section 3 input relay ON	P5003 O	CDMU A	Section 3 input relay status A = closed	= 0	
Section 3 input relay ON	P5013 O	CDMU B	Section 3 input relay status A = closed	= 0	
Section 3 input relay OFF	P5008 O	CDMU A	Section 3 input relay status A = open	= 1	
Section 3 input relay OFF	P5018 O	CDMU B	Section 3 input relay status A = open	= 1	
PCDU section 4 ON	/	TIMER N	Section 4 input relay status B = closed	= 0	P5018 R
PCDU section 4 ON	/	TIMER R	Section 4 input relay status B = closed	= 0	
Section 4 input relay ON	P5004 O	CDMU A	Section 4 input relay status B = closed	= 0	
Section 4 input relay ON	P5014 O	CDMU B	Section 4 input relay status B = closed	= 0	
Section 4 input relay OFF	P5009 O	CDMU A	Section 4 input relay status B = open	= 1	
Section 4 input relay OFF	P5019 O	CDMU B	Section 4 input relay status B = open	= 1	
PCDU section 5 ON	/	TIMER N	Section 5 input relay status B = closed	= 0	P5019 R
PCDU section 5 ON	/	TIMER R	Section 5 input relay status B = closed	= 0	
Section 5 input relay ON	P5005 O	CDMU A	Section 5 input relay status B = closed	= 0	
Section 5 input relay ON	P5015 O	CDMU B	Section 5 input relay status B = closed	= 0	
Section 5 input relay OFF	P5010 O	CDMU A	Section 5 input relay status B = open	= 1	
Section 5 input relay OFF	P5020 O	CDMU B	Section 5 input relay status B = open	= 1	

b .Timer relay commands

Use:

Those latching commands activate (ON/OFF) the coast timer relays of the PCDU in order to connect/disconnect the battery to the timer supply outputs.

Operational constraints:

None

Verification telemetry:

– Coast timer relays status: open or closed.

TELECOMMAND			TELEMETRY		
NAME/FUNCTION	CODE	SOURCE	EXPECTED TELEMETRY		CODE
Coast timer 1 power ON	P5021 O	CDMU A	Coast timer 1 relay status A = closed	= 0	P5078 R
Coast timer 1 power OFF	P5022 O	CDMU A	Coast timer 1 relay status A = open	= 1	
Coast timer 2 power ON	P5023 O	CDMU A	Coast timer 2 relay status A = closed	= 0	P5079 R
Coast timer 2 power ON	P5025 O	CDMU B	Coast timer 2 relay status A = closed	= 0	
Coast timer 2 power OFF	P5024 O	CDMU A	Coast timer 2 relay status A = open	= 1	
Coast timer 2 power OFF	P5026 O	CDMU B	Coast timer 2 relay status A = open	= 1	
Coast timer 3 power ON	P5027 O	CDMU B	Coast timer 3 relay status B = closed	= 0	P5081 R
Coast timer 3 power OFF	P5028 O	CDMU B	Coast timer 3 relay status B = open	= 1	

c .28 V limiter commands

Use:

Those latching commands activate ON/OFF the 28 V distribution limiters.

Operational constraints:

The total output power available depends on the PCDU configuration number of activated BDR sections powered by ORBITER or by BATTERY see § 4.3.1-4-4 **c** for more details.

Verification telemetry:

Limiter status:	OFF = "0"	V = 0 V
	ON = "1"	(3.5 V < V < 5.5 V).
Power current:	gives the value of the current delivered by the limiter.	

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TELECOMMAND			TELEMETRY	
NAME/FUNCTION	CODE	SOURCE	EXPECTED TELEMETRY	CODE
TXA power ON	P5029 O	CDMU A	28 V TXA limiter status = 1	P5037 B
TXA power OFF	P5036 O	CDMU A	28 V TXA limiter status = 0	
RAUA power ON	/	Arming Timer A	28 V RAUA limiter status = 1	P5049 B
RAUA power OFF	P5047 O	CDMU A	28 V RAUA limiter status = 0	
ACP1N power ON	P5032 O	CDMU A	28 V ACP1N limiter status = 1	P5041 B
ACP1N power OFF	P5039 O	CDMU A	28 V ACP1N limiter status = 0	
ACP2N power ON + GCMS2N	/	Arming Timer A	28 V ACP2N limiter status = 1 28 V GCMS2N limiter status = 1	P5047 B P5040 B
ACP2N power OFF	/	Arming Timer A	28 V ACP2N limiter status = 0	P5047 B
GCMS2N power OFF	P5041 O	CDMU A	28 V GCMS2N limiter status = 0	P5040 B
ACP3N power ON	P5040 O	CDMU A	28 V ACP3N limiter status = 1	P5042 B
ACP3N power OFF	P5046 O	CDMU A	28 V ACP3N limiter status = 0	
DISR1N power ON	P5031 O	CDMU A	28 V DISR1N limiter status = 1	P5039 B
DISR1N power OFF	P5038 O	CDMU A	28 V DISR1N limiter status = 0	
DISR2N power ON	/	Arming Timer A	28 V DISR2N limiter status = 1	P5046 B
DISR2N power OFF	P5045 O	CDMU A	28 V DISR2N limiter status = 0	
HASI1N power ON	P5034 O	CDMU A	28 V HASI1N limiter status = 1	P5044 B
HASI1N power OFF	P5043 O	CDMU A	28 V HASI1N limiter status = 0	
HASI2N power ON	/	Arming Timer A	28 V HASI2N limiter status = 1	P5048 B
HASI2N power OFF	/	Arming Timer A	28 V HASI2N limiter status = 0	
GCMS1N power ON	P5030 O	CDMU A	28 V GCMS1N limiter status = 1	P5038 B
GCMS1N power OFF	P5037 O	CDMU A	28 V GCMS1N limiter status = 0	
TUSON power ON	P5033 O	CDMU A	28 V TUSON limiter status = 1	P5043 B
TUSON power OFF	P5042 O	CDMU A	28 V TUSON limiter status = 0	
SSPN power ON	P5035 O	CDMU A	28 V SSPN limiter status = 1	P5045 B
SSPN power OFF	P5044 O	CDMU A	28 V SSPN limiter status = 0	

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TELECOMMAND			TELEMETRY	
NAME/FUNCTION	CODE	SOURCE	EXPECTED TELEMETRY	CODE
TXB power ON	P5049 O	CDMU B	28 V TXB limiter status = 1	P5065 B
TXB power OFF	P5057 O	CDMU B	28 V TXB limiter status = 0	
RAUB power ON	/	Arming Timer B	28 V RAUB limiter status = 1	P5077 B
RAUB power OFF	P5067 O	CDMU B	28 V RAUB limiter status = 0	
ACP1R power ON	P5052 O	CDMU B	28 V ACP1R limiter status = 1	P5069 B
ACP1R power OFF	P5060 O	CDMU B	28 V ACP1R limiter status = 0	
ACP2R power ON + GCMS2R	/	Arming Timer B	28 V ACP2R limiter status = 1 28 V GCMS2R limiter status = 1	P5075 B P5068 B
ACP2R power OFF	/	Arming Timer B	28 V ACP2R limiter status = 0	P5075 B
GCMS2R power OFF	P5062 O	CDMU B	28 V GCMS2R limiter status = 0	P5068 B
ACP3R power ON	P5053 O	CDMU B	28 V ACP3R limiter status = 1	P5070 B
ACP3R power OFF	P5061 O	CDMU B	28 V ACP3R limiter status = 0	
DISR1R power ON	P5051 O	CDMU B	28 V DISR1R limiter status = 1	P5067 B
DISR1R power OFF	P5059 O	CDMU B	28 V DISR1R limiter status = 0	
DISR2R power ON	/	Arming Timer B	28 V DISR2R limiter status = 1	P5074 B
DISR2R power OFF	P5066 O	CDMU B	28 V DISR2R limiter status = 0	
HASI1R power ON	P5055 O	CDMU B	28 V HASI1R limiter status = 1	P5072 B
HASI1R power OFF	P5064 O	CDMU B	28 V HASI1R limiter status = 0	
HASI2R power ON	/	Arming Timer B	28 V HASI2R limiter status = 1	P5076 B
HASI2R power OFF	/	Arming Timer B	28 V HASI2R limiter status = 0	
GCMS1R power ON	P5050 O	CDMU B	28 V GCMS1R limiter status = 1	P5066 B
GCMS1R power OFF	P5058 O	CDMU B	28 V GCMS1R limiter status = 0	
TUSOR power ON	P5054 O	CDMU B	28 V TUSOR limiter status = 1	P5071 B
TUSOR power OFF	P5063 O	CDMU B	28 V TUSOR limiter status = 0	
SSPR power ON	P5056 O	CDMU B	28 V SSPR limiter status = 1	P5073 B
SSPR power OFF	P5065 O	CDMU B	28 V SSPR limiter status = 0	

PYRO

a. Energy intercept relay commands

Use:
Those latching commands activate ON/OFF the energy intercept relays of the PYRO unit in order to connect/disconnect the battery to the PYRO unit.

Operational constraints:
None

Verification telemetry:
Energy intercept relay status: open or closed.

TELECOMMAND			TELEMETRY	
NAME/FUNCTION	CODE	SOURCE	EXPECTED TELEMETRY	CODE
PYRO 1 power ON	/	PCDU	PYRO 1 energy status = closed = 0	P3002 R
PYRO 1 power OFF	P3001 O	CDMU A	PYRO 1 energy status = open = 1	
PYRO 2 power ON	/	PCDU	PYRO 2 energy status = closed = 0	P4002 R
PYRO 2 power OFF	P4001 O	CDMU B	PYRO 2 energy status = open = 1	

b. Arming relay commands

Use:
Those latching commands activate ON/OFF the arming relays of the PYRO. Each command activates all the relays of the same group.

Operational constraints:
None

Verification telemetry:

TELECOMMAND			
NAME/FUNCTION	CODE	SOURCE	EXPECTED TELEMETRY
PYRO 1 group 1 arming	/	Arming Timer A	/
PYRO 1 group 2 arming	/	Arming Timer A	/
PYRO 1 group 3 arming	/	Arming Timer A	/
PYRO 1 group 4 arming	/	Arming Timer A	/
PYRO 1 group 1 disarm	P3003 O	CDMU A	/
PYRO 1 group 2 disarm	P3004 O	CDMU A	/
PYRO 1 group 3 disarm	P3005 O	CDMU A	/
PYRO 1group 4 disarm	P3006 O	CDMU A	/
PYRO 2 group 1 arming	/	Arming Timer B	/
PYRO 2 group 2 arming	/	Arming Timer B	/
PYRO 2 group 3 arming	/	Arming Timer B	/
PYRO 2 group 4 arming	/	Arming Timer B	/
PYRO 2 group 1 disarm	P4003 O	CDMU B	/
PYRO 2 group 2 disarm	P4004 O	CDMU B	/
PYRO 2 groupd 3 disarm	P4005 O	CDMU B	/
PYRO 2 group 4 disarm	P4006 O	CDMU B	/

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c .Selection relays commands

Use:

Those latching commands activate ON/OFF the selection relays of the PYRO.

Each command activates all the relays of the same "mechanism".

Operational constraints:

Only one "group" of relays may be selected simultaneously that means that the OFF command of the previous relays must be activated before the ON command of the next relays.

Verification telemetry:

Selection relays status = "0" if non selected (relay = OFF)
= "1" if selected (relay = ON).

TELECOMMAND			TELEMETRY		
NAME/FUNCTION	CODE	SOURCE	EXPECTED TELEMETRY		CODE
PYRO 1 PDD set	P3007 O	CDMU A	PDD	selection A relays status = 1	P3004 B
PYRO 1 PDD reset	P3013 O	CDMU A	PDD	selection A relays status = 0	
PYRO 1 GCMSIN set	P3008 O	CDMU A	GCMSIN	selection A relays status = 1	P3005 B
PYRO 1 GCMSIN reset	P3014 O	CDMU A	GCMSIN	selection A relays status = 0	
PYRO 1 GCMSOUT set	P3009 O	CDMU A	GCMSOUT	selection A relays status = 1	P3006 B
PYRO 1 GCMSOUT reset	P3015 O	CDMU A	GCMSOUT	selection A relays status = 0	
PYRO 1 BCM set	P3010 O	CDMU A	BC1	selection A relays status = 1	P3007 B
			BC2	selection A relays status = 1	P3008 B
			BC3	selection A relays status = 1	P3009 B
PYRO 1 BCM reset	P3016 O	CDMU A	BC1	selection A relays status = 0	P3007 B
			BC2	selection A relays status = 0	P3008 B
			BC3	selection A relays status = 0	P3009 B
PYRO 1 FSM set	P3011 O	CDMU A	FS1	selection A relays status = 1	P3010 B
			FS2	selection A relays status = 1	P3011 B
			FS3	selection A relays status = 1	P3012 B
PYRO 1 FSM reset	P3017 O	CDMU A	FS1	selection A relays status = 0	P3010 B
			FS2	selection A relays status = 0	P3011 B
			FS3	selection A relays status = 0	P3012 B
PYRO 1 PJM set	P3012 O	CDMU A	PJ1	selection A relays status = 1	P3013 B
			PJ2	selection A relays status = 1	P3014 B
			PJ3	selection A relays status = 1	P3015 B
PYRO 1 PJM reset	P3018 O	CDMU A	PJ1	selection A relays status = 0	P3013 B
			PJ2	selection A relays status = 0	P3014 B
			PJ3	selection A relays status = 0	P3015 B
PYRO 1 DISR Cover set	P3019 O	CDMU A	DISR cover	selection A relays status = 1	P3016 B
PYRO 1 DISR Cover reset	P3020 O	CDMU A	DISR cover	selection A relays status = 0	
PYRO 1 BCM set B	P3021 O	CDMU B	BC1	selection A relays status = 1	P3007 B
			BC2	selection A relays status = 1	P3008 B
			BC3	selection A relays status = 1	P3009 B

TELECOMMAND			TELEMETRY		
NAME/FUNCTION	CODE	SOURCE	EXPECTED TELEMETRY		CODE
PYRO 2 PDD set	P4007 O	CDMU B	PDD	selection B relays status = 1	P4004 B
PYRO 2 PDD reset	P4013 O	CDMU B	PDD	selection B relays status = 0	
PYRO 2 GCMSIN set	P4008 O	CDMU B	GCMSIN	selection B relays status = 1	P4005 B
PYRO 2 GCMSIN reset	P4014 O	CDMU B	GCMSIN	selection B relays status = 0	
PYRO 2 GCMSOUT set	P4009 O	CDMU B	GCMSOUT	selection B relays status = 1	P4006 B
PYRO 2 GCMSOUT reset	P4015 O	CDMU B	GCMSOUT	selection B relays status = 0	
PYRO 2 BCM set	P4010 O	CDMU B	BC1	selection B relays status = 1	P4007 B
			BC2	selection B relays status = 1	P4008 B
			BC3	selection B relays status = 1	P4009 B
PYRO 2 BCM reset	P4016 O	CDMU B	BC1	selection B relays status = 0	P4007 B
			BC2	selection B relays status = 0	P4008 B
			BC3	selection B relays status = 0	P4009 B
PYRO 2 FSM set	P4011 O	CDMU B	FS1	selection B relays status = 1	P4010 B
			FS2	selection B relays status = 1	P4011 B
			FS3	selection B relays status = 1	P4012 B
PYRO 2 FSM reset	P4017 O	CDMU B	FS1	selection B relays status = 0	P4010 B
			FS2	selection B relays status = 0	P4011 B
			FS3	selection B relays status = 0	P4012 B
PYRO 2 PJM set	P4012 O	CDMU B	PJ1	selection B relays status = 1	P4013 B
			PJ2	selection B relays status = 1	P4014 B
			PJ3	selection B relays status = 1	P4015 B
PYRO 2 PJM reset	P4018 O	CDMU B	PJ1	selection B relays status = 0	P4013 B
			PJ2	selection B relays status = 0	P4014 B
			PJ3	selection B relays status = 0	P4015 B
PYRO 2 DISR Cover set	P4019 O	CDMU B	DISR cover	selection B relays status = 1	P4016 B
PYRO 2 DISR Cover reset	P4020 O	CDMU B	DISR cover	selection B relays status = 0	
PYRO 2 BCM set A	P4021 O	CDMU A	BC1	selection B relays status = 1	P4007 B
			BC2	selection B relays status = 1	P4008 B
			BC3	selection B relays status = 1	P4009 B

d .Pyro firing commands

Use:

Those non-latching commands activate the active current limiters of the PYRO in order to deliver a calibrated pulse of current into the selected squibs. Each command activates both half Pyro.

Operational constraints:

The delay between two successive firing commands must be greater than 500 ms.

Verification telemetry:

TELECOMMAND			
NAME/FUNCTION	CODE	SOURCE	EXPECTED TELEMETRY
PYRO 1 and 2 fire A	P3002 O	CDMU A	/
PYRO 1 and 2 fire B	P4002 O	CDMU B	/

D2

4.3.1-6-2 Telemetry

PCDU

a . Input relay status

One of the contact of the relay is used for the telemetry and its position reflects the position of the contacts used for the power.

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	CMD VERIF
P5 001 R	Input relay loop	rel.stat. (1 relay closed = 1 all relays open = 0)	Orbiter	INRELAYLOOP	P5 001 O to P5 020 O PCDU sections 1 to 5 ON, from TIMER N/R
P5 014 R (HK1)	section 1 input relay status A	rel.stat. (closed = 0 open = 1)	CDMU A	INREL1STATA	P5 001 O/P5 011 O P5 006 R/P5 016 R PCDU section 1 ON, from TIMER N/R
P5 015 R (HK1)	section 2 input relay status A	rel.stat. (closed = 0 open = 1)	CDMU A	INREL2STATA	P5 002 O/P5 012 O P5 007 R/P5 017 R PCDU section 2 ON, from TIMER N/R
P5 016 R (HK1)	section 3 input relay status A	rel.stat. (closed = 0 open = 1)	CDMU A	INREL3STATA	P5 003 O/P5 013 O P5 008 R/P5 018 R PCDU section 3 ON, from TIMER N/R
P5 018 R (HK1)	section 4 input relay status B	rel.stat. (closed = 0 open = 1)	CDMU B	INREL4STATB	P5 004 O/P5 014 O P5 009 R/P5 019 R PCDU section 4 ON, from TIMER N/R
P5 019 R (HK1)	section 5 input relay status B	rel.stat. (closed = 0 open = 1)	CDMU B	INREL5STATB	P5 005 O/P5 015 O P5 010 R/P5 020 R PCDU section 5 ON, from TIMER N/R

b .Timer relay status

The status of the timer relays is performed via a FET transistor that operates as a switch.

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	CMD VERIF
P5 078 R (HK1)	coast timer 1 relay status A	rel. stat. (closed = 0 open = 1)	CDMU A	CTIM1STATA	P5 021 O/P5 022 O
P5 079 R (HK1)	coast timer 2 relay status A	rel. stat. (closed = 0 open = 1)	CDMU A	CTIM2STATA	P5 023 O/P5 024 O P5 025 O/P5 026 O
P5 081 R (HK1)	coast timer 3 relay status B	rel. stat. (closed = 0 open = 1)	CDMU B	CTIM3STATB	P5 027 O/P5 028 O
P5 082 R	timer relay loop	rel. stat. (1 relay closed = 1 all relays open = 0)	Orbiter	CTIMLOOP	P5 021 O to P5 028 O

c .Battery voltage

These analogue telemetries give the value of each battery voltage when this battery is connected to the BDR section.

The ratio between the battery voltage and the telemetry voltage is:

$$TLM = 0.0613\ V_{BATT} \pm 0.5\ \%$$

So the expected telemetry values are:

V_{BATT}		V_{TLM}
Nominal	= 70 V	4.291 V
Maximum	= 78 V	4.781 V
Minimum	= 35 V	2.146 V
Disconnected		0 V

In case of single failure the telemetry voltage could reach a max. voltage = 9.3 V.

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	CMD VERIF
P5 002 A (HK2)	Battery 1 Voltage A	8 bit ANA	CDMU A	BAT1VOLTA	/
P5 003 A (HK2)	Battery 2 Voltage A	8 bit ANA	CDMU A	BAT2VOLTA	/
P5 004 A (HK2)	Battery 3 Voltage A	8 bit ANA	CDMU A	BAT3VOLTA	/
P5 005 A (HK2)	Battery 3 Voltage B	8 bit ANA	CDMU B	BAT3VOLTB	/
P5 006 A (HK2)	Battery 4 Voltage B	8 bit ANA	CDMU B	BAT4VOLTB	/
P5 007 A (HK2)	Battery 5 Voltage B	8 bit ANA	CDMU B	BAT5VOLTB	/

d . Bus voltage

This analogue telemetry gives the value of the bus voltage. The ratio between the bus voltage and the telemetry voltage is: $TLM = 0.165\ V_{BUS}$.

With bus voltage equal to 28.21 V, the expected telemetry value is **4.64 V** ± 0.9 % (the tolerance takes into account the accuracy on the telemetry and on the bus regulation).

In case of single failure the telemetry voltage could reach a max. voltage = 7.98 V.

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	CMD VERIF
P5 020 A (HK2)	Main Bus Voltage A	8 bit ANA	CDMU A	BUSVOLTA	/
P5 021 A (HK2)	Main Bus Voltage B	8 bit ANA	CDMU B	BUSVOLTB	/

e .BDR current

These analogue telemetries give the value of each BDR current. The voltage range of the telemetry is between 0 and 5 V corresponding to a current between 0 and 5 A ± 5 %.

The expected telemetry values are not the same for the 5 BDR sections because the transconductance values are adjusted to compensate the battery capacity unbalance.

$$I_{1,5} = \frac{I_{tot}}{N_{1,5} \times 1.14 + N_{2,3,4}} \times 1.14$$

$$I_{2,3,4} = \frac{I_{tot}}{N_{1,5} \times 1.14 + N_{2,3,4}}$$

Where:

- $I_{1,5}$ = current in BDR section 1 or 5
- $I_{2,3,4}$ = current in BDR section 2, 3 or 4
- Itot = total current = $\frac{\text{total power on Bus (W) (*)}}{28.21\text{V}}$
- $N_{1,5}$ = number of activated sections type 1 or 5
- $N_{2,3,4}$ = number of activated sections type 2, 3 or 4.

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	CMD VERIF
P5 008 A (HK2)	BDR 1 current A	8 bit ANA	CDMU A	BDR1CURRA	/
P5 009 A (HK2)	BDR 2 current A	8 bit ANA	CDMU A	BDR2CURRA	/
P5 010 A (HK2)	BDR 3 current A	8 bit ANA	CDMU A	BDR3CURRA	/
P5 011 A (HK2)	BDR 3 current B	8 bit ANA	CDMU B	BDR3CURRB	/
P5 012 A (HK2)	BDR 4 current B	8 bit ANA	CDMU B	BDR4CURRB	/
P5 013 A (HK2)	BDR 5 current B	8 bit ANA	CDMU B	BDR5CURRB	/

(*) including PCDU auxiliary consumption (typical value ≈ 10W).

NOTE: Those current values are given at the outputs of the BDR's at bus level; to have the value of the input current, it is necessary to make a conversion taken into account the ratio between input and output voltages of the BDR and the efficiency of the Orbiter interface when EPSS is powered by Orbiter.

Formulae given hereafter are **indicative** because many parameters depend on power, temperature.

- EPSS powered by Battery:

$$\text{input current} = \text{Battery current} = \frac{\text{BDR current}}{\eta_{BDR}} \times \frac{\text{Bus Voltage}}{\text{Battery Voltage}}$$

$$\eta_{BDR} \approx 88\%$$

- EPSS powered by Orbiter:

$$\text{input current} = \text{POW current} = \frac{\text{BDR current}}{\eta_{ORB}\eta_{BDR}} \times \frac{\text{Bus Voltage}}{\text{Orbiter I/F Voltage}}$$

Where: Orbiter I/F voltage = (SSPS output voltage - Harness voltage drop) x 1.4

$$\eta_{ORB}\eta_{BDR} \approx 75\%$$

f. Current limiter status

All these TMs are in HK1 packet.

Limiter ON: TLM = "1"
Limiter OFF: TLM = "0"

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	CMD VERIF
P5 036 B	28V CDMU A limiter status	DB	CDMU B	CDMUASTAT	/
P5 037 B	28V TX A limiter status	DB	CDMU A	TXASTAT	P5 029 O/P5 036 O
P5 038 B	28V GCMS 1N limiter status	DB	CDMU A	GCMS1NSTAT	P5 030 O/P5 037 O
P5 039 B	28V DISR 1N limiter status	DB	CDMU A	DISR1NSTAT	P5 031 O/P5 038 O
P5 040 B	28V GCMS 2N limiter status	DB	CDMU A	GCMS2NSTAT	ON by Arming Timer A, P5 041 O
P5 041 B	28V ACP 1N limiter status	DB	CDMU A	ACP1NSTAT	P5 032 O/P5 039 O
P5 042 B	28V ACP 3N limiter status	DB	CDMU A	ACP3NSTAT	P5 040 O/P5 046 O
P5 043 B	28V TUSO N limiter status	DB	CDMU A	TUSONSTAT	P5 033 O/P5 042 O
P5 044 B	28V HASI 1N limiter status	DB	CDMU A	HASI1NSTAT	P5 034 O/P5 043 O
P5 045 B	28V SSP N limiter status	DB	CDMU A	SSPNSTAT	P5 035 O/P5 044 O
P5 046 B	28V DISR 2N limiter status	DB	CDMU A	DISR2NSTAT	ON by Arming Timer A, P5 045 O
P5 047 B	28V ACP 2N limiter status	DB	CDMU A	ACP2NSTAT	ON/OFF by Arming Timer A
P5 048 B	28V HASI 2N limiter status	DB	CDMU A	HASI2NSTAT	ON/OFF by Arming Timer A
P5 049 B	28V RAU A limiter status	DB	CDMU A	RAUASTAT	ON by Arming Timer A, P5 047 O

D2

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	CMD VERIF
P5 064 B	28V CDMU B limiter status	DB	CDMU A	CDMUBSTAT	/
P5 065 B	28V TX B limiter status	DB	CDMU B	TXBSTAT	P5 049 O/P5 057 O
P5 066 B	28V GCMS 1R limiter status	DB	CDMU B	GCMS1RSTAT	P5 050 O/P5 058 O
P5 067 B	28V DISR 1R limiter status	DB	CDMU B	DISR1RSTAT	P5 051 O/P5 059 O
P5 068 B	28V GCMS 2R limiter status	DB	CDMU B	GCMS2RSTAT	ON by Arming Timer B, P5 062 O
P5 069 B	28V ACP 1R limiter status	DB	CDMU B	ACP1RSTAT	P5 052 O/P5 060 O
P5 070 B	28V ACP 3R limiter status	DB	CDMU B	ACP3RSTAT	P5 053 O/P5 061 O
P5 071 B	28V TUSO R limiter status	DB	CDMU B	TUSORSTAT	P5 054 O/P5 063 O
P5 072 B	28V HASI 1R limiter status	DB	CDMU B	HASI1RSTAT	P5 055 O/P5 064 O
P5 073 B	28V SSP R limiter status	DB	CDMU B	SSPRSTAT	P5 056 O/P5 065 O
P5 074 B	28V DISR 2R limiter status	DB	CDMU B	DISR2RSTAT	ON by Arming Timer B, P5 066 O
P5 075 B	28V ACP 2R limiter status	DB	CDMU B	ACP2RSTAT	ON/OFF by Arming Timer B
P5 076 B	28V HASI 2R limiter status	DB	CDMU B	HASI2RSTAT	ON/OFF by Arming Timer B
P5 077 B	28V RAU B limiter status	DB	CDMU B	RAUBSTAT	ON by Arming Timer B, P5 067 O

g. Probe Temperatures

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
T 001 T	Probe Temp1 (PCDU box)	temp.	THSS	Orbiter	PROBTEMP1	/
T 002 T	Probe Temp2 (PCDU box)	temp.	THSS	Orbiter	PROBTEMP2	/

h. Current limiter analogue telemetries

These TMs give the values of the current delivered through each current limiter.
They are all in HK2 packet.

The voltage range of the telemetry is between 0 and 4.5 V ± 9 %, corresponding to a current between 0 and I_{LIMIT} (that is a specific value for each current limiter). A more precise calibration will be given in the logbook of each model.
CDMU A monitors the 14 nominal current limiters: A (or N) power current.
CDMU B monitors the 14 redundant current limiters: B (or R) power current.

TM Description	TM CODE	
	CDMU A (Equipment A or N)	CDMU B (Equipment B or R)
28V CDMU Power Current	P5022 A	P5050 A
28V TX Power Current	P5023 A	P5051 A
28V GCMS 1 Power Current	P5024 A	P5052 A
28V DISR 1 Power Current	P5025 A	P5053 A
28V GCMS 2 Power Current	P5026 A (N + R)	P5054 A
28V ACP 1 Power Current	P5027 A	P5055 A
28V ACP 3 Power Current	P5028 A	P5056 A
28V TUSO Power Current	P5029 A	P5057 A
28V HASI 1 Power Current	P5030 A	P5058 A
28V SSP Power Current	P5031 A	P5059 A
28V DISR 2 Power Current	P5032 A	P5060 A
28V ACP 2 Power Current	P5033 A	P5061 A
28V HASI 2 Power Current	P5034 A	P5062 A
28V RAU Power Current	P5035 A	P5063 A

Note: For the specific case of GCMS2 nominal limiter (simplified common current limitation), the telemetry of nominal current limiter gives in fact the summation of the current flowing through nominal and redundant limiters: $I_{TLM\ (N)} = I_N + I_R$ i.e. $I_N \approx I_{TLM\ (N)} - I_{TLM\ (R)}$ (as $I_{TLM\ (R)} = I_R$)

PYRO

a. Energy intercept relay status

One of the contact of the relay is used for the telemetry and its position reflects the position of the contacts used for the power.

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	CMD VERIF
P3 001 R	Pyro energy safety loop	rel.stat. (both relays open = 0 one relay closed = 1)	Launcher	PYENERGLOOP	ON by PCDU, P3 001 O/P4 001 O
P3 002 R (HK1)	Pyro 1 energy status	rel.stat. (closed = 0 open = 1)	CDMU A	PY1ENERSTAT	ON by PCDU, P3 001 O
P4 002 R (HK1)	Pyro 2 energy status	rel.stat. (closed = 0 open = 1)	CDMU B	PY2ENERSTAT	ON by PCDU, P4 001 O

b. Arming relay status

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	CMD VERIF
P3 003 R	Pyro arming safety loop	rel.stat. (all relays open = 0 one relay closed = 1)	Launcher	PYARMLOOP	Arming by Arming Timer A/B, P3 003 O to P3 006 O, P4 003 O to P4 006 O

c. Selection relay status

The status of each selection relay is provided by means of bi-level telemetry (powered by the 5 V supply from the PCDU).
All these TMs are in HK1 packet.

Relay ON: status = 1
Relay OFF: status = 0

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
P3 004 B	PDD selection relay A status	DB	PYRO 1	CDMU A	PDDARELST	P3 007 O P3 013 O
P3 005 B	GCMS 1N selection relay A status	DB	PYRO 1	CDMU A	GCMS1NAREST	P3 008 O P3 014 O
P3 006 B	GCMS OUT selection relay A status	DB	PYRO 1	CDMU A	GCMSOUTAREST	P3 009 O P3 015 O
P3 007 B	BC 1 selection relay A status	DB	PYRO 1	CDMU A	BC1ARELST	P3 010 O P3 016 O
P3 008 B	BC 2 selection relay A status	DB	PYRO 1	CDMU A	BC2ARELST	P3 010 O P3 016 O
P3 009 B	BC 3 selection relay A status	DB	PYRO 1	CDMU A	BC3ARELST	P3 010 O P3 016 O
P3 010 B	FS 1 selection relay A status	DB	PYRO 1	CDMU A	FS1ARELST	P3 011 O P3 017 O
P3 011 B	FS 2 selection relay A status	DB	PYRO 1	CDMU A	FS2ARELST	P3 011 O P3 017 O
P3 012 B	FS 3 selection relay A status	DB	PYRO 1	CDMU A	FS3ARELST	P3 011 O P3 017 O
P3 013 B	PJM 1 selection relay A status	DB	PYRO 1	CDMU A	PJ1ARELST	P3 012 O P3 018 O
P3 014 B	PJM 2 selection relay A status	DB	PYRO 1	CDMU A	PJ2ARELST	P3 012 O P3 018 O
P3 015 B	PJM 3 selection relay A status	DB	PYRO 1	CDMU A	PJ3ARELST	P3 012 O P3 018 O
P3 016 B	DISR cover selection relay A status	DB	PYRO 1	CDMU A	DCOVARELST	P3 019 O P3 020 O

TM REF	DESCRIPTION	TYPE	SOURCE	DESTIN.	MNEMO	CMD VERIF
P4 004 B	PDD selection relay B status	DB	PYRO 2	CDMU B	PDDBRELST	P4 007 O P4 013 O
P4 005 B	GCMS 1N selection relay B status	DB	PYRO 2	CDMU B	GCMS1NBREST	P4 008 O P4 014 O
P4 006 B	GCMS OUT selection relay B status	DB	PYRO 2	CDMU B	GCMSOUTBREST	P4 009 O P4 015 O
P4 007 B	BC 1 selection relay B status	DB	PYRO 2	CDMU B	BC1BRELST	P4 010 O P4 016 O
P4 008 B	BC 2 selection relay B status	DB	PYRO 2	CDMU B	BC2BRELST	P4 010 O P4 016 O
P4 009 B	BC 3 selection relay B status	DB	PYRO 2	CDMU B	BC3BRELST	P4 010 O P4 016 O
P4 010 B	FS 1 selection relay B status	DB	PYRO 2	CDMU B	FS1BRELST	P4 011 O P4 017 O
P4 011 B	FS 2 selection relay B status	DB	PYRO 2	CDMU B	FS2BRELST	P4 011 O P4 017 O
P4 012 B	FS 3 selection relay B status	DB	PYRO 2	CDMU B	FS3BRELST	P4 011 O P4 017 O
P4 013 B	PJM 1 selection relay B status	DB	PYRO 2	CDMU B	PJ1BRELST	P4 012 O P4 018 O
P4 014 B	PJM 2 selection relay B status	DB	PYRO 2	CDMU B	PJ2BRELST	P4 012 O P4 018 O
P4 015 B	PJM 3 selection relay B status	DB	PYRO 2	CDMU B	PJ3BRELST	P4 012 O P4 018 O
P4 016 B	DISR cover selection relay B status	DB	PYRO 2	CDMU B	DCOVBRELST	P4 019 O P4 020 O

4.3.1-7 Operational Constraints

Energy Intercept Relay

The latching ON command is generated only one time by the PCDU: the switch OFF of the relay is possible (by CDMU command), but in this case it will be IMPOSSIBLE to switch ON again the relay.

Note: in fact the ON command is generated each time the PCDU is switched ON after a switch OFF. If during checkout a separation strap is open, the Energy Intercept relay will close. See Contingency PC03 in HUM OPERATIONS Doc n° HUY.AS/c.100.OP.0384.

Pyro Firing Commands

A delay of 500 ms is required between two successive firing commands from the same CDMU, otherwise the value of the current pulse (min 5 A) is not guaranteed.

Input relay commands

It is forbidden to switch ON input relay when the BDR section is already powered by Orbiter.

BDR's Switch ON

A delay of 30 seconds is required between Switch OFF, either of SSPS "i" or Input Relay "i", and the new Switch ON of BDR "i".

Selection relay commands

For each half pyro, no more than 3 selection relays may be closed simultaneously that means that the OFF command of the previous relays must be activated before the ON command of the next relays.

Current Limiters

The 28V distribution lines are protected by active current limiters. In case of overload, they require a TC ON command to recover their nominal behaviour after removal of the external overload.
The only exception is CDMU output for which there is no external TC: in case of overload on this output, it is necessary to switch OFF the PCDU (switch OFF all SSPS or switch OFF the input relays) and to remove the overload before switching ON the PCDU again.

28V Distribution

All the 28V users shall not be connected simultaneously, the total power being limited at 400W when the EPSS is powered by batteries and 180W when the EPSS is powered by Orbiter.

Batteries Depassivation

It is mandatory to perform batteries depassivation before activation of the coast timer relays.

PCDU switch ON by Orbiter

• The 5 POWs have to be activated sequentially, in indifferent order, beginning with the double SSPS (POW2 and POW4).
• The delay between the activation of 2 SSPS switches has to be < 495ms. The delay for complete power ON shall be < 1370ms.
• The delay between the last SSPS activation and switch ON of other 28V limiters has to be > 2s in order to be sure that all the power is available at bus level.

4.3.2 NOMINAL OPERATIONS

List of procedures:

PP01 = EPSS Switch ON/OFF when powered by Orbiter
PP02 = EPSS Switch ON when powered by Batteries
PP03 = Battery Depassivation
PP04 = Mission Timer Switch ON/OFF (powered by Batteries)
PP05 = Pyro Sequence for Checkout
PP06 = Pyro in Safe Mode
PP07 = PCDU Unit Reset

See them in HUM OPERATIONS Doc n° HUY.AS/c.100.OP.0384 § 1.3

4.3.3 BACK-UP OPERATIONS

None

4.3.4 CONTINGENCY OPERATIONS

PC01: Pyro Sequence for Checkout with Direct TCs
To verify Direct TCs "Pyro Set" and "Pyro Fire" Chains 1 and 2.
PC02: PCDU Input Relay Failure
PC03: Energy Intercept Relay Failure
PC04: Arming Relay Failure
PC05: Selection Relay Failure
PC06: Power line from Orbiter to BDR Failure
PC07: Battery Voltage Anomaly
PC08: BDR Current Anomaly
PC09: Current Limiter Status/Power Current Anomaly
PC10: Coast Timer Relay Failure
PC11 = Battery Depassivation: Section 2 (POW2) Failed
PC12 = Battery Depassivation: Section 4 (POW4) Failed

See them in HUM OPERATIONS Doc n° HUY.AS/c.100.OP.0384.

4.4 POSW (PROBE ON-BOARD SOTWARE)

4.4.1 OVERVIEW

The HUYGENS on-board software is divided into two subsystems: the Probe on-board S/W and the Support Avionics S/W. The POSW is physically located within the Command and Data Management System of the Probe and autonomously executes the Mission once powered. The SASW forms part of Cassini Orbiter, and is the communications relay for the Probe. The two S/W systems run independently of each other. There is no synchronisation between POSW and SASW. The POSW communicates with ground via SASW and the CASSINI command and data subsystem (CDS).

The POSW communicates with the SASW in different ways depending on mission phase. Before the probe is spun-up and ejected from the orbiter (about 22 days before Titan encounter), the two software subsystems communicate through an umbilical which contains both commanding and telemetry interfaces. After separation, it is no longer possible to command the probe, and telemetry is transmitted from the probe to the orbiter over a radio link within the probe data relay subsystem (PDRS).

Conventions:

A <u>HUYGENS Bit Numbering Convention</u>

The HUYGENS project imposes a bit numbering convention with the bits numbered starting with the least significant bit as bit zero. This is the opposite to the convention used in both the MIL-STD-1750A and the ESA Packet Telemetry and Telecommand standards. This document uses the HUYGENS project definition of bit numbering

msb															lsb
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

HUYGENS BIT NUMBERING

msb															lsb
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

MIL-STD-1750A & ESA STANDARD BIT NUMBERING

<u>Note</u>: msb is the first bit transmitted.

B Standard Acronyms & Abbreviations

The following acronyms, abbreviations and conventions are used:

APID	Application Process Identifier
ASIC	Application Specific Integrated Circuit
BIU	Bus Interface Unit (1553 bus)
Byte	8 Bit unit of data
CAN	Conversion unit - Analog to Digital
CCSDS	Consultative Committee for Space Data Systems
CDMS	Command and Data Management Subsystem
CDMU	Command and Data Management Unit
CDS	Command and Data Subsystem
CHAT	CUT Housekeeping Acquisition Table
CMD	One command from within a direct TC or Timeline
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
CUT	Computed Unit of Time (sequencer period)
DDB	Descent Data Broadcast
DMA	Direct Memory Access
DSP	Digital Signal Processing
DTSTART	Dead Time Start
EDAC	Error Detection and Correction Device
EEPROM	Electrically Erasable Programmable Read Only Memory
EPT	Experiment Polling Table
ESA	European Space Agency
FIFO	First In/First Out Buffer
FPU	Floating Point Unit
H/W	Hardware
HK	Housekeeping
HOOD	Hierarchical Object Oriented Design
I/O	Input/Output
ICD	Interface Control Document
ISR	Interrupt Service Routine
Kbyte/Kword	1024 bytes/words of data
lsb	least significant bit
LSB/LSW	Least significant byte or word
ML	Memory Load
MMU	Memory Management Unit
msb	most significant bit
MSB/MSW	Most significant byte or word
µP	Microprocessor
MTT	Mission Timeline Tables
OBDH	On-Board Data Handling
PC	Personal Computer
PDL	Program Definition Language
PDRS	Probe Data Relay Subsystem
PLT	Parameter Location Table
POSW	Probe On-Board Software
PRL	Probe Relay Link
PROM	Programmable Read Only Memory
PSA	Probe Support Avionics
PSE	Probe Support Equipment

PST	Polling Sequence Table
RAM	Random Access Memory
RID	Review Item Discrepancy
ROM	Read Only Memory
RT	Real Time
RTDT	Remote Terminal Descriptor Table (of BIU)
RTI	Real Time Interrupt
RTS	Run Time System
RTX	Real Time Executive
S0	Advanced T0 = Mission Time start (POSW time)
S/W	Software
SASW	Support Avionics Software
SQRT	Square Root
T0	Time of start of Descent Phase
TAI	Timer A interrupt
TBI	Timer B interrupt
TC	Telecommand
TLD	TLD Systems Ltd (Suppliers of 1750 Ada compiler)
TM	Telemetry
TMI	Telemetry Interrupt
Word	16 Bit unit of data

C T0 Naming Convention

The T0 acronym is defined as the time of Entry into Titan's atmosphere throughout this paragraph. This definition is however inaccurate.

At Probe level, the T0 acronym is more specifically the time at which the initial "pilot" parachute is deployed. As such T0 denotes the End of the Entry phase of the Cassini/Huygens mission, and the commencement of the Descent phase. The T0 point is determined by theorical analysis and corresponds to the position where the stability and velocity of the Probe are suitable for deployment of the transonic parachute. Current analysis indicates that this point will occur at an altitude of 164.3 km.

The POSW however, defines the T0 acronym as the time of Entry into Titan's atmosphere. As such [redacted] event is the **Software T0** event and represents a theorical point 6.375 seconds before aerodyn[redacted] conditions are correct for parachute deployment. Current analysis indicates that the point will occur [redacted] altitude of 164.8 Km. However the outer reaches of Titan's atmosphere extend to approxim[redacted] 1270 Km. Furthermore the **Software T0** event is referred to as **S0** at Probe level.

Clearly the definition of T0 used within the paragraph 4.4 is inaccurate. However the definition will be maintained as a convention for simplicity and consistency.

Thus to summarise, any references to Titan Atmospheric Entry or the T0 event refer to the Software T0 event, also known as S0 at Probe level.

Note that the Mission Timeline Tables (MTTs) are known as the Pre-T0 MTT and the Post-T0 MTT. As explained above, this is in fact referring to the Software T0 [S0], since the Post-T0 MTT contains the Parachute Deployment sequence.

4.4.1-1 Probe Mission Management

The POSW executes the mission management functionally once powered regardless of the current phase of the Cassini/Huygens mission. Consequently the S/W executed during checkouts is identical to that run during the Descent. Furthermore specific TCs may be used during Probe checkouts to verify correct functioning of the CDMS for all stages of the Descent phase. The primary Probe mission management functions are:

- **Detection of Titan Atmosphere Entry**: Axial accelerometers and G-switches are used to measure the atmospheric deceleration of the Probe during the Entry phase of the mission. This data is acquired by the S/W and processed to determine the T0 event. The S/W subsequently deploys the initial "pilot" parachute when T0 event is detected.

- **Execution of Mission Timeline Tables**: Pyrotechnic devices and other H/W equipments mounted on the Probe are operated by the S/W according to pre-programmed Mission Timeline Tables (MTTs). Two distinct timelines are executed by the S/W, the first for the Entry phase (Pre-T0 MTT) and the second for the Descent and Surface phases (Post-T0 MTT).

- **Determination of the Spacecraft Dynamical State**: H/W sensors and pre-programmed look-up tables contained in S/W are used to determine the spin rate and altitude of the Probe.

- **Transmission of Descent Data Broadcasts to the Experiment Payload**: The experiments mounted on the Probe receive key spacecraft information from POSW, every two seconds.This data is packetised as a Descent Data Broadcast. The information contained in a DDB includes Probe spin rate, Probe altitude, current Mission phase, current time and an indicat[redacted] whether the Probe is Pre or Post-T0.

4.4.1-2 Telecommand Management

The Probe may only be telecommanded from the ground whilst umbilical cord which connects [redacted] Cassini Orbiter is intact. Once the Probe separates from the Cassini Orbiter, the umbilical lead is severed and no telecommanding ability exists. The telecommand management functionality is therefore only available during the Launch, Cruise and Saturn Orbit phases. The provided functionality is summarised below:

- **Collection and Validation of Telecommands**: The S/W collects all TCs destined for the CDMS or Experiment Payload from the umbilical link. These TCs are subsequently validated against the ESA packet telecommand standard [ESA PSS-04-107], and checked for data corruption via a cyclic redundancy check. Only TCs which successfully pass validation are processed further.

- **Execution of CDMS Telecommands**: All successfully validated TCs destined for the CDMS are executed by POSW. CDMS TCs typically operate hardware devices or modify the Probe Mission Management functionality of the S/W.

- **Forwarding of Experiment Telecommands**: All successfully validated TCs destined for an Experiment are forwarded by POSW. These TCs are simply transmitted to the appropriate Experiment across the on-board Data Handling (OBDH) bus.

4.4.1-3 Telemetry Management

The Probe transmits telemetry to the Cassini Orbiter in all Mission phases, except the Coast and Entry phases. However, different hardware transmission mechanisms are used to achieve this. Whilst the Probe is connected to the Cassini Orbiter in the Launch, Cruise and Saturn Orbit phases, telemetry is transmitted via the umbilical link. Once the Probe has separated from the Cassini Orbiter, telemetry is transmitted via a radio relay. However, the radio link is not established until the Probe Back Cover is jettisoned and the High Power Amplifier is powered. Consequently, no telemetry transmission is possible during the Coast and Entry phases. The radio link is established Post-T0 and telemetry is recovered from the Probe during the Descent and Surface phases. The telemetry management functionality is summarised below:

- **Collection of Experiment Packets**: The software collects scientific data from the Experiments and incorporates the received packets into a telemetry transfer frame for transmission back to the Cassini Orbiter. Three look-up tables are used by POSW during the Descent to vary the "data budget" given to each experiment. This collection strategy allows different priorities to be assigned to Experiments at various stages throughout the Descent.

- **Construction of CDMS Housekeeping Packets**: The software acquires key spacecraft parameters during the Mission and formats this data into CDMS Housekeeping Packets. This data is transmitted back to the Cassini Orbiter as part of the telemetry transfer frame. A housekeeping acquisition mechanism is used by S/W to vary the content and format of the housekeeping packets.

- **Transmission of Telemetry Transfer Frames**: The computed telemetry transfer frames which include both Housekeeping and Experiment data are transmitted back to the Cassini Orbiter. The transmission is investigated by the CDMS hardware.

4.4.1-4 Timing Management

The POSW is responsible for:
- Providing a Real Time Counter (**RT Counter**) from the RTI
- Providing a Mission Time Counter (**MT Counter**) from the RTI (synchronous with the RT Counter)

4.4.1-5 Software Flight Operations

The flight operations are characterised by long periods of inactivity, which are interspersed with half yearly in-flight checkouts. The Titan encounter and the final Parachute Descent are executed autonomously by the Probe without any ground interaction.
Two distinct classes of S/W operations are envisaged during the operational lifetime of the Probe:

- **User Operations**: The POSW receives TCs uplinked from the ground and transmits telemetry during the in-flight checkouts. These activities are envisaged as normal routine operations.

- **Maintenance Operations**: The POSW provides a mechanism for reprogramming the functionality executed by the S/W. This mission reprogrammability enables the Entry/Descent mission to be tuned and allows POSW to be updated with refined models of Titan's atmosphere for example. Mission reprogrammability may alternatively be used to overcome or circumvent hardware defects which arise "en-route" to Saturn.
The reprogramming of POSW is a maintenance operation which is complex and Computer analysis must be required to do this.

The Figure 4.4.1-1 gives a flow diagram of POSW functions.

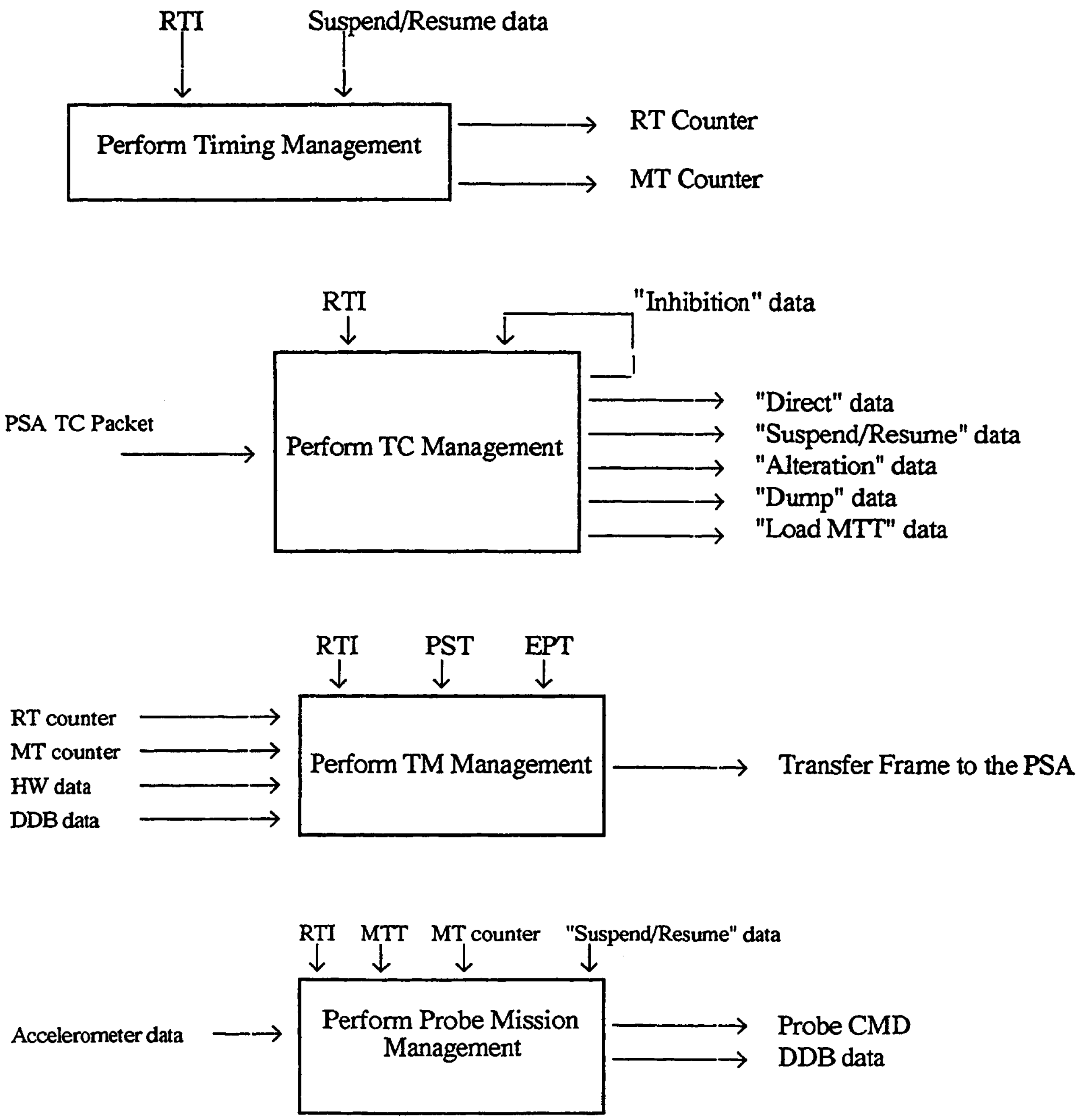

FIGURE 4.4.1-1 POSW DATA FLOW DIAGRAM

4.4.2 POSW DESIGN

4.4.2-1 Mission

The design of the Probe on-board S/W and indeed the CDMS has been driven by the nature of the Cassini/Huygens Mission:

- **Mission Criticality**: The single shot characteristics of the Huygens Mission impose exacting reliability requirements on the S/W. Failure to detect T0 or premature or delayed T0 detection will result in loss of mission. The execution of the Descent Phase and the transmission of an uninterrupted stream of telemetry is also paramount.
System reliability is addressed by both H/W and S/W solutions. In H/W, key elements of the CDMS are duplexed to increase overall system reliability. In particular two parallel processing chains execute the Mission in hot redundancy. Each of these chains is capable of running the Mission independently and may receive TCs and transmit TM unassisted. The S/W is designed and developed to Mission critical standards and runs the Entry/Descent mission once powered. No special S/W is included for the Launch, Cruise or Saturn Orbit phases and consequently the S/W executed during testing and in-flight checkouts is identical to that used for the actual Descent.

- **Autonomous Mission Execution**: The Probe is designed for completely autonomous operations during the Coast, Entry, Descent and Surface phases of the Mission as the Probe will be ≈ 90 light minutes from Earth during the Titan encounter, thereby making TCs from ground impractical. This fact, coupled with an expected Descent time of 2.5 hours leads to a system design where all telecommanding ability is lost when the Probe separates from the Orbiter. The Probe does not contain a radio receiver.

- **Mission Reprogrammability**: No telecommanding of the Probe during the Entry/Descent mission is possible. However, due to the long duration of the Cruise phase, the ability to reprogram and tune the Entry/Descent mission is required. For example, refined models of Titan's atmosphere may be available by the time Cassini arrives in the Saturnian system. Mission reprogrammability is therefore necessary to update the Probe with the most advanced data models. Alternatively mission reprogrammability may be necessary to overcome or circumvent failures encountered with H/W devices.
Mission reprogrammability is provided by use of long term non-volatile memory, EEPROM. During the Cruise and Saturn Orbit phases, S/W patches which contain the modified data are stored in EEPROM. This patches are subsequently applied by POSW when next energised, and POSW executes the modified mission.

4.4.2-2 System Design

POSW Architecture

The Probe on-board S/W is a hard real time embedded system which is written in ADA. The S/W is mission critical and completely deterministic. A hardware generated interrupt, a "heartbeat" is used to drive normal processing activities. This heartbeat is known as the Real Time Interrupt and occurs every 125ms. Once the heartbeat occurs POSW schedules execution of all functionality, namely Probe mission management, telecommand management and telemetry management in a simple iterative manner. POSW essentially uses a simple cyclic executive driven at 8 Hz.

Much of the POSW functionality is executed each 125ms period, or each computed unit of time as it is also known. However several sub-frequencies also exist. Activities such as Probe spin and altitude determination and DDB transmission are conducted at 0.5 Hz. Activities which occur at sub-frequencies are scheduled by the cyclic executive at the appropriate time.

The transfer of telemetry transfer frames to firstly the CDMS and eventually the Orbiter is performed by POSW each second. This transfer is initiated by the telemetry interrupt which is raised when the CDMS H/W requires more data for transmission. When the telemetry interrupt fires each second it is co-incident with the RTI.

During nominal processing POSW only expects the RTI and TMI interrupts to occur. The raising of any other interrupt is due to an error condition and POSW will perform appropriate recovery actions. Ada exception handling is used throughout the S/W to detect and recover from unforeseen events. In addition a CUT overrun mechanism is incorporated into the S/W to allow recovery from processing overruns.

The POSW has two operational modes. One is Mission mode which is the absorbing state. This mode provides all the functionality required for software operations in all phases of the Mission. The other mode is a brief transitory mode used during startup. The initialisation mode lasts for 15 seconds after Power ON and is essentially the configuration of the S/W for the Mission. Any software patches stored in EEPROM are applied to RAM during this mode. Unless otherwise stated, all descriptions heregiven are applicable to Mission Mode.

POSW Interfaces

During the Mission, the Probe on-board S/W interfaces with numerous other systems mounted on the Probe. These interactions are described throughout this section and they are summarized below:

- **Huygens Experimental Payload**: The Probe on-board S/W communicates with five of the six experiments mounted on the Probe. These experiments are DISR, HASI, ACP, SSP and GCMS. Communications with DWE are unnecessary as no DWE data processing is performed on the Probe. All communications are conducted on the OBDH bus. POSW receives telemetry packets from the Experiments and transmits both Descent Data Broadcasts and "ground issued" telecommands to the Experiments.

- **Pyrotechnics and Hardware Devices**: The Probe on-board S/W operates pyrotechnics and other H/W devices via the OBDH bus (examples: firing of parachute deployment mechanism, loading data into the MTUs, energising/de-energising Experiments).

- **Cassini and the Support Avionics Software**: The Probe on-board S/W communicates with Cassini in two dinstinct manners. Prior to the Coast phase, POSW communicates with Cassini via the umbilical link. Both "ground issued" TCs and Probe TM are transmitted over the umbilical. After separation, the umbilical link is severed and no telecommanding ability exists. TM is transmitted however, via the PDRS. This is a radio link.

Hardware Environment

The Probe on-board S/W forms part of the CDMS. As such the CDMS provides the hardware environment in which POSW operates. This environment consists of two duplexed units, which each runs a version of POSW in hot redundancy. These units are called Command and Data Management Units and each CDMU is configured as shown below:

- **Devices:**
  MIL-STD-1750A μProc (MAS281)
  Memory Management Unit
  Direct Memory Access
  On-Board Data Handling Bus
  Watchdog and Processor Valid Port

- **Software Controlled Memory:**
  RAM: 64 kwords (EDAC protected) plus 16 kwords for telemetry buffer
  Startup ROM: 2 kwords
  PROM: 64 kwords
  EEPROM: 16 kwords

- **Hardware Controlled Memory:**
  Telemetry output FIFO: 1 kword
  Telecommand input FIFO: 1 kword

4.4.2-3 Key Design Features

They are the result of both hardware and software design:

Hardware/Software Redundancy

Key elements of the Command & Data Management Sub-system (CDMS) are duplexed within the Probe, to increase the overall system reliability. In particular two CDMUs are fitted, which each execute a version of POSW simultaneously. The two CDMUs are configured to operate in hot redundancy with the first unit being named Chain A and the second Chain B. Each hardware chain is capable of running the mission independently, and may receive telecommands and transmit telemetry unassisted. The two hardware chains are in general terms identical. However several minor differences do exist to facilitate simultaneous operations and to capitalise on the duplicity. These differences are:

1. Telemetry is transmitted at two different frequencies to avoid interference, and thus permit receipt by the Orbiter

2. Chain B telemetry is delayed by approximately 6 seconds, to allow short-term loss of the telemetry link to be circumvented. For instance, a temporary loss of telemetry may arise during the Descent due to a mis-alignment of the antenna as the Probe oscillates beneath the parachute. Providing that the antenna outage is less than 6 seconds a full stream of scientific data will be available by combining the contents of telemetry from both hardware chains.

The software image stored in the programmable read-only memory (PROM) of both hardware chains is identical. However several actions within the software do vary according to the hardware chain. These actions are typically the initialisation of parameters such as the spacecraft identifiers contained in the telemetry transfer frames for example. The determination of the hardware chain, (i.e. whether Chain A or Chain B) is achieved by interrogating the control port fitted within each CDMU.

Processor Health State

Each hardware/software processing has a health state associated to it, which is made available to the Experiments and also reported to ground via housekeeping telemetry. This health state denotes the overall health of the processor and failures are triggered by both hardware and software mechanisms. The health state is physically maintained by the processor valid port, which is a peripheral device fitted to each CDMU. The processor valid port latches failures once reported and the following conditions will set the processor invalid.

- **Hardware Triggered Failures**: The CDMU hardware declares the processor invalid on occurence of a double-EDAC error or an undervoltage on the 5V line.

- **Software Triggered Failures**: The Probe on-board S/W declares the processor invalid on occurence of an Ada exception, CPU machine error and any failure detected during the hardware confidence tests executed start-up. The hardware confidence tests include a dedicated check to detect spurious or unintentional power cycles of the CDMU.

The Experiments use the Chain A processor valid port when interpreting Descent Data Broadcasts, and/or distributing telemetry packets. In general the data returned by the Experiments is identical for both chains. However, Experiments which generate large volumes of data, may transmit different data on the 2 chains.

Single Mission Design

The Probe on-board S/W is designed to execute the nominal Entry/Descent mission once powered. As such the software is not expected to detect its environment, or sense the connection or disconnection of the Probe from the Orbiter. Thus no actions conditional on the Probe's state are included in the S/W. POSW will always execute a single mission regardless of the current phase of the Cassini/Huygens mission.

The design philosophy prevents potential failure modes from arising. In particular the single mission design protects the Entry/Descent mission from disruption by dedicated ground and in-flight checkouts sequences.

Warning: The philosophy of executing a single Entry/Descent mission results in POSW powering ON equipment, and firing pyrotechnic devices in all phases of the Mission. Hardware interlocks are present to prevent inappropriate firing of specific pyrotechnic devices. However, users and operators must not rely on software behaviour for safety or to prevent power drain during checkouts.

Software Modes

The Probe on-board S/W is a high integrity system whose design is underpinned by two states or Software modes:

- **Initialisation Mode**: This is a transitory mode which the S/W enters once powered and lasts for 14.875 seconds. During this time software initialisation and hardware confidence tests are conducted. Software patches are also applied to RAM, if the check of non-volatile EEPROM passed and no Inhibition TC was received. The hardware/software processing chain is also marked as valid or invalid depending on the results of the hardware tests.
  The hardware confidence tests performed include checkouts of the PROM, EEPROM, RAM, DMA device, OBDH bus and a check for spurious CDMU power cycles. The results of these checks are reported in telemetry within the "CDMU init status" parameter.

- **Mission Mode**: This mode is the absorbing state, which commences on conclusion of "start-up" and lasts until the Probe is de-energised. All "mission functionality" is executed within this mode. The Entry/Descent mission is activated and the software automatically generates telemetry and processes telecommands.

Mission Reprogrammability

The POSW may be modified by software patching, both before and after the Launch phase. This reprogramming is a complicated, multi-stage operation which results in patch data being applied to main RAM during initialisation mode. Patching is inherently complex due to the autonomous nature of the Entry/Descent mission, where all software patches must be applied for the Titan encounter without ground assistance.

Patching is initiated by the uplinking of a Patch telecommand, which contains the desired patch data. This patch data will be stored in non-volatile EEPROM, and only applied to main RAM during the next initialisation sequence. A power cycle of the CDMU is required to apply the patch data. However patch data is only applied to main RAM if the EEPROM check conducted during initialisation mode concluded successfully and no Inhibtion TC was received during the pre-defined time window. **POSW will execute the unmodified software contained in PROM if the EEPROM check fails, and therefore no guarantee exists that software patches will be applied for the Titan encounter.**

The Inhibition TC is designed to prevent erroneous patches being applied to main RAM during in-flight checkouts. Under the scenario where an erroneous patch has been stored into EEPROM, the ground may uplink the Inhibition TC during the pre-defined time window to prevent patch application. The time window for reception of an Inhibition TC is from 6.5 to 9.5 seconds after CDMU power ON. For maximum reliability, it is recommended that the Inhibition TC is sent 8 seconds after CDMU power ON. This recommended time is the mid-point between two data extractions from the hardware TC FIFO and thus gives the maximum lee-way.

Software Error Handling

The Probe on-board S/W uses a variety of mechanisms to detect and recover from errors conditions. These mechanisms are implemented in both hardware and software, and together form an effective error detection strategy. The prime objective on detection of an error is to mark the current hardware/software processing chain as invalid, such that the Experiments are informed of the difficulty. The software will also investigate recovery actions in an attempt to resume nominal processing. These detection mechanisms are complex, however an outline of these is given below for information:

- **Data Corruption**: The CDMS incorporates an error detection and correction device to safeguard POSW against corruption of main RAM. This device is invisible to the S/W, and will automatically detect and correct single bit errors that occur in any of the 64 Kwords of main RAM. The EDAC device will also detect double bit errors. However, the device is unable to correct double errors and their occurence is notified to the S/W via a dedicated µprocessor interrupt. The hardware/software chain is marked as invalid whenever a double EDAC error occurs. POSW maintains a count of both the single and double bit EDAC errors events that occur. These counters are reported in telemetry as "RAM single error counter LSB" and "RAM double error counter" respectively. Finally note that the EDAC device can only detect corruption which arises due to solar radiation or a defect in the memory chip. The EDAC device will not detect software induced corruption of memory.

- **Unforeseen Software Errors**: The Probe on-board S/W is written in ADA and uses the ADA exception mechanism to detect and handle unforeseen S/W errors. These unforeseen errors may arise from out of range data or attempts at illegal mathematical operations for example. The ADA run time kernel will detect such events and generate an ADA exception. In response to the exception, the Probe on-board S/W will abort the failed functionality and mark the current hardware/software processing chain as invalid.

The S/W maintains a count of ADA exceptions and this is reported in telemetry. In addition, POSW also sets and reports a health flag to aid fault diagnosis. The functionality executed by POSW each CUT is segregated into a number of distinct activities. A health flag is maintained for each activity and the appropriate activity health flag is set to failed whenever an exception occurs. The parameters reported in housekeeping telemetry for monitoring unforeseen software errors are the "Exception counter", "POSW health MSW status", "POSW health LSW status", "Fixed point overflow counter" and "Floating point overflow counter".

• **Unforeseen Hardware Errors**: The 1750A μprocessor will detect a number of unforeseen hardware errors and raise the dedicated machine error interrupt. These unforeseen errors may arise from an access to an illegal memory address or an attempt to execute an illegal 1750A instruction for example. The POSW will detect the machine error interrupt, mark the current hardware/software chain as invalid and execute appropriate recovery action. The S/W also records the μprocessor fault register and reports the original fault in telemetry. The μprocessor fault register contains details of the nature of the fault and is called the "CPU fault register" in housekeeping.

• **CUT Overrun Mechanism**: The S/W design incorporates a CUT overrun mechanism which is used to detect and recover from processing overruns. This mechanism uses an internal μprocessor timer, namely timer B to measure the processing time used by each CUT. A CUT overrun exception is subsequently handled by the S/W in a similar fashion to that described for unforeseen software errors. The hardware/software processing chain is marked as invalid, and both the exception counter and the dedicated CUT overrun activity health flag are updated. In addition, POSW increments the dedicated CUT overrun counter which is also reported in housekeeping telemetry. All processing in the current, overrunning CUT is aborted and the S/W resumes nominal operations. POSW will re-commence processing in the following CUT, when the real time interrupt occurs.

This overrun mechanism provides protection against "infinite loops" or non-returning procedure calls which can arise due to incorrect re-programming or other hardware faults. The S/W will execute a truncated mission if processing does not complete due to a recurring problem. An overrun may be detected in telemetry by examining the parameters "Overrun counter", "Exception counter" and "POSW health LSW status".

4.4.3 POSW DESCRIPTION

4.4.3-1 POSW Start-up

The POSW enters an initialisation mode or start-up mode as it is also known, once the CDMS is powered. This is a transitory mode which is used to verify the correct operation of the CDMU hardware, and to configure the S/W for the forthcoming mission. The initialisation mode lasts for 15 seconds, and this time may be subdivided into four specific functional windows. These functional windows are illustrated in Table 4.4.3-1 POSW Start-up Functionality below:

Functional Window	Elapsed Time since CDMU Power ON	Event or Software Functionality Executed
1	0 s to 6.5 s	• CDMU hardware confidence checks executed • Software copied to RAM and initialised • Software patches held in EEPROM verified • CDMU clean power-up flag verified
2	6.5 s to 9.5 s	• Three second window allocated for the receipt of an Inhibition TC. POSW simply waits throughout this period
3	9.5 s to 14.8125 s	• Verification of any Inhibit TC received • Application of software patches to main RAM, if no valid Inhibition TC received and the EEPROM check passed successfully
4	14.8125 s to 15 s	• Processing chain marked as valid or invalid according to the outcome of the hardware confidence checks • Mission mode entered on RTI at 15 seconds

TABLE 4.4.3-1 POSW START-UP FUNCTIONALITY

4.4.3-1-1 Hardware Confidence Checks

Several confidence checks are performed on the CDMU hardware during initialisation mode to verify the correct operation of key hardware elements. On conclusion of the start-up period the relevant hardware/software processing chain is marked as valid or invalid according to the outcome of these confidence checks. The failure of any confidence check results in the relevant processing chain being marked as invalid. The results of the confidence checks are notified to ground in HK telemetry, within the "CDMU init status" parameter (S1010H/S2010H). An overview of the individual hardware confidence checks executed by POSW follows.

PROM Confidence Check

The PROM is checked during initialisation mode to ensure that the stored software image has not been corrupted. The confidence check consists of calculating a modulo 2^{16} checksum on the entire 64 Kwords of main PROM. The resultant checksum should equal zero for the nominal "uncorrupted" case, and the calculated value is also reported in HK telemetry within the "POSW Status 1" parameter (S1018W/S2018W).

The PROM checksum equals zero in the nominal "uncorrupted" case, as the last memory location in PROM (FFFFhex) intentionally contains the value necessary to sum the PROM contents to zero. This value is the ones complement of the binary sum of the PROM plus one (the value of FFFFhex for POSW_06 is 73C7hex).

RAM Confidence Check

The RAM is checked during initialisation mode to ensure that every memory location can correctly maintain data. The confidence check consists of writing to and reading from every address in the 64 Kwords main RAM. Any memory read which does not return the previously "stored" data value results in the confidence test failing. The first RAM failure address is reported in HK telemetry as the "RAM first failure address" parameter (TM S1017W/S2017W).

The RAM confidence check is conducted when the contents of PROM are being copied to main RAM for program execution. Consequently the RAM check also verifies that the PROM image is correctly transferred to main RAM.

DMA Confidence Check

The DMA device is checked during initialisation mode to verify the correct operation of the DMA chip. The confidence check consists of transferring 16 words of data from the TC FIFO to main RAM. On completion of the DMA, main RAM is inspected to verify that the TC data was successfully received. The result of the DMA confidence check is only reported in the "CDMU init status" parameter, and no supplementary result parameters are present in HK telemetry.

OBDH Bus Confidence Check

The OBDH bus is checked during initialisation mode to verify the correct operation of the OBDH device. The confidence check consists of executing six interrogations at pre-set OBDH addresses. The results yielded by the OBDH addresses are known in advance and the software confirms that the correct data was returned. The six interrogations consists of three analogue acquisitions at addresses 108, 109 and 110, and three digital bi-level interrogations at addresses 197, 198 and 207. The OBDH confidence check fails if any OBDH interrogation does not yield the expected value. The result of the OBDH confidence check is only reported in the "CDMU init status" parameter and no supplementary result parameters are present in HK telemetry.

EEPROM Patch Confidence Check

The EEPROM is checked during initialisation mode to ensure that any uplinked patches currently stored in EEPROM have not been corrupted. The check consists of calculating a CRC for every patch held in EEPROM. The confidence check fails if any CRC is invalid, and consequently the patch data will not be applied to main RAM. The result of the EEPROM confidence check is only reported in the "CDMU init status" parameter and no supplementary result parameters are present in HK telemetry.

Clean CDMU Power-up Confidence Check

The POSW executes a confidence check to detect spurious or unintentional power cycles of the CDMU, whilst in initialisation mode. The "clean power-up" hardware confidence check is designed to overcome a specific failure scenario which may arise during in-flight operations. In particular an unscheduled power cycle of CDMU A during the Titan encounter, would result in POSW re-initialisation processing Chain A as healthy. The Experiments which monitor the Chain A processor valid status would subsequently utilise DDBs from the erroneous Chain A in preference to Chain B.

The "clean power-up" hardware confidence check uses non-volatile EEPROM as long-term memory to overcome this failure scenario. Ground operators must load a pre-defined pattern into the end of EEPROM, prior to any CDMU power-down. The POSW inspects the data in EEPROM during the next initialisation sequence and if the pre-defined pattern is not identified, the confidence check is marked as failed. The POSW overwrites the data pattern in EEPROM during every initialisation cycle, and it is therefore imperative that the ground reset the EEPROM data before de-energising.

Warning: The CDMU clean power-up confidence check places an operational constraint on the ground; see § 4.4.3-5-5.

The result of the CDMU clean power-up confidence check is only reported in the "CDMU init status" parameter and no supplementary result parameters are present in HK telemetry.

4.4.3-1-2 Software Patching

The POSW permits re-programming of the Entry/Descent mission via software patching. This reprogramming is a complicated, multi-stage operation which results in patch data being applied to main RAM during initialisation mode. However, patch data is only applied to main RAM if a valid Inhibition TC has not been received, and the EEPROM hardware confidence check indicates that the patch data is uncorrupted. Software patching is a maintenance activity , see RD1, SMM.

4.4.3-1-3 Telecommand During Initialisation Mode

The POSW considers **all TCs invalid during the first 9.5 seconds of the Initialisation mode**, except for the Inhibition TC which may only be received during the dedicated three second window. Between 9.5s and 15s after Power-up, TCs are queued for execution at the start of Mission Mode.

4.4.3-1-4 Telemetry During Initialisation Mode

The **POSW does not generate telemetry during the 15 seconds of initialisation mode**. Consequently the first fifteen transfer frames received by ground will be uninitialised. See § 4.4.3-4-1.

4.4.3-2 Probe Mission Management

The POSW will autonomously execute the Entry/Descent Mission once powered.

4.4.3-2-1 Mission Timing Datums

The POSW maintains two sequential counters as timing references. Both these counters are driven from the 8 Hz RTI, and are incremented each time a "heartbeat" occurs. These counters are:

- **Real Time (RT) Counter**: The real time counter provides a straight count of RTI firings from the start of Mission mode. As such the counter logs the length of time the Probe has been energised (excluding the 15 seconds of initialisation mode). This counter has sufficient range to count 16.7 million RTIs or 582.5 hours. Consequently this counter will not wrap-around and is only reset by de-energising the CDMS.

- **Mission Time (MT) Counter**: The mission time counter also maintains a straight count of RTI firings. However this counter is reset on detection of T0 and can also be frozen and artificially set by TCs or reset when T0 is simulated by TC. This counter has sufficient range to count 16.7 million RTIs or 582.5 hours and should not wrap-around during nominal operations.

Mission time is a discontinuous time datum which initially logs the length of time the Probe has been energised (excluding the 15 seconds of initialisation mode). At this stage, mission time is identical to real time, where both counters are numerically equal and in phase. The MT counter is Pre-T0 and logging the duration of the Entry Phase of the Mission. These two timing references will remain synchronised until a time discontinuity occurs. This discontinuity may arise due to the receipt of a Suspend/Resume TC or the T0 detection.

During the Titan encounter, Mission Time will be reset to zero when the T0 event is detected. Consequently Mission Time and Real Time are no longer equal. Key time dependent actions required during the Descent phase, are now instigated by POSW based on the elapsed time since T0 detection. These actions are typically the firing of the parachute deployment device, jettisoning the Back Cover and the Front Shield and powering hardware devices. The scheduling of these actions is specified by the MTTs, and each action is due at an appropriate Post-T0 mission time. Other look-up tables contained in S/W are also specified in terms of Post-T0 mission time, such as the Time/Altitude table.

Discontinuities in mission time may also be introduced by the Suspend/Resume TC. As the name suggests, this TC can be used to freeze or resume mission time at a chosen value Pre or Post-T0. When a Post-T0 resume is uplinked the S/W declares the T0 event and enters the Descent phase of the mission. These TCs may be used during in-flight checkouts to exercise the Probe in all regimes of the Mission.

4.4.3-2-2 Mission Timeline Tables

The POSW operates pyrotechnic devices and other hardware equipments mounted on the Probe according to pre-programmed Mission Timeline Tables (MTTs). Two mutually exclusive timelines are maintained by the S/W, the first for the Entry phase (Pre-T0 MTT) and the second for the Descent and Surface phases (Post-T0 MTT). The S/W commences execution of the Pre-T0 MTT when powered, and automatically switches to the Post-T0 MTT when the T0 event is detected. In parallel, the S/W maintains a record of the number of commands executed in accordance with the MTT. This is the Command Counter, described in § 4.4.4-2-6.
Note that for the MTTs, the Pre-T0 MTT and the Post-T0 MTT refer to S0, because the Post-T0 MTT contains the Parachute Deployment sequence.

Each MTT contains up to 64 time-tagged commands. These TCs may be ON/OFF or MEMORY LOAD commands which are automatically executed on the OBDH bus at the appropriate time. The timing information is given in terms of Mission Time, and may be specified with a precision of 125ms or 1 CUT. The MTT data may be specified in any order, and POSW will identify and execute "due" commands irrespective of the table ordering.

Both MTTs may be modified by software patching. The default data sets included in the S/W are given in § 4.4.4-3-1. The Pre-T0 MTT may also be reprogrammed by the dedicated Load MTT TC. This TC writes directly to RAM, and permits the modification and execution of the Pre-T0 MTT in a single CDMU power cycle. This facility is only available whilst Probe is connected to the Orbiter and cannot be used to reprogram the Post-T0 MTT for the final Descent. A sample of the MTT format is given in Figure 4.4.3-1.

<table>
<tr><td>msb 15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>lsb 0</td></tr>
<tr><td colspan="16">MTT TIME (LSW)</td></tr>
<tr><td colspan="8">MTT TIME (MSB)</td><td colspan="2">TYPE</td><td colspan="6">ADDRESS</td></tr>
<tr><td colspan="16">MEMORY LOAD DATA or CHANNEL SOURCE ADDRESS</td></tr>
</table>

where:

MTT TIME = the two MTT fields form the 24 bit mission time at which the command is due

TYPE = the type of command to be executed on the OBDH bus where:
- 00 = a NULL command
- 01 = a 13ms ON/OFF command
- 10 = a 45ms ON/OFF command
- 11 = a MEMORY LOAD command

ADDRESS = The OBDH address for MEMORY LOAD commands. Note that this field is meanningless for ON/OFF and NULL commands.

MEMORY LOAD DATA or CHANNEL SOURCE ADDRESS = this field gives the memory load data. For ON/OFF commands this field gives the OBDH address. Note that this field is meaningless for NULL commands.

FIGURE 4.4.3-1 MTT DESCRIPTOR FORMAT

Mission Timeline Table Restrictions

Several restrictions are placed on the data incorporated into the MTTs by both POSW and the CDMS hardware. Any software patches uplinked during the operational lifetime of the Probe must obey these restrictions. They are:

1• Each MTT descriptor must contain a unique mission time. Any duplication of mission time in a given table will result in the "duplicated" record being ignored.

2• All redundant or unused MTT descriptors must be initialised to a "Null Format". The worst case performance of POSW will deteriorate if Null records are not completed correctly. This "Null Format" is:

- The least significant word (LSW) of the encoded mission time must be unique, with the value approaching the maximum of FFFFhex. This arises as POSW uses an optimised algorithm to identify due commands. The worst case performance of this algorithm deteriorates if numerous pattern matches occur during a single CUT.
- The most significant byte (MSB) of the encoded mission time must be set to the maximum value, namely FFhex.
- the type field must denote a NULL command, namely 00.
- The OBDH address (Address field) for MEMORY LOAD commands must be the pre-defined Null address. The Null address currently renames the "coast timer 1 load init" command and is 01 (decimal).
- The OBDH channel source data for ON/OFF commands must be the Null address. The Null address currently renames the "TUSO N Power ON" command and is 46 (decimal).

3• No two High Power, 45 ms ON/OFF commands may be scheduled for execution in consecutive CUTs. This restriction originates from the CDMS hardware, which requires a timing constraint of 50ms to be observed between two consecutive High Power ON/OFF commands. See Operation SP03 in Doc n° HUY.AS/c.100.OP.0384.

4.4.3-2-3 Descent Data Broadcasts

The Experiments mounted on the Probe receive key spacecraft information from POSW every two seconds. This data is packetised as an internally generated TC, called a Descent Data Broadcast. The information contained in a DDB includes Probe spin rate, Probe altitude, current mission phase, current time and an indication of whether the Probe is Pre or Post-T0. The complete format and content of the DDB is outlined in Figure 4.4.3-2.

D3

msb 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	lsb 0
0	0	0	1	0	Application Process id										
1	1	Source Sequence Count													
Packet Data Field Length = 7 bytes															
F1		DDB Time													
F2	DDB Altitude														
DDB Spin								DDB Mission Phase							
CRC Word															

where:

Application Process id = DDB broadcast packet identifier. CDMU A (78Fhex) and CDMU B (7AFhex)
Source Sequence Count = Free running sequential count of the DDBs issued since power ON
Packet data field length = Packet standard field length
F1 = Flag denoting whether the Probe is Pre-T0 (01) or Post-T0 (10)
DDB Time = Free running sequential counter where the lsb represents two seconds. However this timing datum is derived from the Real Time counter when Pre-T0, and the Mission Time counter when Post-T0. The DDB time will be discontinuous under certain circumstances and is described hereafter in § **Descent Data Broadcast Time.**
F2 = Flag denoting whether the DDB altitude originated from the Time/Altitude lookup table or radar altimeters. For altimeters (0) and TAT (1).
DDB Altitude = The current altitude of the Probe. In decametres.
DDB Spin = The current spin rate of the Probe. In 0.1 revs/min.
DDB Mission Phase = The current mission phase of the Probe. This parameter is set by Alteration command and may adopt any of the values given in § 4.4.4-3-2.
CRC word = Valid CRC word for the TC.

FIGURE 4.4.3-2 DDB TELECOMMAND FORMAT

Reporting of the T0 Event in Descent Data Broadcasts

The Huygens experiments are notified of the T0 event via the dedicated flag F1 contained in the DDB. This flag represents the Probe level T0 event, which is defined as the time at which the initial "pilot" parachute is deployed.

The POSW however, defines the T0 event as the time of Entry into Titan's atmosphere. As such, this event is the **Software T0** event and represents a theorical point 6.375 seconds before aerodynamic conditions are correct for parachute deployment. This **Software T0** event is also referred to as **S0** at Probe level.

Furthermore, the POSW physically detects the **Software T0** event **(S0)** and commences the "Post-T0 Descent" at this time. In essence the S/W is executing Post-T0 several seconds before the initial "pilot" prachute is deployed. Consequently the reporting of the **Software T0** event **(S0)** within the DDB is delayed, such that the dedicated flag F1 accuratly reports the Probe level T0 event. This delay synchronises the reporting of the T0 event with the deployment of the initial "pilot" parachute. The duration of the reporting delay is specified by a re-programmable data item named DDB_DELAY.

D3

The DDB time is also manipulated such that it accurately reflects "elapsed mission time" since the deployment of the initial "pilot" parachute. However great care must be taken when evaluating Experiment timelines, as commands stored in the Post-T0 MTT are executed relative to the **Software T0** event **(S0)** and not DDB time. The operation of DDB time is described further within § **Descent Data Broadcast Time**.

> **Warning**: *The reporting of the **Software T0** event **(S0)** is delayed within the DDB, such that T0 corresponds to the deployment of the initial "pilot" parachute. However great care must be taken when evaluating Experiment timelines, as commands stored in the Post-T0 MTT are executed relative to the **Software T0** event **(S0)** and not the deployment of the initial "pilot" parachute.*

Descent Data Broadcast Flag F1

The dedicated flag F1, contained in the DDBs accurately reports the status of the Probe level T0 event. Prior to deployment of the initial "pilot" parachute, the flag F1 will indicate Pre-T0. After deployment of the initial "pilot" parachute the flag will indicate Post-T0. These status values are reported irrespective of the **Software T0** event **(S0)**.

Descent Data Broadcast Time

The DDB time is a free running sequential counter, where the lsb represents two seconds. However the DDB time is a "virtual counter" which is simply derived from other timing datums operated by the POSW.

The derivation of DDB time is performed by the DDB time algorithm. This algorithm is complex, and synchronises the DDB time with deployment of the initial "pilot" parachute. The algorithm uses both timing datums and re-programmable data to achieve this, and a walkthrough of the algorithm follows:

1• When the Probe is Pre-T0, the DDB time is simply derived from Real Time and equals Real Time counter scaled into two seconds units. As such the DDB time represents elapsed time since Power ON and is therefore monotonically increasing. The DDB time will be unaffected by Suspend or Resume TCs.

2• When the Probe is Post-T0 and the Mission Time is less than the re-programmable data item DDB_DELAY, the DDB time is simply derived from Real Time. As such the DDB time equals the Real Time counter scaled into two seconds units, and still represents elapsed time since Power ON. The transition from Pre-T0 to Post-T0 is undetectable in DDB time, and indeed the flag F1 indicates that the Probe is still Pre-T0. The DDB time will be unaffected by Suspend or Resume TCs.

3• When the Probe is Post-T0 and Mission Time is equal or greater than the re-programmable data item DDB_DELAY, the DDB time is derived from Mission Time. As such the DDB time equals the Mission Time minus the DDB_DELAY scaled into two second units. The DDB time now represents the "elapsed mission time" since deployment of the initial "pilot" parachute. The DDB time will now be affected by Suspend and Resume TCs, and dis-continuities in DDB time may occur.

The re-programmable data item DDB_DELAY is fundamental to the DDB time algorithm. This parameter represents the delay between the detection of T0 by POSW and the subsequent reporting of T0 detection in the DDBs. The DDB_DELAY value should equate to the time between T0 detection and the deployment of the initial "pilot" parachute. A logical summary of this re-programmable constant is given in Figure 4.4.3-2 **Bis** Miscellaneous Re-programmable Data, and the physical representation is shown in Doc n° HUY. AS/c.100.OP.0384 Operation SP10.

Side Effects of Delayed T0 Event Reporting

The delayed reporting of the T0 event within the DDB produces several side effects or "features" in the POSW. Furthermore several of these features impact Probe Operations. Full details of these side effects follow:

1• The DDB time cannot be suspended prior to the deployment of the initial "pilot" parachute. This arises as the DDB time is derived from the Real Time Counter which is monotonically increasing. The dedicated Suspend TC may be used to freeze Mission Time, however this has no impact on DDB time.

2• The DDB time cannot be explicitely set prior to the deployment of the initial "pilot" parachute. This arises as the DDB time is derived from the Real Time Counter which is monotonically increasing. The dedicated Resume TC may be used to explicitely set Mission Time, however this has no impact on DDB time.

3• The altitude reported within the DDB will initially decrease whilst the DDB is still Pre-T0. This arises as the "Descent" commences once the **Software T0 (S0)** event has been detected.However the reporting of the T0 event is synchronised with the deployment of the initial "pilot" parachute and approximately three Pre-T0 DDBs will be transmitted where the altitude is decreasing.

4• The DDB will revert from a Post-T0 to a Pre-T0 posture whenever a particular series of TCs are uplinked. This arises if a Post-T0 Resume TC is uplinked where the Mission Time is less than the DDB_DELAY, and the previously transmitted DDB was already Post-T0.

The following restrictions are placed upon Probe Operations due to the side effects detailed above:

> **Warning**: *The Suspend TC shall not be used to freeze Mission Time for more than two seconds when the Probe is Pre-T0 where T0 refers to the Probe level event. In more explicit S/W terms, the constraint applies Pre-T0 and Post-T0 where the Mission Time is less than DDB_DELAY.*

> **Warning**: *Post-T0 Resume TCs shall not be uplinked where the Mission Time is less than the re-programmable data item DDB_DELAY, once the Probe is Post-T0. In this case T0 refers to the Probe level event.*

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4.4.3-2-4 T0 Detection and Parachute Deployment

The Probe's entry into Titan's atmosphere and subsequent parachute deployment is a mission critical event, which involves independent hardware and software subsystems. The initial "pilot" parachute is deployed by the POSW shortly after the **Software T0** event **(S0)** is detected. This event is defined as Titan atmospheric Entry, and represents a theorical point 6.375 seconds before aerodynamic conditions are correct for parachute deployment. The Mission Time is reset on the advent of T0 detection and the command to deploy the initial "pilot" parachute is issued shortly thereafter.

The CDMS incorporates an independent mechanism to prevent the inadvertent firing of the parachute deployment pyrotechnic device by software. This mechanism uses hardware processing of the signals generated by the axial accelerometers to control the arming of the pyrotechnic device. The pyrotechnic device is simply armed when an appropriate level of deceleration is achieved.

The POSW uses three independent algorithms to detect the **Software T0 event (S0)**. The algorithms are executed in hot redundancy and the T0 event can be independently triggered by any of these algorithms. Once T0 has been detected, the S/W sets and fires the parachute deployment pyrothecnic device. The set and fire commands are issued by the Post-T0 MTT. A brief synopsis of the three detection algorithms follows:

1• The primary T0 detection algorithm uses axial accelerometers to measure the atmospheric deceleration during the Entry phase of the Mission. These raw accelerometer readings are used in conjonction with re-programmable data to precisely monitor the deceleration profile of the Probe. The algorithm subsequently declares the **Software T0** event **(S0)** when the aerodynamic forces have subsided to a level where parachute deployment may occur. This primary algorithm will detect the **Software T0** event **(S0)** in the nominal case.

2• The secondary or back-up T0 detection algorithm uses G-switches to sample the atmospheric deceleration during the Entry phase of the Mission. The raw G-switch data is used to "coarsely" monitor the deceleration profile of the Probe. The algorithm subsequently declares the **Software T0** event **(S0)** once a specific profile has been identified and an associated algorithmic delay has expired. This G-switch based algorithm will only detect the **Software T0** event **(S0)** under failure conditions. Such failures conditions include the complete loss of axial accelerometer data.

3• The tertiary or back-stop T0 detection algorithm uses a simple time based mechanism. The algorithm declares the **Software T0** event **(S0)**, if the POSW has not detected the T0 event after a given time has elapsed since Power ON. This given time is a re-programmable data item, and represents a "back-stop" value for T0 detection. This tertiary algorithm will only detect the **Software T0** event **(S0)** in the case of extreme failures.

Primary T0 Detection Algorithm

POSW executes the primary T0 detection algorithm every 125ms during the Entry Phase of the Mission. This algorithm uses triply redundant axial accelerometers and re-programmable constants as input data, and determines if the aerodynamic forces exerted on the Probe have subsided to a level where parachute deployment may occur.

The three axial accelerometers are contained in the central accelerometer sensor unit (CASU) of the CDMS. Each hardware/software chain acquires all three accelerometer readings each CUT, and independently executes the T0 detection algorithm. A walkthrough of the detection algorithm which details all of the re-programmable constants used, follows:

1• Each Hardware/Software chain interrogates the CASU and acquires fresh axial accelerometer readings each CUT. The three accelerometer readings are denoted as V1, V2 and V3, and are acquired via the OBDH bus. These accelerometer readings are given in units of CANs. A CAN is an analog-to-digital conversion unit which ranges from 0 to 255. However logically speaking the lsb of each reading represents an acceleration of 0.385 m/s^2. The readings are scaled into accelerations by the second step of the T0 detection algorithm.

2• The raw accelerometer readings are scaled and filtered to produce the intermediate values S1, S2 and S3. The re-programmable constants A1, A2, A3, B1, B2, B3, C1, C2, C3, D1, D2 and D3 are used by the filter. The initial values of these re-programmable data items are given in § 4.4.4-3-3. The filtering algorithm used to scale and condition the inputs is shown below, where the suffix n represents the accelerometer number which is 1, 2 or 3:

$$S_n = A_n + V_n * (B_n + V_n * (C_n + V_n * D_n))$$

The software currently sets the re-programmable data items A1, A2, A3, C1, C2, C3, D1, D2 and D3 to zero, such that the filtering algorithm collapses to $S_n = B_n * V_n$. All re-programmable B_n values are set to 0.385 m/s^2 which means a full range reading of 255 is scaled to 98.1 m/s^2.

3• The intermediate values S1, S2 and S3 are subsequently filtered through a time based algorithm to produce the final values E1, E2 and E3. This time-based algorithm averages the historic "E" and "S" values for each accelerometer to produce the final "E" value. The weighting associated to the historic "E" and "S" value is set by the re-programmable constants E11, E12, F11, F12, E21, E22, F21, F22, E31, E32, F31 and F32. The initial values of these re-programmable data items are given in § 4.4.4-3-3. The time-based algorithm used to derive the final "E" values is shown below, where the suffix n represents the accelerometer number which is 1, 2 or 3. The suffixes (-1) and (-2) refer to values calculated 125ms and 250ms ago respectively.

$$E_n = E_n1 * S_n(-1) + E_n2 * S_n(-2) + F_n1 * E_n(-1) + F_n2 * E_n(-2)$$

The software currently sets the re-programmable data items E12, F11, F12, E22, F21, F22, E32, F31 and F32 to zero, and E11, E21 and E31 to one. Consequently the algorithm collapses to $E_n = S_n(-1)$ and therefore the final "E" value is the intermediate "S" value calculated during the last CUT.

4• The final "E" values are majority voted to determine if the first of the T0 thresholds has been breached. This threshold is called THB and is re-programmable data item. The THB threshold represents a point on the upside of the sharp deceleration spike, which occurs in the predicted deceleration profile of the Probe. The threshold denotes the point where atmospheric deceleration has dramatically increased due to the Probe encountering the dense lower regions of Titan's atmosphere.

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The software currently sets THB to 50 m/s^2. The threshold is considered breached whenever two of the three "E" values are in excess of 50 m/s^2. The initial value of THB is given in § 4.4.4-3-3.

5• Once the first threshold has been breached, the software commences analysis of the second threshold THA. The THA threshold is also a re-programmable data item and represents a point low on the downside of the anticipated deceleration spike, which occurs in the predicted deceleration profile of the Probe. This threshold denotes the point where atmospheric deceleration has subsided due to aerodynamic braking effect of the Front Shield. The stability and velocity of the Probe is now suitable for the declaration of T0 and deployment of the "pilot" parachute.

The software currently sets THA to 10.0 m/s^2. The threshold is considered breached whenever two of the three "E" values fall beneath 10.0 m/s^2. Once breached POSW declares the **Software T0** event **(S0)** and fires the parachute deployment pyrotechnic device shortly after. However note that the detection of the THA threshold does not commence until the CUT following the detection of the THB threshold. The initial value of THA is given in § 4.4.4-3-3.

In summary the primary T0 detection algorithm implemented by the POSW is mission critical. The algorithm contains many re-programmable data items which may be modified by software patching. These patchable data items are grouped into a table known as the TVT (Time/Velocity Table). All parameters in the TVT may be specified to 6 significant figures, and the physical representation of the TVT is shown Operation SP10 in Doc n° HUY.AS/c.100.OP.0384. The logical content of the TVT is summarized in Figure 4.4.3-3 TVT Re-programmable Data.

Primary Algorithm Telemetry

The HK telemetry generated by the POSW contains a single set of parameters for monitoring the primary T0 detection algorithm. These parameters are the raw central accelerometer readings which are used as input data for the algorithm. See § 4.4.3-4-3 **Time Buffering of CDMS HK Parameters** for further details.

G-Switch T0 Detection Algorithm

The POSW executes the back-up G-switch based T0 detection algorithm every 125ms during the Entry phase of the Mission. This algorithm uses G-switch readings and a re-programmable constant as input data, and determines if an emergency declaration of the **Software T0** event **(S0)** is necessary.

The CDMS incorporates four G-switches specifically dedicated to back-up T0 detection. However each hardware/software chain acquires data from just two G-switches, and two different "deceleration-levels' are sensed by the switches mounted within each chain. Consequently each hardware/software chain executes the back-up T0 detection algorithm based upon independent G-switch data each CUT. A walkthrough of the detection algorithm which details re-programmable constant used, follows:

1• Each hardware/software chain interrogates the OBDH bus and acquires fresh G-switch data each CUT. The single digital bi-level acquisition returns data for both G-switches, and a bi-level value of "1" denotes that the pre-set "deceleration level" has been sensed. The first switch: G-switch 1 [redacted]

2• The acquired G-switch values are processed to detect the rising edge of the deceleration profile. The rising edge equates to a deceleration of 62 m/s^2 and denotes the point where atmospheric deceleration has dramatically increased due to the Probe encountering the dense lower regions of Titan's atmosphere. However the rising edge is only considered detected when both G-switches have "measured" the high deceleration level for eight consecutive CUTs. In essence the POSW "[redacted] the G-switch signal over a one second period.

3• Once the rising edge has been detected, the S/W processes the acquired G-switch values to detect the falling edge. The falling edge equates to a deceleration of 12 m/s^2 and denotes the point where atmospheric deceleration has subsided due to the aerodynamic braking effect on the Front Shield. However the falling edge is only considered detected when both G-switches have "measured" the low deceleration level for eight consecutive CUTs. In essence the POSW "[redacted]" the G-switch signal over a one second period.

4• Once the falling edge has been detected, the S/W executes a pre-defined algorithmic delay. This algorithmic delay represents a "time window" and allows the primary algorithm to detect T0 in the nominal case. The algorithmic delay is specified by the re-programmable constant G_DELAY, and the initial value is given in § 4.4.4-3 Software Data.

5• Once the pre-defined algorithmic delay has expired, the **Software T0** event **(S0)** is declared and the initial "pilot" parachute is deployed shortly thereafter. However the G-switch algorithm will only detect the **Software T0** event **(S0)** in the advent of failure. Under nominal operations, the T0 event will occur before the algorithmic delay expires.

In summary the G-switch based T0 detection algorithm implemented by the POSW is mission critical. The algorithm is designed as a back-up to the primary detection algorithm, and only detects T0 under failure conditions. The re-programmable algorithmic delay allows the algorithm to be tuned, thus permitting a sufficient "time margin" to be provided for the nominal case. A logical summary of this re-programmable constant is given in Figure 4.4.3-2 **Bis** Miscellaneous Re-programmable Data, and the physical representation is shown in Doc n° HUY. AS/c.100.OP.0384 Operation SP10.

G-Switch Algorithm Telemetry

The HK telemetry generated by the POSW contains two parameters for monitoring the G-switch T0 detection algorithm. These parameters are the G_SWITCH_BUFFER (S1024W/S2024W) and the G_TIME_OUT_COUNTER (S1025W/S2025W). See § 4.4.4-2-6 TM List for further details.

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Time Based T0 Detection Algorithm

The POSW executes the time based T0 detection algorithm every 125ms during the Entry phase of the Mission. The algorithm consists of two independent time-based mechanisms which each perform distinct functions. These two functions are described hereafter:

T0 Detection Timeout

The POSW incorporates a timeout on the detection of the **Software T0** event **(S0)**. On expiry, this timeout simply marks the current hardware/software processing chain as invalid. The timeout does not declare the T0 event and the parachutes will not be deployed. The T0 timeout is a re-programmable constant which is currently set to 35 minutes, and this initial value is given in § 4.4.4-3-1.

The T0 timeout permits the Experiments to be exercised in both the Pre and Post-T0 flight regimes, when all telecommanding capability is lost on Chain A. Under the scenario where a fault upstream of POSW prevents the reception of telecommands by Chain A, the T0 timeout will mark Chain A as invalid. This condition will be detected by the Experiments, and the Experiments will utilise DDBs from Chain B instead. It is assumed that Chain B may be telecommanded to Post-T0 via the Suspend/Resume TC.

The T0 timeout is specified by the re-programmable data item TIME_OUT. A logical summary of this re-programmable constant is given in Figure 4.4.3-2 **Bis** Miscellaneous Re-programmable Data, and the physical representation is shown in Doc n° HUY. AS/c.100.OP.0384 Operation SP10.

Back-stop T0 Detection

The POSW incorporates a "back-stop" timeout on the detection of the **Software T0** event **(S0)**. This mechanism declares the **Software T0** event **(S0)**, if the POSW has not detected the T0 event after a given time has elapsed since Power ON. This given time is a re-programmable data item, and represents a "back-stop" value for T0 detection. The "back-stop" is currently set to 38 minutes, and this initial value is given in § 4.4.4-3-1.

The "back-stop" T0 detection mechanism will only detect the **Software T0** event **(S0)** in the case of extreme failures. Both the primary and G-switch based detection algorithms should nominally detect the **Software T0** event **(S0)** before the "back-stop". The "back-stop" algorithm provided a simple, reliable mechanism for T0 detection. However the value of "back-stop" is mission critical and must be carefully chosen after detailed mission analysis.

The "back-stop" value is specified by the re-programmable data item BACK_UP. A logical summary of this re-programmable constant is given in Figure 4.4.3-2 **Bis** Miscellaneous Re-programmable Data, and the physical representation is shown in Doc n° HUY. AS/c.100.OP.0384 Operation SP10.

> **Warning:** During ground based testing or in-flight checkout, if the Suspend TC has been sent, then expiry of the "back-stop" T0 timeout **will not** result in the execution of the Post-T0 MTT and **will not** result in reporting of Post-T0 in the DDB packets. This is because the Mission Time will remain suspended due to the Suspend TC. However, the S0 will be declared and Mission Time will be reset to 0 and hence, will be reported at 0 in the HK telemetry.

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Time Based Algorithm Telemetry

The HK telemetry generated by the POSW does not contain any parameters dedicated to monitoring the time based T0 detection algorithm. However the effects of the time based algorithm may be deduced from analysing the Real Time Counter, CONTROL_PORT, and DDB_F1 and DDB_TIME parameters. See § 4.4.4-2-6 TM List for further details.

Name	Units	Data Type	Functional Area	Description
DDB_DELAY	CUTs (Mission Time)	Integer (24 bit) (0 to 16777215)	Descent Data Broadcast	Constant specifying the delay between detection of T0 by the POSW, and the subsequent reporting of T0 detection in the DDBs. This delay synchronises the reporting of T0 detection with the deployment of the initial "pilot" parachute. The value is specified as a Post-T0 Mission Time in CUTs. The value should equate to the Mission Time at which the parachute deployment device is fired, which is specified by the first PYRO_1_AND_2_FIRE_A command in the Post-T0 MTT.
G_DELAY	CUTs	Integer (16 bit) (0 to 65535)	G-switch T0 Detection Algorithm	Constant specifying the algorithmic delay between the detection of the G-switch falling edge and the emergency declaration of the **Software T0** event (**S0**). The value is specified in CUTs and is measured from the "start" of the G-switch falling edge. The value shall always be in the following range: $8 \geq$ G_DELAY ≤ 65535
TIME_OUT	CUTs (Real Time)	Integer (24 bit) (0 to 16777215)	T0 Detection Monitoring	Constant specifying the Real Time at which the current hardware/software chain will be marked invalid, if the T0 event has not been detected. The value is specified in CUTs and equates to elapsed time since Power ON.
BACK_UP	CUTs (Real Time)	Integer (24 bit) (0 to 16777215)	Back-stop T0 detection	Constant specifying the Real Time at which the **Software T0** event (**S0**) will be declared, if the T0 event has not already been detected. The value is specified in CUTs and equates to elapsed time since Power ON.

FIGURE 4.4.3-2 BIS MISCELLANEOUS RE-PROGRAMMABLE DATA

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Name	Units	Data Type	Functional Area	Description
A1,A2 and A3	m/s^2	Real number (6 significant figs)	Axial Accelerometer Data Scaling	Constants used to scale and filter the raw accelerometer data
B1,B2 and B3	m/s^2 CAN	Real number (6 significant figs)	Axial Accelerometer Data Scaling	Constants used to scale and filter the raw accelerometer data
C1,C2 and C3	m/s^2 CAN^2	Real number (6 significant figs)	Axial Accelerometer Data Scaling	Constants used to scale and filter the raw accelerometer data
D1,D2 and D3	m/s^2 CAN^3	Real number (6 significant figs)	Axial Accelerometer Data Scaling	Constants used to scale and filter the raw accelerometer data
E11,E21 and E31	None	Real number (6 significant figs)	Time Dependent Filtering	Constants used to filter historic "S" values generated 125ms earlier
E12,E22 and E32	None	Real number (6 significant figs)	Time Dependent Filtering	Constants used to filter historic "S" values generated 250ms earlier
F11,F21 and F31	None	Real number (6 significant figs)	Time Dependent Filtering	Constants used to filter historic "E" values generated 125ms earlier
F12,F22 and F32	None	Real number (6 significant figs)	Time Dependent Filtering	Constants used to filter historic "E" values generated 250ms earlier
THB	m/s^2	Real number (6 significant figs)	Threshold Evaluation	First deceleration threshold. This data represents a point on the upside of the sharp deceleration spike, which occurs in the predicted deceleration profile of the Probe. This threshold denotes the point where atmospheric deceleration dramatically increased as the Probe encounters the dense lower regions of Titan's atmosphere.
THA	m/s^2	Real number (6 significant figs) THA must be less than THB for T0 detection	Threshold Evaluation	Second deceleration threshold. This data represents a point low on the downside of the anticipated deceleration spike, which occurs in the predicted deceleration profile of the Probe. This threshold denotes the point where atmospheric deceleration has subsided due to the aerodynamic braking effect of the Front Shield. The stability and velocity of the Probe is now suitable for the declaration of the **Software T0** event (**S0**) and the subsequent deployment of the initial "pilot" parachute.

FIGURE 4.4.3-3 TVT RE-PROGRAMMABLE DATA

4.4.3-2-5 Altitude Determination

The POSW determines the altitude of the Probe every two seconds during the Mission. The resultant altitude is included in the DDB and transmitted to the Experiments. Prior to T0 detection, the altitude reported in the DDB has no significance and is set to the maximum value of 327,680 Km.

Once T0 detection has occured, POSW determines the current altitude of the Probe from either hardware sensors or the Time/Altitude lookup tables. This calculation is performed regardless of the current mission phase. POSW will therefore indicate that the Probe is descending during both the Final Descent and the in-flight checkouts, if the Probe is Post-T0.

The nominal descent time of the Probe is 2.5 hours. During this time, POSW calculates three altitudes, and selects the most suitable for inclusion into the DDB. The first altitude is derived from the Time/Altitude table and is known as the TAT predicted altitude. The second and third altitudes originate from radar altimeters fitted to the Probe. These radar altimeters will only return healthy data during the latter stages of the Descent. Once the software has determined all three altitudes, a comparison technique is used to select the most reliable reading for the DDB.

Time/Altitude Table

The Time/Altitude table is a re-programmable table which is contained in S/W. The TAT describes the anticipated altitude of the Probe as a function of Mission Time, and consists of ninety sampling points. This table may be modified by software patching. The default TAT data set included in the S/W is given in § 4.4.4-3-4. A logical representation of the TAT is given in Figure 4.4.3-4.

Record Number (1 to 90)	Mission Time (CUT Number)	Altitude (Decameters)
01	0	16480
02	2691	13760
03	3411	13310
—	—	—
—	—	—
88	64611	94
89	65331	47
90	66067	0

where:

Mission Time = Number of elapsed CUTs since T0 detection, where each CUT represents 125ms. Hence record 02 defines the anticipated altitude of the Probe 5 minutes, 36.375 seconds after T0 detection.

Altitude = Anticipated altitude of the Probe in decameters. This altitude is an unsigned 15 bit integer and shall therefore be positive and range from 0 to 32767 decameters inclusive.

FIGURE 4.4.3-4 TAT LOGICAL REPRESENTATION

Time/Altitude Table Restrictions

Several restrictions are placed on the data values incorporated into the TAT by the POSW altitude algorithm. Any software patches uplinked during the operational lifetime of the Probe must obey these restrictions. Incorrect altitudes will arise if these restrictions are not adhered to. These restrictions are:

1• The first record in the TAT, record 1 must contain a Mission Time of zero
2• All Mission Time data must be chronogically ordered, with no duplicate values
3• All altitude data must be specified in descending order, with no duplicate values
4• The last record in the TAT, record number 90 must contain an altitude of zero

Time/Altitude Table Processing

The POSW uses the TAT to predict the altitude of the Probe every 2 seconds. This TAT altitude prediction is made regardless of whether healthy radar altimeter data is available or not. The predicted TAT altitude is subsequently used when selecting an altitude for inclusion in the DDB. POSW calculates the predicted TAT altitude by simple linear interpolation of the table. However, two indexing modes are used to interpolate the table:

• **Mission Time Indexing:** The time indexing mode is used during the majority of the Descent, whilst an altimeter reading has not been selected for inclusion in the DDB. Under this method the predicted altitude is calculated by simple linear interpolation of the TAT based upon the current Mission Time. This indexing mode is also used whenever a discontinuity in Mission Time arises. Such discontinuities occur whenever the Mission Time is explicitly set by a Resume TC or T0 is detected.

• **Altitude Indexing:** Altitude indexing is only used once an altimeter reading has been selected for inclusion in the DDB. [redacted] Under this method linear interpolation of the TAT is used with the last altitude reported in the DDB being the index into the table. Hence the resultant altitude prediction is a simple linear interpolation of the TAT based on the last DDB altitude. However this last DDB altitude may have originated from either the radar altimeters or the TAT.
Note that the altitude indexing is advantageous as the altitude calculated by the TAT will be normalised whenever a valid radar altimeter reading is received. Consequently altitude discrepancies between the TAT and radar altimeters are resolved. All future predictions from the TAT will commence from the radar altimeter altitude but follow the original glide slope predicted by the TAT.

Radar Altimeters

Two radar altimeters or proximity sensors are fitted to the Probe. These radars are named altimeter A and B, and are connected to the OBDH bus for communications. POSW acquires fresh data from each altimeter every 2 seconds, regardless of the mission phase or whether the altimeters are energised. However the altimeters will only give locked readings during the latter stages of the Descent phase when the distance from the Probe to Titan's surface is sufficiently small.

The altimeters return a 16 bit data word, where one bit indicates the altimeter lock state and the remaining 15 bits give the altitude in meters. POSW performs several checks on this raw data to determine the health of the acquiring reading. These checks must overcome spurious readings which occur if the altimeter is interrogated twice in quick succession, and false locks which may occur above 33 Km. These checks are:

1• Confirmation that the altimeter has been locked for two consecutive readings

2• Confirmation that the absolute difference in altitude between the two consecutive readings is within limits. These limits are specified by the re-programmable data items, INF and SUP. The values of INF and SUP are given in § 4.4.4-3-4. However the S/W currently uses INF as 4 meters and SUP as 2000 meters. Hence the S/W currently confirms that the absolute difference in altitude of two consecutive altimeter readings lies in the range 4 to 2000 meters.

3• Confirmation that the Probe is within 25 Km of the surface of Titan. This check is implemented based upon mission time, and POSW invalidates any altimeter readings acquired before a THRESHOLD time. This time is a re-programmable data item and the current value is given in § 4.4.4-3-4. Although this check is implemented as a time-based mechanism, the functionality is logically associated to a reference height of 25 Km. This height is determined from the electrical and magnetic characteristics of the radar altimeters.

Warning: the re-programmable data item THRESHOLD must be updated whenever the TAT is patched. This THRESHOLD must represent the mission time at which the Probe descents to within 25 Km of the surface of Titan.

These checks confirm that validity of two consecutive readings, or a "reading pair". However detailed failure mode analysis of the altimeters has identified a "plausible" failure mode where invalid altimeter data would be accepted by POSW. This failure arises if single bit corruption of the lock state occurs whilst the altimeters are frequency scanning in "acquisition mode".

To safeguard against this failure mode, the POSW simultaneously analyses five consecutive readings. This is achieved by executing the validity checks described above on four "reading pairs". The current altimeter reading is subsequently considered healthy when all four "reading pairs" have successful passed validation.

In summary, the POSW validates both sets of altimeters readings independently. The resultant health state and altimeter reading are subsequently used to select an appropriate altitude for inclusion in the DDB.

Selection of the DDB Altitude

POSW selects a suitable altitude for inclusion into the DDB every 2 seconds. The selected DDB altitude is transmitted to the Experiments along with a flag which indicates whether the selected reading originated from the TAT or radar altimeters. The format of the DDB is given in Figure 4.4.3-2.

The S/W uses a comparison technique to select the most reliable altitude for inclusion into the DDB. This technique uses the TAT predicted altitude and the conditioned radar altimeter data as inputs. These altitudes are compared and validated against the pre-defined limits, DELTA_1, DELTA_2 and EPSM. These limits are re-programmable data items and their values are given in § 4.4.4-3-4. The DDB altitude selection logic is shown in Figure 4.4.3-5.

Key for Figure 4.4.3-5 DDB Altitude Selection Logic are:

Altimeter Health Status	Flag indicating the validity of readings acquired from the altimeters; see **Radar Altimeters** here above
DDB Altitude	Altitude reading incorporated into the DDB. This reading is given in decameters and ranges from 0 to 32767 decameters
DDB Flag	Flag incorporated into the DDB. This flag indicates whether the DDB altitude originated from the TAT or radar altimeters
A	Altimeter A reading, in meters
B	Altimeter B reading, in meters
T	TAT predicted altitude in meters
DELTA_1	The fixed term limit used in the calculation to bound the allowable deviation of a single altimeter reading from the TAT predicted altitude for the initial selection of altimeter sensor data only. This limit is re-programmable and specified in meters
DELTA_2	The variable term limit used in the calculation to bound the allowable deviation of a single altimeter reading from the TAT predicted altitude. This limit is re-programmable and specified as a ratio of the TAT predicted altitude.
EPSM	Factor used during the evaluation of altimeter data when both altimeters are healthy. This factor is dimensionless

D3

Altimeter A Health	Altimeter B Health	Selection Logic	DDB Altitude	DDB Flag
Unhealthy	Unhealthy	Use TAT predicted altitude	TAT Altitude	TAT derived
Healthy	Unhealthy	Use Altimeter A when the absolute difference between Altimeter A and the TAT predicted altitude is less than or equal to DELTA. Mathematically |A-T| <= DELTA, where DELTA = DELTA_1 + DELTA_2 * TAT for the initial selection of altimeter data and DELTA = DELTA_2 * TAT for all subsequent calculations. DELTA_1 and DELTA_2 are re-programmable and are currently set to 5000m and 0.15 respectively.	Altimeter A	Altimeter derived
		Use TAT predicted altitude when the absolute difference between Altimeter A and the TAT predicted altitude is greater than DELTA. Mathematically |A-T| > DELTA, see above for calculation of DELTA.	TAT Altitude	TAT derived
Unhealthy	Healthy	Use Altimeter B when the absolute difference between Altimeter B and the TAT predicted altitude is less than or equal to DELTA. Mathematically |B-T| <= DELTA, see above for calculation of DELTA.	Altimeter B	Altimeter derived
		Use TAT predicted altitude when the absolute difference between Altimeter B and the TAT predicted altitude is greater than DELTA. Mathematically |B-T| > DELTA, see above for calculation of DELTA.	TAT Altitude	TAT derived
Healthy	Healthy	Use average altimeter reading when the absolute difference between Altimeter A and Altimeter B is less than or equal to the average altimeter reading multiplied by EPSM. EPSM is a re-programmable factor which is currently set to 0.1. Mathematically |A-B| <= EPSM * (A + B)/2.	Average of Altimeter A and Altimeter B	Altimeter derived
		Use Altimeter A when the absolute difference between Altimeter A and Altimeter B is greater than the average altimeter reading multiplied by EPSM (0.1) and Altimeter A is nearest to the TAT predicted altitude. Mathematically |A-B| > EPSM * (A + B)/2 and |A-T| <= |B-T|.	Altimeter A	Altimeter derived
		Use Altimeter B when the absolute difference between Altimeter A and Altimeter B is greater than the average altimeter reading multiplied by EPSM (0.1) and Altimeter B is nearest to the TAT predicted altitude. Mathematically |A-B| > EPSM * (A + B)/2 and |A-T| > |B-T|.	Altimeter B	Altimeter derived

FIGURE 4.4.3-5 DDB ALTITUDE SELECTION LOGIC

Altitude Reporting During the Titan Encounter

In summary, the altitude of the Probe is communicated to the Experimental Payload via the DDB. The DDB altitude is accompanied by a flag which indicates whether the value originated from the TAT or radar altimeters.

During the early stages of the Descent, when the Probe is above 25 Km, the DDB altitude will originate solely from the TAT. As such the DDB altitude will represent a height above a reference datum, for example "sea level" and will always decrease with time. The DDB altitude will simply follow the Descent profile described by the TAT.

During the latter stages of the Descent, when the Probe is below 25 Km, the DDB altitude may originate from either the TAT or radar altimeters. As such the DDB altitude will represent the height of the Probe above the surface of Titan. The DDB altitude may increase and decrease during this stage of the Descent as the Probe drifts across surface features. This is particularly relevant as current atmospheric models of Titan estimate the variation of surface topology as ± 2 Km.

Furthermore a large discontinuity or "jump" in the reported altitude may occur when the first altimeter based reading is incorporated into the DDB. This "jump" arises due to any inaccuracies in the predicted descent profile described by the TAT. The discontinuity represents the transition from theoritical estimation to scientific measurements and may result in either a sharp increase or decrease in the reported altitude.

Finally note that many key data items used in altitude processing are re-programmable. These data items are summarised in Figure 4.4.3-6.

Altitude Telemetry

The HK telemetry generated by the POSW contains two parameters for monitoring the altitude algorithm. These parameters are the raw proximity sensor readings, and the altitude reported in the DDB. For details see § 4.4.3-4-3 **Time Buffering of DDB HK Parameters.**

Furthermore the altitude prediction calculated from the TAT, may be derived from telemetry by using the Mission Time counter and DDB altitude.

D3

Name	Units	Data Type	Functional Area	Description
TAT (Timing Data)	CUTs (Mission Time)	Integer (24 bit) (0 to 16777215)	Time/Altitude Table	The TAT timing data. The anticipated descent profile of the Probe is described in a tabular format by 90 sampling points. This timing data is expresses in Mission Time and represents arbitrary points on the profile.
TAT (Altitude Data)	Decametres	Integer (15 bit) (0 to 32767)	Time/Altitude Table	The TAT altitude data. The altitude data represents the predicted altitude of the Probe for the given Mission Time.
INF	Metres	Integer (15 bit) (0 to 32767)	Radar Altimeters	Lower limit for the altimeter range check. Altimeter data is only considered healthy if the absolute difference in altitude of two consecutive proximity sensor readings is greater than or equal to this limit.
SUP	Metres	Integer (15 bit) (0 to 32767)	Radar Altimeters	Upper limit for the altimeter range check. Altimeter data is only considered healthy if the absolute difference in altitude of two consecutive proximity sensor readings is less than or equal to this limit.
THRESHOLD	CUTs (Mission Time)	Integer (24 bit) (0 to 16777215)	Radar Altimeters	Time until which all proximity sensor data will be automatically invalidated. The data returned by proximity sensors is only considered reliable after the THRESHOLD mission time. This THRESHOLD equates to a distance of 25 Km.
DELTA_1	Metres	Real number (6 significant figs)	DDB Selection Logic	The fixed term used in the calculation of the allowable variation in altitude between a single validated proximity sensor reading and the TAT predicted altitude. Used in the calculation for the initial selection of altimeter data only. Proximity sensor readings in excess of the allowable tolerance are ignored.
DELTA_2	None	Real number (6 significant figs)	DDB Selection Logic	The variable term used in the calculation of the allowable variation in altitude between a single validated proximity sensor reading and the TAT predicted altitude. Used in the calculation for all altimeter value verifications. Proximity sensor readings in excess of the allowable tolerance are ignored.
EPSM	None	Real number (6 significant figs)	DDB Selection Logic	Evaluation factor used to assess the validity of "averaged" proximity sensor data. Averaged proximity sensor data is produced when both altimeters are generating valid readings.

FIGURE 4.4.3-6 ALTITUDE RE-PROGRAMMABLE DATA

4.4.3-2-6 Spin Rate Determination

The POSW determines the angular velocity of the Probe every 2 seconds during the Mission. The resultant angular velocity is included in the DDBs and transmitted to the Experiments. The angular velocity is calculated regardless of T0 and has significance in the Entry and Descent Phases of the Mission. The angular velocity of the Probe is also known as the Spin Rate or DDB Spin.

The CDMS contains two radial accelerometers which measure the centipetal forces experienced by the Probe during the Mission. These accelerometers form the radial accelerometer sensor unit (RASU) and the raw readings are used by the POSW to calculate the DDB spin. The algorithm used to determine the angular velocity of the Probe is based upon elementary mechanisms and is essentially:

$$a = r\omega^2$$

where:

- a = Radial acceleration of an imaginary point n. On the Probe, this value is measured by the RASU, and is given in m/s^2.
- r = Radial offset of the imaginary point n from the spin axis. On the Probe, this value represents the physical distance between the RASU and the spin axis. This is given in meters.
- ω = Angular velocity of the imaginary point n. On the Probe, this value is calculated via the Spin algorithm.

Spin Algorithm

The POSW executes the Spin algorithm every 2 seconds during the Mission. This algorithm uses radial accelerometers and re-programmable constants as input data, and determines the angular velocity of the Probe. The resultant angular velocity is converted to units of 0.1 revolutions per minute and reported in the DDB.

The Spin algorithm is however unusual, due to its dependency on the CDMS hardware chain and the existence of a number of processing sub-frequencies. Each hardware/software chain acquires a single dedicated accelerometer reading each CUT, and independently executes the algorithm using re-programmable data specific to that hardware/software chain. A walkthrough of the Spin algorithm which details all of the re-programmable constants used follows:

1• Each hardware/software chain interrogates the RASU and acquires a fresh radial accelerometer reading each CUT. This accelerometer reading is denoted as V1, and is acquired via the OBDH bus. However the data returned by the RASU will originate from different radial accelerometers for each chain. The RASU contains one radial accelerometer dedicated to Chain A, and one radial accelerometer dedicated to Chain B.

2• The raw accelerometer reading is scaled and filtered to produce the intermediate value E1. This processing is chain dependent. The re-programmable constants A1n, B1n, C1n and D1n are used by the filter where n denotes the hardware chain. The initial values of these re-programmable data items are given in § 4.4.4-3-5. The filtering algorithm used to scale and condition the inputs is shown below where the suffix n represents the hardware chain:

$$E1 = A1n + V1 * [B1n + V1 * (C1n + V1 * D1n)]$$

The software currently sets the re-programmable data items A1A, A1B, C1A, C1B, D1A and D1B to zero, such that the filtering algorithm collapses to E1 = V1 * B1n. All re-programmable B1n values are set to 0.004_705_882 m/s^2 which means a full range reading of 255 is scaled to 1.2 m/s^2.

3• The scaled and filtered accelerometer reading, E1 is used to produce the intermediate value, F1. This intermediate value is the arithmetic mean of all E1 values generated during the last two seconds. As such the intermediate value F1 represents the two second average of the conditioned accelerometer inputs. In mathematical terms F1 is given by:

$$F1 = [E1(-1) + E1(-2) + ... + E1(-16)]/16$$

The suffixes (-1), (-2) and (-16) refer to the E1 values calculated 1, 2 and 16 CUTs ago respectively. The intermediate value F1 is calculated each CUT, and as such this processing is not chain dependent. The raw E1 values used however, vary from chain to chain due to earlier processing.

4• The intermediate value F1 is used to produce the final accelerometer value, G. This final value is the arithmetic mean of all F1 values generated during the last 128 seconds. As such the final value, G represents the conditioned accelerometer inputs averaged over 128 seconds. In mathematical terms, G is given by:

$$G = [F1(-16) + F1(-32) + ... + F1(-1024)]/64$$

The suffixes (-16), (-32) and (-1024) refer to the F1 values calculated 16, 32 and 1024 CUTs ago respectively. The final value G is only calculated each 2 seconds or 16 CUTs, and as such this processing is not chain dependent. The raw F1 values used however, vary from chain to chain due to earlier processing.

5• The angular velocity of the Probe is calculated using the conditioned accelerometer data, G, and re-programmable constants RA and RB as inputs. The two re-programmable data items RA and RB represent the offset of the radial accelerometer from the Probe's spin axis for Chain A and Chain B respectively. The initial values of these re-programmable data items are given in § 4.4.4-3-5.

The algorithm used to calculate the angular velocity ω is given below, where n denotes the processing chain:

$$\omega = SQRT(|G| / Rn)$$

The angular velocity is calculated every 2 seconds by POSW and is given in radians per second.

6• The angular velocity, ω is converted into suitable units for inclusion in the DDB using re-programmable data items, K1 and K2. Data item, K1 is a scaling factor which converts the angular velocity, ω into units of 0.1 revs/min. Data item, K2 is simply an offset which is applied to the result. The initial values of these re-programmable data items are given in § 4.4.4-3-5. The algorithm used to calculate the DDB spin is:

$$DDB\ Spin = Nearest\ Integer\ value\ of\ (\omega * K1 + K2)$$

The DDB Spin which results from this algorithm is saturated to zero when $\omega * K1 + K2 \leq 0.0$, and saturated to 255 when $\omega * K1 + K2 \geq 255.0$. The resultant DDB Spin which is in units of 0.1 revs/min is included in the DDB and transmitted to the Experiments.

In summary, the spin rate of the Probe is derived from a chain dependent algorithm and dedicated hardware sensors. Under nominal operating conditions the DDB Spin calculated by both hardware chains should be identical. Many of the key data items used in the spin algorithm are re-programmable and chain dependent. These patchable data items are grouped into a table known as the SVT. The content of the SVT is summarised in Figure 4.4.3-7.

Name	Units	Data Type	Functional Area	Description
A1A and A1B	m/s^2	Real number (6 significant figs)	Radial Accelerometer Data Scaling	Constants used to scale and filter the raw accelerometer data
B1A and B1B	m/s^2 CAN	Real number (6 significant figs)	Radial Accelerometer Data Scaling	Constants used to scale and filter the raw accelerometer data
C1A and C1B	m/s^2 CAN^2	Real number (6 significant figs)	Radial Accelerometer Data Scaling	Constants used to scale and filter the raw accelerometer data
D1A and D1B	m/s^2 CAN^3	Real number (6 significant figs)	Radial Accelerometer Data Scaling	Constants used to scale and filter the raw accelerometer data
RA	Metres	Real number (6 significant figs)	Angular Velocity Calculation	The distance of the Chain A radial accelerometer from the spin axis of the Probe. This data is pre-set by the physical mounting of the RASU on the spacecraft structure
RB	Metres	Real number (6 significant figs)	Angular Velocity Calculation	The distance of the Chain B radial accelerometer from the spin axis of the Probe. This data is pre-set by the physical mounting of the RASU on the spacecraft structure
K1	CAN Seconds	Real number (6 significant figs)	DDB Spin Scaling	Numerical constant used to scale the angular velocity from radians per second to units of 0.1 revolution per minute.
K2	CAN	Real number (6 significant figs)	DDB Spin Scaling	Numerical constant used to offset the spin rate reported in the DDB. This data item is specified in CANs, where each CAN represents 0.1 revolution per minute.

FIGURE 4.4.3-7 SVT RE-PROGRAMMABLE DATA

Spin Telemetry

The HK telemetry generated by the POSW contains two parameters for monitoring the spin algorithm. These parameters are the raw radial accelerometer readings acquired from the RASU, and the subsequent angular velocity reported in the DDB. For details see § 4.4.3-4-3 **Time Buffering of DDB HK Parameters.**

4.4.3-2-7 Experiment Polling Swapping Operation

The POSW provides a prioritised scheme for collection of scientific data from the Experiment, through the Experiment Polling Tables (EPTs). The tables define the sequence for polling the experiments for data which is then included in the telemetry frames which are returned by the POSW.

In order to allow for changes in the experiment reporting rates during the Descent, three EPTs, known as EPT_1, EPT_2 and EPT_3 and two EPT swap times are provided. These EPT swap times, EPT_SWAP_1 and EPT_SWAP_2 define the Mission Time at which the change is made from EPT_1 to EPT_2 and from EPT_2 to EPT_3 respectively.

For details of the operation of these tables in respect of the overall telemetry function and the details of the swap functionality, see § 4.4.3-4-2 **Experiment Polling Tables**.

4.4.3-3 Telecommand Management

The Probe may be remotely telecommanded from ground whilst the umbilical cord which connects to the Cassini orbiter is intact. This umbilical is the data interface between the Probe and the Orbiter during the Launch, Cruise and Saturn Orbit phases of the Mission. Once the probe separates from Cassini Orbiter, the umbilical lead is severed and no telecommanding ability exists. The POSW includes functionality to receive, validate and execute ground issued TCs.

Telecommands are forwarded to the Probe over the umbilical cord and deposited in the TC FIFO in the CDMU hardware. The POSW subsequently detects, retrieves and actions these TCs in accordance with their type. A two stage mechanism is used to verify the authenticity of the received data. The initial stage is applied globally to all TCs and confirms the destination and basic format of the TC is correct. In addition TCs destined for the CDMU are checked for data corruption through use of a cyclic redundancy check. The second stage of the validation mechanism is type specific.

A count of the "Valid" and "Invalid" TCs received by the software is maintained such that TC reception and verification may be monitored. These counters are reported in housekeeping telemetry as the "valid TC counter" and "invalid TC counter" respectively. The counters are set to zero on POSW initialisation, [redacted]. The TC types supported by POSW are shown below:

- Alteration telecommand. This command permanently updates the "DDB spin" or "DDB mission phase" to the uplinked value.

- Direct telecommand. This command instigates execution of the uplinked ON/OFF or Memory Load command on the OBDH bus.

- Dump telecommand. This command instigates a Dump of either EEPROM or RAM and results in dump telemetry being transmitted to the ground. This command allows the manual inspection of memory.

- Experiment telecommand. These commands are destined for HUYGENS Experiments and are simply transmitted over the OBDH bus by POSW.

- Inhibition telecommand. This command is only valid during software initialisation in a pre-defined time window. If received the command inhibits the application of data patches to RAM.

- Load MTT telecommand. This command modifies the contents of the Pre-T0 Mission Timeline Table which is currently being executed.

- Patch telecommand. This command stores the uplinked patch data into EEPROM, and permits the reprogramming of the POSW.

- Suspend/Resume telecommand. This command suspends or resumes the mission time maintained by POSW accordingly. The Resume TC may be used to declare the T0 event during in-flight checkouts.

Cassini Restrictions on Telecommands

All telecommands uplinked to the Probe are forwarded to POSW by the Probe Data Relay subsystem, which in turn receives the commands from the Cassini Orbiter. However several transmission paths are available in the Cassini Command and Data Subsystem, including the "CDS direct path". In general, the transmission path used places no restrictions on telecommands destined for the Probe. The "CDS direct path" however, restricts the maximum size of the telecommand to 121 words, and consequently all telecommands destined for either POSW or SASW must be limited to 121 words if the "CDS direct path" is used.

> **Warning**: The maximum size of all telecommands destined for both POSW or SASW shall be limited to 121 words, if the "CDS direct path" is used as the transmission medium on board the Cassini Orbiter.

4.4.3-3-1 Rate and Timing of Telecommand Execution

In general, the POSW is capable of processing one telecommand each CUT. However commands which arrive in the TC FIFO in one CUT are not actioned immediately, but extracted and executed in the following CUT. This measure ensures that a complete telecommand is always extracted from the TC FIFO, thereby avoiding data truncation. The initial wait of one CUT allows sufficient time for a complete TC of 128 words to be downloaded via the umbilical cord before any attempt at extraction is made. The PDRS requires 16.4 ms to transmit a complete 128 word TC over the umbilical cord.

As stated the majority of telecommands are extracted from the TC FIFO and processed in a single CUT. However hardware restrictions and performance considerations prevent some telecommands being processed in a single CUT. The Dump telecommand may require several CUTs to complete as one Dump command may require the generation of numerous dump telemetry packets. Similarly the Patch telecommand may require several CUTs to complete as only one word of data is written to EEPROM per CUT. This arises as a 10 ms interval is required between successive writes to EEPROM by the CDMU hardware. **Whilst either a Dump or Patch telecommand is being processed all other telecommands will be rejected.** This rejection applies to all telecommands regardless of whether they were destined for a HUYGENS Experiment or POSW.

> **Warning**: All telecommands will be rejected by POSW if a Patch or Dump telecommands is being processed. This rejection applies equally to commands destined for POSW or for Experiment.

4.4.3-3-2 Telecommand Startup in Mission Mode

Nominal telecommand processing will commence on entry into Mission Mode, when POSW has completed the start-up sequence. The transition into Mission Mode occurs 15 seconds after the Probe is powered ON, and the TC FIFO may contain several TCs at this juncture. The queue of telecommands in the TC FIFO will generally be processed at a rate of one telecommand per CUT, as described in § 4.4.3-2-1. However the detection, extraction and processing of telecommands requires two CUTs and consequently the telecommand uppermost in the TC FIFO will be processed in the second CUT of Mission Mode (CUT 1). This feature imposes an operational limitation on the system and the following restrictions are identified:

- **Alteration Telecommand Constraint.** The values of "DDB spin" & "DDB Mission phase" incorporated into the first DDB (issued at CUT 0) cannot be modified by Alteration TC.

- **Suspend/Resume Telecommand Constraint.** The mission time cannot be suspended by the Suspend/Resume TC in the first CUT (MT counter 0). Consequently the execution of any time-tagged commands in the Pre-T0 MTT (scheduled for MT counter 0) cannot be prevented. Furthermore as MTT processing preceeds the processing of telecommands within a CUT, the execution of any time-tagged commands in the Pre-T0 MTT (scheduled for MT counter 1) cannot be prevented.

- **Load MTT Telecommand Constraint.** The Pre-T0 MTT cannot be modified by the Load MTT TC during the first CUT of Mission Mode. Furthermore as MTT processing preceeds the processing of telecommands within a CUT, the earliest time at which a time-tagged command introduced by the Load MTT TC can be executed is the third CUT of Mission Mode (MT counter 2).

- **Dump, Patch and Direct Telecommands Constraints.** During the first CUT of Mission Mode POSW cannot dump memory, store patch data into EEPROM or execute additional commands on the OBDH bus by the Dump, Patch & Direct TCs respectively.

4.4.3-3-3 CDMU Application Process Identifiers

The POSW receives and processes telecommands destined for the CDMU independently of the hardware chain. Thus telecommands which have the "CDMU A" application process identifier can be processed by either hardware chains A or B. Similarly telecommands carrying the "CDMU B" application process identifier can also be actioned by either hardware chains A or B. This approach ensures that telecommands forwarded to POSW are actioned, even if the incorrect delivery chain is used. This error may arise from flight operations or incorrect hardware wiring.

Telecommands despatched to POSW however, will only be actioned by a single chain as the incoming telecommand is only delivered to one TC FIFO. There is no hardware cross strapping. Consequently the ground is responsible for maintaining symmetry between the two chains during telecommanding operations. Under the circunstance where chain asymmetry is required, ground must ensure that the required telecommand is only deposited into the TC FIFO of the desired chain. It is foreseeable that chain asymmetry will be necessary to overcome particular hardware faults on individual chains, where the selective application of patch telecommands may be the solution.

4.4.3-3-4 Inhibition Telecommand Handling

An Inhibition TC may be sent to the POSW during initialisation mode to prevent the application of software patches to main memory. This TC is designed to permit "recovery" of the Probe whenever fatal or erroneous software patches are present in EEPROM. On receipt of a valid inhibition TC, POSW will execute the functionality contained in PROM only.

An Inhibition TC must be received during a pre-defined time window in the start-up sequence to be valid. The time window for reception of an Inhibition TC is 6.5 to 9.5 seconds after CDMU power ON. For maximum reliability it is recommended that the Inhibition TC is sent 8 seconds after CDMU power ON. This recommended time is mid-point between two data extractions from the hardware TC FIFO and thus gives the maximum lee-way. Under no account must the Inhibition TC be transmitted within the first 2 seconds after CDMU power ON. Failure to obey this restriction will result in all TCs being rejected until the hardware TC FIFO is emptied.

The check for an Inhibition TC is simple and efficient, to ensure the maximum reliability. To this end, data is always extracted from the TC FIFO during start-up and inspected for the presence of an Inhibition TC. This occurs regardless of whether a telecommand had been received by the CDMU or not, and thus removes the dependence on the hardware control port and associated software. However, this approach will always result in either the "valid TC counter" or the "invalid TC counter" being incremented on start-up, even during the Descent onto Titan. Figure 4.4.3-8 indicates the significance of the TC counters after system start-up.

INHIBITION TELECOMMAND STATUS	VALID TC COUNT (absolute value)	INVALID TC COUNT (absolute value)
No TC received up until 9.5 seconds after start-up. This represents the status for the actual Entry/Descent mission, where no telecommanding ability exists.	0	1
TC received but failed packet layout checking. This TC may be an incorrectly formatted Inhibition TC, or any other "Mission Mode" TC.	0	1
Inhibition TC received and passed layout checking, but failed application data field check. Inhibition TC contained incorrect inhibition data.	1	1
Inhibition TC sent and correctly validated. Patching of main RAM will be inhibited, for this CDMU power up.	2	0

FIGURE 4.4.3-8 TELECOMMAND COUNTERS POST START-UP

To summarise RAM patching will be prevented if a valid Inhibition TC is present in the TC FIFO, 9.5 seconds after CDMU power ON. This Inhibition TC must be correctly encoded and the first word of the telecommand header must reside at the top of the TC FIFO. POSW will make a single attempt to identify and execute this telecommand at 9.5 seconds. If this attempt is unsuccessful, no secondary attempt is made and RAM patching will not be inhibited.

4.4.3-4 Telemetry Management

The Probe transmits a stream of telemetry to the Cassini Orbiter in all phases of the Mission, except for the Coast and Entry Phases. However different hardware transmission mechanisms are used to achieve this. Whilst the Probe is connected to the Orbiter in the Launch, Cruise and Saturn Orbit phases, telemetry is transmitted via the umbilical link. Once the Probe has separated from the Orbiter, TM is transmitted via a radio link. However this radio link is not established until the Probe Back Cover is jettisoned and the high power amplifier is powered. Consequently no TM transmission is possible during the Coast and Entry phases. The radio link is established after Entry into Titan's atmosphere and TM is recovered for the Descent and Surface phases. The management of these transmission mechanism is performed by the PDRS, independently of the software. As such POSW has an identical data interface for all of the Mission phases.

The POSW generates TM on both hardware chains simultaneously, giving an overall data rate of 16384 bits per second for the Probe. Both processing chains produce a transfer frame each second, where the frame size is fixed at 512 words. The transfer frame contains a synchronisation marker, a transfer frame header, seven TM packets and Reed Solomon data. The seven TM packets originate from the Experimental Payload and/or POSW, with the data packets containing scientific and spacecraft health data respectively. The TM packet types supported by POSW are summarised below:

- **Experiment packets.** These packets contain scientific data from the HUYGENS experiments. These packets are acquired over the OBDH bus and incorporated into telemetry without modification by POSW. Experiment packets originate from five of the Experiments, and are treated as simple blocks of data by the S/W.

- **Housekeeping packets.** Housekeeping packets contain spacecraft health information and are generated by POSW each 4 seconds. The S/W generate four packet sub-types or variants which are HK1, HK2, HK3 and HK4. Each packet variant has a preset format and contains POSW/CDMS housekeeping data. This information may be used to determine the serviceability of the probe.

- **Report packets.** These packets are generated by POSW when no experimental data is available. They contain a limited number of key CDMS housekeeping parameters.

- **Dump packets.** These packets are generated in response to Dump telecommands, and replace experiment/report packets in TM. They contain the requested dump of either RAM or EEPROM.

4.4.3-4-1 Telemetry Start-up

The emission of telemetry transfer frames will commence as soon as the Probe is powered ON. However uninitialised and partially complete transfer frames will be emitted prior to steady state telemetry operations be achieved. These uninitialised and partially complete transfer frames are a consequence of system startup and are determinate. The transitional effects to overcome during telemetry start-up are:

- POSW initialisation mode activity (15 seconds from Power ON).
- Establishing the 6 second telemetry delay on CDMU chain B.
- Initial acquisition of all data parameters over the 16 second major cycle.
- Establishing the 6.4 minute delay in the issuing of HK 4 packets.

All uninitialised ransfer frames may be identified by examination of the ESA telemetry transfer frame header. These uninitialised transfer frames will contain incorrect transfer frame header details and many fields such as the spacecraft identifier will be erroneous. Conversely partially complete frames will contain the correct header details and may thus be distinguished from their uninitialised counterparts. The first partially complete transfer frame issued by the S/W will contain a source sequence count of zero. A partially complete frame contains a combination of initialised and uninitialised telemetry data packets. All data packets issued by the POSW will contain valid packet header details, where the initial packets will have a source sequence count of zero.

However many of the uninitialised transfer frames will not be received by ground due to the constraints introduced by other S/S. During in-flight checkouts TM will not be available until the Probe's Transmitter is powered ON, and the PSA has synchronised with the incoming TM data stream. This will occur at ≈ 18 seconds after the Probe is energised. However for the Titan encounter TM will not be available until both the Probe's Transmitter and High Powered Amplifier are energised, the Back Cover has been jettisoned and the PSA has synchronised with the incoming data stream. Therefore it is likely that no transitional effects will be detected by the ground during the Entry/Descent mission. Figure 4.4.3-9 describes the transitional effects present in TM assuming full collection of TM from power ON.

TIME (seconds)	FRAMES EMITTED	EVENT	CHAIN A telemetry status	CHAIN B telemetry status
0 to 15	1 to 15	CDMU Power On (Initialisation Mode)	"Dummy" or uninitialised frames, which contain: • CDMU synchronisation marker • Uninitialised frame header, packet headers and data, which is zero • CDMU reed solomon encoding	"Dummy" or uninitialised frames, which contain: • CDMU synchronisation marker • Uninitialised frame header, packet headers and data, which is zero • CDMU reed solomon encoding
15 to 16	16	First telemetry interrupt (Mission Mode)	Uninitialised frames, which contain: • CDMU synchronisation marker • Uninitialised frame header, packet headers and data, which is set to random pattern • CDMU reed solomon encoding	Uninitialised frames, which contain: • CDMU synchronisation marker • Uninitialised frame header, packet headers and data, which is set to random pattern • CDMU reed solomon encoding
17 to 31	17 to 31	Acquiring initial set of data for the HK packets. The first execution of the major acquisition requires 16 seconds from mission mode entry	Initialised frames, with uninitialised data due to 16 second acquisition cycle. Frames contain: • CDMU synchronisation marker • Initialised frame header, packet headers but with incomplete housekeeping data. • CDMU reed solomon encoding	Chain B TM delay is now established. The first frame generated by POSW is sent seven times. The remaining TM startup is identical to that for Chain A, except offset by 6 seconds
32 to 412	32 to 412	Establishing HK 4 delay	Initialised frames with correct packet data, but no HK 4 delay. Frames contain: • CDMU synchronisation marker • Initialised frame headers, packet headers and data but "live HK" 4 packets • CDMU reed solomon encoding	
413 onwards	413 onwards	HK4 delay established. The "live" HK 4 packets are re-sent	Nominal operations established, the HK 4 data stream is re-sent. Frames contain: • CDMU synchronisation marker • Initialised frame header, packet header, data and delayed HK 4 • CDMU reed solomon encoding	

FIGURE 4.4.3-9 TELEMETRY FRAME START-UP

4.4.3-4-2 Transfer Frame Management

Each chain of the POSW generates a TM transfer frame each second. The frame is assembled over a one second period with TM packets being acquired for the first seven CUTs, and the transfer frame header details being completed in the eighth and final CUT. The selection of an appropriate type of TM packet to include in each of the seven data slots in the transfer frame is complex and managed by the polling sequence mechanism. This mechanism is based on a 16 second (128 CUT) major acquisition cycle and is data driven by the tables in POSW. The relevant tables are the Polling Sequence Table (PST) and the Experiment Polling Table (EPT).

Polling Sequence Table

The PST defines the telemetry action to be performed each CUT over the 16 second major acquisition cycle. The Table specifies the type of telemetry packet to load into each of the seven data slots of the transfer frame currently under construction, and the CUT in which to complete the frame header details. The table shares TM bandwidth between POSW and the Experiment payload, by simply specifying whether HK or Experiment packets are to fill each data slot. The PST does not specify from which experiment the data packet is to be collected. The allocation of TM bandwidth to individual Experiments is performed by the EPT.

The PST is a fundamental table within POSW and is **not re-programmable**. The table effectively defines 16 distinct transfer frame packet loads, from which the 16 second major acquisition cycle arises. Similarly the table also defines the format of the TM transfer frame, by virtue of the loading of seven data packets into each frame. A logical representation of the PST is given in Figure 4.4.3-10.

CUT	Transfer Frame Data Packet Slot							
cycle no	1	2	3	4	5	6	7	-
001 to 008	Expt	Expt	Expt	Expt	Expt	Expt	HK1	Nul
009 to 016	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
017 to 024	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
025 to 032	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
033 to 040	Expt	Expt	Expt	Expt	Expt	Expt	HK2	Nul
041 to 048	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
049 to 056	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
057 to 064	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
065 to 072	Expt	Expt	Expt	Expt	Expt	Expt	HK3	Nul
073 to 080	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
081 to 088	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
089 to 096	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
097 to 104	Expt	Expt	Expt	Expt	Expt	Expt	HK4	Nul
105 to 112	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
112 to 120	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul
121 to 128	Expt	Expt	Expt	Expt	Expt	Expt	Expt	Nul

where: Expt = Include an experiment data packet into the appropriate slot of the transfer frame currently under construction
HKn = Include an housekeeping n (n = 1 to 4) packet into the appropriate slot of the transfer frame currently under construction
Nul = Complete the transfer frame header details and move the completed frame into TM RAM to await transmission

FIGURE 4.4.3-10 PST LOGICAL REPRESENTATION

Experiment Polling Table

An EPT defines a prioritised mechanism for the collection of scientific data from the HUYGENS Experiments . The table is invoked whenever the PST requests experimental data for the transfer frame, and is read in an iterative manner. Under nominal conditions one complete iteration of the EPT should occur within the 16 second major acquisition cycle. The table data consists of a sequential list of the HUYGENS Experiments, with the number of occurences of each experiment in the table forming the polling priority or weighting. To permit the polling priorities to be modified during the Descent, three EPTs are defined in POSW with switching from one Table to the next occurring at pre-defined times. The EPTs effectively define the telemetry bandwidth allocated to each of the Experiments. A logical representation of an EPT 1 is given in Figure 4.4.3-11.

Index no:	Experiment from which to collect data						
001 to 006	DISR	HASI	SSP	DISR	DISR	DISR	-
007 to 013	DISR	GCMS	HASI	DISR	DISR	DISR	DISR
014 to 020	DISR	GCMS	HASI	DISR	DISR	DISR	DISR
021 to 027	DISR	GCMS	HASI	DISR	DISR	DISR	DISR
028 to 033	DISR	GCMS	HASI	DISR	DISR	DISR	-
034 to 040	DISR	DISR	GCMS	HASI	DISR	SSP	DISR
041 to 047	DISR	DISR	GCMS	HASI	DISR	DISR	DISR
048 to 054	DISR	DISR	GCMS	HASI	DISR	DISR	DISR
055 to 060	DISR	DISR	GCMS	HASI	DISR	DISR	-
061 to 067	DISR	DISR	DISR	GCMS	HASI	DISR	DISR
068 to 074	DISR	DISR	DISR	GCMS	HASI	DISR	DISR
075 to 081	SSP	DISR	DISR	GCMS	HASI	DISR	DISR
082 to 087	DISR	DISR	DISR	GCMS	HASI	DISR	-
088 to 094	DISR	DISR	DISR	DISR	GCMS	HASI	DISR
095 to 101	DISR	DISR	DISR	DISR	GCMS	ACP	DISR
102 to 108	DISR	DISR	DISR	DISR	DISR	DISR	GCMS

where: DISR = Collect a data packet from DISR this CUT. If no data is available from DISR, attempt to collect data from the next Experiment specified.
HASI, GCMS, ACP, SSP = same as DISR

FIGURE 4.4.3-11 EPT 1 LOGICAL REPRESENTATION

During nominal operations the complete transfer frames will contain housekeeping packets and experiment packets as dictated by the PST and EPT. This is the anticipated content of the transfer frames during the Descent onto the surface of Titan. However under specialised circumstances other types of telemetry packets may be present in the transfer frame. Report packets are generated whenever no scientific data is available from the Experiments. These replace Experiment packets within the transfer frame slot. Dump packets are produced in response to a Dump telecommand and also replace Experiment packets.

[redacted]

The EPTs and the table switching times are re-programmable data items, and a summary of the re-programmable data items is given in Figure 4.4.3-12. The initial data sets for EPT_1, EPT_2, EPT_3, EPT_SWAP_1 and EPT_SWAP_2 are given in § [redacted]

D3

Name	Units	Data Type	Functional Area	Description
EPT_1	None	Enumerated (Codes: HASI, SSP GCMS, DISR, ACP)	Experiment packet acquisition	Table allocating telemetry bandwidth to each of the Experiments, for the early stages of the Descent phase. (Upper atmosphere)
EPT_2	None	Enumerated (Codes: HASI, SSP GCMS, DISR, ACP)	Experiment packet acquisition	Table allocating telemetry bandwidth to each of the Experiments, for the middle stages of the Descent phase.
EPT_3	None	Enumerated (Codes: HASI, SSP GCMS, DISR, ACP)	Experiment packet acquisition	Table allocating telemetry bandwidth to each of the Experiments, for the latter stages of the Descent phase. (Lower atmosphere)
EPT_SWAP_1	CUTs (Mission Time)	Integer (24 bit) (0 to 16,777,215)	Experiment packet acquisition	Constant specifying the mission time at which to swap from EPT1 to EPT2.
EPT_SWAP_2	CUTs (Mission Time)	Integer (24 bit) (0 to 16,777,215)	Experiment packet acquisition	Constant specifying the mission time at which to swap from EPT2 to EPT3.

FIGURE 4.4.3-12 EPT RE-PROGRAMMABLE DATA

Transfer Frame Emission

The CDMU hardware manages the transmission of transfer frames to the Cassini Orbiter and ensures that a constant data stream is always emitted by the Probe. This occurs irrespective of whether POSW is providing data, and ensures that the radio relay with Cassini always remains locked and fully synchronised. The CDMU is also responsible for inserting the synchronisation marker and the Reed Solomon check symbols, and the data stream received by ground will only contain this hardware inserted information if POSW does not provide data.

The CDMU hardware raises a telemetry interrupt each second, when more data is required from POSW for transmission. This TMI is raised prior to the Reed Solomon encoding and indicates that a fresh transfer frame is required in the hardware managed TM FIFO within 125ms. The S/W simply loads a completed frame into the TM FIFO on the occurence of this interrupt. The completed frame is extracted from a S/W implemented telemetry buffer held in extended memory.

This S/W implemented telemetry buffer is held in TM RAM and varies in size for each hardware/software processing chain. The Chain B buffer is sized to delay telemetry by 6 seconds, whereas no appreciable delay exists for Chain A. The S/W TM buffer also receives a completed transfer frame each second, to replace that sent to hardware. This replacement frame is stored in the TM buffer whenever the "nul" entry is encountered in the PST.

Identification of Transfer Frames

Individual transfer frames in the TM data stream are uniquely identified by the frame counters incorporated into the transfer frame header. These frame counters, namely the master frame counter (8 bits) and the virtual frame counter (32 bits) are set to zero for the first transfer frame emitted and are manipulated in accordance with the ESA Packet Telemetry Standard [ESA PSS-04-106]. However both these frame counters will wrap-around at pre-defined values and telemetry decoding must anticipate overflow of the master frame counter during the Mission.

4.4.3-4-3 Housekeeping Packet Management

Housekeeping packets contain spacecraft health information and are generated by POSW every 4 seconds. The S/W generates 4 packet sub-types or variants which are HK1, HK2, HK3 and HK4. Each packet variant has a pre-set format and contains POSW/CDMS housekeeping data. The data contained in an individual HK packet is assembled over a 16 second cycle, by the housekeeping acquisition mechanism. As such the housekeeping acquisition mechanism is responsible for the collection and subsequent storage of data parameters into the HK packets.

This housekeeping acquisition mechanism executes in parallel with the mainstream telemetry activities, but is independent of these telemetry activities which are solely driven by the PST. No control coupling exists between the telemetry activities and housekeeping acquisition. However the housekeeping acquisition mechanism does complete the filling of each HK packet prior to its dispatch, and data synchronisation with the PST is therefore present.

CUT Housekeeping Acquisition Table

At the centre of the housekeeping acquisition mechanism is the CUT Housekeeping Acquisition Table (CHAT) which specifies the acquisition workload for every CUT in the 16 second major acquisition cycle. The table defines which parameters are reported in HK telemetry and the layout of the 4 HK data packets. In addition the table indirectly defines the time differential between each reported parameter and the mission times incorporated into the secondary packet headers. A logical representation of the CHAT is given in Figure 4.4.3-13.

CUT cycle no:	First Parameter Acquired		Second Parameter Acquired		Third Parameter Acquired	
1	Name: Packet: Position:	RA HK2 Byte 91	Name: Packet: Position:	Control Port HK1 Byte 52	Name: Packet: Position:	Inva. TC count HK1 Byte 68
2	Name: Packet: Position:	CA1 HK4 Byte 4	Name: Packet: Position:	CA2 HK4 Byte 20	Name: Packet: Position:	CA3 HK4 Byte 36
-	Name: Packet: Position:	- - -	Name: Packet: Position:	- - -	Name: Packet: Position:	- - -
127	Name: Packet: Position:	RA HK2 Byte 90	Name: Packet: Position:	Mission Phase HK3 Byte 12	Name: Packet: Position:	G-switch Buffer HK4 Byte 53
128	Name: Packet: Position:	DDB Spin HK3 Byte 4	Name: Packet: Position:	DDB Altitude HK3 Byte 23	Name: Packet: Position:	DDB Time HK3 Byte 39

where: Name = The name of the HK parameter to be acquired. This parameter may originate from POSW, or the CDMS S/S
Packet = The HK packet variant in which to store the acquired value. Namely HK1 to HK4.
Position = The memory location in the specified HK packet in which to store the acquired value. This position is given in bytes, with the origin (byte 1) being the first byte immediately after the secondary packet header.

FIGURE 4.4.3-13 CHAT LOGICAL REPRESENTATION

The time of acquisition for any parameter is given in § 4.4.4-3-7 (derived from the CHAT).

The CHAT may be re-programmed to alter the acquisition workload. However the preparation of CHAT data is extremely complex due to the numerous S/W requirements for packet layouts and the parameter acquisition rates. A summary of the re-programmable data items is given in Figure 4.4.3-14.

Name	Units	Data Type	Functional Area	Description
CHAT (Parameter Data)	None	Enumerated (Codes: As defined by RD2 POSW SICD)	Housekeeping Parameter Acquisition	Name of the parameter to be acquired for reporting in HK telemetry. This parameter may originate from either POSW or the CDMS S/S. Any CDMS device mounted on the OBDH bus may be interrogated for HK purposes.
CHAT (Packet Data)	None	Enumerated (Codes: HK1, HK2, HK3 or HK4)	Housekeeping Parameter Acquisition	Name of the HK packet into which the acquired value will be placed.
CHAT (Position Data)	None	Integer (8 bit) (1 to 114)	Housekeeping Parameter Acquisition	Position in the HK packet where the acquired value will be placed. This position is given in bytes, with the origin (byte 1) being the first byte immediately after the secondary packet header.

FIGURE 4.4.3-14 CHAT RE-PROGRAMMABLE DATA

Decoding Housekeeping Telemetry

The nominal layout and content of each of the Housekeeping packets is described in Annex 2 TM/TC Data Tables and is derived from the content of the Flight model CUT Housekeeping Acquisition Table (CHAT). This table is stored in non-volatile PROM, but is subject to change by uplinked S/W patches whilst in RAM. The layout of any housekeeping packet, including those affected by software patching may be calculated from maintenance records or memory dumps of the CHAT & PST tables.

The destination location (position & housekeeping packet) and acquisition rate for any acquirable parameter may be determined by simple inspection of the CHAT table contained in RAM. The acquirable parameter may also be datated by summating the parameter timing offset with the mission time (MT counter) and real time (CUT counter) contained in the secondary header. The parameter timing offset is determined by the interaction of the CHAT and PST, and may be calculated using the following formula:

When: *parameter acquisition CUT ≤ HK packet issue CUT*
Timing offset = *-(HK packet issue CUT - parameter acquisition CUT)*

When: *parameter acquisition CUT > HK packet issue CUT*
Timing offset = *-((HK packet issue CUT + 1) + (127 - parameter acquisition CUT))*

where:

parameter acquisition CUT = The CUT in which the parameter is acquired within the major acquisition cycle. This value is obtained from the memory dump or maintenance records of the CHAT table.

HK packet issue CUT = The CUT in which the destination housekeeping packet is issued within the major acquisition cycle. This value is obtained from the memory dump or maintenance records of the PST table.

Time Buffering of CDMS HK Parameters

Several CDMS parameters which are reported in Housekeeping Telemetry are also acquired and utilised by POSW during nominal program execution. To assist with fault analysis and system diagnosis, the values reported in telemetry are those acquired and used by the software. For example, consider the acquisition of the radial accelerometer during the major housekeeping cycle:

- At a frequency of n, POSW determines the angular velocity (spin rate) of the Probe. To generate input for the spin algorithm, POSW interrogates the OBDH bus to acquire the latest radial accelerometer reading at frequency n. The accelerometer value returned by the OBDH bus is subsequently used in the spin calculation and also stored in memory for reporting in telemetry later.

- Meanwhile the software will be processing through the 128 CUT housekeeping acqusition cycle. Whenever an acquisition of the radial accelerometer is required, POSW will simply collect the data from memory in preference to instigating a fresh hardware acquisition. Consequently the data stored in telemetry is the radial accelerometer value acquired for the spin algorithm earlier. Let the frequency of radial accelerometer acquisition for telemetry purposes be denoted by m.

This approach enhances the post mission analysis capabilities by ensuring that algorithm input data is available in telemetry, in addition to the algorithm output. However CDMS parameters acquired indirectly through software must be analysed cautiously as a "time-buffering" effect may exist. This "time-buffering" will be driven by the frequencies of the algorithm acquisition cycle (n) and the telemetry reporting cycle (m) and their relative phasing. All housekeeping parameters which are indirectly acquired via software are shown in Figure 4.4.3-15. The figure gives all data in terms of periods (CUTs), in preference to the frequencies used in the preceding explanation. The acquisition sampling frequency (n) and the reporting sample frequency (m) may be calculated by multiplying the respective period by 8Hz/CUT.

Housekeeping parameter	Acquisition sample period (CUTs)	Reporting sample period (CUTs)	Time buffering or Phase Lag (CUTs)
"Central Accelero 1 Value A"	1	8	None
"Central Accelero 2 Value A"	1	8	None
"Central Accelero 3 Value A"	1	8	None
"Radial Accelero Value A"	1	2	None
"Prox Sens A Monitoring N"	16	16	3
"Prox Sens B Monitoring R"	16	16	3
"Probe Status 7"	1.185	128	1

FIGURE 4.4.3-15 TIME BUFFERED CDMS PARAMETERS

Note: The acquisition sampling period of Probe Status 7 is an average value and originates from the data contained in the Polling Sequence Table. This parameter is acquired whenever experimental data is needed for the telemetry transfer frame and consequently Probe Status 7 is fetched 108 times within the major acquisition cycle of 128 CUTs. Hence the sampling period is 128/108.

Time Buffering of DDB HK Parameters

The POSW generates an internal DDB telecommand every two seconds during the Mission. The DDB is transmitted to the experiment payload, and is additionally reported in HK telemetry. The acquisition of DDB data for reporting in HK is also performed every two seconds. However a time buffering or phase lag exists and Table 4.4.3-2 Time Buffered DDB Parameters illustrates this effect.

DDB Parameter	Generation sample period (CUTs)	Reporting sample period (CUTs)	Time buffering or Phase Lag (CUTs)
"DDB Spin"	16	16	15
"DDB Mission Phase"	16	16	14
"DDB F2 and DDB Altitude"	16	16	15
"DDB F1 and DDB Time"	16	16	15

TABLE 4.4.3-2 TIME BUFFERED DDB PARAMETERS

Datation of Time Buffered Parameters

The CDMS parameters which are acquired indirectly through software, and DDB HK parameters must be datated by a two part process. The initial step is to datate the parameters in an identical manner to all other data in the Housekeeping packets. On completion of this step, the appropriate buffering period shown in Figure 4.4.3-15 Time Buffered CDMS parameters or in Table 4.4.3-2 Time Buffered DDB parameters must be substracted from the result. The resultant "time-stamp" represents the CUT in which the data was initially acquired from the CDMS hardware, or generated by POSW. This two part datation process is only applicable to the CDMS parameters shown in Figure 4.4.3-15, and DDB parameters shown in Table 4.4.3-2.

4.4.3-4-4 Dump Packet Management

The POSW generates Dump telemetry packets in response to Dump TCs. These Dump telemetry packets overwrite Experiment and/or Report packets in the TM data stream, and as such temporarily prevent the reception of scientific data on the ground. The ground will not receive Dump telemetry once the Probe has separated from the Orbiter as no telecommanding ability exists. The generation of Dump telemetry also produces the side effect of source sequence counter discontinuities as described below.

Packet Source Sequence Count Discontinuities

All telemetry packets generated by POSW conform to the ESA Packet Telemetry Standard [ESA PSS-04-106]. In particular the Source Sequence Count is manipulated as a straight sequential count which is not short cycled. However the generation of a dump telemetry packet may result in counter discontinuities or "packet skip" being visible to the ground. This arises as dump packets replace existing Experiment packets and/or Report packets in the transfer frame currently under construction. To illustrate this point, consider the report packet:

- In CUT (n), POSW generates a Report packet with a source sequence count of say 112, which is visible in the transfer frame and received by ground.

- In the following CUT (n + 1), POSW generates another Report packet with a source sequence count of 113. However in the same CUT, POSW generates a Dump packet which overwrites the Report packet in the transfer frame currently under construction. Consequently Report packet 113 is no longer visible in telemetry and will not be detected by ground.

- In the next CUT (n + 2), POSW generates another Report packet with a source sequence count of 114. This packet is visible in telemetry and will be seen by the ground.

As a direct result of this functionality the Report packet source sequence counter appears discontinous to the ground, with only packets 112 & 114 being received. A "packet skip" has occurred.

4.4.3-5 Operational Constraints

During operation of the probe, several constraints must be observed by the ground. They are:

4.4.3-5-1 ON/OFF Command Timing Constraints

A delay of 50ms must be observed between two consecutive high power ON/OFF commands. This timing constraint may be satisfied by use of the hardware command interrogation port (CIP), the command interrogation port full status flag (CIP_FULL), or via scheduling in S/W. The POSW relies upon S/W scsheduling to satisfy this constraint, and does not utilise the CIP or the CIP_FULL flag.

The basic principle which underlies the S/W scheduling is to ensure that a separation of at least 2 CUTs exists between any two High Power ON/OFF commands. POSW may execute ON/OFF commands via two mechanisms, namely: MTT or Direct TCs. Consequently two constarints exist on these mechanisms:

- **Mission Timeline Table Constraint.** No two High Power ON/OFF commands may be scheduled for execution in consecutive CUTs. This constraint must be observed by the initial MTT data set and by all MTT data patches.

- **Direct Telecommand Constraint.** Direct TCs which execute High Power ON/OFF commands must not clash with the background High Power ON/OFF workload from the MTT. Consequently all ON/OFF commands initiated by TC, must ensure that no High Power ON/OFF command is executed by the MTT in either the preceding or following CUT. This constraint may be satisfied by ensuring that Mission Time is suspended at least one CUT before and after the execution of a High Power ON/OFF command.

4.4.3-5-2 Time/Altitude Table Data

See SP07 in Doc n° HUY.AS/c.100.OP.0384.

4.4.3-5-3 Mission Timeline Table Data Constraints

See SP07 in Doc n° HUY.AS/c.100.OP.0384.

4.4.3-5-4 Constraints on Telecommands/Telemetry during Start-up

The POSW considers **all TCs invalid during the first 9.5 seconds of the Initialisation mode**, except for the Inhibition TC which may only be received during the dedicated three second window 6.5 to 9.5 s after CDMU Power ON. Between 9.5s and 15s after Power-up, TCs are queued for execution at the start of Mission Mode.

The **POSW does not generate telemetry during the 15 seconds of initialisation mode.** Consequently the first fifteen transfer frames received by ground will be uninitialised.

4.4.3-5-5 CDMU Power Down Constraint

During system start-up the POSW executes a dedicated check to detect spurious or unintentional power cycles of the CDMU. This test is executed as one of hardware confidence checks during initialisation mode, and the relevant hardware/software processing chain is marked as invalid if a spurious restart is detected.

The "clean power-up" hardware confidence test is designed to overcome a specific failure scenario which may arise during flight operations. In particular an unscheduled power cycle of CDMU A during the Titan encounter, would result in POSW re-initialising processing Chain A as healthy. The Experiments, which monitor the Chain A processor valid status , would subsequently utilise DDBs from the erroneous Chain A in preference to Chain B.

The "clean power-up" hardware confidence test uses non-volatile EEPROM as long-term memory to overcome this failure scenario. Ground operators must load a pre-defined pattern into the end of EEPROM, prior to any CDMU power-down. The POSW inspects the data in EEPROM during the next initialisation sequence and if the pre-defined pattern is not identified, the start-up sequence is considered spurious or unscheduled. The relevant processing chain is consequently marked as invalid. The POSW overwrites the data pattern in EEPROM during every initialisation cycle, and it is therefore imperative that the ground reset the EEPROM data before de-energising.

The memory address in EEPROM of the pre-defined pattern is 3FFDhex, and any bit pattern in the range 0000 to FFFEhex denotes a clean CDMU start-up. A spurious or unscheduled start-up is denoted by a bit pattern of FFFFhex, and the POSW overwrites the EEPROM address with this bit pattern during every initialisation cycle. A Patch TC is used to reset the EEPROM data for a clean CDMU start, and an example TC is given in SP07 Part A Doc HUY.AS/c.100.OP.0384.

4.4.3-5-6 Suspend and Resume Telecommand Constraints

At Probe level, the mission critical T0 event is defined as the time at which the initial "pilot" parachute is deployed. As such, T0 denotes the end of the Entry phase of the Mission and the commencement of the Descent phase. The T0 point is determined by [redacted] analysis and corresponds to the position where the stability and velocity of the Probe are suitable for deployment of the transonic parachute. Current analysis indicates that this point will occur at an altitude of 164.3 Km.

The POSW however defines the T0 event as the time of Entry into Titan's atmosphere. As such, this event is the **Software T0** event and represents a [redacted] point 6.375 seconds before aerodynamic conditions are correct for parachute deployment. This **Software T0** event is also referred to as **S0** at Probe level.

Furthermore the POSW physically detects the **Software T0** event **(S0)** and commences the "Post-T0 Descent" at this time. In essence the S/W is executing Post-T0 several seconds before the initial "pilot" parachute is deployed. Consequently the reporting of the **Software T0** event **(S0)** within the DDBs is delayed, such that the DDB accurately reports the Probe level T0 event. This delay synchronises the reporting of the T0 event with the deployment of the initial "pilot" parachute. The duration of the reporting delay is specified by a re-programmable data item named DDB_DELAY.

However the delayed reporting of the **Software T0** event **(S0)** produces several side effects or features in the POSW. Several of these features impact Huygens Operations and the following constraints shall be observed:

D3

- The Suspend TC shall not be used to freeze Mission Time for more than two seconds when the Probe is Pre-T0, where T0 refers to the Probe level event. In more explicit S/W terms the constraint applies Pre-T0 and Post-T0 where the Mission Time is less than the re-programmable data item DDB_DELAY.
  However, dedicated Suspend TC may be sent after start-up to explicitly inhibit Pre-T0 MTT processing for ground test purpose.

- When the Probe DDB flag is Pre-T0 and Probe in Suspend Mode, the timeout declares [redacted] after 38mn and Mission Time is reset to '0' but is maintained "Suspended".

- Post-T0 Resume TC shall not be uplinked where the Mission Time is less than the re-programmable data item DDB_DELAY, once the Probe is Post-T0. In this case T0 refers to the Probe level event.

  In Post-T0 if MT is greater than S0 + 6.375s, i.e. DDB time is reporting (MT - 6.375s), then operator shall not resume to a time less than S0 + 6.375s, otherwise the DDB time will show discontinuity, i.e. switch back to RT.

  However, dedicated Resume Post-T0 TC will be used to explicitly raise T0 event during ground test or flight checkout.

4.4.3-5-7 Patch Telecommand Constraints

There are a number of constraints associated with performing patches, which in turn constraint the use of Patch TC. Construction and validation of a Patch TC should be performed in consultation with the RD1 (SMM).

4.4.4 DETAILED DESCRIPTION

This section details the software system input and output parameters, in a lookup format.

4.4.4-1 Telecommands

The POSW will receive and process incoming telecommands but it will only execute TCs when the two stage validation process is successfully passed and the time of arrival of the TCs is correct. These constraints are:

Telecommand Timing

POSW provides no facilities for "time-tagging" telecommands and consequently all telecommands must be placed into the hardware TC FIFO one CUT prior to the required time of execution. In addition the processing of any earlier telecommands must have been completed by POSW. This is of particular relevance when a Patch or Dump telecommand has preceded the current command as these two TCs are processed over several CUTs. The rate and timing of TC execution is described in § 4.4.3-3-1

TC Packet Layout Checking

The first stage of TC validation is a generalised packet layout check which is applied globally to all TCs. The packet layout check confirms that the destination and basic format of all TCs is correct. In addition telecommands destined for the CDMU are checked for data corruption through use of a cyclic redundancy check. The exact verification performed during packet layout checking is described in Figure 4.4.4-1.

	msb 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	lsb 0
Packet Header	0	0	0	1	x	Application Process ID										
	1	1	Source Sequence Count													
	Packet Data Field Length															
Packet Data Field	x	x	x	x	x	x	x	x	TC ID				x	x	x	x
	Application Data Field															
	Cyclic Redundancy Code Word															

FIGURE 4.4.4-1 TELECOMMAND FORMAT

Packet Layout Checks for CDMU destined TCs:

1• Verify that bits 11 to 15 of the first header word equal 00011 binary
2• Verify that bits 14 to 15 of the second header word equal 11 binary
3• Verify that the Application Process ID is CDMU A (785hex) or CDMU B (7A5hex). For more details refer to § 4.4.3-3-3.
4• Verify that all TC ID is valid and that the Packet Data Field Length is correct for this TC type.
5• Verify that the Cyclic Redundancy Check Word is correct.

Packet Layout Checks for Experiments destined TCs:

1• Verify that bits 12 to 15 of the first header word equal 0011 binary
2• Verify that bits 14 to 15 of the second header word equal 11 binary
3• Verify that the Application Process ID is correct.
4• Verify that the Packet Data Field Length does not exceed the maximum permissible size of 249 bytes.

Application Data Field Checking

The second and final stage of TC verification is the Application data field checks. These checks are specific to each TC type and only executed if the initial packet layout checking passed. Note that Application data field checking is only performed if the Packet Layout check passed.

4.4.4-1-1 Alteration Command

See SP06 in Doc n° HUY.AS/c.100.OP.0384.

4.4.4-1-2 Direct Telecommand

See SP03/SP04 in Doc n° HUY.AS/c.100.OP.0384.

4.4.4-1-3 Dump Telecommand

See SP01 in Doc n° HUY.AS/c.100.OP.0384.

4.4.4-1-4 Experiment Telecommand

See SP09 in Doc n° HUY.AS/c.100.OP.0384.

4.4.4-1-5 Inhibition Telecommand

See SP02 in Doc n° HUY.AS/c.100.OP.0384.

4.4.4-1-6 Load MTT Telecommand

See SP08 in Doc n° HUY.AS/c.100.OP.0384.

4.4.4-1-7 Patch Telecommand

See SP07 in Doc n° HUY.AS/c.100.OP.0384.

4.4.4-1-8 Suspend/Resume Telecommand

See SP05 in Doc n° HUY.AS/c.100.OP.0384.

4.4.4-2 Telemetry

The POSW generates telemetry on both hardware chains simultaneously. The format and packetisation of the telemetry is described hereafter.

4.4.4-2-1 Transfer Frame

The POSW generates telemetry transfer frames at a rate of one per second on both hardware chains. The transfer frames are of a fixed size (512 words including hardware inserted data) and of a fixed format. The layout of the telemetry transfer frame and associated data values are shown in Figure 4.4.4-2.

msb 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 lsb	
Synchro Marker 1ACFH	CDMS
Synchro Marker FC10H	Inserted
0 | 0 | Spacecraft ID | 0 | 0 | 0 | 0	FRAME
Master frame count | Frame count	PRIMARY
9800H	HEADER
03H | Frame count	SECONDARY
Frame count	HEADER
Packet slot 1 (63 word pkt)	
Packet slot 2 (63 word pkt)	
Packet slot 3 (63 word pkt)	FRAME
Packet slot 4 (63 word pkt)	DATA
Packet slot 5 (63 word pkt)	
Packet slot 6 (63 word pkt)	
Packet slot 7 (63 word pkt)	
Reed Solomon Data (64 words)	CDMS Inserted

FIGURE 4.4.4-2 TRANSFER FRAME FORMAT

where:

Synchro Marker	= Synchronisation data inserted by the CDMS hardware. This data is used for synchronisation purposes by the Cassini receiver.
Spacecraft ID	= CDMU A (0B7H) or CDMU B (0B9)
Master frame count	= This is a 8 bit counter, with a range of 0 to 255. POSW maintains an individual source sequence counter for both Application Process Identifiers.
Frame count	= The three fiels denoted frame count form the 32 bit virtual frame counter. The least significant byte is contained in the Primary Header, while the most significant byte and middle word are both stored in the Secondary Header.
Packet slots	= Seven slots in which telemetry packets are stored. These packets may be Experiment packets, Housekeeping packets, Dump packets or Report packets.
Reed Solomon Data	= Reed Solomon check data inserted by the CDMS. This data is used to detect data corruption.

All telemetry data packets included in the transfer frame are of a fixed size (63 words), regardless of whether they originate from the Huygens experiments or from POSW itself. In addition the telemetry packets generated by POSW are of a fixed layout.

4.4.4-2-2 Dump Packet

Dump packets are generated in response to a dump telecommand and replace experimental packets and report packets in telemetry. The ground will not receive Dump telemetry once the Probe has separated from the Orbiter as no telecommanding ability exists. The generation of a dump packet leads to discontinuities in the source sequence counters of other telemetry packet types as described in § 4.4.3-4-4.

The exact layout of a dump packet is specified in SP01 of Doc n° HUY.AS/c.100.OP.0384 and is essentially a standard ESA packet header, a four word secondary header and 56 words of dumped data. The secondary header contains the real time (RT counter) and mission time (MT counter) at packet issue, and the memory address of the first word of dumped data. The dumped data may originate from either EEPROM or RAM. Where the end address of a dump extends beyond the end of memory, the remainder of the dump packet will be filled with zeros.

4.4.4-2-3 Experiment Packets

The POSW treats all Experiment packets as simple blocks of data. The scientific data is collected from the Experiments via the OBDH bus, and deposited within the appropriate packet slot of the transfer frame.

4.4.4-2-4 Housekeeping Packets

The POSW produces 4 variants or subtypes of HK packet, which are HK1, HK2, HK3 and HK4. The generation of these packets is governed by the Polling Sequence Table (PST), which issues each packet once within the major acquisition cycle of 128 CUTs. The exact layout of a housekeeping packet is shown in Annex 2 TM/TC Data Tables and is essentially a standard ESA packet header, a three word secondary header and upto 57 words of acquired data parameters.

HK1
An HK1 packet is generated by the POSW every 16 seconds. The packet data field primarily contains probe relay status and S/W health monitoring data.

HK2
An HK2 packet is generated by the POSW every 16 seconds. The packet data field primarily contains electrical data (current & voltage) on the batteries and experiments, probe temperature readings and the raw radial accelerometer data.

HK3
An HK3 packet is generated by the POSW every 16 seconds. The packet data field primarily contains coast timer, experiment status and proximity sensor data. The packet also contains a copy of the DDB data sent to the Experiments.

HK4
An HK4 packet is generated by the POSW every 16 seconds. The packet data field simply contains the raw central accelerometer data.

The transmission of HK4 packets is delayed by 6.4 minutes within the S/W. This intentional delay allows the recovery of central accelerometer data around the T0 event. For the Titan encounter, TM is only received by Cassini once the Back Cover has been jettisoned. This cover is not jettisoned until after T0 and consequently any transfer frames emitted prior to this juncture are lost.

4.4.4-2-5 Report Packet

The POSW generates Report packets whenever no scientific data is available from the Experiment payload. The layout of a Report packet is essentially a standard ESA packet header, a three word secondary header and upto 57 words of acquired data parameters. The contents of the Report packet is given in Annex 2 TM/TC Data Tables.

4.4.4-2-6 TM List

POSW A and B				
TM CODE	**DESCRIPTION**	**TYPE**	**PACKET**	**VALUE**
S1 001 H S2 001 H	RAM single error counter (LSB): the LSB of the EDAC single bit error counter. This is a dedicated hardware counter which is simply acquired and reported by S/W.	byte	HK1	Initial = 0
S1 002 H S2 002 H	Invalid TC counter: a S/W counter used to monitor the number of invalid TCs received by POSW.This dedicated counter is incremented whenever a TC is rejected. TCs may be rejected due to layout errors, data corruption (invalid CRC) or a processing timing clash.	byte	HK1	Initial = 1
S1 014 H S2 014 H	Oversampled Invalid TC counter	byte	HK1	Initial = 1
S1 003 H S2 003 H	Valid TC counter: a S/W counter used to monitor the number of valid TCs received by POSW.This dedicated counter is incremented whenever a TC is received, validated and subsequently processed by POSW. However the counter denotes software execution and does not reflect the overall success or failure of the uplinked TC.	byte	HK1	Initial = 0
S1 004 H S2 004 H	Fixed point overflow counter: a S/W counter used to monitor the number of fixed point overflows which arise during mathematical computation. An exception will also be generated whenever a fixed point overflow occurs.	byte	HK1	Initial = 0
S1 005 H S2 005 H	Floating point overflow counter: a S/W counter used to monitor the number of floating point overflows which arise during mathematical computation. An exception will also be generated whenever a floating point overflow occurs.	byte	HK1	Initial = 0

POSW A and B				
TM CODE	**DESCRIPTION**	**TYPE**	**PACKET**	**VALUE**
S1 006 H S2 006 H	Exception counter: a S/W counter used to monitor the number of Ada exceptions raised by POSW. This dedicated counter is incremented whenever an exception occurs, and the appropriate bit in the POSW health status words will also be set to indicate the source of the exception.	byte	HK1	Initial = 0
S1 007 H S2 007 H	Overrun counter: a S/W counter used to monitor the number of processing overruns which occur. An exception will also be generated whenever a processing overrun occurs, and in addition the CUT overrun health flag will also be set.	byte	HK1	Initial = 0
S1 008 H S2 008 H	RAM double error counter: a S/W counter used to monitor the number of EDAC interrupts raised. An EDAC interrupt signifies a double bit EDAC error, and the S/W will count up to a maximum of one EDAC interrupt per CUT.	byte	HK1	Initial = 0
S1 009 H S2 009 H	CMD counter: used to monitor the number of MEMORY LOAD or ON/OFF commands which have been executed from the MTTs. The CMD counter is incremented whenever POSW identifies a command as "due", and does not reflect the success or failure of command execution on the OBDH bus. Furthermore it does not increment in response to telecommanded MEMORY LOAD or ON/OFF commands.	byte	HK1	Initial = 0
S1 010 H S2 010 H	CDMU init status: Bit 7: OBDH health Bit 6: DMA health Bit 5: RAM health Bit 4: PROM health Bit 3: EEPROM health Bit 2: CDMU clean power up Bit 1: Spare. Set to zero Bit 0: Spare. Set to zero	byte	HK1	 1 = healthy (Bits 7–3) 1 = 'clean' power up
S1 011 H S2 011 H	DDB spin	byte	HK3	LSB = 0.1 rpm

D3

POSW A and B				
TM CODE	**DESCRIPTION**	**TYPE**	**PACKET**	**VALUE**
S1 012 H S2 012 H	DDB mission phase	byte	HK3	00H = entry descent 03H = ground c.o. 0CH = ground c.o. suspended 0FH = ground c.o. deactivate F3H = flight c.o. FCH = flight c.o. suspended FFH = flight c.o. deactivate
S1 013 H S2 013 H	Control port: Bit 7: Spare. Don't care value Bit 6: Spare. Don't care value Bit 5: Processor valid flag Bit 4: TM delay flag Bit 3: TM FIFO full Bit 2: TM FIFO empty Bit 1: TC FIFO full Bit 0: TC FIFO empty	byte	HK1	 0 0 0 = not valid 1 = delayed TM-processing Chain B 0 = full 0 = empty 0 = full 0 = empty
S1 013 W S2 013 W	DDB F2 + DDB altitude: Bit 15: DDB flag F2 Bit 14-0: DDB altitude	word	HK3	 0 = RAU alt.; 1 = TAT alt. LSB = 10 meters
S1 014 W S2 014 W	DDB F1 + DDB time: Bit 15-14: DDB flag F1 Bit 13-0: DDB time	word	HK3	 01 = before T0; 10 = after T0 bits 17-04 of MT counter
S1 015 W S2 015 W	Selection relays status (SRS): Cumulative history of the hardware selection relay status. Bit 15: PDD Bit 14: PAR J1 Bit 13: PAR J2 Bit 12: PAR J3 *Bit 11 to 08: (HASI1N, SSPN, DISR2N, ACP2N) PCDU output* Bit 07: GCMS in Bit 06: GCMS out Bit 05: BC1 Bit 04: BC2 Bit 03: BC3 Bit 02: FS1 Bit 01: FS2 Bit 00: FS3	word	HK1	= 1: squib has been selected since the last acquisition of SRS. Bits 15 to 12 from HK1 Probe status 3 Bits 7 to 0 from HK1 Probe status 2 byte Bits 11 to 8 are not used for SRS, but give valid data for (HASI1N, SSPN, DISR2N, ACP2N) PCDU outputs (≡ P5044B to P5047B).

POSW A and B				
TM CODE	**DESCRIPTION**	**TYPE**	**PACKET**	**VALUE**
S1 016 W S2 016 W	CPU fault register: Bit 15: CPU memory protect error Bit 14: DMA memory protect error Bit 13: Memory parity error Bit 12: PIO parity error Bit 11: DMA channel parity error Bit 10: Illegal I/O command error Bit 9: PIO transmission error Bit 8: Fault 7 Bit 7: Illegal address error Bit 6: illegal instruction error Bit 5: priviledged instruction error Bit 4: Address state error Bit 3: > reserved < Bit 2-0: Built-in test error	word	HK1	Bits 15–3: 0 = OK; 1 = fault Bit 2-0: 0 = OK >0 = Fault
S1 017 W S2 017 W	RAM first failure address: the POSW performs a hardware confidence test on the 64Kwords of the main RAM during initialisation mode. This check is conducted by writing to and reading from every memory location in RAM, and the first failure address is reported in HK telemetry. The reported value is the address of the lowest memory location which failed, and the parameter is set to FFFFhex when no RAM failure is detected. This HK parameter should be interpreted in conjunction with the RAM operational test flag reported as part of the "CDMU init status" parameter.	word	HK1	
S1 024 W S2 024 W	G Switch Buffer: the POSW maintains a buffer of the raw G-Switch status data acquired and used by the G-Switch T0 detection algorithm. The G-Switch buffer is reported in HK TM every second and contains a complete "one second history" of the raw values acquired from both G-Switches. However raw G-Switch status data is only acquired whilst the Probe is Pre-T0 and the G-Switch buffer is frozen once the Software T0 event (S0) has been detected. The format of the G-Switch buffer is given below:	word	HK4	G1n (G2n) = a complete "one second history" of the raw values acquired from G-Switch one (G-Switch two respectively). Each bit represents the bi-level status for a CUT, where the subscript n denotes the number of CUTs which have elapsed since the acquisition. A value of 0000hex denotes a deceleration of less than 12 m/s^2 A value of FFFFhex denotes a deceleration of greater than 62 m/s^2

$G1_7$	$G1_6$	$G1_5$	$G1_4$	$G1_3$	$G1_2$	$G1_1$	$G1_0$	$G2_7$	$G2_6$	$G2_5$	$G2_4$	$G2_3$	$G2_2$	$G2_1$	$G2_0$

D3

POSW A and B				
TM CODE	**DESCRIPTION**	**TYPE**	**PACKET**	**VALUE**
S1 025 W S2 025 W	G Timeout Counter: The POSW operates an algorithmic delay as part of the G-Switch T0 detection algorithm. This algorithmic delay is reported in HK TM as the G Timeout Counter. The parameter indicates whether the G-Switch T0 detection algorithm triggered the **Software T0** event **(S0)**, and is therefore of great significance. The algorithmic delay is a simple software counter which is incremented each CUT after the falling edge of the G-Switch buffer has been identified. Once the pre-defined algorithmic delay has expired, the **Software T0** event **(S0)** is declared and the initial "pilot" parachute is deployed shortly thereafter. Furthermore the value of the algorithmic delay is frozen once the **Software T0** event **(S0)** has been declared, irrespective of which detection mechanism triggered T0.	word	HK4	The initial value of the algorithmic delay is 20 seconds. A timeout counter value of 19 seconds subsequently reported in HK TM denotes detection of the T0 by the G-Switch algorithm. A reported value less than 19 seconds denotes the detection of T0 by a different mechanism with the reported value indicating the elapsed time since the falling edge detection.

Software Health Indicators

Several parameters reported in Housekeeping telemetry monitor the health of POSW. The following tables define these implementation details:

A• POSW Status Parameters

The POSW uses three words in telemetry for internal software reporting. These parameters were used during the software validation phases, but may also assist post mission analysis of the actual Descent onto TITAN. These parameters are reported in Housekeeping telemetry every 128 CUTs and are used for the purposes shown below:

POSW Status 1	PROM checksum (calculated at CDMU power on):	TM S1 018 W/S2 018 W
POSW Status 2	Stack high water mark:	TM S1 019 W/S2 019 W
POSW Status 3	POSW initialisation time:	TM S1 020 W/S2 020 W
POSW Status 4	CUT worst case execution time:	TM S1 021 W/S2 021 W

POSW Status 1 - PROM Checksum

TM codes: POSW A = S1 018 W POSW B = S2 018 W (HK1 packet)
This parameter contains the PROM checksum calculated by the software during start-up, and will consequently remain static in all Housekeeping telemetry. This value is nominally zero for a valid checksum, but will adopt non-zero values when PROM is corrupted. This parameter should be interpreted in conjunction with the PROM checksum health flag reported as part of the "CDMU init status" parameter.

POSW Status 2 - Stack High Water Mark

TM codes: POSW A = S1 019 W POSW B = S2 019 W (HK1 packet)
This parameter contains the stack high water mark and indicates the usage of the stack resource. The stack analysis software executes over a 128 CUT cycle and consequently this parameter is updated at this frequency. The analysis algorithm starts at the stack limit and works towards the base of stack looking for non-zero values. The scan of stack requires 128 CUTs to complete, and the high water mark is recorded "en route". Note that the search algorithm relies on the stack being initialised with zeros when the contents of PROM is copied into RAM.

The POSW status 2 parameter is reported as zero in telemetry whenever the algorithm is searching for the stack high water mark. On identification of the stack high water mark, the parameter contains a logical memory address, and this data may be used to calculate the worst case usage of the stack resource. The resulting worst case may then be analysed in conjunction with the allocated stack resource given by the symbol A$MAIN_STACKSIZE (2000hex) in the TLD map file. The formula to calculate the worst case stack usage is:

Worst case useage of stack = Stack Base - High Water Mark + 1

where:

Worst case stack usage	= Value denoting the maximum number of words used by the stack during software execution.
Stack Base	= Logical address of the base of stack. This is denoted by the symbol A$HEAPND within the TLD map file (EFFFhex).
High Water Mark	= Worst case stack high water mark. The worst case is the lowest value reported in telemetry and should be the value incorporated into the most recent telemetry packet.

POSW Status 3 - POSW initialisation time

TM codes: POSW A = S1 020 W POSW B = S2 020 W (HK1 packet)
The POSW Status 3 parameter is used to report the time taken from start-up for the POSW S/W to complete the initialisation processing. This corresponds to completion of start-up functional window 1 (see 4.4.3-1 POSW Start-up), which completes with the verification of the CDMU clean power-up flag. The parameter value will vary according to the number of patches contained in EEPROM, which is verified as part of initialisation.

The value provided in the timer B reading taken at completion of the initialisation and immediately prior to monitoring for the potential arrival of the Inhibition Telecommand (see SP02 in Doc HUY.AS/c.100.OP.0384). This TC may arrive within the period 6.5 - 9 seconds after CDMU power-ON and therefore it is required that the initialisation is completed before this time.

Timer B is used to indicate expiry of the 6.5 second period and consequently the value reported is the residual value of timer B at the end of initialisation processing. There is some processing prior to initialising Timer B. However, this is less than 100µs and can therefore be ignored. The initialisation time may be calculated by using the following formula:

POSW initialisation time = POSW maximum initialisation duration - ((Timer B time-out - Initialisation completion time) * Timer B clock period)

where:

POSW maximum initialisation duration	= Time until earliest reception of Inhibition Command, namely 6.5 seconds.
Timer B time-out	= Value at which the timer will raise an interrupt, namely 65535 (decimal)
Initialisation completion time	= POSW status 3 parameter (i.e. Timer B value at initialisation completion). Convert to decimal.
Timer B clock period	= The period of the timer B clock, namely 0.1 ms/tick (10 KHz clock).

POSW Status 4 - CUT worst case execution time

TM codes: POSW A = S1 021 W POSW B = S2 021 W (HK1 packet)
This parameter is used to evaluate and monitor the worst case execution time of the software. The value reported is a worst case value over the 128 CUT major acquisition cycle and is actually the residual value of timer B at the end of CUT processing. This residual value is given in timer B clock ticks and may used to calculate the worst case execution time. However any analysis should compensate for the fact that residual timer B acquisition is not the ultimate activity in the CUT. Activities such as polling for EDAC double errors, analysing the health state and resetting the trigger-go port are considered more critical and sufficient margin should be incorporated for these functions during analysis. A margin of 5 ms would be ample for this purpose. Finally this parameter should be analysed in conjunction with the CUT "overrun counter" and on occasions when a CUT overrun occurs POSW Status 4 may contain meaningless data. The worst case execution time may be calculated using the following formula:

Worst case execution time = CUT duration + Processing Margin - ((Timer B timeout - worst case residual value) * Timer B clock period))

where:

Worst case execution time	= Value denoting the maximum processing time used in a single CUT during software execution. Given in seconds.
CUT duration	= Duration of the CUT (Computer Unit of Time), namely 125ms.
Processing Margin	= Time allocated for the execution of residual processing which occurs in the CUT after acquisition of the timer. Say 5ms.
Timer B timeout	= Value at which the timer will raise an interrupt, namely 65535 (decimal)
Worst case residual value	= The highest value of the POSW status 4 parameter reported during software execution. Convert to decimal.
Timer B clock period	= The period of the timer B clock, namely 0.1 ms/tick (10 KHz clock).

D3

B• POSW Health Status Words

The POSW uses two 16 bit health words to monitor exceptions in the software. The health words are reported in Housekeeping telemetry every 128 CUTs and all health bits are reset to healthy once reported. Within the 128 CUT reporting cycle each health flag is manipulated as an independent entity. Individual health flags are set to unhealthy whenever an exception arises in the activity or function which they monitor. The general philosophy behind flag allocation, is that every activity which originates from the cyclic executive will be monitored by a dedicated health flag. In addition several other key events are specifically monitored to give visibility of the true serviceability of the software. For example the start-up activities, T0 detection and interrupt service routines are key events watched by dedicated health flags.

POSW A and B

TM CODE	DESCRIPTION	TYPE	PACKET	VALUE
S1 022 W S2 022 W	POSW health LSW: Bit 15: TM packet algorithm Bit 14: HK packet issue & clear Bit 13: Exper. packet acquisition Bit 12: Report packet generation Bit 11: Tran. frame to TM RAM Bit 10: TC processing Bit 9: HK dump packet issue Bit 8: EDAC 2 errors monitor. Bit 7: POSW performance proc. Bit 6: Interrupt re-enabling Bit 5: Watchdog timer resett. Bit 4: Interrupt mask applic. Bit 3: CUT overrun Bit 2: Cyclic scheduler Bit 1: T0 actions Bit 0: Interrupt routines	word	HK1	0 = healthy; 1 = unhealthy
S1 023 W S2 023 W	POSW health MSW: Bit 15: init mode Bit 14: RTI interrupt processing Bit 13: RTI detection Bit 12: Mission time increment. Bit 11: Tran. frame to TM FIFO Bit 10: T0 algorithm processing Bit 9: Mission time resetting Bit 8: MTT table switch Bit 7: Altit. algor. descent pr. Bit 6: T0 detection handshake Bit 5: MTT table processing Bit 4: Spin algorithm processing Bit 3: Altit. algor. processing Bit 2: DDB data col.& TC form. Bit 1: DDB emission Bit 0: Housekeeping acquisition	word	HK1	0 = healthy; 1 = unhealthy

4.4.4-3 Software Data

4.4.4-3-1 Data for the Mission Timeline Table

A• The data needed for the **Pre-T0 MTT** are given herebelow:

Time (in CUTS)	CMD name	MTT entry	RAM Start @	RAM End @
8	TUSO_N_POWER_ON	1	7BA6	7BA8
9	TX_A_POWER_ON	2	7BA9	7BAB
121	GCMS_1_N_POWER_ON	3	7BAC	7BAE
8521	HASI_1_N_POWER_ON	4	7BAF	7BB1

B• The data needed for the **Post-T0 MTT** are given herebelow:

Time (in CUTS)	CMD name	MTT entry	RAM Start @	RAM End @
17	PYRO_1_PDD_RESET	1	7C66	7C68
18	PYRO_1_BCM_RESET	2	7C69	7C6B
19	PYRO_1_PDD_SET	3	7C6C	7C6E
51	**PYRO_1_AND_2_FIRE_A**	4	7C6F	7C71
53	PYRO_1_PDD_RESET	5	7C72	7C74
69	PYRO_1_BCM_SET_N	6	7C75	7C77
70	PYRO_1_BCM_SET_R	7	7C78	7C7A
71	**PYRO_1_AND_2_FIRE_A**	8	7C7B	7C7D
103	PYRO_1_BCM_RESET	9	7C7E	7C80
131	TUSO_N_POWER_ON	10	7C81	7C83
133	TX_A_POWER_ON	11	7C84	7C86
279	PYRO_1_FSM_SET	12	7C87	7C89
297	ACP_1_N_POWER_ON	13	7C8A	7C8C
311	**PYRO_1_AND_2_FIRE_A**	14	7C8D	7C8F
315	PYRO_1_GCMS_IN_RESET	15	7C90	7C92
316	PYRO_1_GCMS_OUT_RESET	16	7C93	7C95
317	PYRO_1_DISR_COVER_RESET	17	7C96	7C98
343	PYRO_1_FSM_RESET	18	7C99	7C9B
371	ACP_3_N_POWER_ON	19	7C9C	7C9E
395	HASI_1_N_POWER_ON	20	7C9F	7CA1
419	PYRO_1_GCMS_IN_SET	21	7CA2	7CA4
445	SSP_N_POWER_ON	22	7CA5	7CA7
451	**PYRO_1_AND_2_FIRE_A**	23	7CA8	7CAA
483	PYRO_1_GCMS_IN_RESET	24	7CAB	7CAD
484	PYRO_1_GCMS_OUT_SET	25	7CAE	7CB0
516	**PYRO_1_AND_2_FIRE_A**	26	7CB1	7CB3
548	PYRO_1_GCMS_OUT_RESET	27	7CB4	7CB6
549	PYRO_1_DISR_COVER_SET	28	7CB7	7CB9
[redacted]	**PYRO_1_AND_2_FIRE_A**	29	7CBA	7CBC
685	PYRO_1_DISR_COVER_RESET	30	7CBD	7CBF
691	DISR_1_N_POWER_ON	31	7CC0	7CC2
1491	GCMS_1_N_POWER_ON	32	7CC3	7CC5
1731	ACP_1_N_POWER_ON	33	7CC6	7CC8
[redacted]	ACP_3_N_POWER_ON	34	7CC9	7CCB
7219	PYRO_1_PJM_SET	35	7CCC	7CCE
7251	**PYRO_1_AND_2_FIRE_A**	36	7CCF	7CD1
7283	PYRO_1_PJM_RESET	37	7CD2	7CD4
39411	DISR_1_N_POWER_ON	38	7CD5	7CD7
51891	SSP_N_POWER_ON	39	7CD8	7CDA
52851	ACP_3_N_POWER_OFF	40	7CDB	7CDD
52853	ACP_1_N_POWER_OFF	41	7CDE	7CE0

4.4.4-3-2 Descent Data Broadcast Mission Phase Values

The DDB Mission Phase values are given herebelow:

Phase	DDB Values (in hex)
ENTRY_DESCENT	00
GROUND_C_O	03
GROUND_C_O_SUSPENDED	0C
GROUND_C_O_DE_ACTIVATE	0F
FLIGHT_C_O	F3
FLIGHT_C_O_SUSPENDED	FC
FLIGHT_C_O_DE_ACTIVATE	FF

The default value is: "ENTRY_DESCENT" = 00

4.4.4-3-3 Data for the T0 Detection Algorithm

Axial acceleration (m/s^2) = $An + Bnx + Cnx^2 + Dnx^3$ with x range [0 .. 255]

with n = Chain 1 or 2 or 3

Constant	Initial Value	RAM addresses
THA	10 m/s^2	5BC2 - 5BC3
THB	50.0 m/s^2	5BC4 - 5BC5
A1 / A2 / A3	0.0	5BC6 - 5BC7 / 5BC8 - 5BC9 / 5BCA - 5BCB
B1 / B2 / B3	$\frac{98.1}{255}$	5BCC - 5BCD / 5BCE - 5BCF / 5BD0 - 5BD1
C1 / C2 / C3	0.0	5BD2 - 5BD3 / 5BD4 - 5BD5 / 5BD6 - 5BD7
D1 / D2 / D3	0.0	5BD8 - 5BD9 / 5BDA - 5BDB / 5BDC - 5BDD
E11 / E21 / E31	1.0	5BDE - 5BDF / 5BE0 - 5BE1 / 5BE2 - 5BE3
E12 / E22 / E32	0.0	5BE4 - 5BE5 / 5BE6 - 5BE7 / 5BE8 - 5BE9
F11 / F21 / F31	0.0	5BEA - 5BEB / 5BEC - 5BED / 5BEE - 5BEF
F12 / F22 / F32	0.0	5BF0 - 5BF1 / 5BF2 - 5BF3 / 5BF4 - 5BF5

Notes: 1• The filter constants may be defined as following (with DT = 0.125s, TAU = 0.001s):

E11 = E21 = E31 = 1 - EXP(-DT/TAU) * (1 + DT/TAU)
E12 = E22 = E32 = EXP(-DT/TAU) * [EXP(-DT/TAU) -1 + DT/TAU]
F11 = F21 = F31 = 2 * EXP(-DT/TAU)
F12 = F22 = F32 = - EXP(-DT/TAU) * EXP(-DT/TAU)

2• according to Mission timeline T0 will raise at ≈ 28 mn after CDMU power ON

Other data relative to T0 are given herebelow:

DDB_DELAY	= 6.375s	Time between **Software T0** event **(S0)** and "pilot" parachute deployment
G_DELAY	= 20s	Used to declare T0 based on G-Switch entry detection
TIME_OUT	= 35 mn	Used to Timeout T0, if not detected
BACK_UP	= 38 mn	

4.4.4-3-4 Data for the Altitude Algorithm

The data for the entries 01 to 90 of the TAT are given herebelow:

Entry N°	Time (CUTS)	Altitude (Dam)	RAM Address	Entry N°	Time (CUTS)	Altitude (Dam)	RAM Address	Entry N°	Time (CUTS)	Altitude (Dam)	RAM Address
01	0	16480	6620-6622	31	23571	4117	667A-667C	61	45171	1530	66D4-66D6
02	2691	13760	6623-6625	32	24291	3992	667D-667F	62	45891	1468	66D7-66D9
03	3411	13310	6626-6628	33	25011	3871	6680-6682	63	46611	1407	66DA-66DC
04	4131	12890	6629-662B	34	25731	3754	6683-6685	64	47331	1347	66DD-66DF
05	4851	12490	662C-662E	35	26451	3641	6686-6688	65	48051	1288	66E0-66E2
06	5571	12120	662F-6631	36	27171	3532	6689-668B	66	48771	1229	66E3-66E5
07	6291	11760	6632-6634	37	27891	3426	668C-668E	67	49491	1172	66E6-66E8
08	7011	11420	6635-6637	38	28611	3323	668F-6691	68	50211	1115	66E9-66EF
09	7731	10830	6638-663A	39	29331	3224	6692-6694	69	50931	1059	66EC-66EE
10	8451	10130	663B-663D	40	30051	3127	6695-6697	70	51651	1003	66EF-66F1
11	9171	9493	663E-6640	41	30771	3033	6698-669A	71	52371	949	66F2-66F4
12	9891	8922	6641-6643	42	31491	2942	669B-669D	72	53091	895	66F5-66F7
13	10611	8406	6644-6646	43	32211	2853	669E-66A0	73	53811	841	66F8-66FA
14	11331	7939	6647-6649	44	32931	2766	66A1-66A3	74	54531	788	66FB-66FD
15	12051	7518	664A-664C	45	33651	2680	66A4-66A6	75	55251	735	66FE-6700
16	12771	7140	664D-664F	46	34371	2597	66A7-66A9	76	55971	683	6701-6703
17	13491	6799	6650-6652	47	35091	2516	66AA-66AC	77	56691	632	6704-6706
18	14211	6497	6653-6655	48	35811	2436	66AD-66AF	78	57411	581	6707-6709
19	14931	6226	6656-6658	49	36531	2358	66B0-66B2	79	58131	530	670A-670C
20	15651	5981	6659-665B	50	37251	2282	66B3-66B5	80	58851	480	670D-670F
21	16371	5757	665C-665E	51	37971	2207	66B6-66B8	81	59571	430	6710-6712
22	17091	5549	665F-6661	52	38691	2134	66B9-66BB	82	60291	381	6713-6715
23	17811	5354	6662-6664	53	39411	2062	66BC-66BE	83	61011	332	6716-6718
24	18531	5170	6665-6667	54	40131	1992	66BF-66C1	84	61731	284	6719-671B
25	19251	4997	6668-666A	55	40851	1923	66C2-66C4	85	62451	236	671C-671E
26	19971	4832	666B-666D	56	41571	1855	66C5-66C7	86	63171	188	671F-6721
27	20691	4676	666E-6670	57	42291	1788	66C8-66CA	87	63891	141	6722-6724
28	21411	4527	6671-6673	58	43011	1722	66CB-66CD	88	64611	94	6725-6727
29	22131	4384	6674-6676	59	43731	1657	66CE-66D0	89	65331	47	6728-672A
30	22851	4248	6677-6679	60	44451	1593	66D1-66D3	90	66067	0	672B-672D

Dam = decameter (10 meters)
TAT time is referring to **Software T0 threshold event (S0)**

The other data are:

$\Delta 1 = 5000$ m $\Delta 2 = 0.15$
EPSM = 0.1
THRESHOLD = 35000 CUT
INF = 4 m
SUP = 2000 m

Notes: 1• the Radar altimeter data are used after time threshold = T0 + 73 mn which corresponds to an altitude given in the TAT table of ≈ 25 Km.
2• the time at landing is ≈ 137mn38s

4.4.4-3-5 Data for the Spin Algorithm

Constant	Initial Value	Unit	RAM addresses
A1A	0.0	m/s^2	6533 - 6534
B1A	$\frac{1.2}{255}$	m/s^2 CAN	6535 - 6536
C1A	0.0	m/s^2 CAN^2	6537 - 6538
D1A	0.0	m/s^2 CAN^3	6539 - 653A
RA	0.432	meter	653B - 653C
A1B	0.0	m/s^2	653D - 653E
B1B	$\frac{1.2}{255}$	m/s^2 CAN	653F - 6540
C1B	0.0	m/s^2 CAN^2	6541 - 6542
D1B	0.0	m/s^2 CAN^3	6543 - 6544
RB	0.353	meter	6545 - 6546
K1	$\frac{300}{\pi}$	CAN Seconds	6547 - 6548
K2	0.0	CAN	6549 - 654A

Spin in DDB: LSB = 0.1 rpm 1 rpm = $2\pi/60$ rad/s

4.4.4-3-6 Data for the Experiments Polling Tables

The switching times for the transitions (EPT1 --> EPT2), (EPT2 --> EPT3) are given herebelow:

EPT_SWAP_1 = 4735 CUTS
EPT_SWAP_2 = 40831 CUTS

It is recommended to have (EPT_SWAP_1 + 1) or (EPT_SWAP_2 + 1) multiple of 128 in order to keep synchronism in the Experiments Polling scheme.

The EPT 1 to 3 are presented in § 6.
The EPTs addresses in RAM are given hereafter:

EPT1

Index	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
RAM @	5C99	5C9A	5C9B	5C9C	5C9D	5C9E	5C9F	5CA0	5CA1	5CA2	5CA3	5CA4	5CA5	5CA6	5CA7	5CA8
Index	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
RAM @	5CA9	5CAA	5CAB	5CAC	5CAD	5CAE	5CAF	5CB0	5CB1	5CB2	5CB3	5CB4	5CB5	5CB6	5CB7	5CB8
Index	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
RAM @	5CB9	5CBA	5CBB	5CBC	5CBD	5CBE	5CBF	5CC0	5CC1	5CC2	5CC3	5CC4	5CC5	5CC6	5CC7	5CC8
Index	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
RAM @	5CC9	5CCA	5CCB	5CCC	5CCD	5CCE	5CCF	5CD0	5CD1	5CD2	5CD3	5CD4	5CD5	5CD6	5CD7	5CD8
Index	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
RAM @	5CD9	5CDA	5CDB	5CDC	5CDD	5CDE	5CDF	5CE0	5CE1	5CE2	5CE3	5CE4	5CE5	5CE6	5CE7	5CE8
Index	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
RAM @	5CE9	5CEA	5CEB	5CEC	5CED	5CEE	5CEF	5CF0	5CF1	5CF2	5CF3	5CF4	5CF5	5CF6	5CF7	5CF8
Index	97	98	99	100	101	102	103	104	105	106	107	108				
RAM @	5CF9	5CFA	5CFB	5CFC	5CFD	5CFE	5CFF	5D00	5D01	5D02	5D03	5D04				

EPT2

Index	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
RAM @	5D05	5D06	5D07	5D08	5D09	5D0A	5D0B	5D0C	5D0D	5D0E	5D0F	5D10	5D11	5D12	5D13	5D14
Index	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
RAM @	5D15	5D16	5D17	5D18	5D19	5D1A	5D1B	5D1C	5D1D	5D1E	5D1F	5D20	5D21	5D22	5D23	5D24
Index	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
RAM @	5D25	5D26	5D27	5D28	5D29	5D2A	5D2B	5D2C	5D2D	5D2E	5D2F	5D30	5D31	5D32	5D33	5D34
Index	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
RAM @	5D35	5D36	5D37	5D38	5D39	5D3A	5D3B	5D3C	5D3D	5D3E	5D3F	5D40	5D41	5D42	5D43	5D44
Index	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
RAM @	5D45	5D46	5D47	5D48	5D49	5D4A	5D4B	5D4C	5D4D	5D4E	5D4F	5D50	5D51	5D52	5D53	5D54
Index	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
RAM @	5D55	5D56	5D57	5D58	5D59	5D5A	5D5B	5D5C	5D5D	5D5E	5D5F	5D60	5D61	5D62	5D63	5D64
Index	97	98	99	100	101	102	103	104	105	106	107	108				
RAM @	5D65	5D66	5D67	5D68	5D69	5D6A	5D6B	5D6C	5C6D	5D6E	5D6F	5D70				

EPT3

Index	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
RAM @	5D71	5D72	5D73	5D74	5D75	5D76	5D77	5D78	5D79	5D7A	5D7B	5D7C	5D7D	5D7E	5D7F	5D80
Index	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
RAM @	5D81	5D82	5D83	5D84	5D85	5D86	5D87	5D88	5D89	5D8A	5D8B	5D8C	5D8D	5D8E	5D8F	5D90
Index	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
RAM @	5D91	5D92	5D93	5D94	5D95	5D96	5D97	5D98	5D99	5D9A	5D9B	5D9C	5D9D	5D9E	5D9F	5DA0
Index	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
RAM @	5DA1	5DA2	5DA3	5DA4	5DA5	5DA6	5DA7	5DA8	5DA9	5DAA	5DAB	5DAC	5DAD	5DAE	5DAF	5DB0
Index	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
RAM @	5DB1	5DB2	5DB3	5DB4	5DB5	5DB6	5DB7	5DB8	5DB9	5DBA	5DBB	5DBC	5DBD	5DBE	5DBF	5DC0
Index	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
RAM @	5DC1	5DC2	5DC3	5DC4	5DC5	5DC6	5DC7	5DC8	5DC9	5DCA	5DCB	5DCC	5DCD	5DCE	5DCF	5DD0
Index	97	98	99	100	101	102	103	104	105	106	107	108				
RAM @	5DD1	5DD2	5DD3	5DD4	5DD5	5DD6	5DD7	5DD8	5DD9	5DDA	5DDB	5DDC				

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4.4.4-3-7 Timing Information derived from CHAT

The time of acquisition for any parameter is calculated by the algorithm:
Acquisition CUT = RT or MT counter + Timing Offset

Position = position of the parameter in the HK packet, given in bytes, with the origin being the first byte immediately after the secondary packet header.

Warning: CUT_cycle_no numbered from 1 to 128

A• *Timing Information for HK1*

Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle no	parameter acq no
1	RAM single error counter LSB	S1001H/S2001H	-20	115	2
2	Invalid TC counter	S1002H/S2002H	-19	116	2
3	Valid TC counter	S1003H/S2003H	-19	116	3
4	Fixed Point Overflow counter	S1004H/S2004H	-17	118	2
5	Float Point Overflow counter	S1005H/S2005H	-17	118	3
6	Exception counter	S1006H/S2006H	-22	113	2
7	Overrun counter	S1007H/S2007H	-25	110	3
8	RAM double error counter	S1008H/S2008H	-20	115	3
9	CMD counter	S1009H/S2009H	-18	117	3
10	CDMU init status	S1010H/S2010H	-31	104	1
11	Probe Status 1	See hereafter	-28	107	2
12	Probe Status 5	See hereafter	-16	119	2
13	DRR (Probe Status 7)	See hereafter	-15 & -1 (*)	120	1
14	Probe Status 4	See hereafter	-27	108	2
15	Probe Status 2	See hereafter	-15	120	2
16	Probe Status 3	See hereafter	-26	109	2
17	Probe Status 6	See hereafter	-14	121	2
18	Prox. Sensor A AGC voltage	D3005A/D4005A	-123	12	1
19	Prox. Sensor A AGC voltage	D3005A/D4005A	-115	20	1
20	Prox. Sensor A AGC voltage	D3005A/D4005A	-107	28	1
21	Prox. Sensor A AGC voltage	D3005A/D4005A	-99	36	1
22	Prox. Sensor A AGC voltage	D3005A/D4005A	-91	44	1
23	Prox. Sensor A AGC voltage	D3005A/D4005A	-83	52	1
24	Prox. Sensor A AGC voltage	D3005A/D4005A	-75	60	1
25	Prox. Sensor A AGC voltage	D3005A/D4005A	-67	68	1
26	Prox. Sensor A AGC voltage	D3005A/D4005A	-59	76	1
27	Prox. Sensor A AGC voltage	D3005A/D4005A	-51	84	1
28	Prox. Sensor A AGC voltage	D3005A/D4005A	-43	92	1
29	Prox. Sensor A AGC voltage	D3005A/D4005A	-35	100	1
30	Prox. Sensor A AGC voltage	D3005A/D4005A	-27	108	1
31	Prox. Sensor A AGC voltage	D3005A/D4005A	-19	116	1
32	Prox. Sensor A AGC voltage	D3005A/D4005A	-11	124	1
33	Prox. Sensor A AGC voltage	D3005A/D4005A	-3	4	1

(*) See explanation in "Time Buffering of CDMS HK Parameters" and "Datation of Time Buffered Parameters" in § 4.4.3-4-3

Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle no	parameter acq no
34	SRS: memory pyro select LSB (≡ Probe status 2)	S1015W/S2015W	-33	102	1
35	SRS: memory pyro select MSB (≡ Probe status 3)				
36	CPU fault register	S1016W/S2016W	-18	117	2
37					
38	RAM first failure address	S1017W/S2017W	-17	118	1
39					
40	POSW status 1	S1018W/S2018W	-12	123	2
41					
42	POSW status 2	S1019W/S2019W	-12	123	3
43					
44	POSW status 3	S1020W/S2020W	-11	124	2
45					
46	POSW status 4	S1021W/S2021W	-11	124	3
47					
48	POSW health status MSB	S1023W/S2023W	-10	125	3
49	POSW health status (middle word)				
50	POSW health status (middle word)	S1022W/S2022W	-10	125	2
51	POSW health status LSB				
52	Control port	S1013H/S2013H	-6	1	2
53	Oversampled Invalid TC counter	S1014H/S2014H	-126	9	2
54	Oversampled Invalid TC counter	S1014H/S2014H	-118	17	2
55	Oversampled Invalid TC counter	S1014H/S2014H	-110	25	2
56	Oversampled Invalid TC counter	S1014H/S2014H	-102	33	2
57	Oversampled Invalid TC counter	S1014H/S2014H	-94	41	2
58	Oversampled Invalid TC counter	S1014H/S2014H	-86	49	2
59	Oversampled Invalid TC counter	S1014H/S2014H	-78	57	2
60	Oversampled Invalid TC counter	S1014H/S2014H	-70	65	2
61	Oversampled Invalid TC counter	S1014H/S2014H	-62	73	3
62	Oversampled Invalid TC counter	S1014H/S2014H	-54	81	2
63	Oversampled Invalid TC counter	S1014H/S2014H	-46	89	3
64	Oversampled Invalid TC counter	S1014H/S2014H	-38	97	2
65	Oversampled Invalid TC counter	S1014H/S2014H	-30	105	3
66	Oversampled Invalid TC counter	S1014H/S2014H	-22	113	3
67	Oversampled Invalid TC counter	S1014H/S2014H	-14	121	3
68	Oversampled Invalid TC counter	S1014H/S2014H	-6	1	3

Positions 69 to 114 are spare bytes, set to zero.

PROBE STATUS 1: HK1 Byte 11 Timing Offset = -28		
Bit N°	**Parameter Description**	**TM Code POSWA/POSWB**
7	Section 1 input relay status A/Section 5 input relay status B	P5014R/P5019R
6	Section 2 input relay status A/Section 4 input relay status B	P5015R/P5018R
5	Section 3 input relay status A/Spare	P5016R/Spare
4	Spare	Spare/Spare
3	Spare	Spare/Spare
2	Spare	Spare/Spare
1	Coast timer 1 relay status A/Coast timer 3 relay status B	P5078R/P5081R
0	Coast timer 2 relay status A/Spare	P5079R/Spare

PROBE STATUS 2: HK1 Byte 15 Timing Offset = -15		
Bit N°	**Parameter Description**	**TM Code POSWA/POSWB**
7	GCMS IN selection relay status A/B	P3005B/P4005B
6	GCMS OUT selection relay status A/B	P3006B/P4006B
5	BC1 selection relay status A/B	P3007B/P4007B
4	BC2 selection relay status A/B	P3008B/P4008B
3	BC3 selection relay status A/B	P3009B/P4009B
2	FS1 selection relay status A/B	P3010B/P4010B
1	FS2 selection relay status A/B	P3011B/P4011B
0	FS3 selection relay status A/B	P3012B/P4012B

PROBE STATUS 3: HK1 Byte 16 Timing Offset = -26		
Bit N°	**Parameter Description**	**TM Code POSWA/POSWB**
7	PDD selection relay status A/B	P3004B/P4004B
6	PJ1 selection relay status A/B	P3013B/P4013B
5	PJ2 selection relay status A/B	P3014B/P4014B
4	PJ3 selection relay status A/B	P3015B/P4015B
3	28V HASI1 limiter status N/R	P5044B/P5072B
2	28V SSP limiter status N/R	P5045B/P5073B
1	28V DISR2 limiter status N/R	P5046B/P5074B
0	28V ACP2 limiter status N/R	P5047B/P5075B

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PROBE STATUS 4: HK1 Byte 14 Timing Offset = -27		
Bit N°	**Parameter Description**	**TM Code POSWA/POSWB**
7	28V CDMU limiter status B/A	P5064B/P5036B
6	28V GCMS1 limiter status N/R	P5038B/P5066B
5	28V DISR1 limiter status N/R	P5039B/P5067B
4	28V GCMS2 limiter status N/R	P5040B/P5068B
3	28V ACP1 limiter status N/R	P5041B/P5069B
2	28V ACP3 limiter status N/R	P5042B/P5070B
1	28V TUSO limiter status N/R	P5043B/P5071B
0	Spare	Spare/Spare

PROBE STATUS 5: HK1 Byte 12 Timing Offset = -16		
Bit N°	**Parameter Description**	**TM Code POSWA/POSWB**
7	HASI Boom status A/B	E2003R/E2004R
6	Pyro energy status 1/2	P3002R/P4002R
5	TX selection status A/B	R1005R/R2005R
4	Spare	Spare/Spare
3	Spare	Spare/Spare
2	T0/Ta G-Switch 1 status A/B	D1011R/D2011R
1	T0/Ta G-Switch 2 status A/B	D1012R/D2012R
0	Spare	Spare/Spare

PROBE STATUS 6: HK1 Byte 17 Timing Offset = -14		
Bit N°	**Parameter Description**	**TM Code POSWA/POSWB**
7	Spare	Spare/Spare
6	TCXO output level A/B	R1006B/R2006B
5	TUSO status (lock) A/B	E6004B/E6008B
4	28V TX limiter status A/B	P5037B/P5065B
3	28V HASI2 limiter status A/B	P5048B/P5076B
2	28V RAU limiter status A/B	P5049B/P5077B
1	DISR cover selection relay status A/B	P3016B/P4016B
0	MTU Power status	D6007B/D6008B

PROBE STATUS 7: HK1 Byte 13 Timing Offset = -15 & -1		
Bit N°	**Parameter Description**	**TM Code POSWA/POSWB**
7	GCMS packet ready N/R	E1005D/E1006D
6	DISR packet ready N/R	E3005D/E3006D
5	ACP packet ready N/R	E4007D/E4008D
4	HASI packet ready N/R	E2007D/E2008D
3	SSP packet ready N/R	E5005D/E5006D
2	CDMU BL test (5V) A/B	D1007B/D2007B
1	CDMU BL test (0V) A/B	D1006B/D2006B
0	Arming Timer status A/B	D1010B/D2010B

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B• *Timing Information for HK2*

Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle no	parameter acq no
1	Probe Temperature 1A/B (SEPSA/B)	D5001T/D5013T	-100	67	2
2	Probe Temperature 2A/B (SEPSC/A)	D5002T/D5014T	-99	68	2
3	Probe Temperature 3A/B (PJMA/B)	D5003T/D5015T	-98	69	2
4	Probe Temperature 4A/B (PJMC/PDD)	D5004T/D5016T	-98	69	3
5	Probe Temperature 5A/B (batt 1a/4b)	D5005T/D5017T	-91	76	2
6	Probe Temperature 6A/B (batt 3b/2a)	D5006T/D5018T	-90	77	2
7	Probe Temperature 7A/B (batt 5a/3a)	D5007T/D5019T	-84	83	2
8	Probe Temperature 8A/B (PCDU box/batt 1b)	D5008T/D5020T	-83	84	2
9	Probe Temperature 9A/B (TX box A/B)	D5009T/D5021T	-82	85	2
10	Probe Temperature 10A/B (GCMS flange/TUSO box)	D5010T/D5022T	-80	87	2
11	Probe Temperature 11A/B (DISR SH ext/DISR DH int)	D5011T/D5023T	-78	89	2
12	Probe Temperature 12A/B (foam inside/after cone ins.)	D5012T/D5024T	-76	91	2
13	DC/DC converter temperature 1	D1008T/D2008T	-94	73	2
14	DC/DC converter temperature 2	D1009T/D2009T	-92	75	2
15	TUSO temperature 1	E6001A/E6005A	-33	6	1
16	TUSO temperature 2	E6002A/E6006A	-33	6	2
17	TUSO temperature 3	E6003A/E6007A	-33	6	3
18	TX output power	R1002A/R2002A	-17	22	1
19	TX power ampli temperature	R1003A/R2003A	-17	22	2
20	TX secondary supply voltage	R1004A/R2004A	-17	22	3
21	Battery 1 voltage A/Battery 5 voltage B	P5002A/P5007A	-1	38	1
22	Battery 2 voltage A/Battery 4 voltage B	P5003A/P5006A	-1	38	2
23	Battery 3 voltage A/B	P5004A/P5005A	-1	38	3
24	28V CDMU power current A/B	P5022A/P5050A	-62	105	2
25	28V TX power current A/B	P5023A/P5051A	-15	24	2
26	BDR 1 current A/BDR5 current B	P5008A/P5013A	-113	54	1
27	BDR 2 current A/BDR4 current B	P5009A/P5012A	-113	54	2
28	BDR 3 current A/B	P5010A/P5011A	-113	54	3
29	28V GCMS 1N/R power current	P5024A/P5052A	-111	56	2
30	28V GCMS 2N/R power current	P5026A/P5054A	-111	56	3
31	28V DISR 1N/R power current	P5025A/P5053A	-97	70	2
32	28V DISR 2N/R power current	P5032A/P5060A	-97	70	3
33	28V ACP 1N/R power current	P5027A/P5055A	-96	71	3
34	28V ACP 2N/R power current	P5033A/P5061A	-95	72	2
35	28V ACP 3N/R power current	P5028A/P5056A	-95	72	3
36	28V TUSO N/R power current	P5029A/P5057A	-32	7	2
37	28V SSP N/R power current	P5031A/P5059A	-79	88	2
38	28V HASI 1N/R power current	P5030A/P5058A	-81	86	2
39	28V HASI 2N/R power current	P5034A/P5062A	-81	86	3
40	28V RAU A/B power current	P5035A/P5063A	-67	100	2
41	Main Bus voltage A/B	P5020A/P5021A	-31	8	1
42	HPA power supply voltage A/B	R1007A/R2007A	-15	24	1
43	CDMU A/D calibration 4.54V A/B	D1003A/D2003A	-66	101	2

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Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle no	parameter_ acq no
44	CDMU A/D calibration 0.5V A/B	D1005A/D2005A	-65	102	2
45	CDMU A/D calibration 0.3V A/B	D1004A/D2004A	-64	103	2
46	CDMU supply voltage 5V A/B	D1002A/D2002A	-63	104	2
47	Radial accelero 1A/3B	D8001A/D8005A	-126	41	1
48	Radial accelero 1A/3B	D8001A/D8005A	-124	43	1
49	Radial accelero 1A/3B	D8001A/D8005A	-122	45	1
50	Radial accelero 1A/3B	D8001A/D8005A	-120	47	1
51	Radial accelero 1A/3B	D8001A/D8005A	-118	49	1
52	Radial accelero 1A/3B	D8001A/D8005A	-116	51	1
53	Radial accelero 1A/3B	D8001A/D8005A	-114	53	1
54	Radial accelero 1A/3B	D8001A/D8005A	-112	55	1
55	Radial accelero 1A/3B	D8001A/D8005A	-110	57	1
56	Radial accelero 1A/3B	D8001A/D8005A	-108	59	1
57	Radial accelero 1A/3B	D8001A/D8005A	-106	61	1
58	Radial accelero 1A/3B	D8001A/D8005A	-104	63	1
59	Radial accelero 1A/3B	D8001A/D8005A	-102	65	1
60	Radial accelero 1A/3B	D8001A/D8005A	-100	67	1
61	Radial accelero 1A/3B	D8001A/D8005A	-98	69	1
62	Radial accelero 1A/3B	D8001A/D8005A	-96	71	1
63	Radial accelero 1A/3B	D8001A/D8005A	-94	73	1
64	Radial accelero 1A/3B	D8001A/D8005A	-92	75	1
65	Radial accelero 1A/3B	D8001A/D8005A	-90	77	1
66	Radial accelero 1A/3B	D8001A/D8005A	-88	79	1
67	Radial accelero 1A/3B	D8001A/D8005A	-86	81	1
68	Radial accelero 1A/3B	D8001A/D8005A	-84	83	1
69	Radial accelero 1A/3B	D8001A/D8005A	-82	85	1
70	Radial accelero 1A/3B	D8001A/D8005A	-80	87	1
71	Radial accelero 1A/3B	D8001A/D8005A	-78	89	1
72	Radial accelero 1A/3B	D8001A/D8005A	-76	91	1
73	Radial accelero 1A/3B	D8001A/D8005A	-74	93	1
74	Radial accelero 1A/3B	D8001A/D8005A	-72	95	1
75	Radial accelero 1A/3B	D8001A/D8005A	-70	97	1
76	Radial accelero 1A/3B	D8001A/D8005A	-68	99	1
77	Radial accelero 1A/3B	D8001A/D8005A	-66	101	1
78	Radial accelero 1A/3B	D8001A/D8005A	-64	103	1
79	Radial accelero 1A/3B	D8001A/D8005A	-62	105	1
80	Radial accelero 1A/3B	D8001A/D8005A	-60	107	1
81	Radial accelero 1A/3B	D8001A/D8005A	-58	109	1
82	Radial accelero 1A/3B	D8001A/D8005A	-56	111	1
83	Radial accelero 1A/3B	D8001A/D8005A	-54	113	1
84	Radial accelero 1A/3B	D8001A/D8005A	-52	115	1
85	Radial accelero 1A/3B	D8001A/D8005A	-50	117	1
86	Radial accelero 1A/3B	D8001A/D8005A	-48	119	1
87	Radial accelero 1A/3B	D8001A/D8005A	-46	121	1
88	Radial accelero 1A/3B	D8001A/D8005A	-44	123	1

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Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle no	parameter_ acq no
89	Radial accelero 1A/3B	D8001A/D8005A	-42	125	1
90	Radial accelero 1A/3B	D8001A/D8005A	-40	127	1
91	Radial accelero 1A/3B	D8001A/D8005A	-38	1	1
92	Radial accelero 1A/3B	D8001A/D8005A	-36	3	1
93	Radial accelero 1A/3B	D8001A/D8005A	-34	5	1
94	Radial accelero 1A/3B	D8001A/D8005A	-32	7	1
95	Radial accelero 1A/3B	D8001A/D8005A	-30	9	1
96	Radial accelero 1A/3B	D8001A/D8005A	-28	11	1
97	Radial accelero 1A/3B	D8001A/D8005A	-26	13	1
98	Radial accelero 1A/3B	D8001A/D8005A	-24	15	1
99	Radial accelero 1A/3B	D8001A/D8005A	-22	17	1
100	Radial accelero 1A/3B	D8001A/D8005A	-20	19	1
101	Radial accelero 1A/3B	D8001A/D8005A	-18	21	1
102	Radial accelero 1A/3B	D8001A/D8005A	-16	23	1
103	Radial accelero 1A/3B	D8001A/D8005A	-14	25	1
104	Radial accelero 1A/3B	D8001A/D8005A	-12	27	1
105	Radial accelero 1A/3B	D8001A/D8005A	-10	29	1
106	Radial accelero 1A/3B	D8001A/D8005A	-8	31	1
107	Radial accelero 1A/3B	D8001A/D8005A	-6	33	1
108	Radial accelero 1A/3B	D8001A/D8005A	-4	35	1
109	Radial accelero 1A/3B	D8001A/D8005A	-2	37	1
110	Radial accelero 1A/3B	D8001A/D8005A	0	39	1

Position 111 to 114 are spare bytes, set to zero.

See Figure 4.4.3-15 for timing details.

C• *Timing Information for HK3*

See Table 4.4.3-2 for Timing details.

Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle no	parameter_acq_no
1	DDB spin	S1011H/S2011H	-119 & -15 (*)	80	1
2	DDB spin	S1011H/S2011H	-103 & -15 (*)	96	1
3	DDB spin	S1011H/S2011H	-87 & -15 (*)	112	1
4	DDB spin	S1011H/S2011H	-71 & -15 (*)	128	1
5	DDB spin	S1011H/S2011H	-55 & -15 (*)	16	1
6	DDB spin	S1011H/S2011H	-39 & -15 (*)	32	1
7	DDB spin	S1011H/S2011H	-23 & -15 (*)	48	1
8	DDB spin	S1011H/S2011H	-7 & -15 (*)	64	1
9	DDB Mission Phase	S1012H/S2012H	-120 & -14 (*)	79	2
10	DDB Mission Phase	S1012H/S2012H	-104 & -14 (*)	95	2
11	DDB Mission Phase	S1012H/S2012H	-88 & -14 (*)	111	2
12	DDB Mission Phase	S1012H/S2012H	-72 & -14 (*)	127	2
13	DDB Mission Phase	S1012H/S2012H	-56 & -14 (*)	15	2
14	DDB Mission Phase	S1012H/S2012H	-40 & -14 (*)	31	2
15	DDB Mission Phase	S1012H/S2012H	-24 & -14 (*)	47	2
16	DDB Mission Phase	S1012H/S2012H	-8 & -14 (*)	63	2
17 18	DDB F2 and DDB altitude	S1013W/S2013W	-119 & -15 (*)	80	2
19 20	DDB F2 and DDB altitude	S1013W/S2013W	-103 & -15 (*)	96	2
21 22	DDB F2 and DDB altitude	S1013W/S2013W	-87 & -15 (*)	112	2
23 24	DDB F2 and DDB altitude	S1013W/S2013W	-71 & -15 (*)	128	2
25 26	DDB F2 and DDB altitude	S1013W/S2013W	-55 & -15 (*)	16	2
27 28	DDB F2 and DDB altitude	S1013W/S2013W	-39 & -15 (*)	32	2
29 30	DDB F2 and DDB altitude	S1013W/S2013W	-23 & -15 (*)	48	2
31 32	DDB F2 and DDB altitude	S1013W/S2013W	-7 & -15 (*)	64	2
33 34	DDB F1 and DDB time	S1014W/S2014W	-119 & -15 (*)	80	3
35 36	DDB F1 and DDB time	S1014W/S2014W	-103 & -15 (*)	96	3
37 38	DDB F1 and DDB time	S1014W/S2014W	-87 & -15 (*)	112	3
39 40	DDB F1 and DDB time	S1014W/S2014W	-71 & -15 (*)	128	3
41 42	DDB F1 and DDB time	S1014W/S2014W	-55 & -15 (*)	16	3
43 44	DDB F1 and DDB time	S1014W/S2014W	-39 & -15 (*)	32	3

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Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle_no	parameter_acq_no
45 46	DDB F1 and DDB time	S1014W/S2014W	-23 & -15 (*)	48	3
47 48	DDB F1 and DDB time	S1014W/S2014W	-7 & -15 (*)	64	3
49 50	RAU A/B Monitoring N	D3001S/D4001S	-121 & -3 (**)	78	1
51 52	RAU A/B Monitoring N	D3001S/D4001S	-105 & -3 (**)	94	1
53 54	RAU A/B Monitoring N	D3001S/D4001S	-89 & -3 (**)	110	1
55 56	RAU A/B Monitoring N	D3001S/D4001S	-73 & -3 (**)	126	1
57 58	RAU A/B Monitoring N	D3001S/D4001S	-57 & -3 (**)	14	1
59 60	RAU A/B Monitoring N	D3001S/D4001S	-41 & -3 (**)	30	1
61 62	RAU A/B Monitoring N	D3001S/D4001S	-25 & -3 (**)	46	1
63 64	RAU A/B Monitoring N	D3001S/D4001S	-9 & -3 (**)	62	1
65 66	RAU B/A Monitoring R	D4002S/D3002S	-121 & -3 (**)	78	2
67 68	RAU B/A Monitoring R	D4002S/D3002S	-105 & -3 (**)	94	2
69 70	RAU B/A Monitoring R	D4002S/D3002S	-89 & -3 (**)	110	2
71 72	RAU B/A Monitoring R	D4002S/D3002S	-73 & -3 (**)	126	2
73 74	RAU B/A Monitoring R	D4002S/D3002S	-57 & -3 (**)	14	2
75 76	RAU B/A Monitoring R	D4002S/D3002S	-41 & -3 (**)	30	2
77 78	RAU B/A Monitoring R	D4002S/D3002S	-25 & -3 (**)	46	2
79 80	RAU B/A Monitoring R	D4002S/D3002S	-9 & -3 (**)	62	2
81 82	Coast timer 1 value A/B	D6001S/D6002S	-31	40	1
83 84	Coast timer 2 value A/B	D6003S/D6004S	-31	40	2
85 86	Coast timer 3 value A/B	D6005S/D6006S	-31	40	3

(*) See explanation in "Time Buffering of DDB HK Parameters" and "Datation of Time Buffered Parameters" in § 4.4.3-4-3
(**) See explanation in "Time Buffering of CDMS HK Parameters" and "Datation of Time Buffered Parameters" in § 4.4.3-4-3

Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle no	parameter_acq no
87	GCMS A/B status	E1002S/E1003S	-15	56	1
88					
89	DISR A/B status	E3002S/E3003S	-1	70	1
90					
91	ACP A/B status	E4002S/E4005S	-127	72	1
92					
93	HASI A/B status	E2002S/E2005S	-113	86	1
94					
95	SSP A/B status	E5002S/E5003S	-111	88	1
96					

Positions 97 to 114 are spare bytes, set to zero.

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D• *Timing Information for HK4*

See Figure 4.4.3-15 for timing details.

Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle no	parameter_ acq_no
1	Central Accelero 1 value A/B	D7001A/D7004A	-125	106	1
2	Central Accelero 1 value A/B	D7001A/D7004A	-117	114	1
3	Central Accelero 1 value A/B	D7001A/D7004A	-109	122	1
4	Central Accelero 1 value A/B	D7001A/D7004A	-101	2	1
5	Central Accelero 1 value A/B	D7001A/D7004A	-93	10	1
6	Central Accelero 1 value A/B	D7001A/D7004A	-85	18	1
7	Central Accelero 1 value A/B	D7001A/D7004A	-77	26	1
8	Central Accelero 1 value A/B	D7001A/D7004A	-69	34	1
9	Central Accelero 1 value A/B	D7001A/D7004A	-61	42	1
10	Central Accelero 1 value A/B	D7001A/D7004A	-53	50	1
11	Central Accelero 1 value A/B	D7001A/D7004A	-45	58	1
12	Central Accelero 1 value A/B	D7001A/D7004A	-37	66	1
13	Central Accelero 1 value A/B	D7001A/D7004A	-29	74	1
14	Central Accelero 1 value A/B	D7001A/D7004A	-21	82	1
15	Central Accelero 1 value A/B	D7001A/D7004A	-13	90	1
16	Central Accelero 1 value A/B	D7001A/D7004A	-5	98	1
17	Central Accelero 2 value A/B	D7002A/D7005A	-125	106	2
18	Central Accelero 2 value A/B	D7002A/D7005A	-117	114	2
19	Central Accelero 2 value A/B	D7002A/D7005A	-109	122	2
20	Central Accelero 2 value A/B	D7002A/D7005A	-101	2	2
21	Central Accelero 2 value A/B	D7002A/D7005A	-93	10	2
22	Central Accelero 2 value A/B	D7002A/D7005A	-85	18	2
23	Central Accelero 2 value A/B	D7002A/D7005A	-77	26	2
24	Central Accelero 2 value A/B	D7002A/D7005A	-69	34	2
25	Central Accelero 2 value A/B	D7002A/D7005A	-61	42	2
26	Central Accelero 2 value A/B	D7002A/D7005A	-53	50	2
27	Central Accelero 2 value A/B	D7002A/D7005A	-45	58	2
28	Central Accelero 2 value A/B	D7002A/D7005A	-37	66	2
29	Central Accelero 2 value A/B	D7002A/D7005A	-29	74	2
30	Central Accelero 2 value A/B	D7002A/D7005A	-21	82	2
31	Central Accelero 2 value A/B	D7002A/D7005A	-13	90	2
32	Central Accelero 2 value A/B	D7002A/D7005A	-5	98	2
33	Central Accelero 3 value A/B	D7003A/D7006A	-125	106	3
34	Central Accelero 3 value A/B	D7003A/D7006A	-117	114	3
35	Central Accelero 3 value A/B	D7003A/D7006A	-109	122	3
36	Central Accelero 3 value A/B	D7003A/D7006A	-101	2	3
37	Central Accelero 3 value A/B	D7003A/D7006A	-93	10	3
38	Central Accelero 3 value A/B	D7003A/D7006A	-85	18	3
39	Central Accelero 3 value A/B	D7003A/D7006A	-77	26	3
40	Central Accelero 3 value A/B	D7003A/D7006A	-69	34	3
41	Central Accelero 3 value A/B	D7003A/D7006A	-61	42	3
42	Central Accelero 3 value A/B	D7003A/D7006A	-53	50	3

Position	Parameter Description	TM Code POSWA/POSWB	Timing Offset	CUT_cycle no	parameter_acq no
43	Central Accelero 3 value A/B	D7003A/D7006A	-45	58	3
44	Central Accelero 3 value A/B	D7003A/D7006A	-37	66	3
45	Central Accelero 3 value A/B	D7003A/D7006A	-29	74	3
46	Central Accelero 3 value A/B	D7003A/D7006A	-21	82	3
47	Central Accelero 3 value A/B	D7003A/D7006A	-13	90	3
48	Central Accelero 3 value A/B	D7003A/D7006A	-5	98	3
49 50	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-120	111	3
51 52	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-112	119	3
53 54	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-104	127	3
55 56	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-96	7	3
57 58	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-88	15	3
59 60	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-80	23	2
61 62	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-72	31	3
63 64	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-64	39	2
65 66	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-56	47	3
67 68	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-48	55	2
69 70	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-40	63	3
71 72	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-32	71	2
73 74	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-24	79	3
75 76	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-16	87	3
77 78	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-8	95	3
79 80	T0/Ta G-Switch 1 and 2 A/B Buffer	S1024W/S2024W	-0	103	3
81 82	T0/Ta G-Switch Timeout A/B Counter	S1025W/S2025W	-94	9	3

Positions 83 to 114 are spare bytes, set to zero.

E• *CHAT Data*

This table presents the CHAT per CUT (from 1 to 128).

CUT	Parameter 1 POSWA/POSWB	HK	Parameter 2 POSWA/POSWB	HK	Parameter 3 POSWA/POSWB	HK
1	D8001A/D8005A	2	S1013H/S2013H	1	S1014H/S2014H	1
2	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
3	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
4	D3005A/D4005A	1	Null_Acquisition		Null_Acquisition	
5	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
6	E6001A/E6005A	2	E6002A/E6006A	2	E6003A/E6007A	2
7	D8001A/D8005A	2	P5029A/P5057A	2	S1024W/S2024W	4
8	P5020A/P5021A	2	Null_Acquisition		Null_Acquisition	
9	D8001A/D8005A	2	S1014H/S2014H	1	S1025W/S2025W	4
10	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
11	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
12	D3005A/D4005A	1	Null_Acquisition		Null_Acquisition	
13	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
14	D3001S/D4001S	3	D4002S/D3002S	3	Null_Acquisition	
15	D8001A/D8005A	2	S1012H/S2012H	3	S1024W/S2024W	4
16	S1011H/S2011H	3	S1013W/S2013W	3	S1014W/S2014W	3
17	D8001A/D8005A	2	S1014H/S2014H	1	Null_Acquisition	
18	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
19	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
20	D3005A/D4005A	1	Null_Acquisition		Null_Acquisition	
21	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
22	R1002A/R2002A	2	R1003A/R2003A	2	R1004A/R2004A	2
23	D8001A/D8005A	2	S1024W/S2024W	4	Null_Acquisition	
24	R1007A/R2007A	2	P5023A/P5051A	2	Null_Acquisition	
25	D8001A/D8005A	2	S1014H/S2014H	1	Null_Acquisition	
26	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
27	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
28	D3005A/D4005A	1	Null_Acquisition		Null_Acquisition	
29	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
30	D3001S/D4001S	3	D4002S/D3002S	3	Null_Acquisition	
31	D8001A/D8005A	2	S1012H/S2012H	3	S1024W/S2024W	4
32	S1011H/S2011H	3	S1013W/S2013W	3	S1014W/S2014W	3
33	D8001A/D8005A	2	S1014H/S2014H	1	Null_Acquisition	
34	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
35	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
36	D3005A/D4005A	1	Null_Acquisition		Null_Acquisition	
37	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
38	P5002A/P5007A	2	P5003A/P5006A	2	P5004A/P5005A	2
39	D8001A/D8005A	2	S1024W/S2024W	4	Null_Acquisition	
40	D6001S/D6002S	3	D6003S/D6004S	3	D6005S/D6006S	3
41	D8001A/D8005A	2	S1014H/S2014H	1	Null_Acquisition	
42	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
43	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
44	D3005A/D4005A	1	Null_Acquisition		Null_Acquisition	

CUT	Parameter 1 POSWA/POSWB	HK	Parameter 2 POSWA/POSWB	HK	Parameter 3 POSWA/POSWB	HK
45	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
46	D3001S/D4001S	3	D4002S/D3002S	3	Null_Acquisition	
47	D8001A/D8005A	2	S1012H/S2012H	3	S1024W/S2024W	4
48	S1011H/S2011H	3	S1013W/S2013W	3	S1014W/S2014W	3
49	D8001A/D8005A	2	S1014H/S2014H	1	Null_Acquisition	
50	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
51	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
52	D3005A/D4005A	1	Null_Acquisition		Null_Acquisition	
53	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
54	P5008A/P5013A	2	P5009A/P5012A	2	P5010A/P5011A	2
55	D8001A/D8005A	2	S1024W/S2024W	4	Null_Acquisition	
56	E1002S/E1003S	3	P5024A/P5052A	2	P5026A/P5054A	2
57	D8001A/D8005A	2	S1014H/S2014H	1	Null_Acquisition	
58	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
59	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
60	D3005A/D4005A	1	Null_Acquisition		Null_Acquisition	
61	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
62	D3001S/D4001S	3	D4002S/D3002S	3	Null_Acquisition	
63	D8001A/D8005A	2	S1012H/S2012H	3	S1024W/S2024W	4
64	S1011H/S2011H	3	S1013W/S2013W	3	S1014W/S2014W	3
65	D8001A/D8005A	2	S1014H/S2014H	1	Null_Acquisition	
66	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
67	D8001A/D8005A	2	D5001T/D5013T	2	Null_Acquisition	
68	D3005A/D4005A	1	D5002T/D5014T	2	Null_Acquisition	
69	D8001A/D8005A	2	D5003T/D5015T	2	D5004T/D5016T	2
70	E3002S/E3003S	3	P5025A/P5053A	2	P5032A/P5060A	2
71	D8001A/D8005A	2	S1024W/S2024W	4	P5027A/P5055A	2
72	E4002S/E4005S	3	P5033A/P5061A	2	P5028A/P5056A	2
73	D8001A/D8005A	2	D1008T/D2008T	2	S1014H/S2014H	1
74	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
75	D8001A/D8005A	2	D1009T/D2009T	2	Null_Acquisition	
76	D3005A/D4005A	1	D5005T/D5017T	2	Null_Acquisition	
77	D8001A/D8005A	2	D5006T/D5018T	2	Null_Acquisition	
78	D3001S/D4001S	3	D4002S/D3002S	3	Null_Acquisition	
79	D8001A/D8005A	2	S1012H/S2012H	3	S1024W/S2024W	4
80	S1011H/S2011H	3	S1013W/S2013W	3	S1014W/S2014W	3
81	D8001A/D8005A	2	S1014H/S2014H	1	Null_Acquisition	
82	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
83	D8001A/D8005A	2	D5007T/D5019T	2	Null_Acquisition	
84	D3005A/D4005A	1	D5008T/D5020T	2	Null_Acquisition	
85	D8001A/D8005A	2	D5009T/D5021T	2	Null_Acquisition	
86	E2002S/E2005S	3	P5030A/P5058A	2	P5034A/P5062A	2
87	D8001A/D8005A	2	D5010T/D5022T	2	S1024W/S2024W	4
88	E5002S/E5003S	3	P5031A/P5059A	2	Null_Acquisition	
89	D8001A/D8005A	2	D5011T/D5023T	2	S1014H/S2014H	1
90	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
91	D8001A/D8005A	2	D5012T/D5024T	2	Null_Acquisition	

CUT	Parameter 1 POSWA/POSWB	HK	Parameter 2 POSWA/POSWB	HK	Parameter 3 POSWA/POSWB	HK
92	D3005A/D4005A	1	Null_Acquisition		Null_Acquisition	
93	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
94	D3001S/D4001S	3	D4002S/D3002S	3	Null_Acquisition	
95	D8001A/D8005A	2	S1012H/S2012H	3	S1024W/S2024W	4
96	S1011H/S2011H	3	S1013W/S2013W	3	S1014W/S2014W	3
97	D8001A/D8005A	2	S1014H/S2014H	1	Null_Acquisition	
98	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
99	D8001A/D8005A	2	Null_Acquisition		Null_Acquisition	
100	D3005A/D4005A	1	P5035A/P5063A	2	Null_Acquisition	
101	D8001A/D8005A	2	D1003A/D2003A	2	Null_Acquisition	
102	S1015W/S2015W	1	D1005A/D2005A	2	Null_Acquisition	
103	D8001A/D8005A	2	D1004A/D2004A	2	S1024W/S2024W	4
104	S1010H/S2010H	1	D1002A/D2002A	2	Null_Acquisition	
105	D8001A/D8005A	2	P5022A/P5050A	2	S1014H/S2014H	1
106	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
107	D8001A/D8005A	2	Probe Status 1	1	Null_Acquisition	
108	D3005A/D4005A	1	Probe Status 4	1	Null_Acquisition	
109	D8001A/D8005A	2	Probe Status 3	1	Null_Acquisition	
110	D3001S/D4001S	3	D4002S/D3002S	3	S1007H/S2007H	1
111	D8001A/D8005A	2	S1012H/S2012H	3	S1024W/S2024W	4
112	S1011H/S2011H	3	S1013W/S2013W	3	S1014W/S2014W	3
113	D8001A/D8005A	2	S1006H/S2006H	1	S1014H/S2014H	1
114	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
115	D8001A/D8005A	2	S1001H/S2001H	1	S1008H/S2008H	1
116	D3005A/D4005A	1	S1002H/S2002H	1	S1003H/S2003H	1
117	D8001A/D8005A	2	S1016W/S2016W	1	S1009H/S2009H	1
118	S1017W/S2017W	1	S1004H/S2004H	1	S1005H/S2005H	1
119	D8001A/D8005A	2	Probe Status 5	1	S1024W/S2024W	4
120	DRR (Probe Status 7)	1	Probe Status 2	1	Null_Acquisition	
121	D8001A/D8005A	2	Probe Status 6	1	S1014H/S2014H	1
122	D7001A/D7004A	4	D7002A/D7005A	4	D7003A/D7006A	4
123	D8001A/D8005A	2	S1018W/S2018W	1	S1019W/S2019W	1
124	D3005A/D4005A	1	S1020W/S2020W	1	S1021W/S2021W	1
125	D8001A/D8005A	2	S1022W/S2022W	1	S1023W/S2023W	1
126	D3001S/D4001S	3	D4002S/D3002S	3	Null_Acquisition	
127	D8001A/D8005A	2	S1012H/S2012H	3	S1024W/S2024W	4
128	S1011H/S2011H	3	S1013W/S2013W	3	S1014W/S2014W	3

4.5 SASW (SUPPORT AVIONICS SOFTWARE)

4.5.1 OVERVIEW

The HUYGENS on-board software is divided into two subsystems: the Probe on-board S/W and the Support Avionics S/W. The SASW forms part of the Probe Support Equipment (PSE) mounted on the Cassini Orbiter, and is the communications relay for the Probe. The two S/W systems run independently of each other. There is no synchronisation between POSW and SASW. The POSW communicates with ground via SASW and the CASSINI command and data subsystem (CDS).

The POSW communicates with the SASW in different ways depending on mission phase. Before the probe is spun-up and ejected from the orbiter (about 22 days before Titan encounter), the two software subsystems communicate through an umbilical which contains both commanding and telemetry interfaces. After separation, it is no longer possible to command the probe, and telemetry is transmitted from the probe to the orbiter over a radio link within the probe data relay subsystem (PDRS).

Conventions:

A HUYGENS Bit Numbering Convention

The HUYGENS project imposes a bit numbering convention with the bits numbered starting with the least significant bit as bit zero. This is the opposite to the convention used in both the MIL-STD-1750A and the ESA Packet Telemetry and Telecommand standards. This document uses the HUYGENS project definition of bit numbering

msb															lsb
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

HUYGENS BIT NUMBERING

msb															lsb
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

MIL-STD-1750A & ESA STANDARD BIT NUMBERING

Note: msb is the first bit transmitted.

B Standard Acronyms & Abbreviations

The following acronyms, abbreviations and conventions are used:

APID	Application Process Identifier
ASIC	Application Specific Integrated Circuit
BIU	Bus Interface Unit (1553 bus)
Byte	8 Bit unit of data
CCSDS	Consultative Committee for Space Data Systems
CDMS	Command and Data Management Subsystem
CDMU	Command and Data Management Unit
CDS	Command and Data Subsystem
CHAT	CUT Housekeeping Acquisition Table
CMD	One command from within a direct TC or Timeline
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
CUT	Computed Unit of Time (sequencer period)
DDB	Descent Data Broadcast
DMA	Direct Memory Access
DSP	Digital Signal Processing
DTSTART	Dead Time Start
EDAC	Error Detection and Correction Device
EEPROM	Electrically Erasable Programmable Read Only Memory
EPT	Experiment Polling Table
ESA	European Space Agency
FIFO	First In/First Out Buffer
FPU	Floating Point Unit
H/W	Hardware
HK	Housekeeping
HOOD	Hierarchical Object Oriented Design
I/O	Input/Output
ICD	Interface Control Document
ISR	Interrupt Service Routine
Kbyte/Kword	1024 bytes/words of data
lsb	least significant bit
LSB/LSW	Least significant byte or word
ML	Memory Load
MMU	Memory Management Unit
msb	most significant bit
MSB/MSW	Most significant byte or word
µP	Microprocessor
MTT	Mission Timeline Tables
OBDH	On-Board Data Handling
PC	Personal Computer
PDL	Program Definition Language
PDRS	Probe Data Relay Subsystem
POSW	Probe On-Board Software
PRL	Probe Relay Link
PROM	Programmable Read Only Memory
PSA	Probe Support Avionics
PSE	Probe Support Equipment
PST	Polling Sequence Table

RAM	Random Access Memory
RID	Review Item Discrepancy
ROM	Read Only Memory
RT	Real Time
RTDT	Remote Terminal Descriptor Table (of BIU)
RTI	Real Time Interrupt
RTS	Run Time System
RTX	Real Time Executive
RUSO	Receiver Ultra Stable Oscillator
S/W	Software
SASW	Support Avionics Software
SQRT	Square Root
S0	Advanced T0 = Mission Time start (POSW time)
T0	Time of Entry into Titan's Atmosphere
TAI	Timer A interrupt
TBI	Timer B interrupt
TC	Telecommand
TLD	TLD Systems Ltd (Suppliers of 1750 Ada compiler)
TM	Telemetry
TMI	Telemetry Interrupt
Word	16 Bit unit of data

4.5.1-1 SASW Overview

The main purpose of the SASW is to provide a means of communication between the Orbiter and the Probe, during the Cruise phase and the Descent phase. During the Mission phase, when the Probe is separated, telemetry reception is maintained by means of a radio link (after HPAs switched ON) but telecommanding is not possible. When the Probe is connected to the orbiter, both telecommanding and telemetry reception are possible by means of an umbilical link; the telecommands are sent over the umbilical TC link, while the telemetry is received over an RF link within the umbilical, which is considered to be part of the PDRS. Note that from the SASW viewpoint there is no difference between receiving probe telemetry via the umbilical or via the RF subsystem. All the differences are handled by the receiver (RX) interface which is part of the PSA equipment.

Communication between the SASW and the Orbiter CDS is by means of a 1553 bus. A bus interface unit (BIU) provides a means of communicating over the 1553 bus whilst reducing the load on the SASW processor. Telecommands from CDS are placed in shared memory (referred to as BIU RAM) for the SASW to read. Similarly SASW places telemetry packets in BIU memory for collection by the Cassini CDS over the BIU over the bus.

The SASW handles the reception of Probe Transfer Frames via a Frame Data Interface (FDI). Telemetry from the probe is transmitted to the SASW either by the umbilical RF link (when the probe is connected) or by the Probe Relay Link (PRL) (when the probe is separated). This data is delivered to the FDI by the RX subsystem.

The SASW also generates its own telemetry in the form of PSA HK packets which contain PSA health information, and status data collected from the RX Interface.

The main SASW functions are summarised below:

4.5.1-2 BIU Management

The BIU serves as a Remote Terminal on the 1553 bus providing the only interface through which SASW is able to communicate with Cassini CDS. The CDS acts as the 1553 Bus Controller. Communication is achieved by the use of shared memory that resides in the BIU. SASW manages the BIU by regular examination and updates to this shared memory (also called BIU RAM). TCs destined for both SASW and POSW are placed into BIU RAM by CDS and TM from SASW or POSW is placed into BIU RAM by SASW fo collection by CDS.

The BIU is also responsible, through commanding by CDS, for generating the RTI and the DTSTART (Dead Time START) interrupt and also for providing SASW with the Spacecraft time.

The SASW provided BIU Management functionality is summarized below:

- **Receiving Telecommands**: The SASW examines the BIU RAM every CUT for any TCs deposited by the Cassini CDS. If one is found then it is collected and processed.

- **Sending Telemetry**: The SASW examines the BIU RAM every CUT for TM packets that have been picked up by Cassini. If one has been picked up and further packets are available, SASW queues the next packet in the TM FIFOs.

• **Receiving Spacecraft Time**: The SASW examines the BIU RAM every CUT for the arrival of the Spacecraft Time (also known as the BIU Time). This will nominally arrive in CUT 6. If SASW detects the arrival of the time it is collected for distribution, and inclusion in TM packets, at the next RTI 0 boundary.

• **Detecting Telemetry Mode Change**: The SASW examines the BIU RAM every CUT for any telemetry mode changes. Nominally there are two CDS telemetry modes, (i) Collecting telemetry and (ii) not collecting telemetry. SASW checks for a transition form not collecting to collecting and purges the TM FIFOs when this transition is about to take place.

• **Recovery from BIU Failures**: The SASW examines the BIU registers every CUT to determine if a BIU failure has occured since the last CUT. If a BIU failure is detected, then appropriate recovery actions are taken by SASW.

4.5.1-3 Telecommand Management

The SASW examines any received TCs to determine their destination address. Those destined for the Probe (either POSW or Experiments) are transmitted over the umbilical TC link. Those destined for the PSA are handled by the SASW. The provided functionality is summarised below:

• **Collection and Validation of Telecommands**: The SASW collects all TCs destined for the PSA, CDMS or Experiment Payload from the BIU RAM. These TCs are subsequently validated against the ESA packet telecommand standard [ESA PSS-04-107] for Packet Header, and checked for data corruption via a cyclic redundancy check for PSA TCs only. The CRC on TCs destined for POSW are ignored by SASW (but checked by POSW itself). Only TCs which successfully pass validation are processed further.

• **Execution of PSA Telecommands**: All successfully validated TCs destined for the PSA are executed by SASW. PSA TCs typically operate hardware devices, modify the receiver frequency or allow the functionality of SASW to be managed and monitored via patches and dumps. No TCs will be sent to SASW during the Mission phase.

• **Forwarding of POSW and Experiment Telecommands**: TCs destined for the POSW undergo a reduced set of validation tests. All successfully validated TCs destined for POSW are simply transmitted across the umbilical link.

Note should TCs arrive in the BIU RAM which are destined for the POSW during the Mission phase, SASW will simply attempt to transmit the TCs across the umbilical even though there will be no umbilical link during this phase.

4.5.1-4 Telemetry Management

The SASW transmits telemetry to the Cassini Orbiter by writing the telemetry into the BIU RAM for collection by CDS. SASW will autonomously start writing PSA HK packets and Dump Super packets into the BIU RAM once it has been energised and entered its Mission phase. However, Probe frames will only be written into the BIU RAM once theystart to arrive and will replace the Dump Super packets. The telemetry management functionality is summarised below:

• **Construction of SASW PSA HK Packets**: The software acquires key spacecraft and S/W parameters during the Mission and formats this data into PSA HK Packets. One PSA HK packet will be generated and placed into the BIU RAM every 8 CUTs (1 second)

• **Transmission of Super Packets/Dump Super Packets**: Whilst the Probe is not sending any Probe Transfer Frames SASW will generate Dump Super Packets in their place and place these into the BIU RAM once every 8 CUTs (assuming CDS is collecting Probe Frames once every 8 CUTs). These Dump Super Packets will essentially consist of a dump of the SASW RTDT in the BIU RAM.

Once Probe Transfer Frames start to arrive, SASW will start to transfer the Probe Transfer Frames directly into the BIU RAM, add a six word SASW telemetry header and then make these Super packets available to CDS for collection. Generation of Dump Super packets will stop.

4.5.1-5 Timing Management

The SASW is responsible for:

• Providing a Real Time Counter (**RT counter**) from the RTI

4.5.1-6 Software Flight Operations

The flight operations are characterised by long periods of inactivity, which are interspersed with half yearly in-flight checkouts. The Titan encounter and the final Parachute Descent are executed autonomously by the Probe without any ground interaction.

Two distinct classes of S/W operations are envisaged during the operational lifetime of the Probe. They are:

• **User Operations**: The SASW receives TCs uplinked from the ground and transmits telemetry during the in-flight checkouts. These activities are envisaged as normal routine operations.

• **Maintenance Operations**: The SASW provides a mechanism for reprogramming and tuning the functionality executed by the S/W. This mission reprogrammability enables the mission to be tuned and allows SASW to be updated with new functionality. Thus reprogrammability may be used to overcome or circumvent hardware defects which arise "en-route" to Saturn.

The reprogramming of SASW is a maintenance operation which is complex and Computer analysts must be required to do this.

The Figure 4.5.1-1 gives a flow diagram of SASW functions.

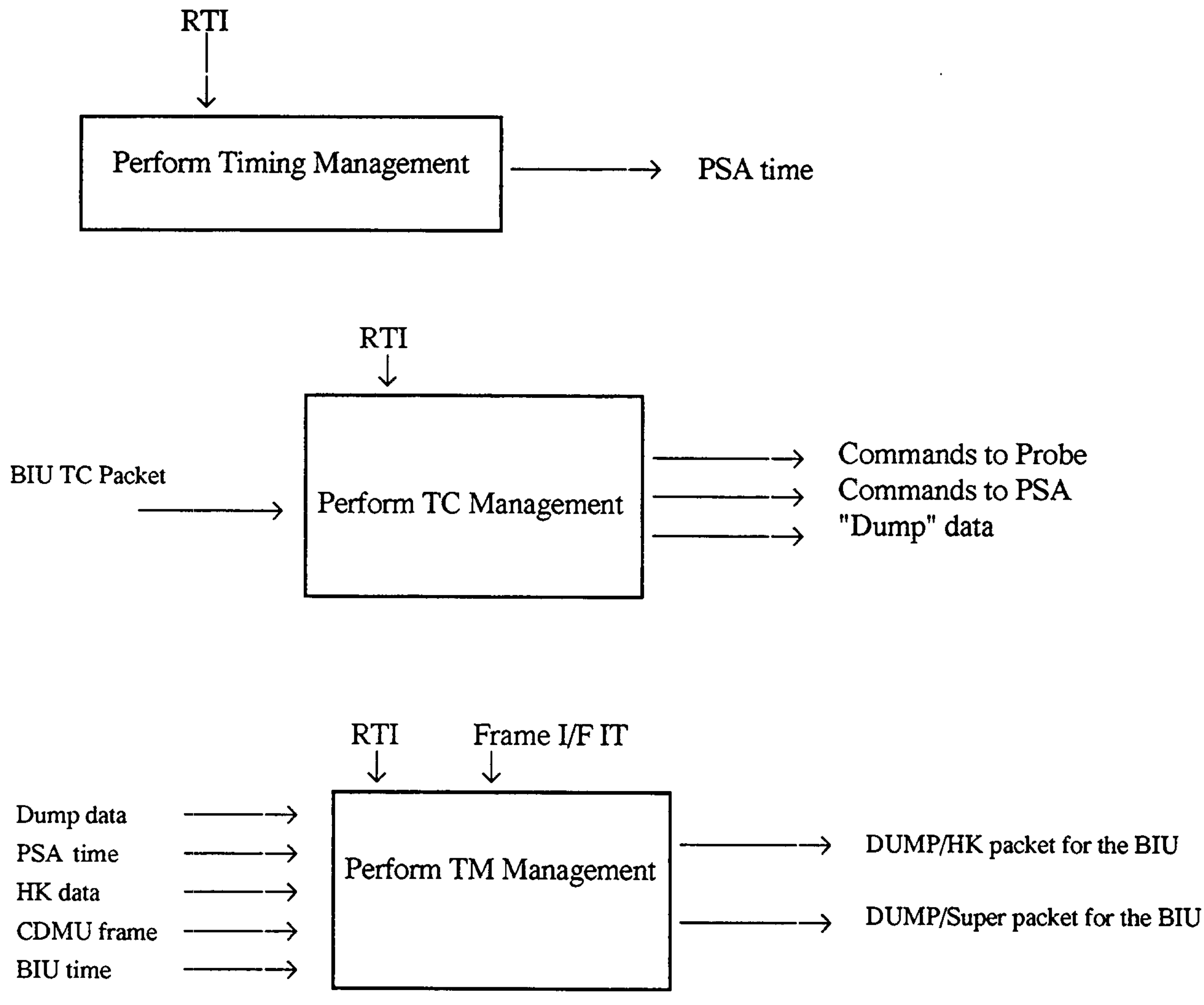

FIGURE 4.5.1-1 SASW DATA FLOW DIAGRAM

4.5.2 SASW DESIGN

4.5.2-1 Mission

The design of the SASW and indeed the PSA has been driven by the nature of the Cassini/Huygens Mission:

• **Mission Criticality**: The single shot characteristics of the Huygens Mission impose exacting reliability requirements on the S/W. Failure to convoy the Probe Frames to CDS will result in the loss of the mission.
System reliability is addressed by both H/W and S/W solutions. In H/W, key elements of the PSA are duplexed to increase overall system reliability. In particular two parallel processing chains execute the Mission in hot redundancy. Each of these chains is capable of running the Mission independently and may receive TCs and transmit TM unassisted. The S/W is designed and developed to Mission critical standards and runs autonomously once powered. No special S/W is included for the Launch, Cruise or Saturn Orbit phases and consequently the S/W executed during testing and in-flight checkouts is identical to that used for the actual Descent.

• **Autonomous Mission Execution**: The SASW is designed for completely autonomous operations during the Coast, Entry, Descent and Surface phases of the Mission as Cassini will be ≈ 90 light minutes from Earth during the Titan encounter, thereby making TCs from ground impractical.

• **Mission Reprogrammability**: Due to the long duration of the Cruise phase, the ability toreprogram the S/W is required. For example, to overcome or circumvent failures encountered with H/W devices.
Mission reprogrammability is provided by use of long term non-volatile memory, EEPROM.During the Cruise and Saturn Orbit phases, S/W patches which contain the modified data are stored in EEPROM. This patches are subsequently applied by SASW when next energised, and SASW executes the modified S/W.

• **Time Critical Asynchronous Activities**: SASW is both cyclic and interrupt driven. Some of the SASW activities are very time critical and the SASW has to respond in a very short period of time to handle these asynchronous activities.
Because of this constraint the SASW has to perform certain activities at the interrupt level. For example the arrival of the Probe Frame is signalled by the FDI interrupt and SASW then has 1.85 ms in which to program the DMA before the first Probe Frame word is overwritten by thenext incoming one.
CDS handles many Remote Terminal Units (RTU), the PSA being one of them, and thus SASW is allowed only 5ms at the end of every CUT period (known as the DTSTART period) in which it is allowed to access the BIU RAM. In this DTSTART period SASW checks for the arrival of TCs or the complete acquisition of TM by CDS and responds accordingly.

• **Bus Interface Unit**: The BIU is responsible for generating the RTI heartbeat as well as signalling the arrival of the DTSTART period via an interrupt. Without the RTI the SASW is unable to perform any activities, thus the SASW cannot survive RTI loss. However SASW is able to survive DTSTART interrupt loss as it automatically assumes DTSTART period after 120ms after the arrival of the RTI.
SASW is robust against RTI dropout up to 4s; a FIFO will buffer Probe Data and therefore no data will be lost.

Because SASW can only access the BIU RAM during the DTSTART period, this poses an obstacle during SASW startup/initialisation. During startup the SASW is not synchronised with the RTI so it relies on the DTSTART interrupt in order to initialise the BIU RAM and to detect the arrival of the Inhibition TC. If DTSTARTs are lost during startup, SASW will wait indefinitely until DTSTART interrupts arrive before attempting to initialise the BIU RAM and check for Inhibition TCs.

4.5.2-2 System Design

SASW Architecture

The SASW is a hard real time embedded system which is written in ADA. The S/W is mission critical and completely deterministic. A hardware generated interrupt, a "heartbeat" is used to drive normal CUT processing activities. This heartbeat is known as the Real Time Interrupt (RTI) and occurs every 125ms. Once the heartbeat occurs SASW schedules execution of all CUT level functionality, namely Probe telecommand management and telemetry management in a simple iterative manner. Superimposed on this cyclic scheduling is the interrupt level processing that is required to handle the arrival of the Probe Frame, the programming of the DMA to transfer the frame into BIU RAM and the handling of the subsequent completion of the DMA transfer.

Much of the SASW functionality is executed each CUT period, or every 8 CUT period. The interrupt activities are asynchronous and can occur at any time within the CUT, however once the interrupt driven activities start arriving they should occur every 8 CUTs.

During nominal processing SASW only expects the RTI, FDI and DMA interrupts to occur. The raising of any other interrupt is due to an error condition and SASW will perform appropriate recovery actions. Ada exception handling is used throughout the S/W to detect and recover from unforeseen events. In addition a CUT overrun mechanism is incorporated into the S/W to allow recovery from processing overruns.

The SASW has two operational modes. The first is the initialisation mode lasting for 15 seconds after power ON and is essentially the configuration of the S/W for the Mission. Any software patches stored in EEPROM are applied to RAM during this mode. The second is Mission mode. This mode provides all the functionality required for software operations in all phases of the Mission. Unless otherwise stated, all descriptions heregiven are applicable to Mission Mode.

SASW Interfaces

During the Mission, the SASW interfaces with the Probe and the Cassini CDS as well as various hardware devices on the PSA and the Receiver Interface. These interactions are described throughout this section and they are summarized below:

- **Hardware Devices**: The SASW operates H/W devices such as the TCXO and RUSO. For example, the selection of the RUSO or TCXO and the powering ON/OFF of the RUSO.

- **Receiver Interface**: The SASW allows for the selection of the Receiver frequency between the default (Doppler frequency) and the base frequency. The Receiver is also responsible for delivering Probe Transfer Frames to SASW.

• **Probe**: The SASW commmunicates with the Probe in two distinct manners. Prior to the Coast phase, SASW communicates with Probe via the umbilical link. Both "ground issued" TCs and Probe TM are transmitted over the umbilical. After separation, the umbilical link is severed and no telecommanding ability exists. TM is transmitted however, via the PDRS. This is a radio link.

• **Cassini**: The SASW communicates with Cassini through the BIU. TCs arriving from CDS are placed in the BIU RAM at pre-defined addresses. The SASW examines these addresses every CUT during the DTSTART period to detect the arrival of any TCs. Any TCs arriving into the BIU RAM are extracted and executed accordingly.

TM generated by SASW or that arriving from the Probe is written into the BIU RAM at pre-defined addresses thus making it available for collection by CDS.

Hardware Environment

The SASW forms part of the PSE. As such the PSA provides the hardware environment in which SASW operates. This environment consists of two units, which each runs a version of SASW in hot redundancy. These units include:

• **Devices**:
  MIL-STD-1750A µProc (MAS281) running at 10 Mhz
  Memory Management Unit (MMU)
  Direct Memory Access (DMA)
  Error Detection And Correction (EDAC)
  Bus Interface Unit (BIU)
  Umbilical serial line

• **Memory**:
  RAM: 64 kwords (EDAC protected)
  Startup ROM: 2 kwords
  PROM: 32 kwords
  EEPROM: 8 kwords
  BIU RAM: 8 kwords

4.5.2-3 Key Design Features

They are the result of both hardware and software design:

Hardware/Software Redundancy

The PSA hardware is duplexed to increase the overall system reliability. The two PSAs are configured to operate in hot redundancy with the first unit being named Chain A and the second Chain B. Each hardware chain is capable of running the mission independently and there is no cross strapping between the two units. Each unit may receive telecommands and transmit telemetry unassisted. The two hardware chains are in general terms identical.apart from the following differences:

1. Telemetry is treceived at two different frequencies to avoid interference.

2. Only one unit is connected to the high stability oscillator (RUSO) used for the Doppler wind Experiment.

The software images stored in the programmable read-only memory (PROM) of both hardware chains are identical. However several actions within the software do vary according to the hardware chain. These actions are typically the initialisation of parameters such as the spacecraft identifiers contained in the telemetry for example. The determination of the hardware chain, (i.e. whether Chain A or Chain B) is achieved by interrogating the PSA Status register which is provided by the PSA hardware.

Single Mission Design

The SASWis designed to execute the nominal mission once powered. As such the software is not expected to detect its environment, or sense the connection or disconnection of the Probe from the Orbiter. Thus no actions conditional on the Probe's state are included in the S/W. SASW will always execute a single mission regardless of the current phase of the Cassini/Huygens mission.

The design philosophy prevents potential failure modes from arising in case the mission is disrupted by a flight checkout sequence. Thus if specific S/W actions or inhibitions are required in a particular environment these must be invoked by procedures following activation of the S/W.

Software Modes

The SASW is a high integrity system whose design is underpinned by two states or Software modes:

- **Initialisation Mode**: This is a transitory mode which the S/W enters once powered and lasts for 14.875 seconds. During this time the hardware/memory confidence tests are conducted and the software is loaded from the PROM into main RAM and initialised. Software patches are also applied to RAM, if the check of non-volatile EEPROM passed and no Inhibition TC was received within the required time window.

  The hardware/memory confidence checks include checkouts of the main PROM, EEPROM, main RAM, BIU RAM and the DMA device. The results of these checks are reported in the PSA HK packet in the PSA INIT status parameter (TM A1008H/A2008H).

• **Mission Mode**: This mode commences on conclusion of "startup" and lasts until the SASW is de-energised. All "mission functionality" is executed within this mode. The SASW does not differentiate between the states "Probe connected" and "Probe disconnected" and runs the nominal mission when powered up, thus Mission mode refers to both the checkout phases (when the Probe is connected) and the real mission (Coast/Entry/Descent) phases (when the Probe is separated).

The software automatically generates PSA HK telemetry, processes telecommands and forwards incoming Probe Transfer Frames to Cassini.

Mission Reprogrammability

The SASW may be modified by software patching, before and after the Launch. This reprogramming is a complicated, multi-stage operation which results in patch data being applied to main RAM during initialisation mode. Patching is inherently complex due to the autonomous nature of the mission, where all software patches must be applied for the Titan encounter without ground assistance.

Patching is initiated by the uplinking of a Patch telecommand, which contains the desired patch data. This patch data will be stored in non-volatile EEPROM, and only applied to main RAM during the next initialisation sequence. A power cycle of the PSA is required to apply the patch data. However patch data is only applied to main RAM if the EEPROM check conducted during initialisation mode concluded successfully and no Inhibtion TC was received during the pre-defined time window. **SASW will execute the unmodified software contained in PROM if the EEPROM check fails, and therefore no guarantee exists that software patches will be applied for the Titan encounter.**

The Inhibition TC is designed to prevent erroneous patches being applied to main RAM during in-flight checkouts. Under the scenario where an erroneous patch has been stored into EEPROM, the ground may uplink the Inhibition TC during the pre-defined time window to prevent patch application. The time window for reception of an Inhibition TC is from 6.5 to 9.5 seconds after power ON. For maximum safety it is recommended that the command is sent 8 seconds after the power ON command. That is if the power ON command is sent in second 0, the Inhibit patch command should be sent in second 8.

Software Error Handling

The SASW uses a variety of mechanisms to detect and recover from errors conditions. These mechanisms are implemented in both hardware and software, and together form an effective error detection strategy. The prime objective on detection of an error is to mark the current activity as invalid. The software will also investigate recovery actions in an attempt to resume nominal processing. These detection mechanisms are complex, however an outline of these is given below for information:

• **Data Corruption**: The PSA incorporates an Error Detection And Correction (EDAC) device to safeguard SASW against corruption of main RAM. This device is invisible to the S/W, and will automatically detect and correct single bit errors that occur in any of the 64 Kwords of main RAM. The EDAC device will also detect double bit errors. However, the device is unable to correct double errors and their occurence is notified to the S/W via a dedicated μprocessor interrupt.

The SASW reports in its PSA HK TM the EDAC register which enables ground to ascertain whether a single bit error has occured within the last 8 CUTs. This register only allows detection of the error, not the number, so if more than one error occurs within the last 8 CUTs this wwill not be evident.

No action is taken by SASW to correct single bit errors, so it is likely that every access to the erroneous address will result in another correction by the EDAC.

Double bit errors will cause a machine error interrupt, which results in the MMU page registers being reset. The EDAC circuitry does not correct double bit errors and this may result in nsubsequent machine error interrupts.

Double bit errors are reported to ground by reporting the EDAC register and the CPU Fault Register in the PSA HK packet. Like the single bit error, if more than one double bit error has occured within the last 8 CUTs then ground will not be aware of how many, only that an error has occured.

Finally note that the EDAC device can only detect corruption which arises due to solar radiation or a defect in the memory chip. The EDAC device will not detect software induced corruption of memory.

• **Unforeseen Software Errors**: The SASW is written in ADA and uses the ADA exception mechanism to detect and handle unforeseen S/W errors. These unforeseen errors may arise from out of range data or attempts at illegal mathematical operations such as division by zero for example. The ADA run time kernel will detect such events and generate an ADA exception.

When an Ada exception is raised the current activity is aborted and variables which can be reset are reset. This mechanism allows SASW to return variables to a stable state in case they have been corrupted out of range and hence led to the exception.

The S/W maintains a count of ADA exceptions and this is reported in telemetry. In addition, SASW also sets and reports a health flag to aid fault diagnosis. The functionality executed by SASW each CUT is segregated into a number of distinct activities. A health flag is maintained for each activity and the appropriate activity health flag is set to failed whenever an exception occurs. There are 7 main activities executed by SASW each CUT and the activity health flags are described in § 4.5.4-2-5. The parameters reported in housekeeping telemetry for monitoring unforeseen software errors are the "Exception Counter TM A1005H/A2005H", "SASW Health MSW status TM A1004W/A2004W", "SASW Health LSW status TM A1003W/A2003W", "Fixed Point Overflow Counter TM A1004H/A2004H" and "Floating Point Overflow Counter TM A1004H/A2004H".

• **Unforeseen Hardware Errors**: The 1750a μprocessor will detect a number of unforeseen hardware errors and raise the dedicated machine error interrupt. These unforeseen errors may arise from an access to an illegal memory address or an attempt to execute an illegal 1750a instruction. The SASW will detect the machine error interrupt, and execute appropriate recovery action. The S/W also records the μprocessor fault register and reports the original fault in telemetry. The μprocessor fault register contains details of the nature of the fault and is called the "CPU Fault Register TM A1001W/A2001W" in housekeeping.

• **CUT Overrun Mechanism**: The S/W design incorporates a CUT overrun mechanism which is used to detect and recover from processing overruns. This mechanism uses an internal μprocessor timer, namely timer B to measure the processing time used by each CUT. A CUT overrun exception is raised if SASW is still actively processing after 124.8ms. The CUT overrun exception is subsequently handled by the S/W in a similar fashion to that described for unforeseen software errors. The CUT overrun counter is incremented and reported in housekeeping telemetry. All processing in the current, overrunning CUT is aborted and the S/W resumes nominal operations. SASW will re-commence processing in the following CUT, when the real time interrupt occurs.

This overrun mechanism provides protection against "infinite loops" or non-returning procedure calls which can arise due to incorrect re-programming or other hardware faults.

The reset of the current activity/object may take several milliseconds, which is more than 0.2ms allocated by SASW for overrun recovery, resulting in the next CUTs processing being delayed. However the current CUT processing margins can accomodate this delay.

Note the recovery time cannot be set to any value greater than 0.2ms as the last 5ms of the CUT is allocated for DTSTART processing, and since the processing performed by SASW during the DTSTART period is time crirical, as much time as possible has been allocated for this activity.

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4.5.3 SASW DESCRIPTION

4.5.3-1 SASW Start-up

The SASW enters its start-up (initialisation mode) processing when the PSA is powered up. During this mode the SASW performs hardware/memory confidence checks, initialises the Support Avionics Software and handles the application of patches.

During start-up all interrupts are deliberately masked to prevent any interrupt level processing. The SASW considers **all TCs invalid during the first 9.5 seconds of the Initialisation mode,** except for the Inhibition TC which may only be received during the dedicated three second window 6.5 to 9.5 s after PSA Power-up. Between 9.5s and 15s after Power-up, TCs are queued for execution at the start of Mission Mode.
No telemetry is generated during start-up, however, SASW will place a Dump Super packet in the BIU RAM by the end of the start-up period.

The SASW is required to complete its start-up activities within 14.875 seconds after which SASW enters Mission mode.

The results of the start-up checks are reported in PSA HK telemetry in the PSA INIT STATUS parameter TM A1008H/A2008H.

The activities performed during the SASW start-up include the following:

CPU Initialisation: Before any confidence checks are performed, the CPU is initialised by masking all interrupts (all interrupts remain masked throughout start-up), initialising the top 32 Kwords of main RAM, establishing the stack, initialising the CPU internal timer B to time the start-up sequence and initialising the MMU page registers to allow access to extended memory (BIU RAM and EEPROM).

PROM Check: The PROM is checked by performing a modulo 2^{16} checksum calculation on the entire contents of the PROM. If the PROM is valid this calculated checksum should equal zero. A valid checksum of zero results to the fact that the ones complement of the pre-flight calculated checksum + 1 is burnt into the last address in PROM 7FFFhex (the value contained in this location for SASW_4_3 is 4DADhex).
For example, if the pre-flight calculated checksum is 5555hex, the value burnt in PROM will be AAAAhex + 1 = AAABhex.

The calculated checksum is reported in the PSA HK packet along with the PROM health check.

DMA Check: A memory-to-memory transfer of a set number of words is performed to verify the functioning of the DMA chip. Although SASW does not perform any memory-to-memory transfer during the Mission, during start-up it is the only test possible on the DMA as the DMA channels established for the TC/TM transfer cannot be used. The result of the DMA check is reported in the PSA HK packet as the DMA health flag.

BIU RAM Check: The BIU RAM is checked by writing a value into the BIU RAM and reading and verifying the read-back data. The address of any invalid data read from the BIU RAM is reported as the first BIU RAM failure address in the PSA HK packet. Only the first failure address is reported and any subsequent failure cannot be reported. The BIU RAM health flag is also set accordingly and reported in the PSA HK packet.

PROM Copy: While the PROM image is being copied into main RAM each data word written into RAM is verified against the contents of the PROM. If the entire PROM copy is successful, the RAM health flag is set and reported in the PSA HK packet. If a word copied into RAM is invalid then the RAM address is noted and reported in the PSA HK packet. Only the first RAM failure address is reported, any subsequent failures will not be reported.

SASW Initialisation: The Support Avionics Software objects are initialised and the SASW RTDT is established in the BIU RAM. As part of the BIU RAM initialisation, SASW waits until the DTSTART interrupt is detrected before making any updates to BIU RAM.

EEPROM Check: All patches in the EEPROM are validated by performing a CRC on each patch. If all patches are valid the EEPROM is marked as healthy. The health flag is reported in the PSA HK packet.

Patch Application: If the EEPROM checks are successful and no Inhibition TC is sent during the appropriate time window, then SASW will copy patches present in EEPROM into main RAM.

At the end of the start-up period, SASW applies the Mission interrupt mask, enables all interrupts and enters Mission mode where it waits for the RTI before initiating any Mission related activities. Mission mode is always entered even if any of the above checks fail.

The 14.875 second initialisation period is subdivided into specific time windows in which the various start-up activities are performed. This is illustrated in the Table below:

Time Window	Time since Power ON	SASW Event
A	0 second	1• Hardware/memory confidence checks performed 2• PROM contents copied into RAM 3• Start SASW initialisation 4• Wait for DTSTART 5• Initialise BIU RAM 6• Complete SASW initialisation 7• Check EEPROM 8• Wait until 6.5 seconds
B	6.5 seconds	1• Wait until 9.5 seconds. This three second window is allocated for receipt of an Inhibition TC.
C	9.5 seconds	1• Wait for DTSTART 2• Check for Inhibition TC 3• Apply patches if no Inhibition TC 4• Wait until 14.875 seconds
D	14.875 seconds	1• Enter Mission Mode

During time windows "A" and "C" SASW waits for the arrival of DTSTART interrupts before attempting BIU RAM initialisation and checking for the Inhibition TC respectively. It is imperative that DTSTART interrupts start arriving as soon as SASW is powered up. If no DTSTART interrupts arrive during SASW initialisation (i.e. from 0 to 15 seconds) then entry into Mission Mode will be delayed. The absence of RTIs during start-up is not critical and SASW can complete start-up without RTIs, however, entry into Mission Mode will be triggered by the first RTI to arrive after 14.875 seconds.

4.5.3-2 Cassini Interface and BIU Management

The HUYGENS probe, and the PSA rely on the CASSINI orbiter for support functions including power during the cruise phase of the overall mission, and for telecommand and telemetry to the ground. During most of the flight to Saturn the PSA and the probe will be powered off. Periodic checkouts will be initiated by the CDS powering on the HUYGENS subsystems.

In principle the software does not constrain the HUYGENS subsystems to be powered up in any particular order. However the start-up sequence of both SASW and POSW includes various timings. It is assumed for nominal running that both PSA equipments (and hence SASW functions) will be powered ON simultaneously, and allowed to reach a steady state. After which both CDMUs can be powered up, to enable POSW functions. The SASW will require 15 seconds to start up, after which it will start to produce telemetry, and to forward telecommands.

The expected sequence of start-up during the actual mission is:

- PSA (SASW) powered ON
- Allow SASW to complete initialisations (Minimum of 15 seconds)
- CDS transition to collect SASW TM mode
- CDMU (POSW) power ON
- First data from Probe arrives.

Warning: If the above sequence is not followed then data from the Probe may be lost. For example, if CDS is not in TM collecting mode when probe data starts to arrive the SASW FIFO will fill and any subsequent probe data arriving will be lost. Furthermore when the mode is switched to collecting, the FIFOs are purged to leave only one packet in the FIFO.

4.5.3-2-1 MIL-STD 1553B Bus

The BIU interface to the CDS is a dual-redundant bi-directional MIL-STD-1553B bus. All communication is initiated and controlled by the CDS 1553B Bus Controller. Cassini CDS uses this bus to transmit and receive data from all subsystems of Cassini, and the HUYGENS PSA (each of the Huygens PSA's has a different RTU address). This transmission is done at a regular cadence, in synchrony with the RTI.

The BIU includes a 1553B controller chip, known as the Bus Controller, Remote Terminal, Monitor (BCRTM). This chip implements the low-level 1553B protocol requirements for SASW and is driven by tables and internal registers. The tables referred as Descriptor Tables, reside in BIU RAM and determine where data is to be placed or picked up from.

In addition the CASSINI CDS recognises mission critical periods, and during these periods operates the 1553 bus in a "critical" mode. This means that all TC data is delivered to the critical TC address in the BIU, and that TC packets are limited to 32 words. This allows messages to be sent in one 1553 data packet, and supports retry in the event of failure.

Warning: The SASW does not support the reception of TCs at any BIU addresses other than the normal and critical addresses. Thus the fault protection address is not supported by the SASW, and TC packets sent as retries to this address will be lost.

4.5.3-2-2 RTI and DTSTART Broadcasts

The Cassini CDS provides the SASW with a synchronisation signal 8 times each second known as the Real-Time Interrupt (RTI). The CDS also broadcasts a "quiet" time period signal 8 times each second (following the RTI) to allow SASW to access the BIU RAM. This signal is called the Dead Time Start (DTSTART). As both these signals are broadcast messages on the bus it is impossible to protect them with a retry mechanism. There is thus a very small probability that one of these messages could become corrupted and lost. There is also a possibility that the CDS may "fail-over" to its backup unit, resulting in a prolonged absence of these signals.

The RTI is broadcast every 125ms ± 100µs and is used by SASW as its "heartbeat" to schedule SASW activities. SASW does not perform any background processing during its absence. However Probe TM will continue to be collected on an interrupt basis, and the SASW FIFO is sized to allow 5 seconds worth of Probe TM to be buffered.

The "quiet" period allows SASW to make uninterrupted access to the BIU memory. SASW uses this period to check for the arrival of any TCs and to check for transmission of queued TM data. Although this period is signalled by the DTSTART interrupt, CDS additionally guarantees no bus activity in the last 5ms of each CUT, hence if the DTSTART signal is lost, SASW will automatically start its DTSTART processing 120ms into the CUT.

The diagram below illustrates the relationship between the RTI, "quiet" time and the DTSTART signal:

```
                              CUT 125ms
<----------------------------------------------------------------------------->

                                120ms
<------------------------------------------------------------------>|
                                                                    |
RTI                         DTSTART          Quiet Time            |        RTI
                               |<-----------------------------------|---------->
                               ↓                                    |
|___________________________________________________________________|_________|
                                                                         ↑
                                                                     5ms Bus
                                                                     Dead Time
```

The DTSTART period can be as small as 5ms, however should any interrupts occur during this time (for example the FDI/DMA interrupt), this time period will be reduced further by the time it takes to service the interrupt. Thus it is essential any further modifications to the S/W which deals with DTSTART processing or the FDI/DMA interrupt handling does not compromise this time constraint.

The DTSTART period will typically be > 5ms as CDS will send commands such as TCs and/or read TM followed immediately by the DTSTART command. CDS does not wait until 120ms have elapsed since the RTI before sending the DTSTART command. During the actual mission there will be no TCs sent to SASW and TM will only be collected once every 8 CUTs, hence most CUTs will consist of the RTI command followed by the DTSTART command.

However, if the DTSTART command is sent too quickly after the RTI (i.e. within 0.5ms), then due to the Ada calling and processing overhead there is a possibility the DTSTART interrupt may be lost. This is not a problem for SASW as it automatically starts its DTSTART processing 120ms after the RTI. In order to provide SASW with the maximum amount of quiet time in which to do its DTSTART processing, an operational constraint has to be imposed on Cassini to ensure the inter-message gap between the DTSTART and RTI commands is > 0.5ms. Since the Cassini CDS will service a number of Remote Terminals on the 1553B bus (PSA being one of them), it is assumed the inter-message gap between the RTI and DTSTART will be > 0.5ms for the PSA.

Warning: It is recommended that the DTSTART signal is sent at least 0.5ms after the RTI signal.

The SASW is protected from the loss of the DTSTART signal by an internal timer which allows it to time-out after 120ms; however, this is only possible if an RTI has arrived which results in the initialisation of this timer. The SASW cannot be protected from the loss of RTIs and will remain in a dormant (i.e. waiting for RTI) state until RTIs start to arrive.

4.5.3-2-3 BIU RTDT Handling

The SASW communicates with the Cassini CDS through the use of the SASW Remote Terminal Descriptor Table (RTDT) present in BIU RAM. This RTDT is composed of 32 Transmit SA on which data arrives from CDS, 32 Receive SA on which CDS can pick up data and 16 Mode Code SA through which CDS manages the flow of data on the bus transparently to SASW.

SA Descriptor Format

Each SA descriptor entry consists of four 16 bit words as shown below:

msb 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0 lsb	
unused					a	b	c	d	index							(1)
message status list pointer																(2)
data list pointer																(3)
reserved																(4)

where:

a	1 = illegal broadcast sub-address
b	1 = illegal sub-address
c	1 = interrupt when addressed
d	1 = interrupt when index is 0
Index	Number 1553B messages (32 words/message) that can be processed at the SA
Word (2)	Pointer to buffer in BIU RAM where status information is written by the BCRTM regarding each 1553B data block transaction
Word (3)	Pointer to buffer in BIU RAM where data is stored
Word (4)	Unused

The format of the message status word is as follows:

msb 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0 lsb
a	b	c	word count					time tag							

where:

a	subsystem fail input was asserted during this message
b	message was broadcasted
c	message error
word count	number of words in the 1553B message
time tag	time of message completion

SASW RTDT

On PSA power-up the BIU self initialises and establishes an Auto initialisation RTDT to allow minimal commanding of the BIU by the CDS. During SASW start-up the SASW establishes its own RTDT which allows SASW to communicate with the Cassini CDS. Some of SASW RTDT entries are set up as in the auto initialisation RTDT, however the main SA's handling the TC and TM are initialised according to the user requirements. The table hereafter shows the logical representation of the SASW RTDT:

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SA	Title	Receive Function	Transmit Function
1	BIU boot kernel	Set up as in Auto-Table but point data list pointer to Rx subaddress 2	Set up as in Auto-Table but point data list pointer to Rx subaddress 2
2	BIU/REU/XBA ML	Set up as in Auto-Table	Set up as in Auto-Table
3	BIU discrete	Set up as in Auto-Table	Set up as in Auto-Table
4	XBA, DMA	Illegalise	Illegalise
5	SURAM load	Illegalise	Illegalise
6	XBA/REU status	Illegalise	Illegalise
7	Non-critical TC	Process	Illegalise
8	Critical TC	Process	Illegalise
9	Fault Protection TC	Set up 1 msg in Phantom RAM	Illegalise
10	Data Broadcasts	Set up 1 msg in Phantom RAM	Illegalise
11	Probe TM	Illegalise	Sending of Probe TM
12	PSA TM	Illegalise	Sending of PSA TM
13	Reserved	Illegalise	Illegalise
14	Reserved	Illegalise	Illegalise
15	Reserved	Illegalise	Illegalise
16	Reserved	Illegalise	Illegalise
17	Reserved	Illegalise	Illegalise
18	Reserved	Illegalise	Illegalise
19	State Table Transfers	Set up 1 msg in Phantom RAM	Illegalise
20	Periodic RT to RT	Illegalise	Illegalise
21	Aperiodic RT to RT	Illegalise	Illegalise
22	Critical RT to RT	Illegalise	Illegalise
23	Reserved	Illegalise	Illegalise
24	Reserved	Illegalise	Illegalise
25	Reserved	Illegalise	Illegalise
26	Reserved	Illegalise	Illegalise
27	Reserved	Illegalise	Illegalise
28	Reserved	Illegalise	Illegalise
29	Spacecraft Time	Process	Set up for readback
30	BIU data wrap test	Set up 1 msg in BIU RAM	Set up for readback
31	n/a	Illegalise	Illegalise
32	Unused	Illegalise	Illegalise

All Mode code SAs are initialised according to the Auto-init table.

Key:

Phantom RAM — BIU RAM outside the physical 8Kword area. SAs pointing to Phantom RAM use this area to send unwanted data. BCRTM writes to this memory have no affect on the BIU or the BIU RAM.

Illegalise — SAs not handled by SASW. These are initialised to indicate to the BCRTM that a command with this SA is illegal.

Set up for readback — The TX SA is initialised such that its Data list pointer points to the same area in BIU RAM as its equivalent RX SA Data list pointer. This allows any data to be sent on the RX SA to be read back via the TX SA.

Supported Subaddresses

Although SASW will initialise all RTDT SAs it only fully supports the following Receive and Transmit subaddresses:

RX SA-7	To receive Non-Critical TC (128 words max)
RX SA-8	To receive Critical TC (32 words max)
RX SA-29	To receive the S/C Time (8 words max)
TX SA-11	To transmit Super Packets/Dump Super Packets (516 words max)
TX SA-12	To transmit PSA HK packets (91 words max)

The SASW maintains two parallel data streams for the Cassini CDS to retrieve data. There are TX SA-12 for the PSA HK TM and TX SA-11 for the TM data stream from the Huygens Probe (or in the absence of Probe TM data, a dump of the BIU RAM).

The SASW also maintains three data streams for the Cassini CDS to transmit data. These are RX SA-7, RX SA-8 and RX SA-29.

RX SA-7 is used by Cassini CDS to transmit Non-Critical TC packets. These messages can be up to 128 words long and are not re-transmitted in the event of a failure. RX SA-8 is used to transmit Critical TC packets and can be up to 32 words long. These messages are re-transmitted on the second 1553 bus should a failure occur. RX SA-29 is used to transmit the S/C Time (also known as the BIU Time). This is typically sent in CUT 6 (CUTs being numbered 0 --> 7) however the time that is broadcast is what the S/C time will be at the arrival of the second RTI after the arrival of the time, i.e. the next CUT 0.

The SASW will service its main SA in the period when the BIU is not updating them. This period is indicated by the DTSTART signal.

SASW handles the 5 main SA individually during each DTSTART period and does not swap RTDTs as some BIU documentation may suggest. SASW interrogates RX SA-7/8 for the arrival of any TCs, if a TC has arrived it marks this event and swaps TC buffers so that any incoming TCs in the following CUT do not overwrite the last packet. In the following CUT SASW will extract and process the TC.

TCs arriving on RX SA-8 take precedence over any arriving on RX SA-7, in the same CUT. Furthermore if more than one TC has been sent by the CDS then although SASW makes provision for more than one non-critical TC in the BIU RAM, it will ignore all TCs apart from the first one to arrive, even though they are buffered in BIU RAM. These remaining TCs are not processed at any time in the following CUTs and will be overwritten by further incoming TCs.

SASW will also interrogate RX SA-29 each DTSTART period for the arrival of the S/C time, if it has arrived it will extract and store the time. This time is then distributed at the next RTI 0.

TX SA-11 and TX SA-12 are interrogated to determine if queued TM has been extracted by CDS, if it has, then the next TM packets in the TM FIFO is queued by updating the Data List pointer of the appropriate SA;

BIU Memory Load and Readout

The RTDT descriptors for RX SA-1 and TX SA-1 have been set up, as requested by JPL, to point to the memory areas for RX SA-2. Once these SAs have been initialised by SASW it does not handle these SAs any further.

RX SA-1 can be manipulated to modify the descriptor entry at RX SA-2, since RX SA-1 Data List Pointer points to the start of RX SA-2. The modification of RX SA-2 is made such that the Data List Pointer for RX SA-2 is made to point to the start of the Descriptor entry of TX SA-2.

The modification of RX SA-2 can be verified by reading from TX SA-1 which is initialised to point to the descriptor entry of RX SA-2. A message can be sent to RX SA-2 to modify the Descriptor entry at TX SA-2. This modification is made such that the Data List Pointer at TX SA-2 is made to point to the relevant area in BIU RAM that needs to be dumped. Once the Descriptor entry for TX SA-2 has been modified, Cassini can issue a read command to TX SA-2 and retrieve data without SASW intervention.

Note this procedure can also be used to load new data into the BIU RAM, transparently to SASW, for maintenance purposes. However this procedure should be carried out with extreme caution as it could result in loss of data.

4.5.3-2-4 Spacecraft Time and TM Mode Handling

Messages on RX SA-29 of the BIU carry the current Cassini CDS "S/C Telemetry Mode" (STM), and the CDS S/C time. The Cassini CDS maintains a one second cycle, as well as the 8Hz cycle of RTIs. The BIU time and STM is output in RTI 6 of the one second cycle, and is valid from RTI 0 of the next cycle. The SASW performs this buffering itself.

The S/C time broadcast message is 8 words in length, with a 32 bit value giving the S/C Time. The S/C time is captured by the SASW, and recorded in the TM packets. The time recorded will be the last time received by the SASW, or zero if no time has been received since start up.

The SASW examines various other fields in the S/C Time message to detect STM changes from a mode where SASW TM is not collected to a mode where it is collected. This is necessary for FIFO management in the SASW. However there is no inhibition in the SASW to prevent the Cassini CDS from collecting TM whatever the current CDS STM. Only mode transition causes the SASW to make internal adjustments.

The format of the S/C time message is shown below:

Word	Description
LSW 0	Message ID, STM pending indicator
1	Current S/C time (MSW)
2	Current S/C time (LSW)
3	Current STM (MSW)
4	Current STM (LSW)
5	Next STM time
6	Next STM (MSW)
MSW 7	Next STM (LSW)

where:

Word 0	S/C time message ID, Bit 6 of this word indicates if STM is pending
Word 1 & 2	32 bit S/C time
Word 3	Current STM mode indicator
Word 4	Not used by SASW
Word 5	Time at which the next STM is to occur
Word 6	Next STM mode indicator
Word 7	Not used by SASW

It is expected that the SASW will start up at a time when the Cassini CDS is not collecting data (otherwise the CDS would be reporting "no data" errors once a second during start up). It is also expected that the SASW will enter Mission Mode before TM starts to arrive from the Probe. However, the SASW will run the nominal Mission once powered up and provide TM regardless of the Cassini CDS STM or whether the Probe is transmitting any Transfer Frames.

Warning: It is recommended that the PSA is powered up and SASW allowed to enter Mission Mode before any TM mode change is initialised by the Cassini CDS.

If CDS is not collecting then within 21 seconds of power ON the PSA HK FIFO will overflow and any further packets generated by SASW will be discarded. If the Probe is not transmitting any Transfer Frames, then the Super Packet FIFO will remain empty and SASW will generate Dump Super Packets. However, once the Probe starts to transmit TM and if CDS is not collecting, the Super Packet FIFO will also overflow and any further packets arriving will be discarded.

The SASW monitors the STM and when it detects a transition from "not collecting" to "collecting" it will purge both the PSA HK and the Super Packet FIFOs and abort any ongoing TM transfers.

This purging results in only one packet remaining in the FIFO, the earliest generated packet (i.e. the very first packet generated by SASW after entering Mission Mode). The purging is necessary for the Mission as it will allow the FIFOs to be used for any brief collection delays and clock drifts etc. See § 4.5.3-4-1 SASW TM FIFO for more details.

The table below illustrates the conditions SASW checks to detect the STM change. Assuming a STM change is about to take place at time = n, SASW will purge the FIFOs in the CUT just before the STM change is about to take place (i.e. CUT 7 of second n-1).

Second	S/C Time Packet	Contents
n-2	New mode pending	Yes
	S/C time LSW	n-1
	Current STM	A
	Next STM time	n
	Next STM	B
n-1	New mode pending	No
	S/C time LSW	n
	Current STM	B
	Next STM time	n
	Next STM	B
n	New mode pending	No
	S/C time LSW	n+1
	Current STM	B
	Next STM time	n+ARC
	Next STM	B
n+1	New mode pending	No
	S/C time LSW	n+2
	Current STM	B
	Next STM time	n+ARC
	Next STM	B

Note the STM only changes on Aggregate Repeat Cycles (ARC).

A TM mode change from collecting to not-collecting is ignored by SASW.

4.5.3-2-5 BIU Error Handling

The BIU can be reset to varying degrees by both SASW and the Cassini CDS. Typically the BIU is reset when powered ON or when SASW detects a failure.

The table below shows the various BIU failure/reset categories:

Reset/Failure Event	Description	Auto-initialisation	Interrupt 11 raised	Recovery Action taken by SASW
Power ON	Comprehensive BIU reset when the BIU is powered up	Yes	No	No
Host reset	Effectively the same as the PORn reset and is initiated by the SASW via the BIU_CONTROL register	Yes	No	Yes
Watchdog Time-out	If CDS communication is lost for more than 4 seconds, the BIU automatically undergoes a similar reset to RSTIn. In such a case transmission from the BIU is inhibited although it can still receive messages. CDS must clear the WD_XPIRD flag before normal communication can resume.	Yes	Yes	Yes
Host write to the BCRTM register # 12	This reset causes the BCRTM to stop processing 1553B messages and the BIU memory is not affected. Use of this reset should be followed immediately with a write to BCRTM registers #0 and #2.	No	No	No
CDS issues reset RT Mode code (#8)	Identical reset to a host write to register #12, except BCRTM does not stop processing 1553B messages.	No	No	No
CDS sets BIU Discrete command bit 1	The setting of this bit raises interrupt 11 but does not automatically reset the BIU.	No	Yes	Yes
BCRTM BIT failure	BIU Built In Test failure. Note that the BCRTM's BIT routine is not automatically invoked at power up by the BIU and neither CDS nor SASW will invoke BIT routine during normal operations.	No	Yes	Yes
Write Protection Violation	If SASW attempts to write to the write protected lower 320 words of the BIU RAM, WP_VILTN is asserted.	No	Yes	Yes

BIU resets or failures can occur asynchronously to the actions of the SASW and each type of reset or failure is distinguished by whether it causes the BIU to "Auto initialise" and whether SASW is able to detect it.

Auto initialisation causes the default Auto initialisation RTDT to be established. The BCRTM Control register is also modified as is register #2 to point to the auto initialisation table.

SASW detects BIU failures by monitoring interrupt 11, and BIU resets if BCRTM register #2 is not pointing to the SASW RTDT (for example after an Auto initialisation). When it detects a failure, SASW will then perform its own BIU reset, by writing 0000hex and then 0040hex after a gap of at least 2µs to the BIU control register, BIU_CONTROL. Following the BIU reset the SASW RTDT is re-established and other appropriate recovery actions are performed(see below).

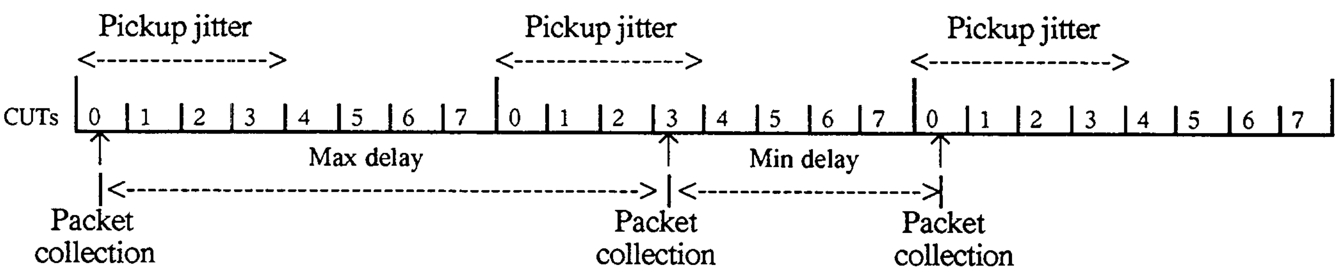
During any recovery actions by the SASW some data may be lost, for example any TC transfer to the Probe will be aborted and incoming Probe frames will be discarded.

The recovery actions performed by SASW are complex in nature and occur over several CUTs. The sequence of events performed by SASW is described in the table hereafter:

CUT	Period	Recovery Procedure
n	CUT	• BIU failure occurs
	DTSTART	• SASW checks for BIU failure • If a BIU failure has occured, all interrupts are masked • Any TM DMA transfer is aborted • BIU is reset via BIU_CONTROL register • Any pending FDI interrupts are cleared • All interrupts are unmasked • (Note BIU register 2 will now be pointing to the default Auto-init table)
n + 1	CUT	• BIU RAM reinitialised, i.e. SASW RTDT re-established • Internal FIFO counters preserved so no TM is lost
	DTSTART	• BIU register 2 set to SASW RTDT once again
n + 2	CUT	• Cassini can resume TM collection, TC sending
	DTSTART	• SASW can resume normal BIU DTSTART handling

4.5.3-2-6 Telemetry Collection

Packet jitter is guaranteed not to exceed 1/2 of the nominal inter packet collection interval and packet jitter is non accumulative. The nominal inter packet collection interval for TM packets is one second. Thus packet collection by CDS will range between 1 ± 1/2 seconds, that is the maximum interval between packet collection is 11 CUTs and the minimum is 5 CUTs. This is illustrated in Figure below:



4.5.3-2-7 BIU RAM Initialisation during Start-up

During the early phase of SASW start-up the BIU RAM is checked by writing to each address location (0 --> 2000H) its own address value and then reading it for confirmation. This check is the hardware/memory confidence check. See § 4.5.2-3 *Software Modes* **Initialisation Mode.**

The BIU RAM is initialised for SASW use (i.e. SASW RTDT established) within 6.5 seconds of power-up, as described in § 4.5.3-2-3 **SASW RTDT**. Note the BIU RAM is not EDAC protected.

4.5.3-2-8 BIU Discrete Command and Status Handling

In addition to the communication through the BIU interface, Cassini is also able to command and monitor the PSA through the BIU interface independently of the SASW software. The PSA provides a Discrete Command and Status interface through the use of subaddress 3 as identified in § 4.5.3-2-3. The BIU Discrete Command and Status provides for eight discrete command bits each for commanding by Cassini and status provision by the PSA.

For the PSA only two of the command status bits, bit 0 and bit 1, are supported. These provide the following functionality:

- Bit 0: is connected to the processor reset input and will cause the processor to restart, which in turn will cause the re-initialisation of SASW.

- Bit 1: is connected to interrupt 11 of the processor and will cause SASW to reset the BIU, as it is considered as a BIU error and is processed as described in § 4.5.3-2-5.

Note that the operation of Bit 0 is such that, when set high (= 1) it will cause the processor to reset and will hold the processor until Bit 0 is reset (= 0). Therefore, in order to reset the PSA processor through the BIU Discrete Command, two commands must be sent: the first to set Bit 0; and the second to reset Bit 0. Failure to send the reset command will result in the PSA processor remaining in reset mode.

Warning: When using the BIU Discrete Command to reset the PSA processor, two commands must be sent: the first to set Bit 0; and the second to reset Bit 0. Failure to send the reset command will result in the PSA processor remaining in reset mode.

None of the discrete status bits are utilised. Instead the eight discrete bits are set high as part of the processor initialisation and remain high until SASW detects a BIU error, when they are reset as part of the BIU error processing, see § 4.5.3-2-5. The status bits are the most significant bit of the BIU_CONTROL word, see RD2 SASW SICD.

4.5.3-3 Telecommand Management

Telecommands may be sent to the SASW via the CASSINI CDS. A number of possible sources in the CDS can generate TCs (e.g. time tagged commands, CDS automatic routines, ground relay). In addition TCs can be delivered to 2 sub-addresses on the BIU. The SASW supports TCs delivered to sub-address 7 (Non-critical commanding sub-address) and sub-address 8 (Critical commanding sub-address). The non-critical SA is capable of buffering several TCs, however only the first TC will be accepted in any one CUT. The critical SA can only buffer a single 32 word TC and should more than one TC arrive in any CUT the second will overwrite the first. Furthermore, should a TC arrive on both sub-addresses at the same CUT then only the TC on the critical (SA-8) will be accepted.

Warning: The SASW will accept telecommands on either of these sub-addresses, regardless of any mode indications on the bus.

Warning: The SASW BIU handling will reject all but the first TC if more than one command is delivered by the Cassini CDS in a single CUT. Due to the granularity of the delivery of commands by the Cassini CDS, commands to the Huygens S/S may be lost if two commands are uplinked with the same delivery time in seconds, or if an autonomous process in the Cassini CDS generates commands for any Huygens S/S at the same time as a time-tagged or direct command is issued. Time Tagged commands uplinked to CASSINI must be sequenced with a maximum rate of 1 TC/second/chain.

In general, the telecommands are simply sent by Cassini and consequently the length of the telecommands can be up to 128 words long. However, it is also possible to use the Cassini CDS telecommand "CDS DIRECT PATH" to forward telecommands to SASW and in this case the maximum size for the encapsulated telecommand is limited to 121 words.

Warning: In case of a Telecommand sent through the use of the Cassini CDS telecommand "CDS DIRECT PATH" the maximum size of the encapsulated telecommand is 121 words.

As there is no direct connection between any elements of the Probe and the bus, the SASW will accept and forward commands for the POSW, and for the Probe Experiments.

The SASW keeps internally a count of "Valid TC" and "Invalid TC" received. These counters are reported in the PSA HK telemetry, and so may be used to verify TC reception. However these counters are updated as a result of a number of specific software requirements, and so the numbers reported may be incremented more than once by a single TC, or not at all under certain circumstances. This is explained in more detail in Operations AP01 to AP05 in Doc n° HUY.AS/c.100.OP.0384. Both counters are initialised to zero at start-up, and will "wrap round" should they reach their maximum values.

SASW does not provide any facility for time-tagged TCs. This functionality is provided by the Cassini CDS.
CASSINI does not guarantee the CUT of delivery of TCs. Thus it is required to send TC at a maximum rate of 1 TC/second/chain.

The following telecommands are supported by the SASW:

• Alteration Telecommand: This command permits the loading of a data word in the Receiver CMD register. It thus allows some control over receiver processing for example changing the Receiver freqency from base frequency to Doppler frequency.

• Direct Telecommand: This command instructs the SASW to issue an ON/OFF command directly to various attached hardware devices.

• Dump Telecommand: This command iinstigates a dump of either EEPROM or RAM and results in dump TM being transmitted to the ground. This command allows the manual inspection of memory. Dump packets overwrites PSA HK packets.

• Experiment and POSW Telecommands: These commands are destined for the Probe or its Experiments and are simply forwarded over the umbilical to POSW.

• Inhibition Telecommand: This command is only valid during S/W initialisation in a pre-defined time window. If received the command inhibits the application of data patches to RAM.

• Patch Telecommand:This command store the uplinked patch data into EEPROM, and permits the reprogramming of the SASW.

4.5.3-3-1 Rate and Timing of Telecommand Execution

The SASW is capable in general of processing one TC per CUT. Commands which arrive in one CUT will usually be executed in the next CUT. However some TCs require more than one CUT to execute, and the orbiter CDS does not guarantee the delivery time of commands to more than one second. Thus a simple operating procedure is to limit processing to one TC per second. If this rate is to be exceeded then additional measures may be necessary to ensure successful processing.

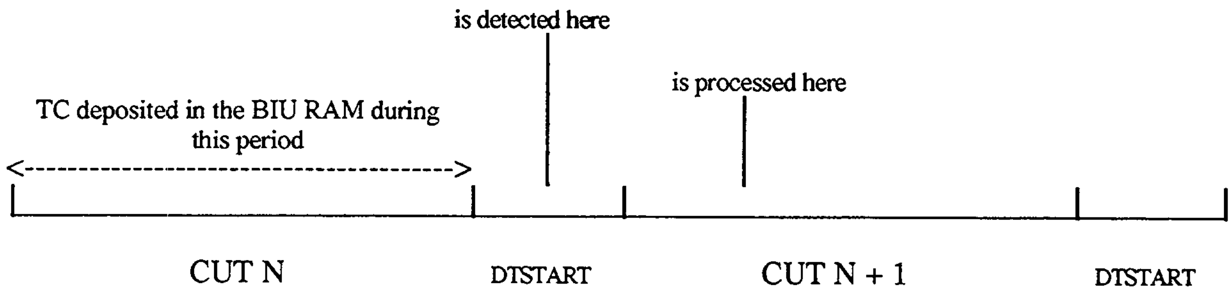
As stated the majority of TCs are extracted from the BIU RAM and processed in a single CUT. However hardware restrictions and performance considerations prevent some TCs being processed in a single CUT. The dump TC may require several CUTs to complete as one dump command may require the generation of numerous dump TM packets. Similarly the patch TC may require several CUTs to complete as only one word of data is written to EEPROM per CUT. This arises as a 10ms interval is required between successive writes to EEPROM by the PSA H/W. Whilst either a dump or patch TC is being processed all other TC will be rejected. This rejection applies to all TCs regardless of whether they were destined for the SASW or the Probe.

Warning: If a telecommand arrives while another telecommand is still being processed the new telecommand will be rejected, and the invalid TC counter incremented. This will occur for telecommands destined for the POSW and Probe Experiments.

The dump command overwrites the PSA HK TM packets with dump packets, and thus is limited to the data rate allowed for PSA HK TM, i.e. one packet per second. Thus one dump packet will be output in one second and if two are requested, in two seconds, etc..

4.5.3-3-2 Telecommand Handling in Mission Mode

Nominal TC processing will commence on entry into Mission Mode, when SASW has completed the startup sequence. The transition into Mission Mode occurs 15 seconds after the PSA is powered ON and as such TCs may be present in the BIU RAM at this juncture. SASW is capable of processing TCs at a rate of one TC per CUT. However the detection, extraction and processing of the TCs requires two CUTs and consequently a TC detected in the BIU RAM in CUT number 0 will be processed in CUT 1 of Mission Mode, as shown below:



Furthermore, if the BIU RAM contains more than one buffered TC only the first will be procesed and the remaining TCs will be ignored. The TC counters will not be affected in such a situation.

This feature imposes an operational limitation on the system and the following restrictions have been identified:

• **Alteration and Direct Telecommand Constraint.** The receiver frequency cannot be altered, or any hardware devices switched ON/OFF, in the very first CUT of Mission Mode, even if the TC is sent before Mission Mode is entered.

• **Dump and Patch Telecommands Constraints.** During the first CUT of Mission Mode SASW cannot dump memory, store patch data into EEPROM.

Warning: SASW will not execute TCs in the very first CUT of Mission Mode (CUT number 0), due to the time delay introduced by detection and extraction of TCs from the BIU RAM.

4.5.3-3-3 PSA Application Process Identifiers

The SASW receives and processes TCs destined for the PSA, or downstream POSW, independently of the hardware chain they are executing on. For example TCs which have the "CDMU A" packet identifier as the application process identifier will be forwarded to CDMU A if received by PSA A or CDMU B if received by PSA B. This approach ensures that TCs forwarded to SASW are actioned even if the incorrect delivery chain is used.

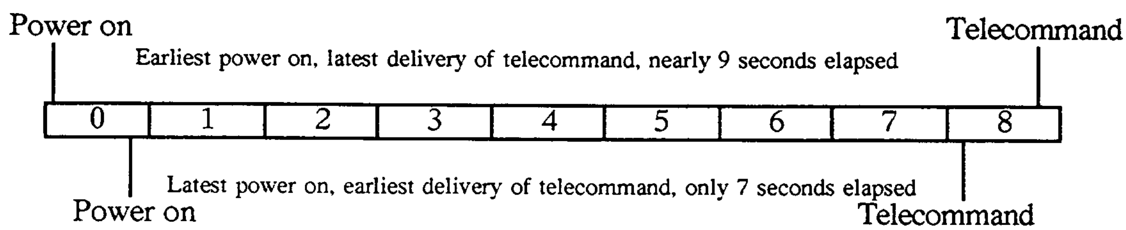
Similarly TCs despatched to SASW will be processed by PSA A or PSA B regardless of the APID. For example PSA A will process TCs destined for PSA B if the TC is delivered incorrectly to PSA A. However, CDS can only deliver a TC to a single PSA as each PSA is represented by a unique RTU address. **Consequently the ground is responsible for maintaining symmetry between the two chains during telecommanding operations by physically sending TCs to PSA A and PSA B separately**. Under the cicumstance where chain asymmetry is required, ground must ensure that the required TC is only sent to the relevant RTU (PSA A or B). It is foreseeable that chain asymmetry will be necessary to overcome particular hardware faults on individual chains, where the selective application of patch TCs may be the solution.

4.5.3-3-4 Inhibition Telecommand Handling

An Inhibition TC may be sent to the SASW during initialisation mode to prevent the application of software patches to main memory. This TC is designed to permit "recovery" of the SASW whenever fatal or erroneous software patches are present in EEPROM. On receipt of a valid inhibition TC, SASW will execute the functionality contained in PROM only.

The Inhibit TC may be delivered in either the normal or the critical sub-address of the BIU. If data are received on both addresses only the critical commanding data will be examined for a valid TC.

An Inhibition TC must be received during a pre-defined time "window" in the start-up sequence to be valid. The time window for the reception of this command is from 6.5 to 9.5 seconds after PSA power ON. For maximum reliability it is recommended that the command is sent 8 seconds after PSA power ON. That is if the power ON command is sent is second 0, the inhibit patch command should be sent in second 8. The reason for this is that commands from the Cassini CDS are only guaranteed to be delivered to the nearest second. In considering the worst cases the effect is nearly a two second difference in the possible delivery time. This is illustrated in the figure below. This shows that even with the worst case effects on time delivery in second 8 the TC is guaranteed to arrive in the window that SASW allows for this command.



TIMING OF START-UP TELECOMMANDS FROM THE CASSINI CDS

The Inhibition TC must not be transmitted within the first 6.5 seconds after PSA power ON. Failure to obey this restriction will result in the loss of the TCs as SASW will be undergoing BIU initialisation and the SASW RTDT will not have been set up.

Similarly, **an Inhibition TC sent after 9.5 seconds after PSA power ON will be rejected** as the window to inhibit the EEPROM patches will have been missed and the patches will have been applied.

Note that he SASW BIU handling knows if a TC is present or not, and will not increment the Invalid TC count at power up, unless an invalid TC is detected. This is in contrast to the POSW start-up sequence where the Invalid TC count is incremented by one even if no Inhibition TC is sent. The possible values of the TC counters after SASW startup is given in the table below:

Inhibition TC Status	**Valid TC Count (absolute value)**	**Invalid TC Count (absolute value)**
No inhibition TC sent or Inhibition TC sent between 0 to 6.5 seconds	0	0
No inhibition TC sent but fails layout check, or if TC arrives after 9.5 seconds	0	1
Inhibition TC sent, passes layout check but fails application data field check	1	1
Inhibition TC sent and correctly validated	2	0

SASW will make a single attempt to identify and execute this TC at 9.5 seconds. If this attempt is unsuccessful, no secondary attempt is made and RAM patching will not be inhibited. Thus if the first TC to be sent during start up is not the Inhibition TC, it will be rejected. Any further attempts to send an Inhibition TC will then fail as SASW will only next process TCs in Mission Mode and will then reject the Inhibition TC.

Warning: SASW makes a single attempt to identify and execute an Inhibition TC during startup. If this attempt fails, no secondary attempt is made and RAM patching will not be inhibited.

Warning: No other TC apart from the Inhibition TC should be sent during the first 9.5 seconds of startup, as this will "block" the processing of the Inhibition TC until Mission mode (which will then be rejected).

4.5.3-4 Telemetry Management

SASW is responsible for generating its own TM and collecting and forwarding Probe TM as there is no data connection between the Probe and Cassini. SASW starts to automatically queue TM in the BIU RAM, ready for CDS collection, as soon as it enters Mission Mode. The first HK packet is generated and queued by CUT 7. If Probe TM has not started to arrive then SASW will generate Dump Super packets in their place and queue those instead. SASW enters Mission Mode with a Dump Super packet ready for collection by CUT 0.

The Probe transmits a stream of telemetry to the Cassini Orbiter in all phases of the Mission, except for the Coast and Entry Phases. However different hardware transmission mechanisms are used to achieve this. Whilst the Probe is connected to the Orbiter in the Launch, Cruise and Saturn Orbit phases, telemetry is transmitted via the umbilical link. Once the Probe has separated from the Orbiter, TM is transmitted via a radio link. However this radio link is not established until the Probe Back Cover mechanism is jettisoned and the high power amplifier is powered. Consequently no TM transmission is possible during the Coast and Entry phases. The radio link is established after Entry into Titan's atmosphere and TM is recovered for the Descent and Surface phases.

The POSW sends Probe Transfer Frames to SASW at a cadence of one per second. Each Transfer Frame contains a synchronisation marker, and Probe data (consisting of a Probe Frame header, seven TM packets and Reed Solomon data). The frame size is fixed at 512 words. The packet received from the Probe have the first two "sync words" removed (by the PSA hardware), and a six-word "super packet" header added (by the SASW) before being forwarded to Cassini.

Telemetry is not "sent out" from the SASW, because the hardware does not include any transmission capabilities. Rather it is "made available for collection", by establishing the required data structures in the BIU RAM. It is the responsibility of the Cassini CDS to collect the TM packets at a sufficient rate to prevent data loss. The SASW provides First-in, First-out buffers (FIFOs) in the software to allow for minor perturbations in the data collection scheme.

The SASW supports the presentation of TM packets on two sub-addresses of the 1553 bus. Sub-address 11 is used for Super packets which are constructed from Probe Transfer Frames treceived from the Probe and sub-address 12 is used for PSA HK TM generated internally by the SASW.

In the case where Probe TM is not available and the Super packet TM FIFO is empty sub-address 11 will provide "Dump Super packets" consisting of the contents of an area of BIU RAM (namely the SASW RTDT).

In the case where a TC has requested memory dumps of main RAM or EEPROM the resulting memory dump packets will overwrite the PSA HK TM packets on sub-address 12.

Warning: The PSA HK TM packets may contain the data for the Doppler wind experiment. Thus the use of dump telecommands during the mission must be prevented, or this data could be lost.

In general Cassini is expected to collect packets at a rate of once per second on each of the two sub-addresses. The exact CUT of collection is not specified, and so a max. period of 11 CUTs and a min. period of 5 CUTs may elapse between the collection of packets. See § 4.5.3-2-6 Telemetry Collection for more details.

The SASW maintains internally a real-time counter (RT) of CUTs since power ON. The value of the RT counter will be included in each PSA HK and Dump packet, at the time when the packet is completed by the SASW. The RT counter will be 0 in the first CUT of Mission Mode (15 seconds after power ON). In addition the BIU provides a Cassini time reference signal (BIU Time). This will be included in all output telemetry when the packet is completed by the SASW.

The SASW also maintains a sequence count for each of the possible TM packet types. These sequence counts are initialised to zero, and increment by one with each packet produced. The first packets generated by SASW will have a source sequence count of 1.

The SASW supports the following types TM packets:

PSA HK Telemetry. These packets contain PSA and SASW HK information and are generated once each 8 CUTs.

Dump Telemetry. These packets contain RAM or EEPROM data as requested by a dump TC and overwrite the PSA HK Telemetry while dumping is in progress.

Super Packets. These packets are constructed from Probe Transfer Frames received from the Probe. A six word header is supplied by the SASW for identification and onward routing

Dump Super Packets. These packets contain a dump of a fixed area of the BIU RAM, and are output whenever Probe TM is not being received and the Super packet FIFO is empty.

Only two types of packets are output at any one time (i.e. PSA HK packets or Dump packets and Probe Frames or Dump Super packets), and both types of packets are available for collection by the Cassini CDS at a cadence of once per second. Because of the actions of internal FIFOs the software is capable of supporting a collection rate of one packet per CUT if the FIFOs contain additional packets.

4.5.3-4-1 SASW Telemetry FIFOs

The SASW implements two internal FIFOs for its TM output. One FIFO is for the PSA HK TM packets and the other for the Super Packets. Both FIFOs are sized at five elements. This size was selected in consideration of the following requirements:

- drift between Cassini clocks and Probe clocks, allowing Probe to generate one more data packet than expected over a 3 hour mission.
- jitter in the clock signals between Cassini and Probe allowing an extra packet to accumulate.
- possible 20 CUT outage during changeover from Cassini CDS A to CDS B in the event of a failure of a Cassini CDS.
- Cassini bus mode change leading to 15 CUTs between two successive collections
- loss of a broadcast RTI on the 1553 bus

The FIFOs are located in the BIU RAM at specified addresses and are manipulated entirely by SASW and not by the BIU. When Probe Transfer Frames start to arrive, the SASW programs the DMA to transfer the Transfer Frame into BIU RAM directly at the Tail of the Super Packet FIFO. On completion of the DMA SASW adds a six-word header to the Transfer Frame which now becomes a Super Packet.

If CDS is in collecting mode then SASW manipulates the Data List Pointer of TX SA-11 to point to the Head of the Super Packet FIFO. In the meantime any further Probe Transfer Frames arriving will be written to the Tail of the Super Packet FIFO. SASW will check the TX SA-11 descriptor entry every CUT to determine if the previously queued Super packet has been collected by Cassini CDS, if it has then the next Super packet will be queued at the Head of the Super Packet FIFO. If the Super Packet FIFO is empty, the SASW will generate a Dump Super Packet and queue this instead (note the Dump Super Packet is not added to the Super Packet FIFO). Thus SASW ensures there is always a packet ready for collection on TX SA-11.

If Cassini is not collecting and Probe Transfer Frames are arriving, then **once of the Super Packet FIFO is full, all further Probe Transfer Frames will be discarded.**

In a similar way SASW also maintains a PSA HK packet FIFO. PSA HK packets are generated once every 8 CUTs and are added to the PSA HK FIFO at its Tail. Meanwhile SASW checks every CUT the TX SA-12 descriptor entry to determine if the previously queued PSA HK packet has been taken by Cassini. If it has then SASW will queue the next packet from the Head of the PSA HK FIFO.

If Cassini is not in collecting mode, then once the PSA HK FIFO is full all further PSA HK packets will be discarded. Unlike TX SA-11 where a Dump Super packet is queued in the absence of Probe Transfer Frames, no similar packets are queued by SASW for TX SA-12. Thus if Cassini collects packets from TX SA-12 faster than SASW generates them, meaningless PSA HK packets will be retrieved as SASW does not queue any other packets in their absence.

4.5.3-4-2 Telemetry during Startup

PSA HK and Dump Super packets will become available for collection by Cassini at different times during start-up and may be incomplete if there are taken early in the start-up sequence. These incomplete packets are a consequence of system start-up while SASW is undergoing its internal initialisations.

PSA HK telemetry will not be available for collection until one cycle of housekeeping collection has completed. This means that the first PSA HK TM packet will be available from the SASW 16 seconds after PSA power ON. A Dump Super packet will be set up as soon as the SASW has initialised the BIU RAM, i.e. after 6.5 seconds, however this packet will be incomplete.

Warning: It is advised the collection of TM by Cassini is started after 16 seconds, i.e. when SASW is in Mission Mode. Otherwise no guarantee can be given as to the validity of the packet contents and the packets will be meaningless.

If the Probe is not transmitting, then the very first packet to be taken by Cassini will be an incomplete Dump Super packet, thereafter all Dump Super packets will be complete, provided Cassini starts collection after 16 seconds. If the Probe is transmitting before SASW enters Mission Mode, then TM availability will be unpredictable and incomplete Super packets may be picked up.

During start-up the Dump Super packet initialised in the BIU RAM will be incomplete as some of the SASW parameters will not be available (invalid) until CUT 0. Furthermore the parameters in the header will be different depending on what time the packet is taken during the start-up sequence. For example Source Sequence Count is 0 between 6.5 .. 9.5 seconds whilst SASW is initialising, however between 9.5 seconds and 15 seconds the Source Sequence Count is set to 1.

The following table shows the expected Dump Super packet header fields if the packet is collected during (A) 6.5 .. 9.5 seconds, (B) 9.5 .. 15 seconds or (C) after 15 seconds:

Dump Super packet header	Incomplete (6.5 - 9.5 seconds) A	Incomplete (9.5... seconds) B	Complete (> 15 seconds) C
APID	invalid (0)	valid (078F/07AF)	valid (078F/07AF)
Source Sequence Count	invalid (0)	valid (1)	valid (1)
Packet Data Field Size	valid (1025 bytes)	valid (1025)	valid (1025)
BIU Time	invalid (0)	invalid (0)	valid (last S/C time)
RT Count	invalid (0)	invalid (FF)	valid (CUT count)

If CDS collection starts after SASW has entered Mission Mode and Probe Transfer Frames arrive much later, SASW will enter Mission Mode with an incomplete Dump Super packet (as in B). This packet will remain in the BIU RAM until it is taken by CDS, thus the very first packet taken by CDS will be an incomplete Dump Super packet no matter when it is taken. It is only after this packet is removed from the BIU RAM that SASW can start to build complete packets.

During Init mode all interrupts are masked and disabled. If the Probe starts to transmit Probe Transfer Frames before SASW enters Mission Mode then the FDI interrupt will not be serviced and no Probe TM will be placed in the BIU RAM. Thus SASW will enter Mission mode with a Dump Super packet queued on TX SA-11. The FDI interrupt will only be serviced in Mission mode.

During the actual Mission the CDMU will be powered up much later than the PSA (12 mn later). Probe Transfer Frames will only start arriving after the Probe Back Cover is discarded during the Descent sequence, the High Power Amplifier and the Probe's Transmitter energised and the PSA has synchronised with the incoming data stream. All this will typically take place 19 mn after CDMU power up. Thus the first data packet from the Probe in the actual mission will arrive 31 mn after PSA power up. During the checkout phases, Probe Frames will start arriving as soon as the CDMU is powered up, i.e. after 12 mn.

4.5.3-4-3 Super Packet/Dump Super Packet Management

SASW provides the Cassini CDS with Super packets. These are composed of Probe Transfer Frames with a 6 word header added by SASW. They are only made available to CDS after SASW has added the 6 word header. The data from the Probe is left untouched.

SASW provides a five packet buffer (FIFO) for the storage of the Super packets to overcome possible delays in packet acquisition due to jitter in clock signals or Cassini failure etc.. If Cassini stops taking Super packets for longer than 5 seconds then any new Probe Frames arriving will be rejected by SASW.

If no TM arrives from the Probe, then SASW will generate its own Dump Super packets to replace the Probe Frames. These Dump Super packets consist of a dump of the BIU RAM, namely the SASW RTDT.

Both types of packets will have their own individual Source Sequence counters.

4.5.3-4-4 PSA HK Packet/Dump Packet Management

The HK acquisition mechanism is responsible for the collection and subsequent storage of PSA and SASW health parameters into the PSA HK packets. These parameters may originate from the SASW, PSA, BIU or the Receiver interface. In general this HK data indicates the overall health state of the PSA.

The PSA HK packet is deposited into the BIU RAM at the end of the 8 CUT period (in CUT 7, where CUT range is 0 --> 7). Parameters reported in the PSA HK data are recorded during the current CUT and the previous seven CUTs. Thus to recover the collection time of any particular data element it is necessary to subtract a number of CUTs from the RT counter according to when the data element was collected (see § 4.5.4-3-2). Data collected every CUT is placed in the PSA HK TM packet in time order as it is collected. Data which is collected less frequently than once per CUT is collected in a CUT specified by internal software table.

The SASW HK Parameter Acquisition Table defines acquisition workload for each CUT, which parameters are reported and the layout of the PSA HK packet. SASW is able to acquire 8 HK parameters in each CUT, hence a total of 8*8 parameters can be acquired every second.

The table essentially consists of 3 entries per parameter (a) parameter name, (b) Index into the HK packet and (c) data type. Some entries in the table have been intentionally left null so that they may be modified at a future date to acquire further parameters.

A sample of the HK parameters acquired during CUT 0 is given below. The table also shows the logical layout of the SASW HK Parameter Acquisition Table.

	Parameter (to be acquired)	Byte Index (position in the PSA HK TM where data is to be stored given as a byte index)	Data Type (Word or Byte type data)
#1	PSA_A RECEIVER HK	51	Word
#2	RUSO_A_TEMP_1	6	Byte
	–	–	–
	–	–	–
#8	SASW_STATUS_10	133	Word

The layout and contents of the HK packet is given in Annex 2 TM/TC Tables PSE HK Packet.

Warning: The software table that defines which parameter is reported and its position in the HK packet may have been patched, so it is necessary to refer to latest maintenance records, or a dump of the table, to be sure of the collection time of the data.

The BIU time recorded in the PSA HK packet header is the S/C time, in the CUT in which all the parameters have been acquired and the header is composed. The header is then added to the packet and the packet is written into the BIU RAM.

The receiver housekeeping is triggered in one CUT, and collected in the next CUT. This is because of the timing required for the receiver to respond to a data request. Thus an additional CUT must be subtracted from the RT in the PSA HK TM header in order to recover the collection time for these parameters.

Warning: The collection time of all parameters is not guaranteed to be at any specific time within a CUT. This is because the actions of interrupts, and the various software paths followed, may change the timing of data collection from CUT to CUT. In particular once per 8 CUTs the FDI and DMA interrupt will occur in quick succession, probably introducing a few millisecond delay in data acquisition.

Dump packets are generated by SASW on receipt of a Dump TC and replace PSA HK packets for a given 8 CUT period. Both PSA HK and Dump packets are identical in length and both types of packets have their own individual Source Sequence counters.

4.5.3-4-5 Packet Source Sequence Count Discontinuities

All telemetry packets generated by SASW conform to the ESA Packet Telemetry Standard [ESA PSS-04-106]. In particular the Source Sequence Count is manipulated as a straight sequential count which is short cycled (i.e. continues to increment to its maximum value). On reaching the maximum value, it "wraps round" (returns to zero), and continues to increment as normal.

The generation of a dump telemetry packet will result in counter discontinuities or "packet skip" in the PSA HK TM packet sequence count being visible to the ground. This arises as dump packets directly replace existing PSA HK packets.

Loss of Probe TM, and its subsequent re-acquisition will not cause Super packet sequence count to be discontinuous. This is because only the packets received by the SASW, and made available to the Cassini CDS will be allocated sequence numbers. Information within the Super packet data (which is not examinated by the SASW) will allow ground processing to establish the continuity of the POSW data stream (refer to § 4.4 POSW for more details).

Warning: PSA HK telemetry packet source sequence count may appear discontinuous to the ground whilst dumping memory. Super packets or Dump Super packets are not affected.

4.5.3-5 SASW Datation

The SASW uses a 24 bit free running counter to record time since power up (called RT counter in the SRD, and sometimes known as the CUT counter). This counter is incremented on each occurence of the CDS RTI. As the mission of the HUYGENS Probe is limited to three hours no special precautions have been taken to prevent this counter from wrapping round (which will require about 18 hours). Users should note that in the event of the SASW remaining powered for this period of time the CUT counter value will become ambiguous. The current implementation makes the CUT counter a free-running counter.

4.5.3-6 Operational Constraints

During operation of the SASW, several constraints must be observed by the ground. They are:

4.5.3-6-1 DTSTART Interrupts During Start-up

During the first 14.875 seconds of start-up, SASW will wait indefinitely, on two occasions, for the DTSTART signal. This is necessary before SASW makes any access to the BIU RAM. Thus DTSTART signals must be broadcast as soon as the PSA is powered up.

4.5.3-6-2 DTSTART Interrupt Loss

During Mission Mode, DTSTART commands sent within 0.5ms of the RTI command being sent will not be detected by SASW. This feature is due to a combinational effect of the Ada calling and processing overhead and SASW clearing the Pending Interrupt register within the RTI ISR.

SASW is able to handle this DTSTART signal loss as it will automatically time-out 120ms after the RTI to perform its DTSTART processing.

This feature is not pertinent in Init Mode since all interrupts are masked and the ISR handling the RTI is not called during Init Mode.

4.5.3-6-3 TC delivery to SASW during Start-up

No TC apart from the Inhibition TC should be sent to SASW during start-up if the patching from EEPROM is to be inhibited. SASW will only extract the first TC from BIU RAM and ignore any others that may be present so if the first TC is not the Inhibition TC, SASW will reject it and will proceed with patching.

The SASW considers **all TCs invalid during the first 9.5 seconds of the Initialisation mode**, except for the Inhibition TC which may only be received during the dedicated three second window 6.5 to 9.5 s after PSA Power-up. Between 9.5s and 15s after Power-up, TCs are queued for execution at the start of Mission Mode.

4.5.3-6-4 Inhibition TC

The Inhibition TC must be delivered to SASW within a specific time "window". If this TC is delivered too soon, i.e. while SASW is initialing during the first 6.5 seconds from power-up, then the TC will be lost when SASW initialises the BIU RAM. After 6.5 seconds SASW waits a further 3.0 seconds for the Inhibit TC. If the TC does not arrive within 9.5 seconds of power-up, SASW will apply any patches present in the EEPROM and continue into Mission Mode. Thus ground must ensure delivery of the Inhibit TC to SASW is within the 6.5 - 9.5 second window for its successful execution.

4.5.3-6-5 BIU Write Discrete Command Bit 0

BIU Discrete Command Bit 0 is linked to CPU reset. After setting of this bit by the ground, the ground shall clear this bit to allow the CPU to restart.

The CPU stays in Reset state whenever Bit 0 is set.

4.5.3-6-6 BIU Watch Dog Expired

When the watch-dog timer expired flag (WD_XPIRD) is set, the PSA cannot send any message and CDS must clear this flag using BIU discrete command services to allow PSA transaction to resume. This is autonomously achieved on board, by the bus fault protection, only during Probe Relay Telemetry mode, in case of vital pair terminal failure, and only for the prime PSA. The disable watch-dog timer expired flag command may be used for the same purpose.

4.5.3-6-7 Alteration TC

PSA switches to Doppler frequency after 60s receiver unlocked, so when the TX is switched ON, PSA is returned on Doppler frequency. Therefore, it has been decided that Alteration TC must be sent twice with a delta of 20 seconds between them, 1 minute after TX is switched ON.

4.5.4 DETAILED DESCRIPTION

This section details the software system input and output parameters, in a reference format.

4.5.4-1 Telecommands

The SASW will receive and process incoming TCs. All TCs will be checked according to the following criteria before being executed:

1• **Critical/Non-Critical TC Check.** The first check made by SASW is to determine on which RX SA (channel) the TC has arrived. If two TCs arrive in the same CUT, one on RX SA-7 (Non-Critical) and one on RX SA-8 (Critical), the one on the Non-Critical SA is rejected and the Invalid TC Count incremented. The TC on the Critical channel is accepted and the next series of checks are then performed.

2• **TC Processing Check.** The second check SASW performs is to check if it is already processing a TC. This specifically applies to Dump or Patch TCs as both can take several CUTs to complete.
If SASW is already processing one of these TCs then all incoming TCs are rejected and the Invalid Count incremented. No further checks on the TC are made in such a case.

3• **TC Layout Check.** The third check is the TC Layout check: Format and CRC on SASW TCs must be valid.
As described in § 4.5.3-2-3, both chains identifiers, A or B, are accepted during this checking. The CRC on the POSW TCs is ignored (in general it is assumed that the final destination will check commands for validity).

4• **Application Data Check.** The final check consists of additional checks only performed on the Application Data Fiels of Patch and Inhibition TCs. See AP02 to AP05 in Doc n° HUY.AS/c.100.OP.0384.

Figure hereafter illustrates the TC validation checks in the form of a flow chart:

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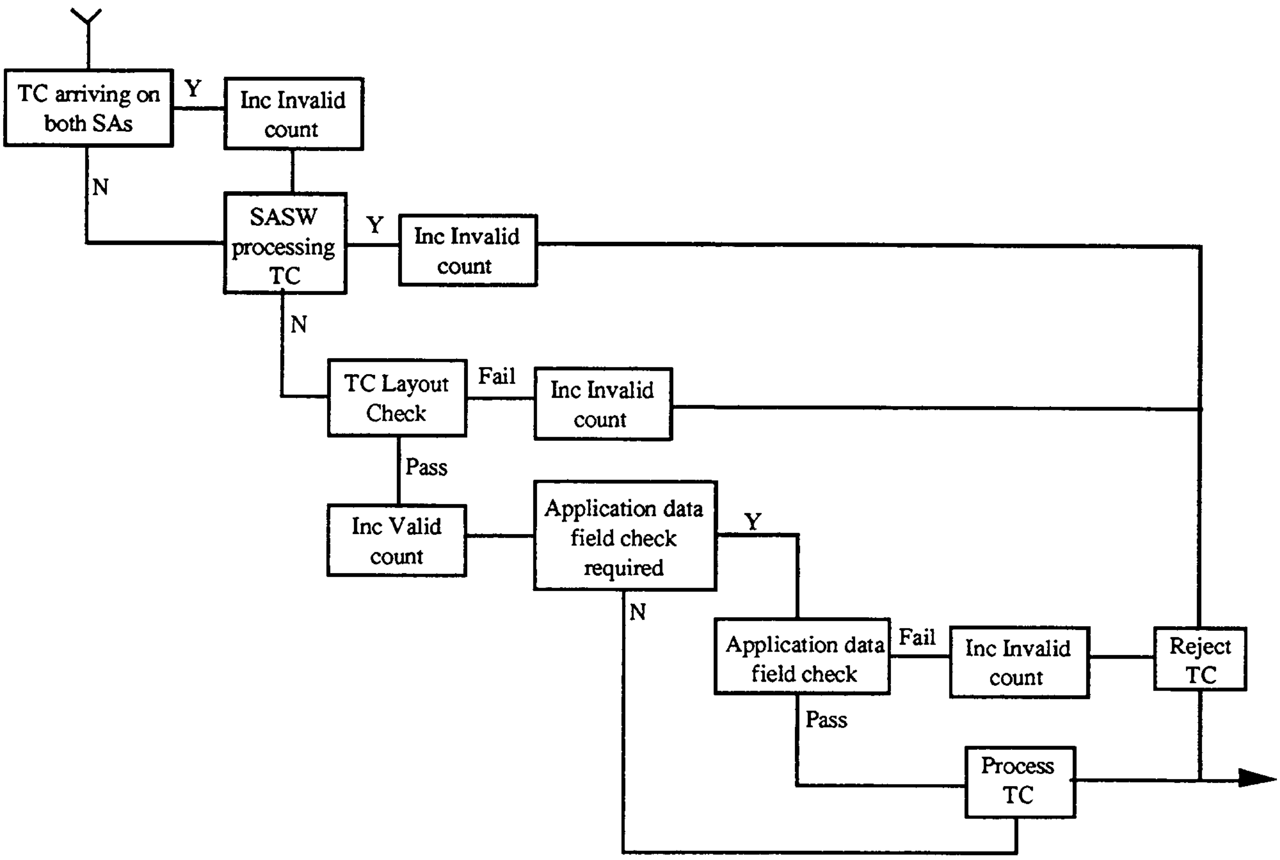

MDP

TC VALIDATION FLOW CHART (excluding Inhibition TC)

TC Layout checks are performed on each PSA TC once the checks for the arrival of the TC on both SA, and if SASW is already processing a TC, has been performed. The checks made are described hereafter.

	msb 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	lsb 0
Packet Header	0	0	0	1	1	Application Process ID										
	1	1	Source Sequence Count													
	Packet Data Field Size (bytes-1)															
Packet Data Field	x	x	x	x	x	x	x	x	TC ID				x	x	x	x
	Application Data Field															
	Cyclic Redundancy Code Word															

- Verify that bits 11 to 15 of the first header word equal 00011 binary
- Verify that bits 14 to 15 of the second header word equal 11 binary
- Verify the Application Process ID in bits 0 to 10 of the first header word
- Verify that the TC ID is valid and that the Packet Data Field Size is correct for this TC type. Note that packet data field size is given in bytes as:
  [number of words in TC (in Packet Data Field) * 2] - 1
- Verify that the Cyclic Redundancy Check Word is correct.

Note no checks on the Source Sequence Count is made.

For non PSA TCs only the following checks are performed:

- Verify that bits 12 to 15 of the first header word equal 0001 binary
- Verify that bits 14 to 15 of the second header word equal 11 binary
- Verify that the Application Process ID is correct.
- Verify that the Packet Data Field Size is $\leq$ 125 words

Application data field checking represents the last stage of TC validation and is type specific. The data field checks are performed on each individual TC type. Finally note that application data field checking is only performed if the initial TC packet layout checking passed.

4.5.4-1-1 Alteration Telecommand

See AP04 in Doc n° HUY.AS/c.100.OP.0384.

4.5.4-1-2 Direct Telecommand

See AP03 in Doc n° HUY.AS/c.100.OP.0384.

4.5.4-1-3 Dump Telecommand

See AP01 in Doc n° HUY.AS/c.100.OP.0384.

4.5.4-1-4 InhibitionTelecommand

See AP02 in Doc n° HUY.AS/c.100.OP.0384.

4.5.4-1-5 Patch Telecommand

See AP05 in Doc n° HUY.AS/c.100.OP.0384.

4.5.4-1-6 Experiment and Probe Telecommand

Functional Description

These TCs are destined for the Probe and passed through SASW with minimal processing

All TCs forwarded to the Probe are padded to 128 words. This is required as the Probe does not know how long commands are when they are buffered in its TC reception hardware (a hardware FIFO). Thus the Probe will wait to allow a maximum length TC to arrive, and then DMA 128 words from this FIFO. If short commands were sent in quick succession the second command could be partially read by this DMA. Padding TCs to 128 words allows TCs to be forwarded to the Probe at the rate of one per CUT, without risk of corruption by early readout of the FIFO by the Probe. The padding is done with the value "AAAA" in hex.

Probe TC Format

The layout of the command is shown in Annex 2 TM/TC Data Tables.

TC Transmission

Only Probe TCs smaller than, or equal to, 32 words in total can be transmitted on RX SA-8 (Critical) channel. All other Probe TCs must be transmitted on RX SA-7 (Non-Critical) channel.

TC Validation

The layout check performed on Probe TCs is a reduced subset of the TC layout check performed on PSA TCs, namely:

- Verify that bits 12 to 15 of the first header word equal 0001 binary
- Verify that bits 14 to 15 of the second header word equal 11 binary
- Verify that the Application Process ID is correct for a Probe TC.
- Verify that the Packet Data Field Size is ≤ 125 words

Cautions & Warnings

- TC should not be sent whilst SASW is handling a Patch or Dump TC
- While a Dump/Patch TC is being processed TCs destined for the Probe are rejected and the Invalid Count incremented
- The SASW uses a background DMA transfer to deliver TCs to the Probe and downstream experiments, via the Umbilical. This will require about 16 ms to complete. However the POSW and SASW clocks are not synchronised, and so the exact CUT of delivery cannot be guaranteed.

Detectable System Outputs

1• The Valid and Invalid TC counters iwithin the PSA HK TM will be updated as shown below:

#	Probe TC		Valid TC Count	Invalid TC Count
1	TC arriving on both SA		–	+1
2	SASW processing TC		–	+1
3	TC Packet Layout Check	Pass	+1	–
		Fail	–	+1
4	Application Data Field Check	Pass	–	–
		Fail	–	–

2• TC packet is forwarded to the Probe via the umbilical.

4.5.4-2 Telemetry

The SASW forwards to Cassini CDS Probe Transfer Frames as they arrive. If Probe Transfer Frames fail to arrive the SASW generates its own Super Dump Packets every second to replace the Probe Transfer Frames. The SASW also generates its own PSA HK Packets at a rate of one per second. All TM packets are of a fixed size and of a fixed format.

For the overall layout of the telemetry packets refer to Annex 2 TM/TC Data Tables.

4.5.4-2-1 Dump Super Packet

These packets are generated when the Probe is not transmitting Transfer Frames. The SASW TM FIFO must be empty for a Dump Super packet to be generated.

The Dump Super packet contains a 6 word header, and the contents of BIU memory from address 0400H upwards. These locations are used for the BIU SASW RTDT.

Annex 2 TM/TC Data Tables shows the format of this packet in § 4.4.

See the layout of BIU RAM in § 4.5.4-3-1.

4.5.4-2-2 Super Packet

These packets are queued to RX SA-11 when Cassini requests data and there is Probe data available. The rate at which these packets are queued depends on the rate at which Cassini takes them. As soon as Cassini has taken a packet, SASW will queue another packet (if available). In the nominal mission, Cassini will take one Super Packet every second (see § 4.5.3-2-6 Telemetry Collection). The Probe Transfer Frame is described in § 4.4 POSW. The Probe Transfer Frame is modified, with 2 synch words removed by the PSA hardware, and an ESA standard 6 word Super packet header added by the SASW. It is 516 words in total length.

The layout of this packet is shown in Annex 2 TM/TC Data Tables § 4.1.

The Probe Transfer Frames are delivered to the SASW via a serial-to parallel converter at the rate of one word per 16/8192 seconds. This is managed by a DMA which copies the words into BIU RAM. At the completion of a packet the DMA interrupt signals the SASW software, which fills in the header, and queues the packet to the end of the FIFO used to send Super packets to Cassini.

The BIU time in the header of the Super packet is the time of arrival of the last Probe Transfer Frame word at the SASW.

4.5.4-2-3 PSA Housekeeping Packet

These packets are generated by SASW and queued for collection by Cassini on RX SA-12 each 8 CUTs.

The PSA HK TM packet is generated in CUT 7 (CUTs being numbered 0 --> 7) and is thus available for pickup by the CDS in the next CUT 0.

The formatting and layout of the PSA HK packet is specified by the CUT Housekeeping Acquisition Table. This table also specifies the timing characteristics (timing offset) of each acquired parameter.

The general layout is given in Annex 2 TM/TC Data Tables PSE Housekeeping Packet § 4.2.

4.5.4-2-4 Dump Packet

These packets are queued to TX SA-12 and are generated in response to a Dump TC. The Dump packet replaces a PSA HK packet for that 8 CUT period. Each packet will include up to 83 words of memory (RAM or EEPROM), starting from the current dump address. If the address spans the end of memory the remainder of the packet will be filled with zeros.

The layout of the Dump packet is given in AP01 in Doc n° HUY.AS/c.100.OP.0384.

Dump packets will be available for collection by Cassini in the CUT following the reception of the Dump TC. However the action of the Cassini data collection scheme, and the SASW FIFOs may delay the time before the packet is available to Cassini. This delay will not effect the time to complete the TC. Note that if the data is not being collected by Cassini the FIFO may fill, in which case new packets (either dump or PSA HK TM) will be discarded.

4.5.4-2-5 TM List

SASW A and B				
TM CODE	**DESCRIPTION**	**TYPE**	**PACKET**	**VALUE**
A1 001 H A2 001 H	Invalid TC counter	byte	PSE	Initial = 0
A1 002 H A2 002 H	Valid TC counter	byte	PSE	Initial = 0
A1 003 H A2 003 H	Fixed point overflow counter: a S/W counter used to monitor the number of fixed point overflows which arise during mathematical computation. An exception will also be generated whenever a fixed point overflow occurs.	byte	PSE	Initial = 0
A1 004 H A2 004 H	Floating point overflow counter: a S/W counter used to monitor the number of floating point overflows which arise during mathematical computation. An exception will also be generated whenever a floating point overflow occurs.	byte	PSE	Initial = 0
A1 005 H A2 005 H	Exception counter: a S/W counter used to monitor the number of Ada exceptions raised by SASW. This dedicated counter is incremented whenever an exception occurs, and the appropriate bit in the SASW health status words will also be set to indicate the source of the exception.	byte	PSE	Initial = 0
A1 006 H A2 006 H	Overrun counter: a S/W counter used to monitor the number of CUT overruns which arise if CUT/DTSTART processing is not completed in time	byte	PSE	Initial = 0
A1 007 H A2 007 H	Status EDAC register LSB: Bit 7-2 = spare Bit 1 = memory double error (not corrected) Bit 0 = memory single error (corrected)	byte	PSE	 0 = none 0 = none
A1 008 H A2 008 H	PSA init status (see Note 1): Bit 7: DMA health Bit 6: PROM health Bit 5: RAM health Bit 4: EEPROM health Bit 3: BIU RAM health Bit 2: spare Bit 1: spare Bit 0: spare	byte	PSE	Bits 7–3: 0 = unhealthy; 1 = healthy 0 0 0
A1 009 H A2 009 H	A software counter used to monitor the number of BIU resets performed by the SASW when it detects a BIU failure	byte	PSE	Initial = 0

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SASW A and B				
TM CODE	DESCRIPTION	TYPE	PACKET	VALUE
A1 001 W A2 001 W	CPU fault register: Bit 15: CPU memory protect fault Bit 14: DMA memory protect fault Bit 13: memory parity fault Bit 12: Program.I/O ch. parity fault Bit 11: DMA channel parity fault Bit 10: illegal I/O command fault Bit 9: Program. I/O transm. fault Bit 8: spare Bit 7: illegal address fault Bit 6: illegal instruction Bit 5: priviledged instruction fault Bit 4: address state fault Bit 3: > reserved < Bit 2-0: fail code	word	PSE	Bits 15-4: 0 = OK; 1 = fault Bit 2-0: 0 = OK >0 = Fault
A1 002 W A2 002 W	RAM first failure address (see Note 1)	word	PSE	
A1 009 W A2 009 W	BIU RAM first failure address (see Note 1)	word	PSE	
A1 010 W A2 010 W	BIU fail register: Bit 15 = BIU self test result Bit 14 = BIU watch dog Bit 13 = BIU write protection Bit 12 = discrete command bit 1 Bit 11-0 = don't care	word	PSE	 1 = failure 1 = expired 1 = violation 1 = interrupt 11 raised

Note 1: The PSA Init Status should be used in conjunction with the PROM checksum parameter reported as SASW STATUS 1 and the two PSA HK parameters RAM_FIRST_FAILURE_ADDRESS & BIU_RAM_FIRST_FAILURE_ADDRESS which provide information on the address of the first error encountered while performing checks on main RAM and BIU RAM respectively.

SASW Health status

The SASW uses two 16 bit health words to monitor exceptions in the software. They are reported in the PSA HK packet each 8 CUTs and cleared once reported. Each health flag is manipulated as an independent entity, within the 8 CUT reporting cycle.

Individual health flags are set to unhealthy whenever an exception arises in the activity or function which they monitor. The general philosophy behind flag allocation is that every activity which originates from the cyclic executive will be monitored by a dedicated health flag. In addition several other key events are specifically monitored to give visibility of the true serviceability of the software. For example the startup activities and Interrupt Service Routines are key events watched by dedicated health flags.

A health bit of "0" denotes a healthy state.

SASW A and B			
TM Code	**Description**	**Type**	**Comments**
A1 003 W A2 003 W	SASW Health LSW: Bit 15: BIU ISR Health Bit 14: FDI ISR Health Bit 13: DMA ISR Health Bit 12: ISR Health Bit 11: Start-up Init Health Bit 10: Start up Timer B Health Bit 9: Start up Patch RAM Health Bit 8: Start up Extra Act Health Bit 7: set BIU Reg Health Bit 6: Init Mission Health Bit 5: Record Stack HWM Health Bit 4: Record CUT Free Time Health Bit 3: Ctrl Mask Int Health Bit 2: spare Bit 1: spare Bit 0: spare	word	 BIU ISR FDI ISR DMA ISR CPU ints (FXOV,FLOV,ME,TIMERB) Ada start-up initialisation Ada start-up waiting for Timer B Ada start-up EEPROM copy Start-up extra activities (currently NULL) Init Mission activity Health of INIT_MISSION op Run Mission internal activity Run Mission internal activity Run Mission internal activity
A1 004 W A2 004 W	SASW Health MSW: Bit 15: Initialise SASW Health Bit 14: Initialise CPU Health Bit 13: Initialise MEM_OPS Health Bit 12: Initialise BIU_HANDLER Health Bit 11: Initialise PROBE_FRAMES Health Bit 10: Initialise DMA Health Bit 9: Initialise TM_OUTPUT Health Bit 8: Initialise TC Health Bit 7: Initialise HK_TM Health Bit 6: BIU RTI Arrived Health Bit 5: BIU HK Health Bit 4: Gen. HKTM Pkt Health Bit 3: Handle TC Health Bit 2: Detect BIU DTSTART Health Bit 1: BIU DTSTART Health Bit 0: Controller Loop Health	word	 Initialisation of SASW_HEALTH object Initialisation of CPU object Initialisation of MEM_OPS object Initialisation of BIU_HANDLER object Initialisation of PROBE_FRAMES object Initialisation of DMA object Initialisation of TM_OUTPUT object Initialisation of TC object Initialisation of HK_TM object Run Mission activity #1 Run Mission activity #2 Run Mission activity #3 Run Mission activity #4 Run Mission activity #5 Run Mission activity #6 Main 'Run Mission' Scheduler

PSA Status Register

This register is reported once every 8 CUTs. It provides status information about the RUSO, TCXO and the PSA chain ID (TM R5013R, R5014R and R5015B, see § 4.2.1-6-2). During start-up, this register is read by SASW in order to determine the PSA chain it is executing on. SASW then stores the chain ID internally and uses it to allocate the correct TM packet headers.

Receiver HK Words

There are 4 Receiver HK words (TM R5001S to R5004S and R6001S to R6004S) which are reported each CUT by SASW. These words provide status information about the Receiver hardware and software. See details in Annex 2 TM/TC Data Tables in § 8.7.2.2.

Internal software status parameters

The SASW Status parameters are for Software internal use only. These parameters will continue to be collected during the actual mission and may be used to assist post mission analysis. All these parameters are reported once every 8 CUTs.

SASW Status 1	PROM checksum (calculated once at power up):	TM A1 005 W/A2 005 W
SASW Status 2	Stack high water mark:	TM A1 006 W/A2 006 W
SASW Status 3	CUT processing end time (pre DTSTART):	TM A1 007 W/A2 007 W
SASW Status 4	DTSTART processing end time:	TM A1 008 W/A2 008 W
SASW Status 5	FDI ISR start time:	TM A1 011 W/A2 011 W
SASW Status 6	DMA ISR start time:	TM A1 012 W/A2 012 W
SASW Status 7	FDI ISR end time:	TM A1 013 W/A2 013 W
SASW Status 8	DMA ISR end time:	TM A1 014 W/A2 014 W
SASW Status 9	DTSTART start time:	TM A1 015 W/A2 015 W
SASW Status 10	Spare	TM A1 016 W/A2 016 W

SASW Status 1 - PROM Checksum

TM codes: SASW A = A1 005 W SASW B = A2 005 W (PSE packet)
The PROM checksum is calculated by the software during startup and will remain static in all PSA HK TM packets. This value is nominally zero for a valid checksum, but will adopt a non-zero value when the PROM is corrupted. This parameter should be interpreted in conjunction with the PROM checksum health flag as part of the PSA Init Status parameter.

SASW Status 2 - Stack High Water Mark

TM codes: SASW A = A1 006 W SASW B = A2 006 W (PSE packet)
The Stack high water mark is used to calculate usage of stack resources by SASW and is reported in the PSA HK packet once every 8 CUTs. The algorithm used starts at the limit of the stack space allocation, and works towards the base of stack looking for non-zero values and is the address of the first non-zero value found. It relies on the fact that all stack memory is initialised to zero.

In order to reduce computational overheads, SASW examines 10 words in stack memory every CUT. Thus, given a stack size of 8 Kwords, it will take ≈ 1.7 mn to examine the complete stack space. Note that as stack grows towards low memory the value should decrease.

The stack high water mark reported in TM is a logical memory address, and this parameter may be used to calculate the worst usage of the stack resource. The resulting worst case may then be analysed in conjunction with the allocated stack resource given by the symbol A$MAIN_STACKSIZE in the TLD map file. The formula for calculating the worst case stack usage is;

Worst case usage of stack = Stack Base - SASW Status 2 + 1

where:

- Worst case stack usage = Maximum number of stack words used by the stack during software execution
- Stack Base = Logical address of stack base. This is denoted by the TLD symbol A$HEAPND within the TLD map file. The stack base is located at RAM address EFFFhex
- SASW Status 2 = Worst case stack high water mark. The worst case is the lowest value reported in TM and should be the value incorporated into the most recent TM packet.

Note that the Stack High Water Mark will appear as 0 while it is being computed. Once the HWM has been detected, the value will remain set in the PSA HK packet until such time a new HWM is detected.

SASW Status 3 - CUT processing end time

TM codes: SASW A = A1 007 W SASW B = A2 007 W (PSE packet)
The parameter is used to monitor the worst case CUT execution time (pre DTSTART processing) for the SASW. The value reported in the PSA HK TM is a worst case value in an 8 CUT period and is a snapshot of the timer B at the end of normal CUT processing. It is cleared once reported.

Timer B is a free running unsigned 16 bit counter and is clocked at 10 KHz. It is set at the arrival of the BIU RTI to overflow in 124.8 ms. This parameter should be analysed in conjunction with the CUT overrun counter and on occasions when the CUT overrun occurs this parameter may contain meaningless data. Any analysis should also compensate for the fact that residual timer B acquisition is not the ultimate activity in the CUT.

The worst case CUT processing time (in ms) can be calculated using the following formula:

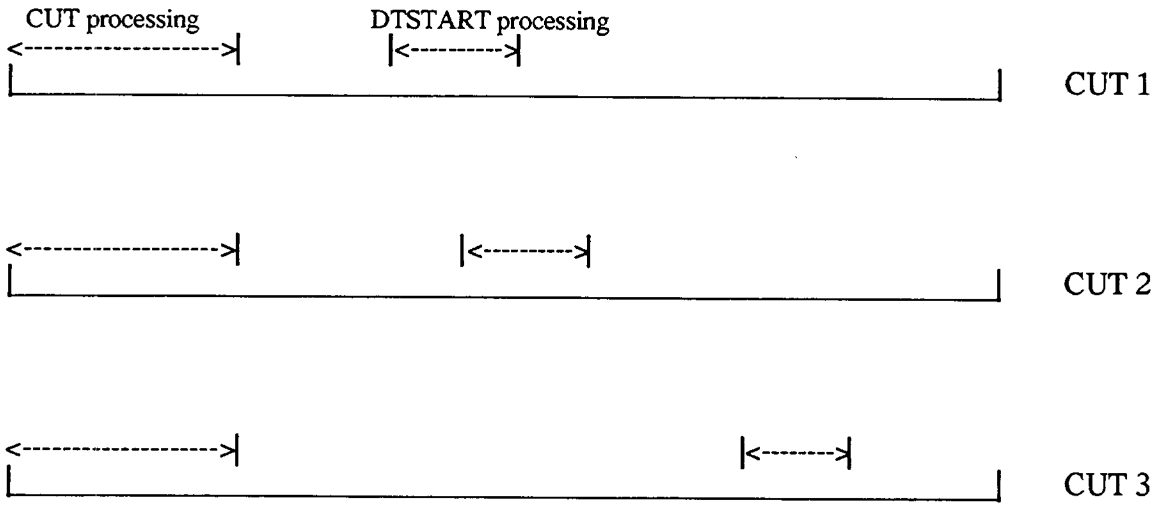
CTU duration + processing margin - ((Timer B time out - SASW Status 3) * Timer B clock period)

where:

CUT duration	Duration of CUT, namely 125 ms
Processing Margin	Time allocated for the execution of residual processing which occurs in the CUT after acquisition of the timer
Timer B time out	Value at which the timer will raise an interrupt, namely 65535
SASW Status 3	The highest value of the SASW Status 3 parameter reported during S/W execution (in decimal)
Timer B clock period	Period of timer B clock, namely 0.1 ms/tick (10 KHz clock)

SASW Status 4/9 - DTSTART processing end/start time

TM codes: SASW A = A1 008 W SASW B = A2 008 W (PSE packet) Status 4
TM codes: SASW A = A1 015 W SASW B = A2 015 W (PSE packet) Status 9
These two parameters are used in conjunction to monitor the DTSTART execution time for the case where the DTSTART end time is the worst case in an 8 CUT period. For example in the scenario presented hereafter, although the DTSTART processing in CUTs 1 and 2 may be longer than in CUT 3, it is the timer B values for CUT 3 that are reported, as that DTSTART is the closest to the end of the CUT and hence has the greater potential for a CUT overrun.



The values reported in the PSA HK TM are snapshots of the timer B at the start and end of DTSTART processing and are cleared once reported. These parameters should be analysed in conjunction with the CUT overrun counter and on occasions when the CUT overrun occurs these parameters may contain meaningless data.

The worst case DTSTART processing time (in ms) can be calculated using the following formula:

(SASW Status 4 - SASW Status 9) * Timer B clock period

where

SASW Status 4	Value denoting the end of the DTSTART processing (converted to decimal)
SASW Status 9	Value denoting the start of the DTSTART processing (converted to decimal)
Timer B clock period	Period of timer B tick, namely 0.1 ms/tick (10 KHz timer)

Note that if the DTSTART signal is not provided by the 1553 BIU then the S/W will start DTSTART processing when 120ms has elapsed since the last RTI.

SASW Status 5/7 - FDI ISR start/end time

TM codes: SASW A = A1 011 W SASW B = A2 011 W (PSE packet) Status 5
TM codes: SASW A = A1 013 W SASW B = A2 013 W (PSE packet) Status 7
These two parameters are used in conjunction to monitor the FDI ISR execution time in an 8 CUT period. The values reported in the PSA HK TM are snapshots of the timer B at the start and end of the FDI ISR and are cleared once reported. These parameters should be analysed in conjunction with the CUT overrun counter and on occasions when the CUT overrun occurs these parameters may contain meaningless data.

The FDI ISR processing time (in ms) can be calculated using the following formula:

(SASW Status 7 - SASW Status 5) * Timer B clock period

where

SASW Status 7	Value denoting the end of the FDI IST processing (converted to decimal)
SASW Status 5	Value denoting the start of the FDI ISR processing (converted to decimal)
Timer B clock period	Period of timer B tick, namely 0.1 ms/tick (10 KHz timer)

Nominally there should be only one FDI interrupt in each 8 CUT period.

SASW Status 6/8 - DMA ISR start/end time

TM codes: SASW A = A1 012 W SASW B = A2 012 W (PSE packet) Status 6
TM codes: SASW A = A1 014 W SASW B = A2 014 W (PSE packet) Status 8
These two parameters are used in conjunction to monitor the DMA ISR execution time in an 8 CUT period. The values reported in the PSA HK TM are snapshots of the timer B at the start and end of the DMA ISR and are cleared once reported. These parameters should be analysed in conjunction with the CUT overrun counter and on occasions when the CUT overrun occurs these parameters may contain meaningless data.

The DMA ISR processing time (in ms) can be calculated using the following formula:

(SASW Status 8 - SASW Status 6) * Timer B clock period

where

SASW Status 8	Value denoting the end of the DMA IST processing (converted to decimal)
SASW Status 6	Value denoting the start of the DMA ISR processing (converted to decimal)
Timer B clock period	Period of timer B tick, namely 0.1 ms/tick (10 KHz timer)

Nominally there should be only two DMA interrupts in each 8 CUT period, TC or TM transfer completion. However the TC DMA time will always be less than the TM DMA as there is little processing at the end of a TC transfer.

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4.5.4-3 Software Data

4.5.4-3-1 BIU RAM Layout

A• BIU RAM

BIU RAM	BIU RAM Address (hex)	
Unused	1FFF 1A14	
Super Packet FIFO (5*516)	1000	
Unused	0EA2	
Wrap Round Data	0E82	
Critical TC#2	0E62	
Message Status Word for Rx SA-8 (Cr. TC#2)	0E61	
Critical TC#1	0E41	
Message Status Word for Rx SA-8 (Cr. TC#1)	0E40	
Non Critical TC#2	0A40	
Message Status Word for Rx SA-7 (N-C TC#2)	0A20	
Non Critical TC#1	0620	
Message Status Word for Rx SA-7 (N-C TC#1)	0600	
Scratch Area #2	0540	DUMP SUPER PACKET
SASW RTDT	0400	
Dump Super Packet header	03FA	
Unused	03C7	
HK FIFO = 5*91 words	0200	
Scratch Area #1	0140	
Auto-Initialise Table	0	

B• SASW RTDT

Receive Subaddresses	SASW RTDT	BIU RAM Address	SASW RTDT Initialisation Data			
			Control word	Msg Stat list	Data List	Reserved
1	BIU Boot kernel	0400	0000	C4FF	0404	C4FF
2	BIU/REU/XB ML	0404	0000	0181	0400	0181
3	BIU discrete	0408	0000	0182	E000	E182
4	XBA DMA	040C	0600	057A	A000	0000
5	SURAM load	0410	0600	057B	A000	0000
6	XBA/REU status	0414	0600	057C	A000	0000
7	Non-Critical TC	0418	0420	0600	0620	0000
8	Critical TC	041C	0400	0E40	0E41	0000
9	Fault Protection TC	0420	0400	057F	A000	0000
10	Data Broadcasts	0424	0000	0580	A000	0000
11	Not used	0428	0600	0581	A000	0000
12	Not used	042C	0600	0582	A000	0000
13	Reserved	0430	0600	0583	A000	0000
14	Reserved	0434	0600	0584	A000	0000
15	Reserved	0438	0600	0585	A000	0000
16	Reserved	043C	0600	0586	A000	0000
17	Reserved	0440	0600	0587	A000	0000
18	Reserved	0444	0600	0588	A000	0000
19	State Table Transfers	0448	0000	0589	A000	0000
20	Periodic RT to RT	044C	0600	058A	A000	0000
21	Periodic RT to RT	0450	0600	058B	A000	0000
22	Critical RT to RT	0454	0600	058C	A000	0000
23	Reserved	0458	0600	058D	A000	0000
24	Reserved	045C	0600	058E	A000	0000
25	Reserved	0460	0600	058F	A000	0000
26	Reserved	0464	0600	0590	A000	0000
27	Reserved	0468	0600	0591	A000	0000
28	Reserved	046C	0600	0592	A000	0000
29	S/C Time	0470	0000	0593	0540	0000
30	BIU Data Wrap test	0474	0400	0594	0E82	0000
31	Reserved	0478	0600	0595	A000	0000
32	Reserved	047C	0600	0596	A000	0000

Msg Stat list = Message Status list

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Transmit Subaddresses	SASW RTDT	BIU RAM Address	SASW RTDT Initialisation Data			
			Control word	Msg Stat list	Data List	Reserved
1	BIU Boot kernel	0480	0000	C4FF	0404	C4FF
2	BIU/REU/XB ML	0484	0000	01A1	0400	01A1
3	BIU discrete	0488	0000	01A2	E000	E1A2
4	XBA DMA	048C	0600	059A	A000	0000
5	SURAM load	0490	0600	059B	A000	0000
6	XBA/REU status	0494	0600	059C	A000	0000
7	Not used	0498	0600	059D	A000	0000
8	Not used	049C	0600	059E	A000	0000
9	Fault Protection TC	04A0	0600	059F	A000	0000
10	Data Broadcasts	04A4	0600	05A0	A000	0000
11	Super Packet	04A8	0400	0563	03FA	0000
12	PSA HK Packet	04AC	0400	0574	05C7	0000
13	Reserved	04B0	0600	05A3	A000	0000
14	Reserved	04B4	0600	05A4	A000	0000
15	Reserved	04B8	0600	05A5	A000	0000
16	Reserved	04BC	0600	05A6	A000	0000
17	Reserved	04C0	0600	05A7	A000	0000
18	Reserved	04C4	0600	05A8	A000	0000
19	Reserved	04C8	0000	05A9	A000	0000
20	Reserved	04CC	0600	05AA	A000	0000
21	Reserved	04D0	0600	05AB	A000	0000
22	Reserved	04D4	0600	05AC	A000	0000
23	Reserved	04D8	0600	05AD	A000	0000
24	Reserved	04DC	0600	05AE	A000	0000
25	Reserved	04E0	0600	05AF	A000	0000
26	Reserved	04E4	0600	05B0	A000	0000
27	Reserved	04E8	0600	05B1	A000	0000
28	Reserved	04EC	0600	05B2	A000	0000
29	S/C Time read back	04F0	0400	05B3	0540	0000
30	BIU Data Wrap read back	04F4	0400	05B4	0E82	0000
31	Reserved	04F8	0600	05B5	A000	0000
32	Reserved	04FC	0600	05B6	A000	0000

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Mode Codes	SASW RTDT	BIU RAM Address	SASW RTDT Initialisation Data: Control word	Msg Stat list	Data List	Reserved
0/16	Dynamic Bus Control/Tx Vector Word	0500	2A00	01C0	01D0	01D0
1/17	Sync with Data word/without Data word	0504	0400	01C1	7984	79C5
2/18	Tx Status/Tx last Cmd	0508	0A00	01C2	01E0	01E2
3/19	BIT/Tx BIT word	050C	0A00	01C3	01E0	01E3
4/20	XMTR Shutdown/Selected XMTR Shutdown	0510	0600	01C4	01E0	01E4
5/21	Override XMTR Shutdown/Override select.	0514	0600	01C5	01E0	01E5
6/22	Inhibit Terminal Flag/Reserved	0518	0600	01C6	01E0	01E6
7/23	Override Inhibit Terminal Flag/Reserved	051C	0600	01C7	01E0	01E7
8/24	Reset RT/Reserved	0520	0600	01C8	01E0	01E8
9/25	N/A	0524	2600	01C9	01E0	01E9
10/26	N/A	0528	2600	01CA	01E0	01EA
11/27	N/A	052C	2600	01CB	01E0	01EB
12/28	N/A	0530	2600	01CC	01E0	01EC
13/29	N/A	0534	2600	01CD	01E0	01ED
14/30	N/A	0538	2600	01CE	01E0	01EE
15/31	N/A	053C	2600	01CF	01E0	01EF

C• Scratch Area #2

Scatch Area #2	BIU RAM Address
S/C Time	0540
Unused	0548
Interrupt Log List	0560
Message Status Words Tx SA-11 (Super pkts)	0563
Message Status Words Tx SA-12 (PSA HK)	0574
Message Status Words Rx SA-1	0577
Message Status Words Rx SA-2	0578
Message Status Words Rx SA-3	0579
Message Status Words Rx SA-4	057A
Message Status Words Rx SA-5	057B
Message Status Words Rx SA-6	057C
Unused	057D
Unused	057E
Message Status Words Rx SA-9	057F
Message Status Words Rx SA-10	0580
Message Status Words Rx SA-11	0581
Message Status Words Rx SA-12	0582
Message Status Words Rx SA-13	0583
Message Status Words Rx SA-14	0584
Message Status Words Rx SA-15	0585
Message Status Words Rx SA-16	0586
Message Status Words Rx SA-17	0587
Message Status Words Rx SA-18	0588
Message Status Words Rx SA-19	0589
Message Status Words Rx SA-20	058A
Message Status Words Rx SA-21	058B
Message Status Words Rx SA-22	058C
Message Status Words Rx SA-23	058D
Message Status Words Rx SA-24	058E
Message Status Words Rx SA-25	058F
Message Status Words Rx SA-26	0590
Message Status Words Rx SA-27	0591
Message Status Words Rx SA-28	0592
Message Status Words Rx SA-29	0593
Message Status Words Rx SA-30	0594

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Scatch Area #2	BIU RAM Address
Message Status Words Rx SA-31	0595
Message Status Words Rx SA-32	0596
Message Status Words Tx SA-1	0597
Message Status Words Tx SA-2	0598
Message Status Words Tx SA-3	0599
Message Status Words Tx SA-4	059A
Message Status Words Tx SA-5	059B
Message Status Words Tx SA-6	059C
Message Status Words Tx SA-7	059D
Message Status Words Tx SA-8	059E
Message Status Words Tx SA-9	059F
Message Status Words Tx SA-10	05A0
Unused	05A1
Unused	05A2
Message Status Words Tx SA-13	05A3
Message Status Words Tx SA-14	05A4
Message Status Words Tx SA-15	05A5
Message Status Words Tx SA-16	05A6
Message Status Words Tx SA-17	05A7
Message Status Words Tx SA-18	05A8
Message Status Words Tx SA-19	05A9
Message Status Words Tx SA-20	05AA
Message Status Words Tx SA-21	05AB
Message Status Words Tx SA-22	05AC
Message Status Words Tx SA-23	05AD
Message Status Words Tx SA-24	05AE
Message Status Words Tx SA-25	05AF
Message Status Words Tx SA-26	05B0
Message Status Words Tx SA-27	05B1
Message Status Words Tx SA-28	05B2
Message Status Words Tx SA-29	05B3
Message Status Words Tx SA-30	05B4
Message Status Words Tx SA-31	05B5
Message Status Words Tx SA-32	05B6
Message Status Words MC-00/16	05B7
Message Status Words MC-01/17	05B8
Message Status Words MC-02/18	05B9
Message Status Words MC-03/19	05BA
Message Status Words MC-04/20	05BB
Message Status Words MC-05/21	05BC
Message Status Words MC-06/22	05BD
Message Status Words MC-07/23	05BE
Message Status Words MC-08/24	05BF
Message Status Words MC-09/25	05C0

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Scatch Area #2	BIU RAM Address
Message Status Words MC-10/26	05C1
Message Status Words MC-11/27	05C2
Message Status Words MC-12/28	05C3
Message Status Words MC-13/29	05C4
Message Status Words MC-14/30	05C5
Message Status Words MC-15/31	05C6
Dummy PSA HK TM Header	05C7
Unused	05CE
.....	
Unused	05FF

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4.5.4-3-2 Timing Information for PSA HK

The Timing Offset given in the following table can be used to determine when a particular parameter was acquired by SASW. For example a "0" indicates the parameter was acquired in the nominal CUT 7 (CUTs ranging from 0 .. 7) and "-7" indicates the parameter was acquired in nominal CUT 0. This information can also be used to determine the exact Mission CUT in which the parameter was acquired by simply summing the Timing Offset with the CUT counter in the PSA HK packet header. So if the CUT counter given in the PSA HK packet header was 700 for example, the Fixed Point Overflow counter was reported in CUT 694 and the Valid TC counter in CUT 699.

Position = position of the parameter in the PSA packet, given in bytes, with the origin being the first byte immediately after the secondary packet header.

Position	Parameter Description	TM Code SASWA/SASWB	Timing Offset
1	PSA RX supply voltage A/B	R5008A/R6008A	0
2	PSA secondary supply voltage A/B	R5007A/R6007A	-1
3	PSA TCXO temperature A/B	R5010T/R6010T	-4
4	LNA supply voltage A/B	R3002A/R4002A	-2
5	RUSO A status/Spare	E7003B/Spare	-3
6	RUSO A Temp 1/Spare	E7001A/Spare	-7
7	RUSO A Temp 2/Spare	E7002A/Spare	-6
8	RUSO A Temp 3/Spare	E7004A/Spare	-5
9	PSA status Bit 7: PSA selection status A/B Bit 6: RUSO power status/Spare Bit 5: PSA chain identifier A/B Bits 4 to 0: unused	 R5014R/R6014R R5013R/Spare R5015B/R6013B Spare	-7
10	PSA init status	A1008H/A2008H	-7
11	Invalid TC counter	A1001H/A2001H	-1
12	Valid TC counter	A1002H/A2002H	-1
13	Fixed Point Overflow counter	A1003H/A2003H	-6
14	Float Point Overflow counter	A1004H/A2004H	-5
15	Exception counter	A1005H/A2005H	-3
16	Overrun counter	A1006H/A2006H	-1
17	Status EDAC Register LSB (CUT 0)	A1007H/A2007H	-7
18	Status EDAC Register LSB (CUT 1)	A1007H/A2007H	-6
19	Status EDAC Register LSB (CUT 2)	A1007H/A2007H	-5
20	Status EDAC Register LSB (CUT 3)	A1007H/A2007H	-4
21	Status EDAC Register LSB (CUT 4)	A1007H/A2007H	-3
22	Status EDAC Register LSB (CUT 5)	A1007H/A2007H	-2
23	Status EDAC Register LSB (CUT 6)	A1007H/A2007H	-1
24	Status EDAC Register LSB (CUT 7)	A1007H/A2007H	0
25 26	CPU Fault Register	A1001W/A2001W	-4
27 28	RAM First Failure Address	A1002W/A2002W	-6

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Position	Parameter Description	TM Code SASWA/SASWB	Timing Offset
29	SASW Health MSW Status	A1004W/A2004W	-3
30			
31	SASW Health LSW Status	A1003W/A2003W	-3
32			
33	BIU RAM First Failure Address	A1009W/A2009W	-2
34			
35	BIU Fail Register (CUT 0)	A1010W/A2010W	-7
36			
37	BIU Fail Register (CUT 1)	A1010W/A2010W	-6
38			
39	BIU Fail Register (CUT 2)	A1010W/A2010W	-5
40			
41	BIU Fail Register (CUT 3)	A1010W/A2010W	-4
42			
43	BIU Fail Register (CUT 4)	A1010W/A2010W	-3
44			
45	BIU Fail Register (CUT 5)	A1010W/A2010W	-2
46			
47	BIU Fail Register (CUT 6)	A1010W/A2010W	-1
48			
49	BIU Fail Register (CUT 7)	A1010W/A2010W	0
50			
51	PSA A/B Receiver HK Word 1 (CUT 0)	R5001S/R6001S	-7
52			
53	PSA A/B Receiver HK Word 1 (CUT 1)	R5001S/R6001S	-6
54			
55	PSA A/B Receiver HK Word 1 (CUT 2)	R5001S/R6001S	-5
56			
57	PSA A/B Receiver HK Word 1 (CUT 3)	R5001S/R6001S	-4
58			
59	PSA A/B Receiver HK Word 1 (CUT 4)	R5001S/R6001S	-3
60			
61	PSA A/B Receiver HK Word 1 (CUT 5)	R5001S/R6001S	-2
62			
63	PSA A/B Receiver HK Word 1 (CUT 6)	R5001S/R6001S	-1
64			
65	PSA A/B Receiver HK Word 1 (CUT 7)	R5001S/R6001S	0
66			
67	PSA A/B Receiver HK Word 2 (CUT 0)	R5002S/R6002S	-7
68			
69	PSA A/B Receiver HK Word 2 (CUT 1)	R5002S/R6002S	-6
70			
71	PSA A/B Receiver HK Word 2 (CUT 2)	R5002S/R6002S	-5
72			

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Position	Parameter Description	TM Code SASWA/SASWB	Timing Offset
73	PSA A/B Receiver HK Word 2 (CUT 3)	R5002S/R6002S	-4
74			
75	PSA A/B Receiver HK Word 2 (CUT 4)	R5002S/R6002S	-3
76			
77	PSA A/B Receiver HK Word 2 (CUT 5)	R5002S/R6002S	-2
78			
79	PSA A/B Receiver HK Word 2 (CUT 6)	R5002S/R6002S	-1
80			
81	PSA A/B Receiver HK Word 2 (CUT 7)	R5002S/R6002S	0
82			
83	PSA A/B Receiver HK Word 3 (CUT 0)	R5003S/R6003S	-7
84			
85	PSA A/B Receiver HK Word 3 (CUT 1)	R5003S/R6003S	-6
86			
87	PSA A/B Receiver HK Word 3 (CUT 2)	R5003S/R6003S	-5
88			
89	PSA A/B Receiver HK Word 3 (CUT 3)	R5003S/R6003S	-4
90			
91	PSA A/B Receiver HK Word 3 (CUT 4)	R5003S/R6003S	-3
92			
93	PSA A/B Receiver HK Word 3 (CUT 5)	R5003S/R6003S	-2
94			
95	PSA A/B Receiver HK Word 3 (CUT 6)	R5003S/R6003S	-1
96			
97	PSA A/B Receiver HK Word 3 (CUT 7)	R5003S/R6003S	0
98			
99	PSA A/B Receiver HK Word 4 (CUT 0)	R5004S/R6004S	-7
100			
101	PSA A/B Receiver HK Word 4 (CUT 1)	R5004S/R6004S	-6
102			
103	PSA A/B Receiver HK Word 4 (CUT 2)	R5004S/R6004S	-5
104			
105	PSA A/B Receiver HK Word 4 (CUT 3)	R5004S/R6004S	-4
106			
107	PSA A/B Receiver HK Word 4 (CUT 4)	R5004S/R6004S	-3
108			
109	PSA A/B Receiver HK Word 4 (CUT 5)	R5004S/R6004S	-2
110			
111	PSA A/B Receiver HK Word 4 (CUT 6)	R5004S/R6004S	-1
112			
113	PSA A/B Receiver HK Word 4 (CUT 7)	R5004S/R6004S	0
114			
115	SASW Status 1 - PROM checksum	A1005W/A2005W	-7
116			

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Position	Parameter Description	TM Code SASWA/SASWB	Timing Offset
117 118	SASW Status 2 - Stack High Water Mark	A1006W/A2006W	-6
119 120	SASW Status 3 - Free CUT time before DTSTART	A1007W/A2007W	0
121 122	SASW Status 4 - Free CUT time after DTSTART	A1008W/A2008W	-4
123 124	SASW Status 5 - FDI ISR start time	A1011W/A2011W	-5
125 126	SASW Status 6 - DMA ISR start time	A1012W/A2012W	-2
127 128	SASW Status 7 - FDI ISR end time	A1013W/A2013W	-5
129 130	SASW Status 8 - DMA ISR end time	A1014W/A2014W	-2
131 132	SASW Status 9 - DTSTART start time	A1015W/A2015W	-4
133 134	SASW Status 10 - Spare	A1016W/A2016W	-7
135	BIU Fail Counter	A1009H/A2009H	-6

Bytes 136 to 168 are Unused.

4.5.4-3-3 HK Parameter Acquisition Table

The following table presents the HK_PAT per CUT:

CUT	Parameter 1 SASWA/SASWB	Parameter 2 SASWA/SASWB
0	4 PSA RX HK Words	E7001A/Spare
	A1008H/A2008H	PSA Status
	A1005W/A2005W	A1007H/A2007H
	A1010W/A2010W	A1016W/A2016W
1	4 PSA RX HK Words	E7002A/Spare
	A1003H/A2003H	A1002W/A2002W
	A1006W/A2006W	A1007H/A2007H
	A1010W/A2010W	A1009H/A2009H
2	4 PSA RX HK Words	E7004A/Spare
	A1004H/A2004H	A1011W/A2011W
	A1013W/A2013W	A1007H/A2007H
	A1010W/A2010W	NULL_ACQUISITION
3	4 PSA RX HK Words	R5010T/R6010T
	A1001W/A2001W	A1008W/A2008W
	A1015W/A2015W	A1007H/A2007H
	A1010W/A2010W	NULL_ACQUISITION
4	4 PSA RX HK Words	E7003B/Spare
	A1004W/A2004W	A1003W/A2003W
	A1005H/A2005H	A1007H/A2007H
	A1010W/A2010W	NULL_ACQUISITION
5	4 PSA RX HK Words	R3002A/R4002A
	A1009W/A2009W	A1012W/A2012W
	A1014W/A2014W	A1007H/A2007H
	A1010W/A2010W	NULL_ACQUISITION
6	4 PSA RX HK Words	R5007A/R6007A
	A1006H/A2006H	A1002H/A2002H
	A1001H/A2001H	A1007H/A2007H
	A1010W/A2010W	NULL_ACQUISITION
7	4 PSA RX HK Words	R5008A/R6008A
	A1007H/A2007H	A1010W/A2010W
	A1007W/A2007W	COMPILE_PKT_HEADER
	TX_PKT	NULL_ACQUISITION

4.6 THSS

4.6.1 SUBSYSTEM DESCRIPTION

4.6.1-1 Subsystem Concept/Configuration

The accommodation of the Probe on Orbiter is shown in Figure 2.2-7 in § 2.2. During all sun oriented phases of the mission, the Probe is protected from direct solar illumination by HGA. During off sun pointing modes, the Probe has to tolerate direct solar exposure for a duration which is function of sun range.

The thermal control of the Probe shall solve two very different types of problems:

- the first ones, more or less classical to satellite design, are met during the Launch, Cruise and Coast phases of the Probe, with nevertheless an important particularity during the Cruise phase: the large excursions of the Solar Constant.

- the second ones specific to Huygens Probe are inherent to the Entry into Titan atmosphere at very high velocity, and the Descent in this very cold atmosphere.

To ensure a correct thermal control through the environment of the Cruise phase, 7 years attached to the Orbiter, and the Coast phase, 22 days after separation with a Solar Constant close to zero, the Probe is based on thermal hardware classical to spacecraft. Essentially an extensive use of multilayer insulation blankets, on Probe Front Shield and Back Cover, prevents both overcooling in shadow or under very low solar input, and overheating under high solar exposures imposed by the Orbiter attitude manoeuvres.

A white painted reduced surface on the Front Shield is used as radiative area to reject unit heat dissipation during Checkout.

To go through the different phases of the Mission, passive thermal control based on thermal protection and thermal coatings is obviously not sufficient. A limited heating power is requested (mainly for the Coast phase). As no electrical power is available, 35 Radioisotope Thermal Units (RHU) are installed on the Experiment and Top Platforms, each of them characterized by a constant heat dissipation of about one watt.

A negative consequence of this permanent heat dissipation is a Battery storage temperature under fairing which can reach up to 45°C. This battery temperature not desirable is nevertheless acceptable and taken into account to establish electrical power losses.

To survive to the very high aerothermodynamic fluxes generated by the Entry into the Titan atmosphere at a velocity of 6.5 Km/s, the Probe Descent module is surrounded by an Entry module which consists of:

- a Front shield covered of specific thermal protection (AQ60 and Prosial)
- a Back Cover coated with Prosial

These two main hardwares of the Entry phase are respectively released, thank to separation mechanisms and parachutes, soon after the Titan atmosphere entry.

After separation, during the Descent to Titan with a duration about 2h15mn (± 15mn), the Descent Module thermal control essentially has to face convective thermal exchanges with the cold Titan atmosphere. To avoid important structure mass increase, pressure balance on the Descent module walls is ensured by a venting hole on the top platform.

During this phase, overcooling of the Probe is prevented:

- for a very limited amount by the RHU's, equipment and experiment units dissipations; the total dissipation remains reduced (< 300 watts)

- essentially by the use of thermal foam. Thick blocks of foam (45 and 70 mm) are fixed on the inner surface of all the Descent Module walls (foredome, after cover, top platform).

The passive thermal control of the Huygens Probe, supplemented by RHUs is shown in Figure 2.2-16 in § 2.2.

4.6.1-2 Functional Design

The functions or the reasons for the different thermal control elements are described hereafter:

- MLI: all external areas of the Probe are covered by multilayer insulation. These are the front and rear side of the Front Shield, the external side of the Back Cover and the separation mechanisms. A small part of the front side of the Front Shield is not covered by MLI. The multilayer insulation serves to prevent that the Probe cools too much during the Cruise and Coast phases. It also serves to prevent that the Probe heats up too fast in cases of sudden solar illumination

- Foam: all external areas of the Descent module are covered on the inside by 45/70 mm Basotect Foam. The foam serves to prevent that the Descent module cools too much during the Descent phase. In this phase the very cold gas of Titan's atmosphere (-200°C) cools down the outer shell of the Descent module. Some of this gas enters also the Probe through the venting hole. The foam is dimensionned such that the components do not get too cold during the Descent phase

- Radioisotope Heater Units (RHU): these heater units are located on the main platform and on the top platform. The RHUs serve to keep the Probe sufficiently warm during the Cruise and Coast phases

- Thermal Window: a section of 60° of the external area on the front side of the Front Shield is covered by white paint. This area is 0.17 m^2 and is located at the rim of the spherical part of the Front Shield near to the conical part. The window is shifted in the direction of the +zp axis of the Probe, such that at small negative solar aspect angles the Sun shines with even smaller angles of incidence on the window. The white paint HINCOM/NS43G is used. The thermal or radiative window ensures that the RHU power and the check out power of the components can escape during the Cruise phase. Its purpose is to have a well defined thermal control area. Due to this window the thermal design is not so much dependent on the efficiency of the MLI.

- Sealings: special sealings are used for four instruments DISR, GCMS, ACP and SSP. The sealings prevent that the cold gas of Titan's atmosphere streams continously through the Descent module during the Descent phase. The sealings are dimensionned such that the leak rate is sufficiently small, but that all the movements are possible between the Experiments and the outer structure

- Venting Hole: this hole is located in the upper platform. The venting hole allows the depressurisation during the Launch phase and the gas of Titan's atmosphere to enter into the Descent module during the Descent phase. The hole ensures that the pressure difference between the outside and inside of the Descent module is always ≤ 0.005 bar

- AQ60: this high temperature insulation material is placed on the front side of the Front Shield. This material serves to prevent that the CFRP honeycomb structure of the Front Shield and other components become too warm due to aerodynamic heating during the Entry phase

- Prosial: this high temperature insulation material is placed on the rear side of the Front Shield and on the outer area of the Back Cover. This material serves also to prevent that the CFRP honeycomb structure of the Front Shield and other components as e.g. the Back Cover become too warm during the Entry phase.

Note: The materials AQ60 and Prosial do not belong to the subsystem THSS. They are elements of the subsystems FRSS and BCSS, but are mentionned here for reasons of completeness.

4.6.1-3 Performance Characteristics

RHU Power Dissipations

A major performance is the power dissipation of the Radioisotope Heater Units (RHU). 31 of these heater units are located on the main platform and 8 of them are placed on the top platform. The mean dissipated power of one RHU decreases from 1.01 W (October 97) to 0.96 W (June 2004).

Temperature Ranges

Table 4.6.1-3-1 contains calculated minimum and maximum temperatures considering all the phases of the mission and the qualification limits for the different units and components of the Probe.

Note:

CA	= Coast Phase	CC	= Cruise Cold	CG	= Ground C/O
CH	= Checkout	CR1	= Cruise Non-operating (Day 1)	9AU	= Orbiter separation
DS	= Descent Phase	PL	= Pre-launch	EN	= End of Entry
SC	= Saturn Cold	SH	= Saturn Hot		

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Component	Tmin (°C)			Tmax non-op (°C)			Tmax op (°C)		
	limit	calc.	Phase	limit	calc.	Phase	limit	calc.	Phase
ACP	/	-50	DS	/	43	PL	/	38	CH
ACP Interface	-30	-2	DS	70	45	PL	60	39	CH
SSP top hat	-210	-202	DS	70	40	PL	60	41	CH
SSP electronic box	-30	-6	DS	70	45	PL	60	49	CH
GCMS	-30	-4	CA	70	44	PL	60	48	CG
HASI accelerometer	-30	-7	DS	70	44	PL	60	41	CH
HASI DPU	-30	-1	DS	70	44	PL	60	43	CH
HASI I1 & I2	-30	-19	DS	70	45	PL	60	44	CH
HASI booms	-210	-201	DS	70	27	PL	50	23	CG
HASI stub	-210	-193	DS	70	32	PL	50	24	CG
DISR SH exterior	-210	-158	DS	70	40	PL	50	28	CG
DISR SH interior	/	-79	DS	/	43	PL	/	29	CH
DISR SH interface	-60	-12	DS	70	45	PL	60	29	CG
DISR electronic box	-30	-9	DS	70	45	PL	60	38	CH
DISR Cover	-65	-45	EN	45	32	PL	-15	-40	EN
DWE (TUSO)	-30	-4	DS	70	44	PL	60	42	CH
Batteries	-20	-2	CA	60	51	CR1	40	18	DS
PCDU	-30	-14	DS	70	43	PL	60	46	CH
RAU A/B	-40	-19	DS	70	44	PL	20	9	DS
Pyro Unit	-30	-8	DS	70	45	PL	60	38	CH
CDMU A/B	-30	-4	DS	70	45	PL	60	44	CH
MTU	-30	-5	DS	70	45	PL	60	39	CH
Transmitter A/B	-30	-3	CA	70	45	PL	60	41	CH
RASU	-30	-6	DS	70	45	PL	60	39	CH
CASU	-30	-2	CA	70	45	PL	60	38	CH
Radar Antennae	-210	-196	DS	70	31	PL	50	24	CG
Main Parachute	-210	-201	DS	70	35	PL	50	27	CG
PDD/Pilot Chute	-60	-49	EN	70	35	PL	25	-39	EN
Probe Antennae	-210	-198	DS	70	38	PL	50	30	CG
PJM	-120	-57	DS	50	35	PL	50	-44	DS
BCM/FSM (PIF)	-80	-77	EN	70	27	PL	70	-56	EN
USM	-70	-63	9AU	70	28	PL	50	-53	9AU
SED (SIF)	-70	-63	9AU	70	29	PL	50	-53	9AU
RFE	-30	-20	SC	70	51	SH	60	31	CH
PSA	-5	12	CC	60	40	SH	60	40	SH
RUSO	-30	14	CC	70	41	SH	60	41	SH

TABLE 4.6.1-3-1 SPECIFIED AND CALCULATED EXTREME TEMPERATURES OF EXPERIMENTS AND BOXES

4.6.1-4 Interfaces

See location of RHUs in Figures 4.6.1-4-1 and 4.6.1-4-2.
See location of sensors in Figures 4.6.1-5-1 to 4.6.1-5-4.

See electrical interfaces of sensors in RD3: § 2.5 pages 11 and 12 and § 2.8 pages 4 and 5.

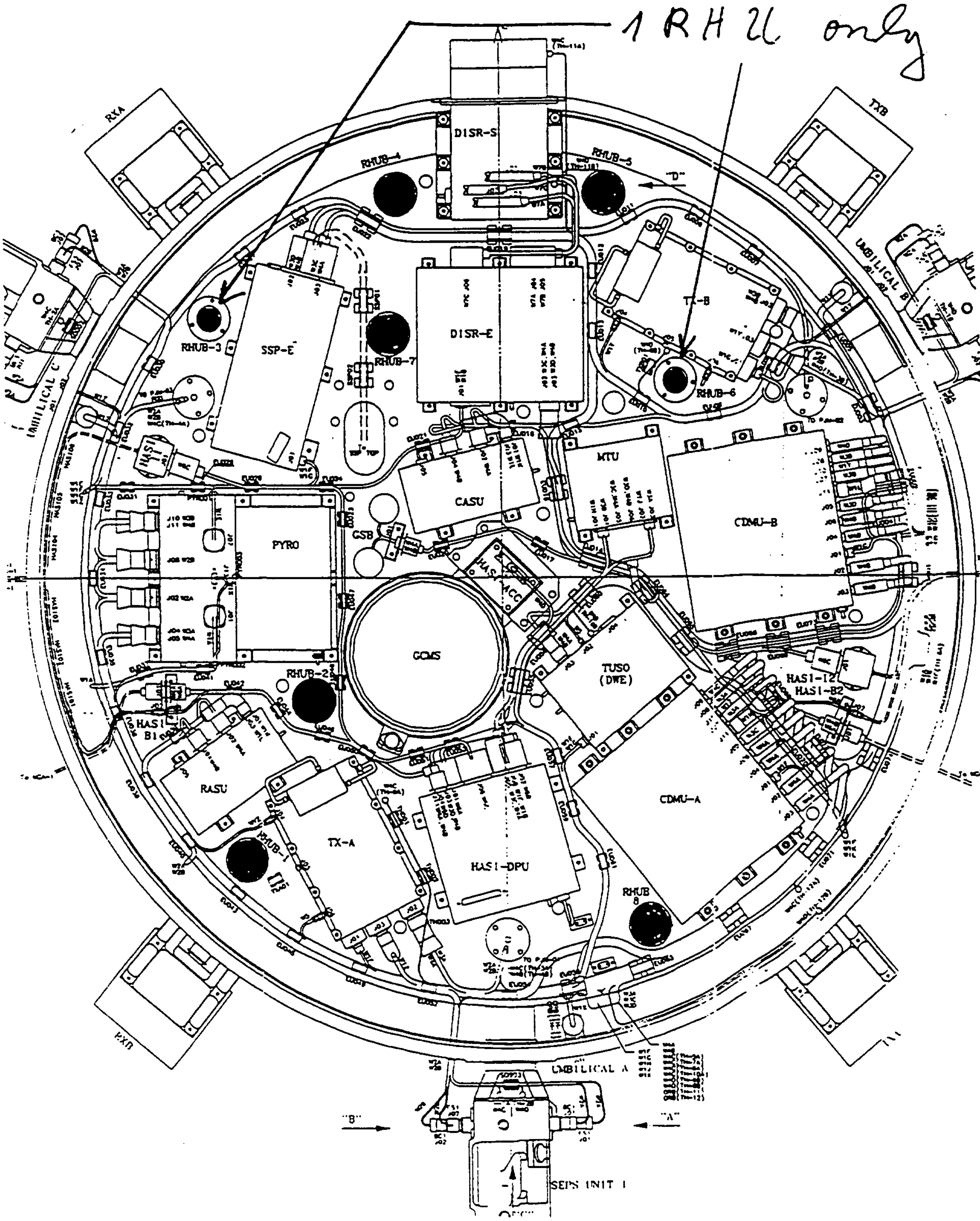

FIGURE 4.6.1-4-1 RHU LOCATION ON EXPERIMENT PLATFORM UPPER SIDE

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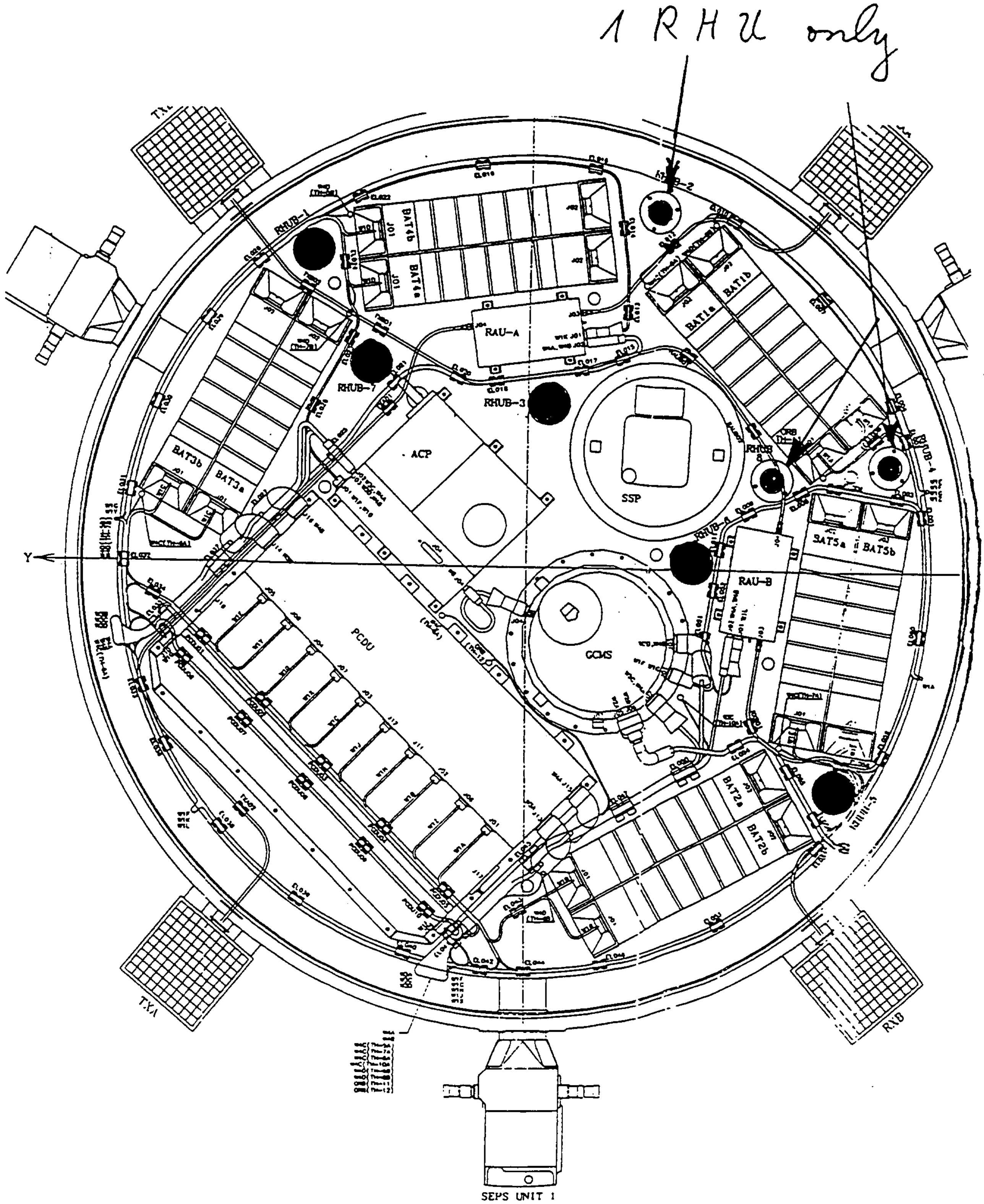

FIGURE 4.6.1-4-2 RHU LOCATION ON EXPERIMENT PLATFORM LOWER SIDE

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4.6.1-5 TM/TC

4.6.1-5-1 Telecommand

None

4.6.1-5-2 Telemetry

Two series of sensors are used on Probe and PSE according to their monitoring:

Sensors monitored directly by the Orbiter CDS

Table 4.6.1-5-1 contains the sensors which are monitored directly by the CDS of the Orbiter. The location of sensors is presented in Figures 4.6.1-5-1 and 4.6.1-5-2.

Sensor type: 1 Platinium resistor ROSEMOUNT 118 BDU-5
2 Platinium resistor ROSEMOUNT 118 AKT-2
3 Platinium resistor ROSEMOUNT 118 BJA

REF TM	LOCATION	SENSOR TYPE	TEMP. RANGE	ACCURACY	FIGURE
R3 003 T	RFE/LNA A (internal)	1	-40°C/+70°C	1.0°C	NA (internal)
R4 003 T	RFE/LNA B (internal)	1	-40°C/+70°C	1.0°C	NA (internal)
R5 011 T	PSA A (internal)	2	-20°C/+60°C	1.0°C	NA (internal)
R6 011 T	PSA B (internal)	2	-20°C/+60°C	1.0°C	NA (internal)
M1 001 T	SEPS temp. 1 (SEPS A)	3	-80°C/+90°C	1.0°C	4.6.1-5-1
M1 002 T	SEPS temp. 2 (SEPS A)	3	-80°C/+90°C	1.0°C	4.6.1-5-1
M1 003 T	SEPS temp. 3 (SEPS B)	3	-80°C/+90°C	1.0°C	4.6.1-5-1
M1 004 T	SEPS temp. 4 (SEPS C)	3	-80°C/+90°C	1.0°C	4.6.1-5-1
T 001 T	PCDU (on box side)	3	-30°C/+70°C	1.0°C	4.6.1-5-2
T 002 T	PCDU (on box side)	3	-30°C/+70°C	1.0°C	4.6.1-5-2

TABLE 4.6.1-5-1 FLIGHT TEMPERATURE SENSORS CONNECTED TO ORBITER CDS

Sensors monitored by the Probe CDMS

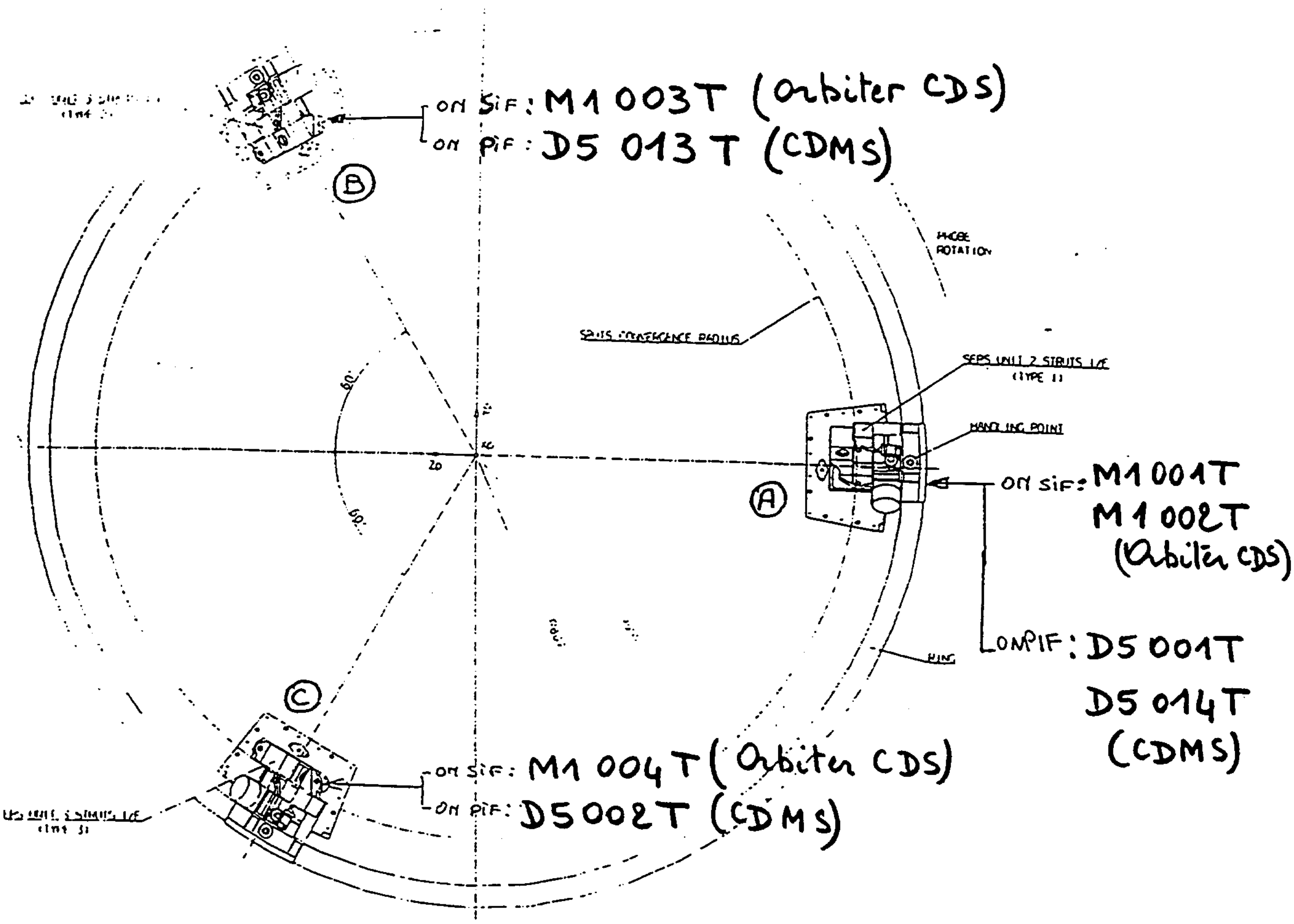
Table 4.6.1-5-2 describes the sensors which are monitored by the CDMS of the Probe. The location of the sensors is shown in Figures 4.6.1-5-1 to 4.6.1-5-4.

These sensors are YELLOWSPING 44006 thermistors.

All these TMs are in HK2 packet.

REF TM	LOCATION	CDMU	TEMP. RANGE	ACCURACY	FIGURE
D5 001 T	Probe Temp. 1A (SEPS A)	A	-80°C/+90°C	10°C	4.6.1-5-1
D5 002 T	Probe Temp. 2A (SEPS C)	A	-80°C/+90°C	10°C	4.6.1-5-1
D5 003 T	Probe Temp. 3A (PJM A)	A	-80°C/+90°C	10°C	4.6.1-5-4
D5 004 T	Probe Temp. 4A (PJM C)	A	-80°C/+90°C	10°C	4.6.1-5-4
D5 005 T	Probe Temp. 5A (Batt 1a)	A	-30°C/+70°C	2°C	4.6.1-5-2
D5 006 T	Probe Temp. 6A (Batt 3b)	A	-30°C/+70°C	2°C	4.6.1-5-2
D5 007 T	Probe Temp. 7A (Batt 5a)	A	-30°C/+70°C	2°C	4.6.1-5-2
D5 008 T	Probe Temp. 8A (PCDU box)	A	-30°C/+70°C	2°C	4.6.1-5-2
D5 009 T	Probe Temp. 9A (TX A box)	A	-30°C/+70°C	2°C	4.6.1-5-3
D5 010 T	Probe Temp. 10A (GCMS flange)	A	-30°C/+70°C	2°C	4.6.1-5-2
D5 011 T	Probe Temp. 11A (DISR SH ext.)	A	-80°C/+90°C	10°C	4.6.1-5-3
D5 012 T	Probe Temp. 12A (foam 3 inside)	A	-80°C/+90°C	10°C	4.6.1-5-3
D5 013 T	Probe Temp. 1B (SEPS B)	B	-80°C/+90°C	10°C	4.6.1-5-1
D5 014 T	Probe Temp. 2B (SEPS A)	B	-80°C/+90°C	10°C	4.6.1-5-1
D5 015 T	Probe Temp. 3B (PJM B)	B	-80°C/+90°C	10°C	4.6.1-5-4
D5 016 T	Probe Temp. 4B (PDD)	B	-80°C/+90°C	10°C	4.6.1-5-4
D5 017 T	Probe Temp. 5B (Batt 4b)	B	-30°C/+70°C	2°C	4.6.1-5-2
D5 018 T	Probe Temp. 6B (Batt 2a)	B	-30°C/+70°C	2°C	4.6.1-5-2
D5 019 T	Probe Temp. 7B (Batt 3a)	B	-30°C/+70°C	2°C	4.6.1-5-2
D5 020 T	Probe Temp. 8B (Batt 1b)	B	-30°C/+70°C	2°C	4.6.1-5-2
D5 021 T	Probe Temp. 9B (TX B box)	B	-30°C/+70°C	2°C	4.6.1-5-3
D5 022 T	Probe Temp. 10B (TUSO box)	B	-30°C/+70°C	2°C	4.6.1-5-3
D5 023 T	Probe Temp. 11B (DISR SH ext.)	B	-80°C/+90°C	10°C	4.6.1-5-3
D5 024 T	Probe Temp. 12B (foam 3 outside)	B	-80°C/+90°C	10°C	4.6.1-5-3

TABLE 4.6.1-5-2 FLIGHT TEMPERATURE SENSORS CONNECTED TO PROBE CDMUs



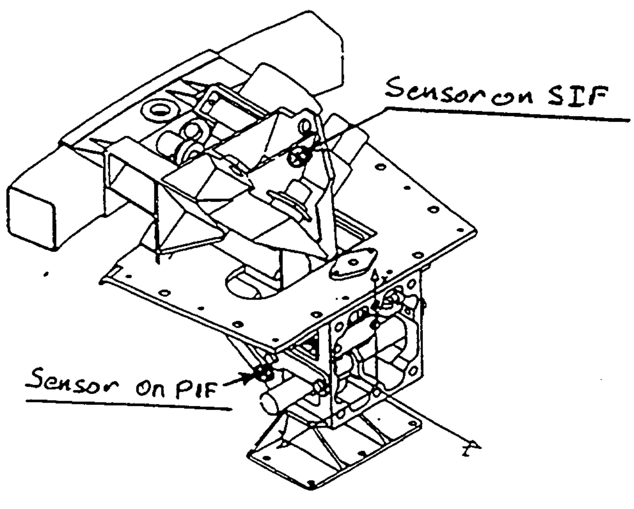


FIGURE 4.6.1-5-1 SENSORS ON MECHANISMS

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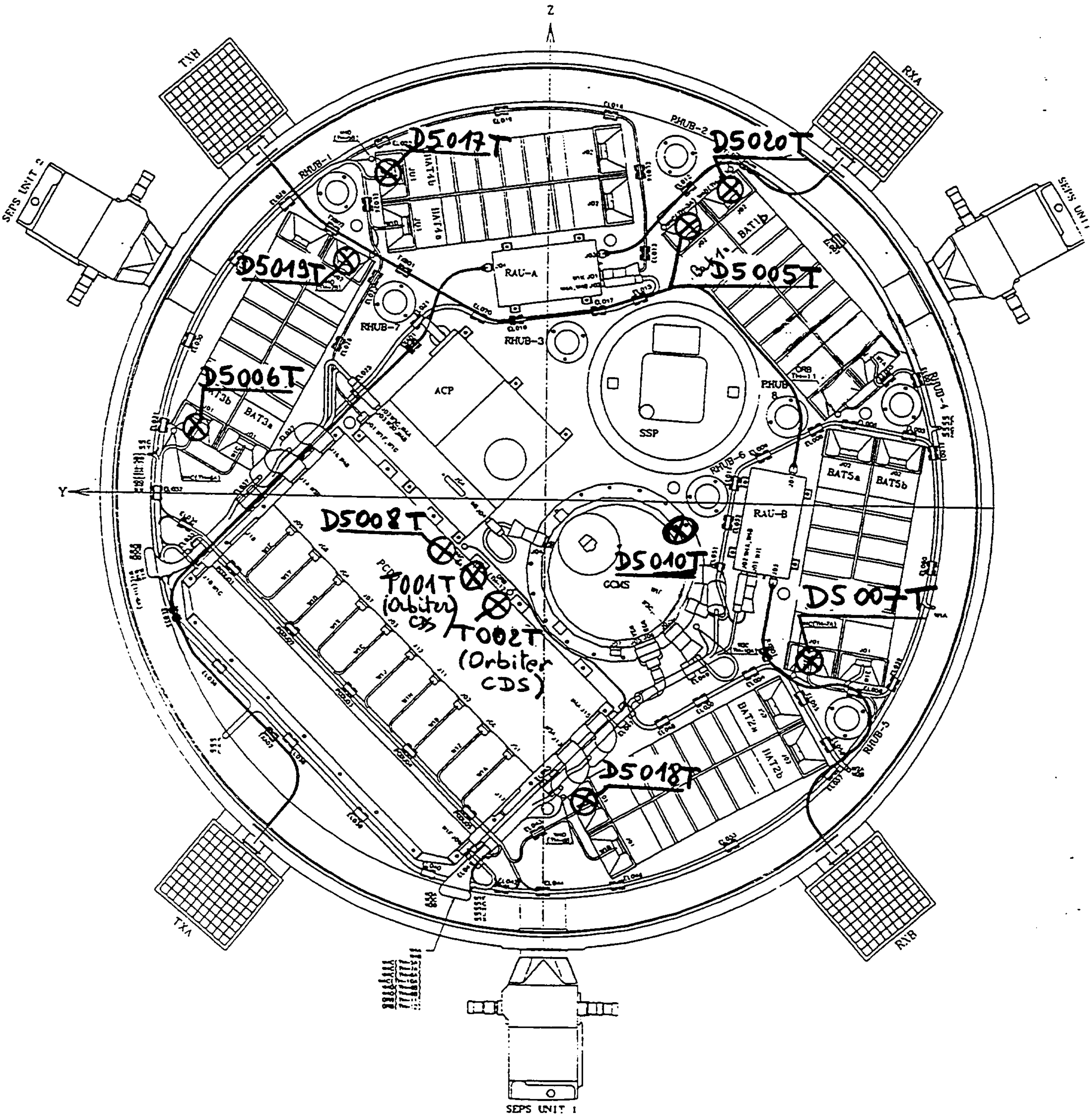

FIGURE 4.6.1-5-2 SENSORS BELOW EXPERIMENT PLATFORM

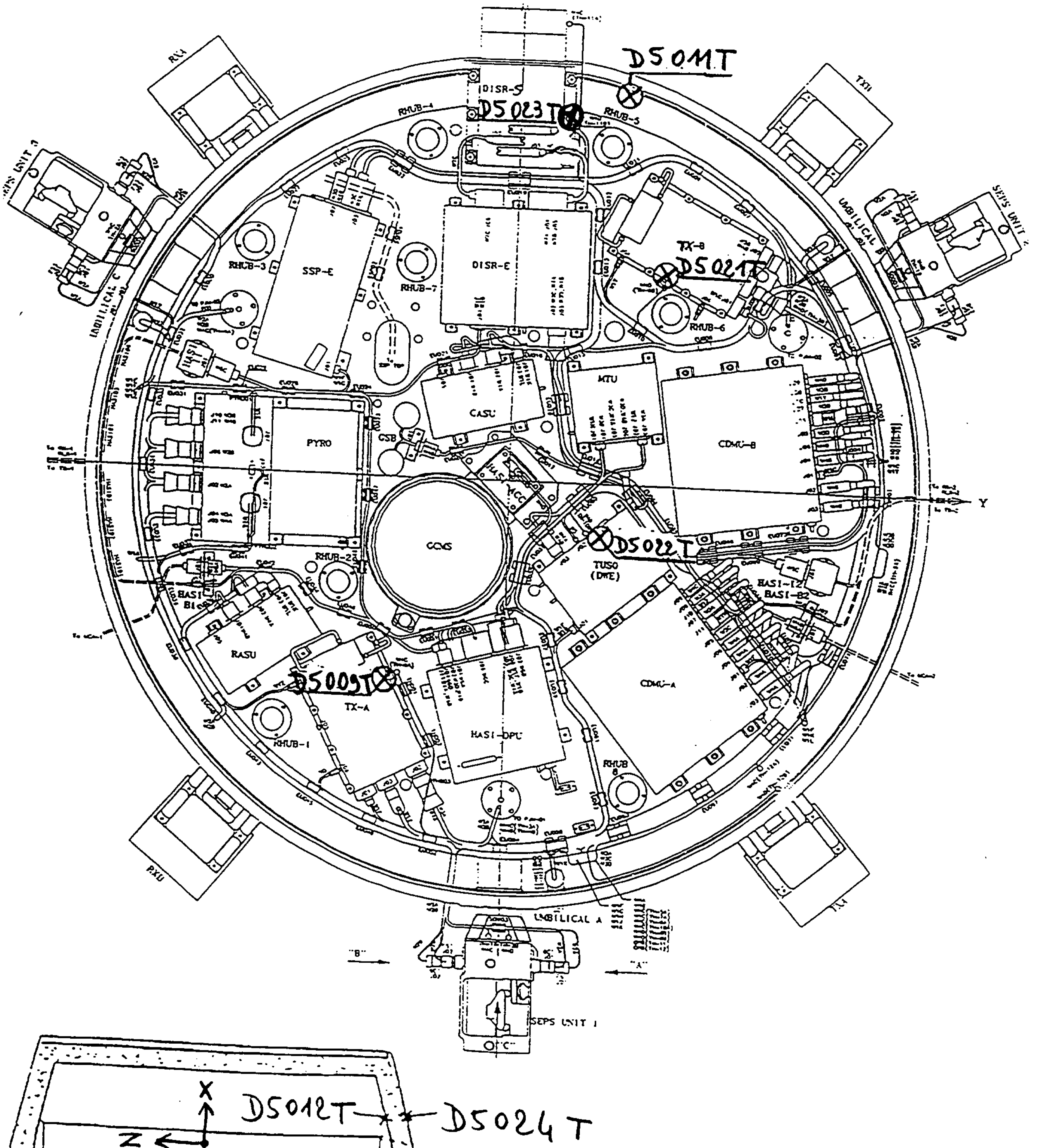

FIGURE 4.6.1-5-3 SENSORS ABOVE EXPERIMENT PLATFORM

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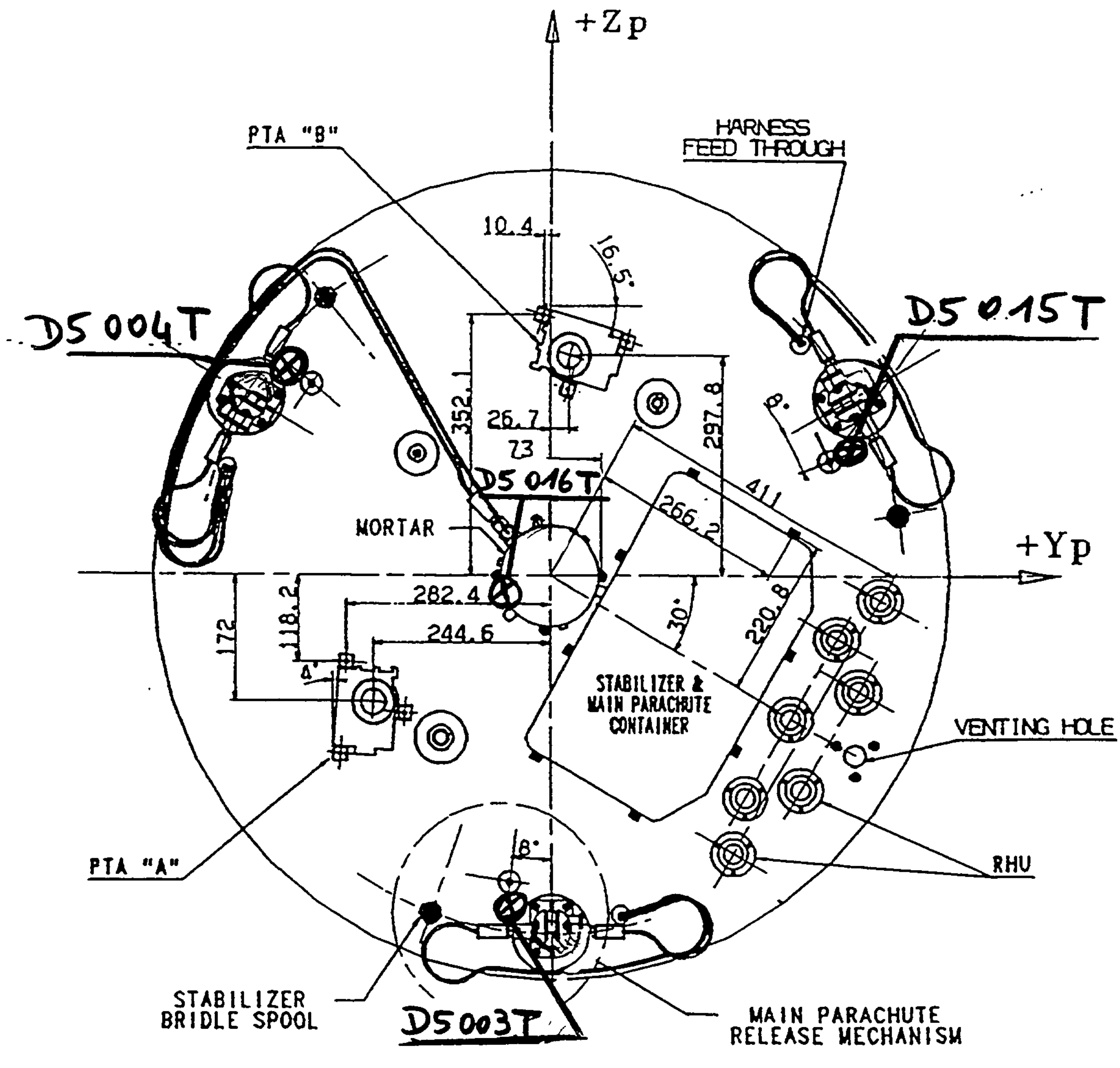

FIGURE 4.6.1-5-4 SENSORS ON TOP PLATFORM

4.6.1-6 Operational Constraints

1- The Orbiter shall remain in sun pointing mode during check out.

2- For heliocentric distance lower than 3 A.U check outs shall not take place just after a long period of off sun pointing mode of the orbiter.

3- Probe Solar Exposure Period Duration

The Probe shall be maintained in a sunshaded (by HGA) orientation when the S/C solar distance is less than 5 AU with allowable deviations described in Doc n° HUY.AS/c.100.OP.0394 RULE T1.

Over exposure of the Probe's Front Shield or radiative window can risk damage to the Probe's thermal protection system. In addition, excess thermal exposure heating will compromise the life and power output of the Probe's batteries.

4- Orbiter Earth Pointing Mode

The mission phases where the -Z axis of Orbiter is continuously pointed to the Earth shall be limited to:

- 25 days at 1.5 AU sun range (period beginning at 436 days from Launch)
- when sun range is > 2.7 AU.

4.6.2 NOMINAL OPERATIONS

The increase of experiment/unit temperatures during the cruise check-out shall be carefully monitored with Procedure TP01 described in Doc n° HUY.AS/c.100.OP.0384.

4.6.3 BACK-UP OPERATIONS

None.

4.6.4 CONTINGENCY OPERATIONS

Only two types of contingency operations are possible if the temperatures of the Probe components become too high.

First Contingency Operation is a return from Orbiter off sun pointing mode to sun pointing mode if the internal Probe temperature becomes too high after a sun exposure. The driving element is the battery for which a temperature higher than 35°C is highly undesirable during Cruise phase.

The second Contingency Operation consists in a change of checkout operation in case that this power is the reason for a too high heating of Probe units, most critical unit being PCDU. Such a modification could be a reduction of the checkout sequence duration or an early switch OFF of most dissipative experiments (GCMS:30 W) and finally the Probe switch OFF with PP01 Part B after the switching OFF of all the PCDU loads.

4.7 SEPS

4.7.1 SUBSYSTEM DESCRIPTION

SEPS Baseline Overview is shown Figure 2.2-11 in § 2.2.

4.7.1-1 Subsystem Configuration

The SEPS (Separation Subsystem) consists of 3 basically identical units which are located between the CASSINI Struts and the HUYGENS Probe Inner Structure. The 3 units are placed 120° apart on a circle with a diameter of approximately 1600 mm.

Each of the 3 units includes the following four mechanisms:

- SED Spin up and Ejection Device:
  (mechanical connection/separation between HUYGENS and CASSINI)
- USM Umbilical Separation Mechanism:
  (electrical connection/separation between HUYGENS and CASSINI)
- BCM Back Cover Mechanism
  (mechanical connection/separation between Probe and BCSS)
- FSM Front Shield Mechanism:
  (mechanical connection/separation between Probe and FRSS).

4.7.1-2 Functional Design and Operating Principles

The **SED** has three functions:

- Position and fix the Probe mechanically to the spacecraft during the time between integration of HUYGENS with CASSINI and separation of the Probe from the Spacecraft.

- Transfer the loads between Probe and Spacecraft during launch.

- Separate the HUYGENS Probe from the CASSINI Spacecraft and provide the Probe with a well defined relative linear velocity with respect to the Sapcecraft, in order to meet the trajectory parameters of the Probe, and to spin it up in order to stabilise its entry into the TITAN atmosphere.

SED Baseline Design:

The SED consists of three SED subunits spaced at intervals of 120° on the so-called SED ring, which interconnects them. Each SED subunit consist of a pyrotechnical release device (pyro-nut), a spring actuator and a guiding device to compensate for eventual asymmetries of the actuators and Probe c.g position.

The pyrotechnical release device has to withstand the launch loads of HUYGENS. It will be fired by an electrical signal and in a sequence given by the CASSINI Spacecraft. Each actuator consists of one prestressed spring, which will push in separation direction, a spring retainer (to limit the spring stroke and to hold the spring after separation) and a guiding device, consisting of rollers which revolve on helical tracks, thus ensuring the required kinematics after the Probe separation.

The SED ring has to compensate for the limited stiffness of the CASSINI Spacecraft struts (which are the mechanical interfaces between the Probe and the Spacecraft) in order to get a stable ejection.

The **USM** has two functions:

- Insure a safe electrical connection between the HUYGENS Probe and the CASSINI Spacecraft during the time from integration of HUYGENS on CASSINI until separation of the Probe from the Spacecraft

- Separate the HUYGENS Probe electrically from the Spacecraft at a given electrical command at the time of or immediately before the mechanical separation of the Probe from the Spacecraft.

The USM is divided into three sub-units, in order to avoid asymmetric loads during separation, in particular since the rack-connectors rely on the SED actuators for their separation.

The **BCM** has three functions:

- Position and fix the Back Cover mechanically to the Probe during the time from launch until its separation.

- Transfer the loads between the Back Cover and the Probe during launch till entry into TITAN atmosphere and pilot parachute deployment.

- Release the mechanical fixation between the Back Cover and the Probe at a given electric command.

BCM baseline design:

The BCM is divided into three identical subunits without any mechanical synchronization between each other. Each subunit consists of a pyrotechnic separation device (bolt-cutter) with fixing elements to the Back Cover and the Probe Interface Fittings (see hereafter). The pyrotechnic devices are fired electrically in a sequence given by the Probe electronics.

The **FSM** has four functions:

- Position and fix the Front Shield mechanically to the Probe during from launch until its separation.

- Transfer from the Front Shield to the Probe the inertia loads during launch, the thermal loads during Cruise and Coast phases and the thermal and aerodynamics loads during TITAN atmosphere entry.

- Reduce the heat flux from the Front Shield to the Mechanisms and the Inner Structure.

- Release the mechanical fixation between the Front Shield and the Probe at a given electric command and aid the Front Shield ejection.

FSM baseline design:

The FSM is divided into three identical subunits without any mechanical synchonization between each other. Each subunit consists of a pyrotechnic separation device (bolt-cutter) with fixing elements to the Front Shield and the Probe Interface Fittings (see hereafter). Prestressed springs serve to ensure a safe and clean separation of the Front Shield and a ball bearing like device allows for compensation of the differences in thermal deformation of the Front Shield and the Inner Structure. A low thermal conductivity (thermal insulation) between the Front Shield and the FSM is needed in order to keep the FSM pyro-devices as well as the Inner Structure at reasonable temperatures. The pyrotechnic devices are fired electrically in a sequence given by the Probe electronics.

The **Interface Fittings** have the following primary functions:

- Housing of the USM, SED, BCM and FSM within a common mounting structure.

- Provide the mechanical interface between the CASSINI Spacecraft struts and the Probe Inner Structure, the Back Cover and the Front Shield.

- Withstand and transmit the reaction forces, during launch (generated by the masses and the inertias of the Probe itself, the Inner Structure, the Back Cover and the Front Shield) and entry into TITAN atmosphere, to the interfaces with the spacecraft struts and Inner Structure respectively.

- Limit the heat loss from the Inner Structure to the parts of the SEPS that are exposed to deep space environment.

Each Interface Fitting consists of a Spacecraft I/F-Fitting and a Probe I/F Fitting:

- The Spacecraft I/F-Fittings provides the mechanical link of the Probe to the Spacecraft struts. All the SEPS elements which stay with the CASSINI spacecraft after the SED separation (pyro element of SED with initiators, actuator springs, SED ring, Spacecraft fixed parts of the guidding system and the USM) are fixed to the spacecraft I/F Fittings.

- The Probe I/F-Fittings provide the interfaces to the Inner Structure, the Back Cover, the Front Shield and to the probe fixed parts of the USM and the SED (including some parts of the guiding system). The Probe I/F Fittings stay with the Probe after the SED separation.

4.7.1-3 Units Description

4.7.1-3-1 Spin-up and Ejection Device (SED)

Each of the 3 SEPS units located 120° apart on a ring between the Probe and the Spacecraft, contains one SED mechanism. The main components of the SED mechanism are:

- 2 fittings; the Probe and the Spacecraft Interface Fittings
- an actuator (one spring)
- a guiding system and
- a pyro-nut hold-down and release device.

The 2 fittings are positioned against each other by means of 3 conical studs and are held fixed together till release by a pyro-nut holddown device. The pyro-nut and the conical studs longitudinal axes are in line with the separation direction, to allow separation of the two fittings.

The main body pyro-nut is located on the Spacecraft Interface Fitting whereas the bolt is caught by a bolt-catcher located on the Probe Interface Fitting.

One spring actuator is located between the 2 fittings providing the ejection force. On one side the spring is attached to and so remains with the Spacecraft Interface Fitting after separation. On the other side it acts on the Probe Interface Fitting in the separation direction.

The guiding system is also located between the 2 fittings. It consists of 2 axial rollers rolling on a T-shaped helical track. The rollers are fixed to the Probe Interface Fitting and travel on the T-shaped track which is an integral part of the Spacecraft Interface Fitting. The axial rollers provide guidance in the separation direction by invoking a spin rotation of the probe along the separation axis.

Apart from providing the Interface to the Spacecraft Struts by means of two resp. three single point attachments, the Spacecraft Interface Fitting also interfaces with the inner diameter of a ring which connects the three units to each other to provide for a sufficient stiffness during the combined separation of the SED and the USM.

The Probe Interface Fitting provides the interfaces to the Probe Inner Structure, to the Back Cover Mechanism and to the Front Shield mechanism.

4.7.1-3-1-1 Spacecraft Interface Fitting

The Spacecraft Interface Fitting is a machined part made of aluminium alloy, designed for maximum stiffness and minimum weight. Each of the 3 Spacecraft Interface Fittings configurations varies at the spacecraft interface side because of the varying interfaces with the Spacecraft Struts (2 fittings joined by 3 struts, 1 fitting joined by 2 struts).

On the Spacecraft Interface Fitting the following parts are integrated:

- one half of the USM connector (female part)
- Actuator (spring) unit
- Guiding track (integral part)
- Pyro-Nut and
- Conical Studs
- MLI supports

4.7.1-3-1-2 SED Ring

The SED Ring connects the 3 Spacecraft Interface Fittings in order to provide the needed stiffness between the 3 guiding and actuator units during the spin-up and ejection phase (the stiffness of the struts alone is found as too low for this purpose).

The Ring cross-section is 45*45*1.5 and in CFRP (Carbon-Fibre Reinforced Plastic) material. The ring accommodates also the 3 handling points for the ground support equipment of the complete HUYGENS Probe.

4.7.1-3-1-3 Probe Interface Fitting

The Probe Interface Fitting are machined parts made of aluminium alloy, designed for maximum stiffness and minimum weight. The three Probe Interface Fittings are identical.

- one half of the USM connector (male part)
- Bolt cutter and interface plate of BCM
- Bolt cutter and Bearing bracket of FSM
- Roller unit of SED - guiding via the BCM interface plate.

4.7.1-3-1-4 Interface between Probe- and Spacecraft Interface Fittings

A pyro-nut holddown and release device is used for the inter-connection of the 2 Interface Fittings.

The elements used are:

- Pyro-unit placed on the Spacecraft Interface Fitting supplied by PYROSPACE (France).

- Corresponding 1/2" bolt -catcher placed on the Probe Interface Fitting.

The resulting loads on the 3 interface points cannot be resisted by friction with the 1/2"-bolt pre-tensioning. Therefore fitted elements are needed to transmit the loads perpendicular to the bolt axis. At the same time a safe separation must be guaranteed. Conical studs have been chosen then for the transverse load transmission. A rough calculation of the torque induced by vibration of the ring (and other components) showed that one positioning cone cannot cope with the rotation around the bolt axis. The resulting design then is a 3 cone arrangement which guarantees the required load and torque transmittance with minimum deformations. This plus the proper material combination and surface treatment, will rule out the danger of wold welding.

4.7.1-3-1-5 Guiding

<u>General</u>

The guiding system defines the spin-&ejection kinematics which is a helical motion of the probe. The system has in each of the 3 points 2 axial rollers. This division of the radial from the axial function has the following advantages:

- Radial clearance (3 - 5 mm) is independent from axial clearance (± 0.5 mm)
- No bending moments act on the roller bearings
- Easier manufacturing of the track
- Easier adjustment during assembly.

Radial Guiding

Radial guiding is ensured by the body of the axial rollers bracket.

Axial Guiding

The separation analysis showed, that both rollers will alternately contact the track during the separation.

Description of the subunits

- Guiding Roller Unit

The axial rollers of each subunit are located on the Roller Bracket.

- Roller Bracket

Machined part made of aluminium-alloy. It is bolted onto the Back-Cover-I/F bracket which for the SED-separation belongs to the Probe side. The SED spring actuator acts on the Roller Bracket.

- Roller & Bearings

The rollers will be machined from titanium. Both roller bearings are dry film lubricated AMPEP bearings.

- Guiding Rail Unit

The track is an integral part of the S/C-Fitting made of aluminium-alloy.

NOTE:
The track has a conical inlet. The rollers have no contact with the track during launch and 8 years in space because during this period they are positioned on the wide side of the track inlet. Contact will occur after 1-2 mm SED motion.

4.7.1-3-1-6 SED Actuator (Spring) Unit

1 Helical spring is used per subunit providing the energy source for the Probe separation.

The dimensioning of the spring is done to keep its loading low, to a torsional stress level of 400 N/mm^2 in order to have an adequate margin.

The spring has a β (expansion factor) of 0.75 (β of 0.75 up to 0.95 can be incorporated in the available volume, and its outside diameter was chosen to be as large as possible, thus having a short length and therefore a good lateral stability.

Spring attachment:

The spring is located between 2 parallel faces, one fixed to the Spacecraft-Fitting the other pushing against the roller bracket.

The use of ball joints for the spring fixation was rejected because:

- Spring is more sensitive concerning lateral vibration forces

- A possible misalignment during launch would remain for the following 8 years because of the friction in the ball joint.

The chosen design is less sensitive concerning lateral forces and can self-align itself after launch.

The stroke of the spring acts on a helical curve with radius 870 mm and a pitch of 30°. For its first part with a length of max. 60 mm the helical stroke can be approximately with a radius of 1250 mm.

The angular change of the spring parallel faces is therefore at the end of the stroke approximately 2.5°. This can be taken up by the spring bending.

Stroke limitation:

The stroke of the spring is limited by 2 coaxial tubes with an end flange, each fixed to one of the parallel spring faces.

At the end of the stroke the whole spring unit remains on the S/C-Fitting.

NOTE:
During launch as well as during cruise there are no moving parts in contact with each other. No friction forces and no cold welding problems are expected to occur for the spring unit.

4.7.1-3-2 Umbilical Separation Mechanism (USM)

The electrical link between the HUYGENS probe and the spacecraft is ensured by 3 umbilical harnesses belonging to the Probe.

The function of the USM then is to separate the electrical link between the probe and the spacecraft during the Probe release.

The USM consists of 3 rack connector connections. Each of the 3 SEPS-Units accomodates one connector to which one harness is attached. The receptacle (female part) is located on the spacecraft fitting. The connector (male part) is located on the Probe fitting. See Figure 4.7.1-3-1.

The axis of the connection is in line with the separation direction. The separation of the connection is performed by means of the SED actuator spring force.

The harness side which is attached to the connector, is fed through the BCM I/F-Plate cut-out, in a sealed housing. The other side of the harness attached to the receptacle, can easily be fixed to the strut since there is an angle difference between receptacle and the strut.

4.7.1-3-3 Back Cover Mechanism (BCM)

Each of the 3 SEPS units contains one Back-Cover mechanism (BCM).

The BCM consists basically of the following subunits:

- Back Cover Interface Plate onto which the Back Cover is bolted
- Bolt Cutter unit which links the BC Interface Plate with HUYGENS via the probe I/F Fitting.
- BC/FS sealing plate bolted onto the BC I/F Plate, to provide a seal between BC & FS in the area of the SEPS.

The Back Cover I/F Plate is flanged onto the probe I/F Fitting with 1 Bolt and positioned by 2 conical studs. The stud located close to the actuator porvides and maintains the position of the I/F Plate in relation to the Back-Cover during back-Cover assembly and disassembly, and of the rollers (with their brackets fixed onto the Back-Cover I/F Plate) in relation to the guiding tracks.

The Bolt which protrudes through the Bolt Cutter and the 2 studs have their axis in line with the BC separation direction.

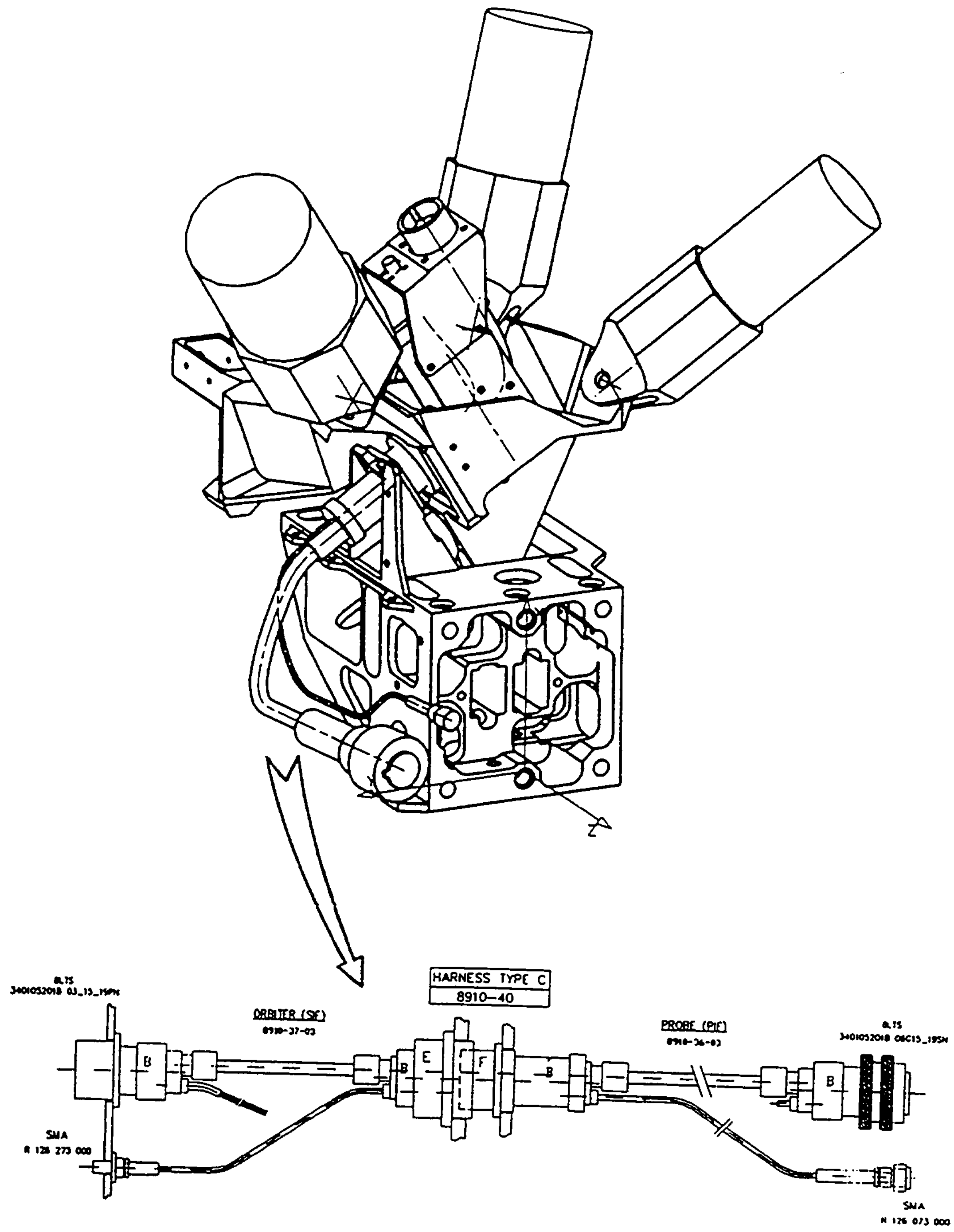

FIGURE 4.7.1-3-1 UMBILICAL SEPARATION MECHANISM

4.7.1-3-3-1 BCM-I/F-Plate

Machined part made of aluminium alloy. Designed for maximum stiffness and minimum weight.

8 M4 threads per subunit are sufficient to transmit the loads by friction and to guarantee a tight I/F/

The design fulfils the following points:

- The I/F's between BC, BCM and Probe I/F Fitting are tight to the point that no gas of the Titan atmosphere can enter the Probe's inner volume except via the filter placed in the BC.
- The cut-out in the BCM I/F Plate is big enough to have a free SED and BC separation.

The BC I/F Plate alos supports the following parts:

- SED guiding roller unit
- BC/FS sealing plate
- Bolt catcher unit of BCM
- A conical and a wedge stud and pads.

4.7.1-3-3-2 BCM-I/F

The connection between BCM and Probe I/F Fitting fulfills the following:

- Separation after 11 years

The elements used are:

- Bolt M6 + corresponding nut
- Bolt cutter with 2 knifes (pyrotechnically & mechanically redundant)

For positioning and load transfer 2 conical studs have been chosen.

Unlike the SED & FSM connection, these cones allow the planar faces to be clamped in order to have the required tightness.

Appropriate material combinations & surface treatment will avoid cold welding.

4.7.1-3-3-3 Back Cover/Front Shield Sealing Plate

Belongs principally to the BC Structure. Because of assembly/disassembly reasons the BC structure has to have cut-outs in the area of the SEPS.

The BC/FS sealing plate fills this cut-out and allows the BC to be removed without touching the BCM and without removing the ring.

The sealing element is identical to the one used on the BC-structure.

4.7.1-3-4 Front Shield Mechanism (FSM)

Each of the 3 SEPS units located 120° apart contains one Front Shield Mechanism (FSM).

The FSM consists basically of the following subunits:

- FSM I/F Bracket which is bolted onto the FS. It also incorporates the 2 helical springs which provide the necessary force for the FS separation.

- FSM Bearing Bracket which links the FSM I/F Bracket and the Probe I/F Fitting.

- Bolt cutter which connects the FSM I/F Bearing Bracket with HUYGENS via the Probe I/F Fitting. 1 Bolt plus 3 conical studs are used with their axis being in line with the separation direction.

At each of the 3 FSM's a spherical bearing is used, connecting the FS bracket to the FSM.

The advantages of this concept are:

- Because of the stiff connection there is a good load distribution between the 3 I/F points of the FS during launch.

- The resulting bending moments which have to be transmitted by the separable I/F are low.

4.7.1-3-4-1 FSM-I/F-Bracket

Machined part made of titanium alloy. Designed for maximum stiffness and minimum weight.

The bracket is rigidly bolted onto the FS bracket. The interface with 4 M5 bolts per subunit, is foreseen for this connection plus conical guides which also act as conical studs taking the shear loads.

The FSM I/F Bracket carries the following parts:

- Pivot with a sphere at one end and thread at the other end which mates with the bracket. With this thread the FS connection can be preloaded if necessary (not foreseen at the moment). As material inconel will be used.

- 2 helical springs provide and guarantee a positive separation of the FS. The springs are fixed to the FSM I/F Bracket and act on the Probe I/F Fitting. The spring material is the same as for the SED-spring.

4.7.1-3-4-2 FSM Bearing Bracket

Machined parts made of titanium alloy.

3 conical studs are used to position the Bracket to the Probe-I/F-Fitting and to transmit the loads perpendicular to the bolt axis.

This arrangement as well as the materials and surface treatments are identical with the SED-I/F.

4.7.1-3-4-3 FSM Bolt Cutter Unit

The elements used are:

- Bolt M6 plus corresponding nut
- Bolt cutter with 2 knifes (pyrotechnically and mechanically redundant).

The Bolt Cutter AMD 7 CCD 65 PWH 0 is used to be able to cut a bolt diameter of 6.5mm.

4.7.1-4 Performance Characteristics

4.7.1-4-1 Mass

The mass of the entire SEPS, without MLI is: 21.7 Kg

Of the total SEPS mass, 11.4 Kg remain with the Spacecraft after the mechanical separation of the Probe.

4.7.1-4-2 Thermal Performances

The SEPS mechanisms withstand the loads induced due to the thermal deformations of the Probe during flight. The temperatures of the various structural elements of the Probe are as follows:

UNIT	DESIGN LIMITS OPER.	CRUISE 0.6AU	CRUISE 9AU	CHECK-OUT TMAX	COAST	ENTRY TMAX	DESCENT TMIN
BCM/FSM (PIF)	-60/60	-41/-39	-56	-36	-72	-61	/
USM	-60/40	-42/-40	-58	-39	/	/	/
SED (SIF)	-60/40	-42/-41	-59	-39	/	/	/

All temperatures are in °C.

4.7.1-5 Interfaces

The mechanical interfaces between:

SEPS and Spacecraft Struts
SEPS and Inner Structure
SEPS and Front Shield
SEPS and Back Cover

are shown in RD4 MTICD.

The electrical interfaces between:

SEPS and Spacecraft
SEPS and Probe

are shown in RD3 EICD.

4.7.1-6 TM/TC

4.7.1-6-1 Telecommand

Only Pyro Commands are involved in BCM and FSM.
See § 4.3.1-6 TM/TC PYRO in EPSS description.

4.7.1-6-2 Telemetry

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	HK PACKET
M1 001 T	SEPS temperature 1 (SEPS A)	Temp.	Orbiter	SEPSTEMP1	/
M1 002 T	SEPS temperature 2 (SEPS A)	Temp.	Orbiter	SEPSTEMP2	/
M1 003 T	SEPS temperature 3 (SEPS B)	Temp.	Orbiter	SEPSTEMP3	/
M1 004 T	SEPS temperature 4 (SEPS C)	Temp.	Orbiter	SEPSTEMP4	/
D5 001 T	Probe Temp. 1A (SEPS A)	Temp.	CDMU A	PTEMP1A	HK2
D5 002 T	Probe Temp. 2A (SEPS C)	Temp.	CDMU A	PTEMP2A	HK2
D5 013 T	Probe Temp. 1B (SEPS B)	Temp.	CDMU B	PTEMP1B	HK2
D5 014 T	Probe Temp. 2B (SEPS A)	Temp.	CDMU B	PTEMP2B	HK2

See location of the Temperatures sensors in § 4.6 Figure 4.6.1-5-1.

4.7.1-7 Operational Constraints

None.

4.7.2 NOMINAL OPERATIONS

See MP01 in Doc n° HUY.AS/c.100.OP.0384 which describes the Pyro sequence during the Descent Phase.

4.7.3 BACK-UP OPERATIONS

During Descent Phase, as no TC can be sent, there is no possibility to have a Back-up of Pyro sequence.

4.7.4 CONTINGENCY OPERATIONS

No contingency can be foreseen as no TC can be sent.

4.8 DCSS

4.8.1 SUBSYSTEM DESCRIPTION

4.8.1-1 Subsystem Configuration

The DCSS (Descent Control Subsystem) consists of:

- Pilot Deployment Assy with:

  - PDD Parachute Deployment Device
  - PCA Pilot Chute Assembly

- Descent Assembly with:

  - CA Container Assembly
  - MPA Main Parachute Assembly
  - Swivel Assembly
  - PJM Parachute Jettison Mechanism
  - SDA Stabilising Drogue Assembly.

4.8.1-2 Functional Design and Operating Principles

The probe enter the Titan atmosphere at a velocity of 5.75 ± 0.05 km/s at a nominal altitude of 1270 km. This phase lasts for a nominal 4 to 5 minutes, during which the Probe velocity decreases to a nominal Mach number of 1.50 at an altitude of 159 km above the surface.

The PDD houses the packed pilot chute during the launch, coast and cruise phases.

PDD Initiation

On initiation the PYRO Unit supplies separate, simultaneous, firing pulses to the two NASA standard initiators (NSIs) in the PDD. Either NSI provides sufficient energy to ignite the PDD cartridge which generates a hot gas and the breech is charged to a high pressure. Gas from the breech is transferred into the volume behind a sabot until the force generated by the gas pressure shears the pins holding on the PDD cover and the parachute bas is ejected.

Pilot Chute Deployment

The pilot chute is pressure packed in a deployment bag housed within the PDD body. When the PDD cartridge is initiated the pressure under the PDD sabot starts to accelerate the sabot, chute and closure.

After the assembly has moved approximately 42.6 mm the PDD Closure contacts the back cover breakout patch and shears its connecting pins.

Once the Breakout Patch has been detached from the back cover it remains attached to the pilot chute deployment bag both during the rest of the PDD stroke and subsequently.

Once the PDD sabot clears the PDD body the combustion products are vented to the atmosphere.

The PDD sabot is allowed to move away from the probe unrestrained.

As the pilot chute deployment bag moves away from the probe the pilot chute bridle is first deployed, followed by the riser, the lines and the canopy. As the bag separates from the canopy it begins to inflate.

The deployment bag/PDD cap/breakout patch remain interconnected and continue to move away from the probe.

The pilot chute canopy will be fully deployed less than 1.4 seconds after PDD initiation.

Back cover separation

The back cover is released a nominal 2.5 seconds after PDD initiation, at which time the pilot chute will be fully inflated under all conditions.

The pilot chute bridle is attached to the rear face of the back cover so that when the cover is released the pilot chute pulls it away from the probe. The pilot chute is sized to separate the back cover from the probe under all possible conditions.

The back cover is connected by the Main Parachute Extraction Lanyard (MPEL) to the main parachute deployment bag which is packed in the CA on the upper platform of the probe. As the back cover moves away from the probe under the aerodynamic force from both the pilot chute and back cover the main parachute is extracted in its bas from the container.

Main Parachute Deployment

The main parachute is packed in a deployment bag, which in turn is packed into the parachute container. A deployment lanyard links the back cover to the main parachute bag through the container closure system so that as the back cover moves away from the probe the container is opened by removal of a tear off patch. This releases the main parachute and bag from the container to allow the deployment lanyard to extract them. As the back cover continues to move away from the probe along with the deployment bag first the bridle, then the swivel, the riser, the lines and finally the canopy are deployed from the bag. Subsequently, the bag separates from the canopy and remains attached to the back cover, descending at a slower rate than the probe/main parachute.

The canopy inflated after the deployment bag has been stripped.

Descent under Main Parachute

The main parachute inflates at a supersonic velocity and rapidly decelerates the probe through the transonic region.

During the transonic phase the main parachute prevents the dynamically unstable probe from tumbling. During descent the swivel decouples any rotation of the parachute from the probe.

Front Shield Separation

At a velocity of less than Mach 0.6, 32.5 seconds after PDD initiation the front shield is released at the three attachment points situated around its diameter.

At this point the main parachute has damped the transonic instability sufficiently to prevent any recontact with the shield on separation. The main parachute is sized to separated the probe from the shield under all specified conditions so that the shield falls away from the probe as the probe continues to descent under the main parachute.

Main Parachute Separation

The main parachute is sized to separate the probe from the front shield and guarantee probe stability through the transonic regime. However, this results in a parachute that is too large to achieve the required descent time. It is therefore necessary to release the main parachute and subsequently deploy a smaller parachute to stabilise the probe down to the ground. This will increase the rate of descent and thus allow the design aim to be reached.

At a time of T_0 + 900 seconds the PYRO Unit sends two simultaneous, independent, firing pulses to each of the Parachute Jettison Mechanisms (PJMs) connecting the main parachute to the probe. Each PJM has two separate ESIs, each connected to one of the firing lines. The operation of either ESI is sufficient to operate the device. On operation the PJM cuts the bolt holding the main parachute spool assembly to the probe upper platform allowing the main parachute to separate from the probe.

Once the parachute has been detached it quickly decelerates, pulling the small stabilising drogue, in its deployment bag, from the CA by means of an extraction lanyard.

Stabilising Drogue Deployment

The stabilising drogue is packed in a deployment bag which is in turn packed into the parachute container, underneath the main parachute. It is restrained by a closure system. As the main parachute separates from the probe a lanyard operates the closure system and releases the bagged stabilising drogue. As it is pulled away from the probe by the main parachute first the bridle, then the riser, lines and canopy are extracted.

As the drogue is deployed the probe accelerates from its terminal velocity under the main parachute under the influence of the Titan gravity.

The drogue inflates at a very low dynamic pressure and the probe continues to accelerate downwards until it reaches a terminal velocity. The maximum load on the drogue is thus not its opening load but its steady state descent load.

Descent under Stabilising Drogue

After deployment of the stabilising drogue the probe descent continues until it reaches the surface of Titan, between 2 and 2.5 hours after PDD initiation.

During this stage of descent the drogue maintains the probe attitude as close as possible to the local vertical to maintain the Probe Relay Link and controls probe pitch rate within an acceptablevalue to allow the DISR to operate.

See Parachute Deployment sequence in Figure 2.2-10 in § 2.2.

4.8.1-3 Units Description

4.8.1-3-1 PDD

The PDD consists of an aluminium housing into which an aluminium sabot with dual 'O' seals is seated. The PC pack is located above the sabot and beneath the PDD closure cap retained by shear pins. The PDD body incorporates four mounting feet which attach it to the upper platform of the descent module via four M4 bolts.

The nominal ejected mass from the PDD increases when the break-out patch is impacted. The nominal ejected masses is **1.288 Kg**.

The cartridge is a basic high/low pressure producing system. The cartridge contains a multi perforation composite propellant grain. The propellant material is a carboxyl terminated polybutadiene/ammonium perchlorate (CTPB).

The propellant is ignited by a metal oxide interface charge which is initiated by either NSI. The gas generated by the burning propellant escapes through an exit nozzle installed in the body output end. The cartridge is hermetically sealed by welds at the port locations and body/manifold interface.

4.8.1-3-2 PCA

Parachute

A schematic of the PCA is given in Figure 4.8.1-3-1.

The pilot chute is a DGB design. It has a D_0 of 2.59 m and S_0 of 5.27 m^2.
The strop ensures that the parachute hem flies 10 entry module calibres (27 m) behind the probe so as to ensure inflation at supersonic velocities in the probe wake.

The 3-leg bridle is attached to the back cover via three attachment points. The bridle confluence is attached to the lower end of the strop using an aluminium interconnecting ring. Another ring is used to attach the strop to the parachute line confluence.

D7

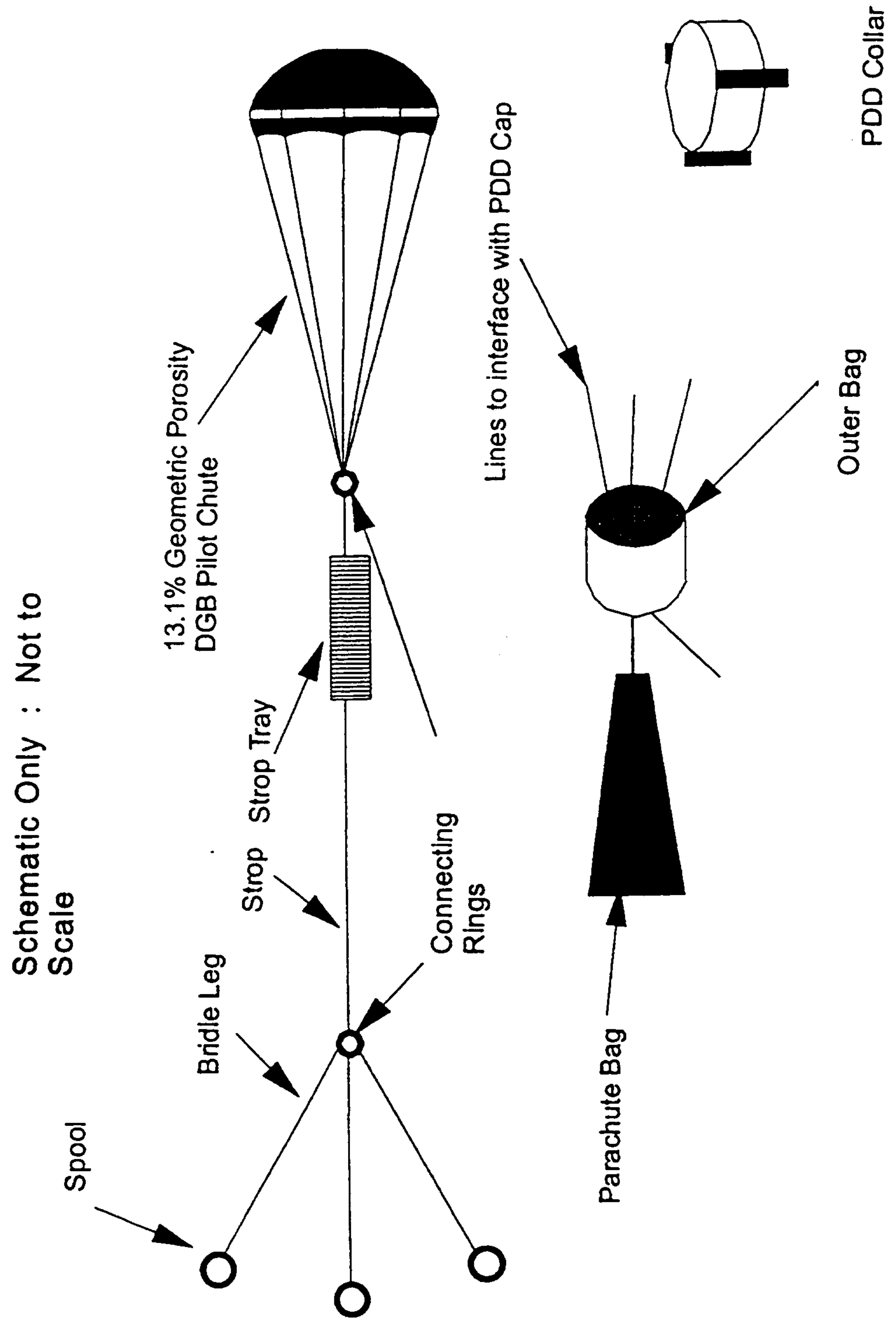

FIGURE 4.8.1-3-1 PILOT CHUTE ASSEMBLY SCHEMATIC

Deployment System

The PCA deployment system consists of three items; illustrated in Figure 4.8.1-3-2. The parachute and lines are packed into a sleeve, while the strop is packed into a line tray consisting of 26 tunnels. Both these items are then packed into an outer bag sized to give a pack that will fit neatly into the PDD. The connecting ring that attaches the strop to the bridle, and part of the bridle itself is also packed into the bag. Two mouthlocks are incorporated in this bag. The outer restrains the bridle legs and line tray, the inner restrains the sleeve.

Three Kevlar ties pass through beckets on the top of the PCA bag and inserts in the PDD cap to secure the bag to the cap. The PDD cap is then connected to the breakout patch by three multi-strand wire cable assemblies. This means that when the PC is inflated the deployment system will separate from the probe but remain attached to the breakout patch which acts as a decelerator to ensure separation from the probe and prevent recontact.

4.8.1-3-3 Container Assembly

Its location is shown in Figure 4.8.1-3-3.

The container furniture contains and restrains both the MPA and the SDA. The SDA is stowed at the bottom of the CA, under two flaps closed by the SD extraction lanyard. This is attached to the MP bridle. These flaps are not exposed until the MP is deployed.

The MPA is packed on top of the SDA closure flaps and is restrained within the CA by the tear-off patch. This incorporates two Kevlar tapes running down the lengthways edges. These are each sewn by a single row of polyester thread stitching to the part of the container furniture that remains with the CA.

The MPEL (Main Parachute Extraction Lanyard) joins the two Kevlar tapes down the sides of the tear-off patch to the back cover using three legs terminated in spools to facilitate attachment to the back cover. These spools are identical to those used for the PCA and are made of titanium for thermal control. Two of these legs are stowed on top of the CA, emerging directly to the back cover lugs. The third is taken via a velcro patch to the lug on the other side of the PDD from the CA.

The MPA and SDA parachute bridles emerge from the parachute container and are routed to the appropriate attachment points via velcro tunnels and patches.

A single layer of aluminised Kapton is attached to the tear-off patch by velcro. It protects the CA top from back cover heating during the entry phase.

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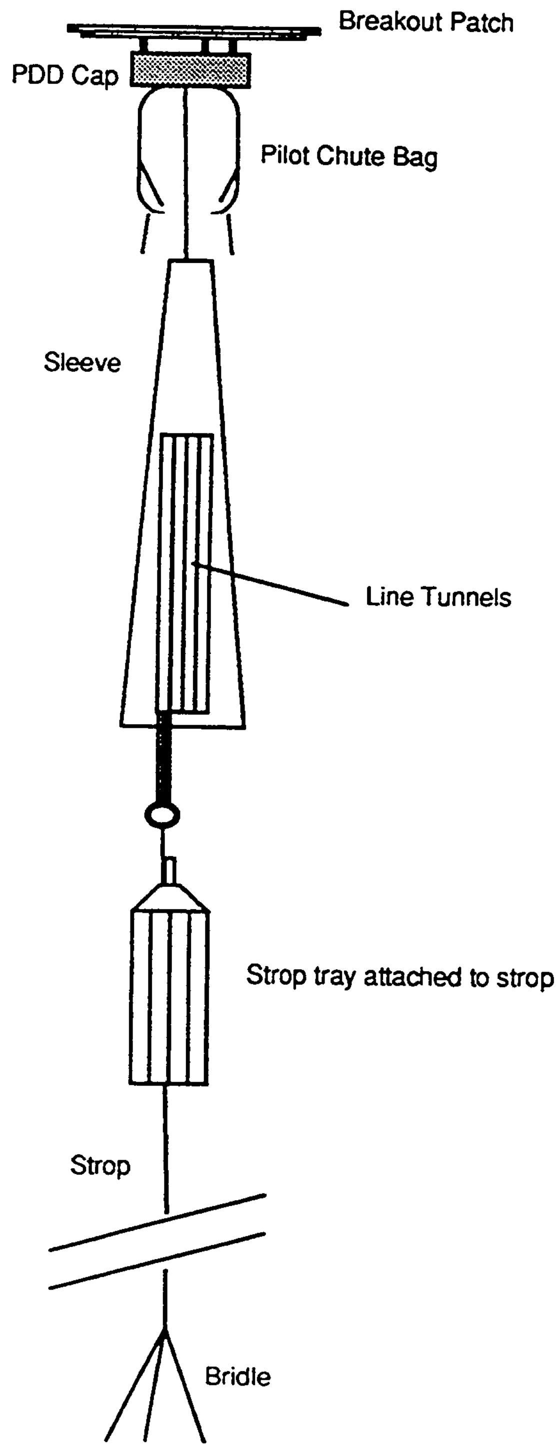

FIGURE 4.8.1-3-2 PILOT CHUTE DEPLOYMENT ASSEMBLY

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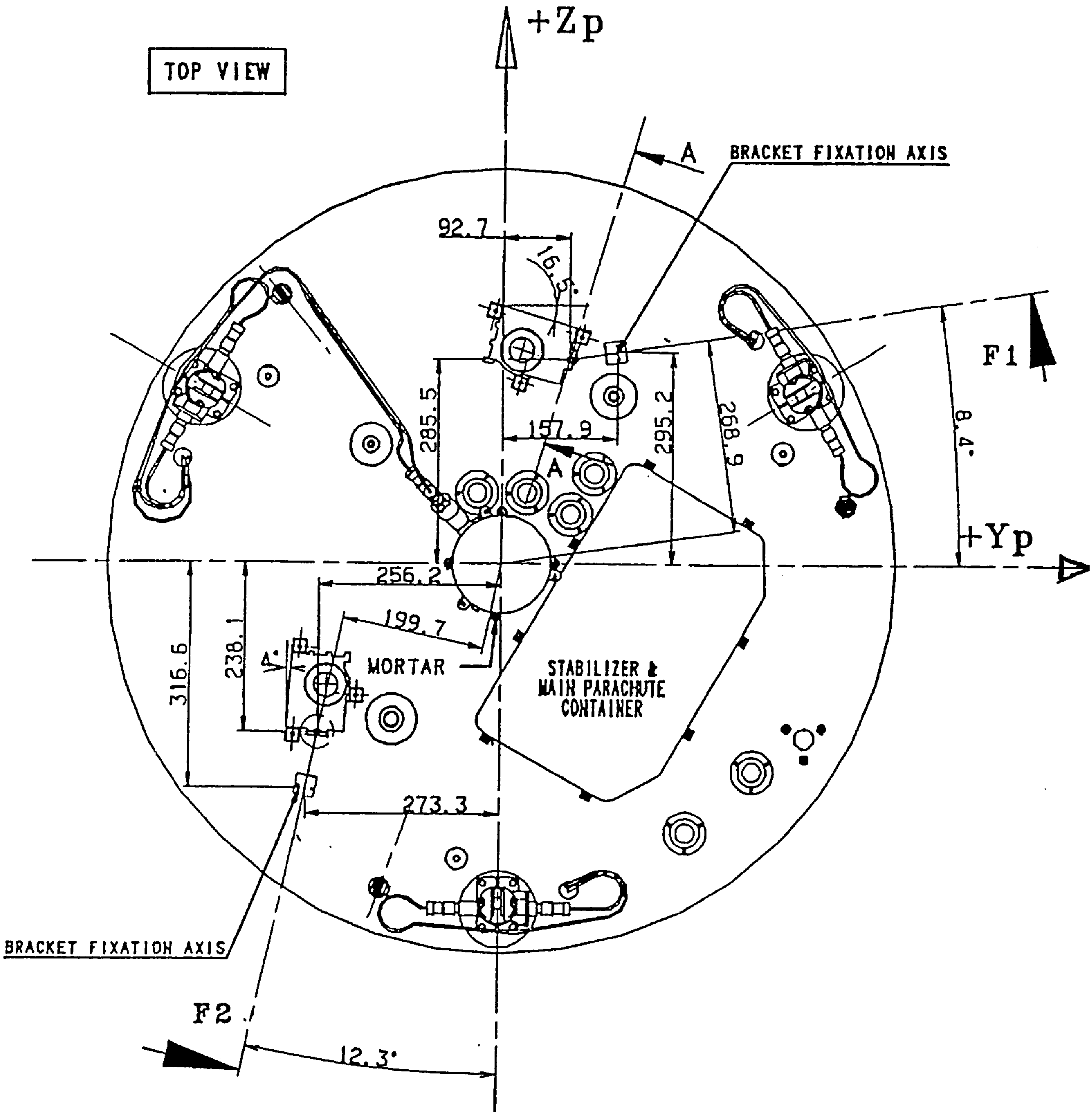


FIGURE 4.8.1-3-3 CONTAINER ASSEMBLY LOCATION

4.8.1-3-4 MPA

Parachute

A schematic of the MPA is given as Figure 4.8.1-3-4.

The MP is a modified DGB design with a geometric porosity of 22.4 %. It has a D_0 of 8.30 m and S_0 of 54.06 m2.

The strop ensures that the parachute hem flies 10 entry module calibres (27 m) behind the probe so as to ensure positive inflation at supersonic velocities in the probe wake. It incorporates the swivel, and terminated at the bridle.

The bridle attaches the strop to the probe upper platform via the three PJM mechanisms. Each of the 3 legs is 3.91 m long. The bridle confluence is attached to the lower end of the strop using and aluminium interconnecting ring. Another ring is used to attach the strop to the parachute line confluence. The stabilising drogue extraction lanyard is attached to a suitable part of the bridle adjacent to one PJM spool.

Deployment System

The MPA deployment system consists of a bag, which is restrained within the Container Assembly (CA) by a tear-off patch. The MP is packed inside the bag, while the lines, strop and swivel are stowed on the side of the bag. The lines and strop are stored in line tunnels, while the swivel is secured by two fastenings.

The three MP bridle legs run out of the container and attach to the PJMs via spools. The bridle is secured to the probe upper platform by a tiedown system consisting of velcro tunnels.

The MP extraction lanyard has three legs, which attach to the back cover clevises, adjacent to the PC bridles. these three legs then converge to a double strop, which is attached to the tear-off patch. the sides of the tear-off patch are reinforced by Kevlar tapes, which continue to form a loop to which the top of the MP bag is attached. Two of the legs are secured before use to the top of the CA and the third is secured via a velcro patch to the upper platform.

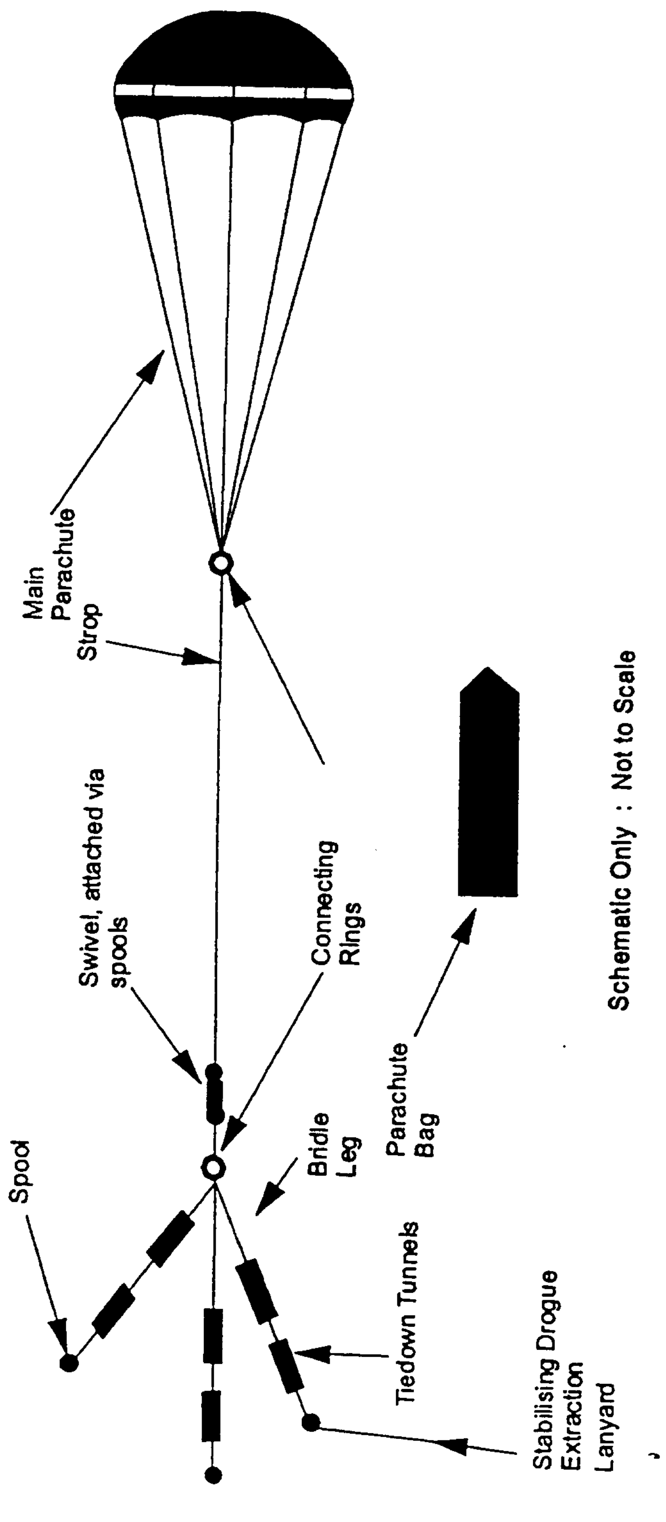


FIGURE 4.8.1-3-4 MAIN PARACHUTE ASSEMBLY SCHEMATIC

4.8.1-3-5 Swivel Assembly

A redundant bearing concept is used in the design. See Figure 4.8.1-3-5. The bearings use an RF sputtered Molybdenum Disulphide dry film lubricant.

The arrangement of the bearings is performed so that no oversizing of the redundant bearing occurs. Both main load carrying bearings are sized according to the peak axial load of 14.7 kN. This layout also ensures that regardless of which bearing fails, the lowest possible friction torque could always be achieved.

A preload will be applied to the bearing by a belleville spring to so that the design is insensitive to reliability-critical thermally-induced loads (differential expansion, gradients).

The swivel housing is made from aluminium 7075 with low density and a low thermal expansion characteristics.

The housing includes the interface to the parachute. The connection between the spools and the swivel ensure low friction by means of a Molybdenum Disulphide film.

The shaft is made from titanium selected to cope with the load, the thermal expansion, to be compatible with the bearing race materials and to provide low mass.

4.8.1-3-6 PJM

The main parachute is attached to the probe at three equispaced points on the upper platform of the probe. A PJM assembly as shown in Figure 4.8.1-3-6 is located at each of these points.

The MP bridle spool is attached to a bridle clevis by a clevis pin. The base of the bridle clevis is attached to an interface bracket by a 6.5 mm stainless steel bolt. The interface bracket is attached to the upper platform by four mounting bolts. In order to prevent excessive lateral movement of the bolt at the time of MP inflation, the bridle clevis is located in a recess in the interface bracket.

On receipt of a current of 5A from the pyro harness, two ESIs ignite an intermediate powder charge which provides sufficient energy to ensure that the rod is cut event in the event of only a single blade operating.

The rod cutters are mounted on the interface bracket perpendicular to the rod. The rod passes through an orifice in the rod cutter.

When the rod is cut, the clevis assembly and top half of the bolt separate from the probe under the force of the cutting action and the force from the MP bridle legs. The lower half of the bolt remains in the volume between the interface bracket and the strut.

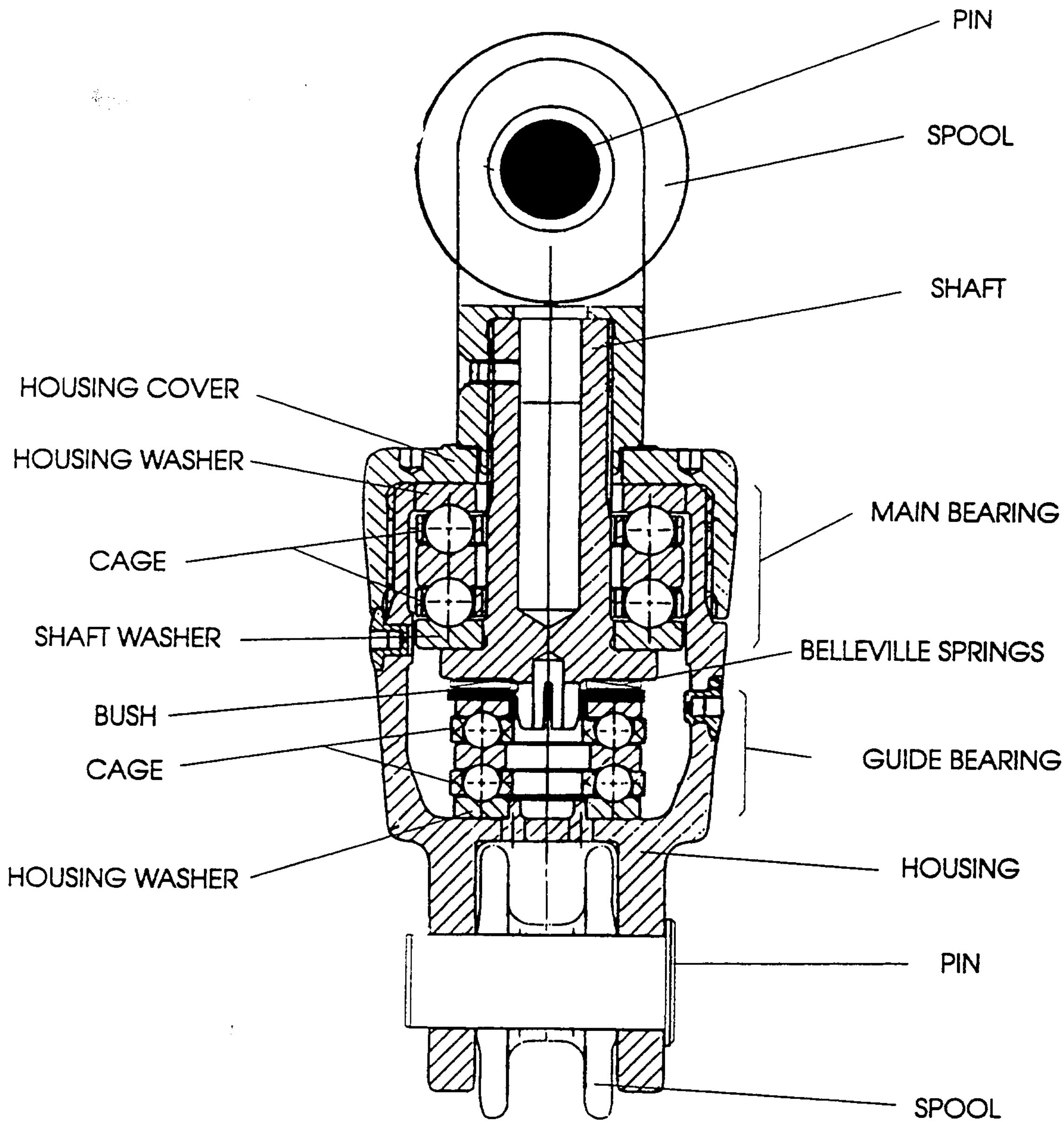


FIGURE 4.8.1-3-5 BASELINE SWIVEL DESIGN

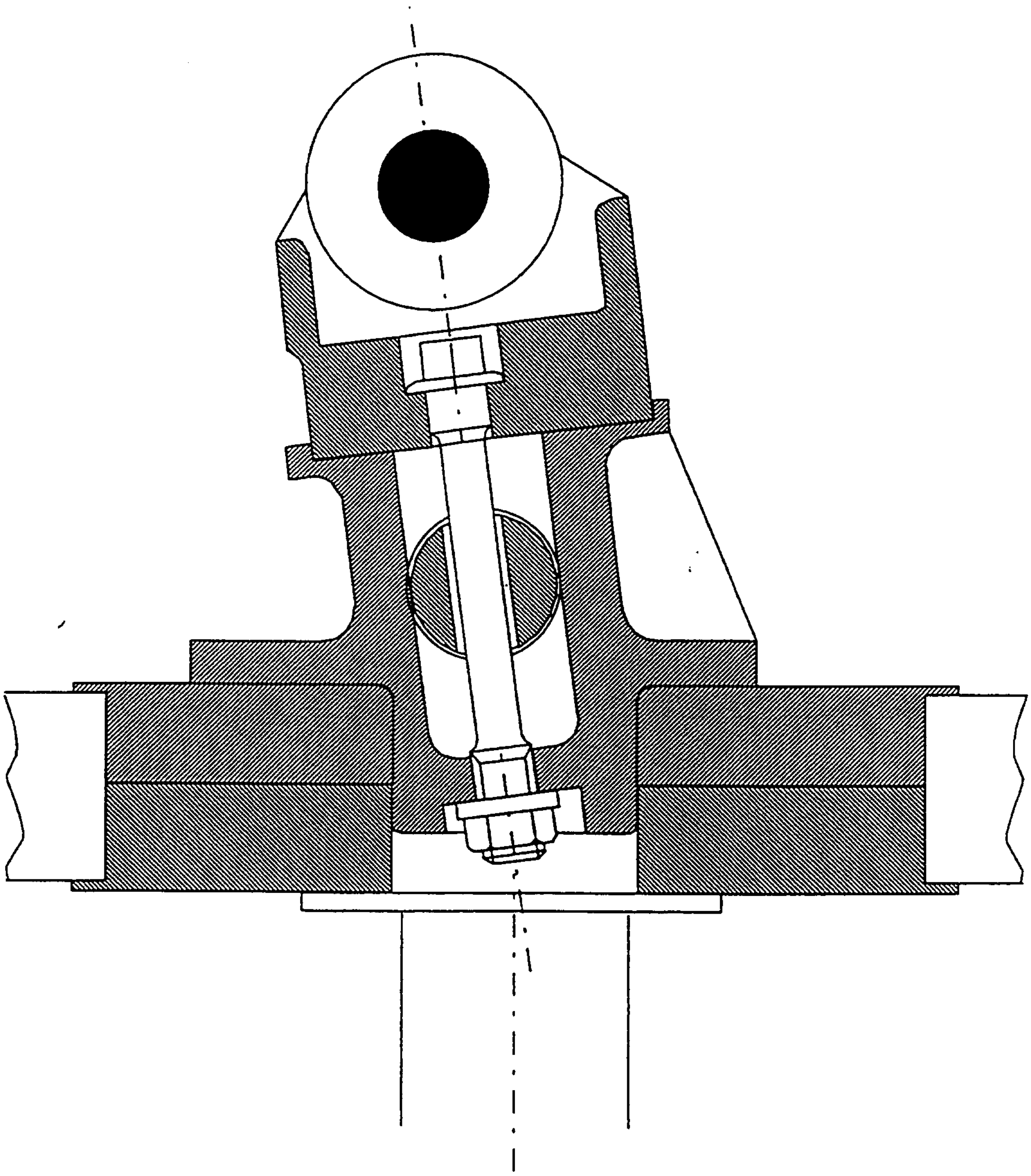


FIGURE 4.8.1-3-6 PJM ASSEMBLY

4.8.1-3-7 SDA

Parachute

A schematic of the SDA is given as Figure 4.8.1-3-7.

The stabilising drogue is a modified DGB design with a geometric porosity of 22.4 %. Is has a D_0 of 3.03 m and S_0 of 7.23 m2.

The strop ensures that the parachute hem flies sufficiently far behind the probe so as to keep interference with the subsonic probe wake to an acceptable level - a distance of at least 7 calibres is required. The upper and lower strops are attached to the swivel. A shock attenuation device is incorporated in the lower portion of the strop. This reduces the snatch load seen in the bridle and lower strop when the swivel is deployed from the bag to acceptable limits by breaking polyester thread stitching.

The bridle attaches the strop to the upper platform of the probe via spools attached to clevises. Each of the 3 legs is 3.91 m long. The bridle is sized so as to ensure stability of the probe during the descent.

Deployment System

The stabilising drogue is packed into the SD sleeve. The parachute lines are stowed in tunnels, and the strop and swivel are stowed on the side of the sleeve.

This sleeve is packed into the CA. It is restrained within the CA by 2 flaps, secured closed by the SDEL. The top of the SD sleeve is attached to the end of the SDEL. The other end of the SDEL is attached to the MPA bridle.

The three bridle legs extend out of the parachute container to the attachment clevises on the probe upper platform.

4.8.1-3-8 Break Out Patch

The BoP ejectable part, as shown in Figure 4.8.1-3-8, is a solid disc manufactured from aluminium alloy. The BoP incorporates 3 stepped radial webs emanating from a central circular contact area terminating at a circumferential stiffening ring.

In addition, each web includes an M3 locking insert. A flexible steel cable assembly is attached to the BoP at each point. The steel cable provides a method of attaching the BoP ejected part to the lugs on the PDD cap to enhance deployment.

In the centre of the upper face of the ejected part is a tapped M4 hole which is for handling purposes.

The top surface of the BoP ejectable part has thermal protection applied to it and the remainder of the ejectable part has an alocrom finish to provide low emissivity.

The BoP assembly when impacted by the PDD Cap assembly must release from the Back Cover. The ejected part should deploy so as to allow correct PC deployment and not collide with the probe structure.

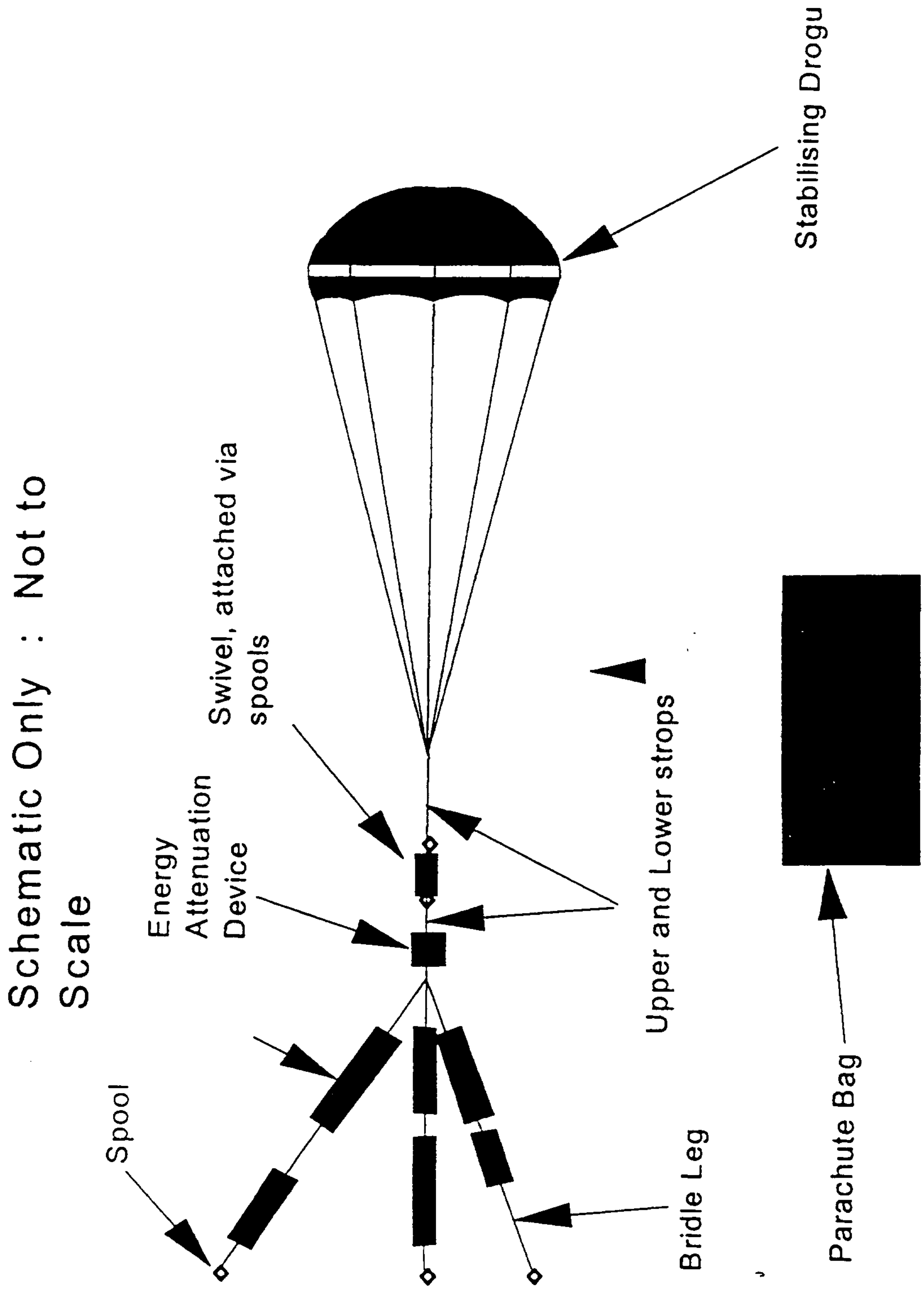


FIGURE 4.8.1-3-7 STABILISING DROGUE ASSEMBLY SCHEMATIC

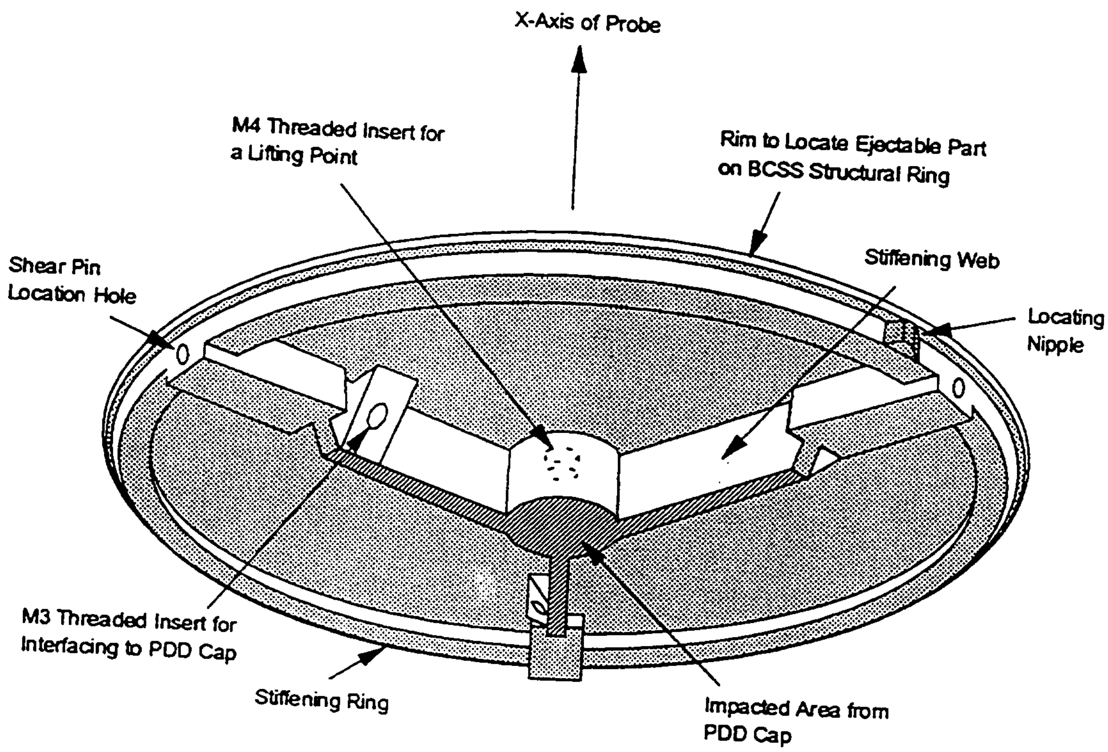


FIGURE 4.8.1-3-8 BREAK OUT PATCH EJECTABLE PART

4.8.1-4 Performance Characteristics

4.8.1-4-1 Mass

The total mass of the DCSS is: 12.34Kg.

4.8.1-4-2 Power Need

The DCSS incorporates a total of 2 NASA Standard Initiators for the PDD cartridge and 6 ESA Standard Initiators for the PJM rod cutters.

The recommended firing current for ESI/NSIs is 5 Amps for a duration of 10 ms.

4.8.1-4-3 Descent Profile and Timeline

The nominal descent time is set to be 8100 seconds. The sequence timeline is given below:

	Time	Minimum Time	Maximum Time
PDD Initiation	T0		
Pilot Chute Lines Taut	T1	T0 + 1.15s	T0 + 1.40s
Pilot Chute Inflated	T2	T0 + 1.20s	T0 + 1.47s
Back Cover Released	T3	T0 + 2.5s	T0 + 2.5s
Main Parachute Deployed	T4	T3 + 1.40s	T3 + 2.45s
Main Parachute Inflated	T5	T3 + 1.58s	T3 + 2.65s
Main Parachute Released	T6	T0 + 900s	T0 + 900s
Stabilising Drogue Deployed	T7	T6 + 0.94s	T6 + 1.02s
Stabilising Drogue Inflated	T8	T7 + 1.38s	T7 + 1.59s

The probe will descend under the 8.30 m main parachute for 15 minutes after which it will complete its descent under a 3.03 m stabilising drogue giving a nominal descent time of 2.25 hours.

D7

4.8.1-4-4 Thermal Temperatures Prediction

UNIT	DESIGN LIMITS OPER.	CRUISE 0.6AU	CRUISE 9AU	CHECK-OUT TMAX	COAST	ENTRY TMAX	DESCENT TMIN
Main Parachute	-200/40	-22	-35	-18	-45	-44	-199
PDD/Pilot Chute	-50/15	-22	-35	-18	-44	-44	/
PJM	-110/40	-23/-21	-35	-18	-45/-44	-45/-43	-57

– All temperatures are in °C.

4.8.1-5 Interfaces

4.8.1-5-1 Internal Interfaces

Pilot Chute to PDD

The Pilot Chute is packed within the PDD in the volume between the sabot and the closure cap. The pilot chute strop emerges from the PDD via acute out in the closure cap.

The pilot chute bag is connected to the PDD cap by three Kevlar ties which pass through fabric loops on the pilot chute bag, through inserts in the PDD cap and are terminated above the cap. These ensure the breakout patch and PDD cap assist the deployment of the parachute.

PDD to Breakout Patch

The PDD cap is connected to the breakout patch via three cables. The cables are attached to the breakout patch at their upper ends, passed through fittings on the PDD cap and terminated at their lower ends with a ball fitting. The PDD cap is allowed to slide up the cables during deployment but is not allowed to separate from the cables due to ball fittings on their ends.

Main and Stabilising Chutes to Container

The main parachute and the stabilising drogue will be packed into the container assembly via a Kevlar pack which will enclose both parachutes and incorporate the closure systems for both parachutes. This pack will interface with the container shell using riveted attachments.

Main Parachute to PJM

The main parachute will interface with the PJM via a bridle clevis assembly. The bridle clevis assembly incorporates a 12 mm diameter clevis pin which interfaces with the main parachute bridle spool.

Pilot, Main and Stabilising Parachutes to Tie Down

The tie down system comprises Velcro pads attached to the upper platform, main parachute and stabilising drogue bridles. The hook pads will be attached using Araldite AV138 to the probe upper platform, the loop pads will be sewn onto the Kevlar bridles.

Main Parachute to Swivel

The main parachute strop interfaces with the swivel via clevis assemblies. The swivel clevis assemblies incorporate 12 mm diamater clevis pins which interface with the main parachute spools.

Stabilising Drogue to Swivel

The stabilising drogue stop interfaces with the swivel via clevis assemblies. The swivel clevis assemblies incorporate 12 mm diamater clevis pins which interface with the stabilising drogue strop spools.

Main Parachute to Stabilising Drogue

The stabilising drogue extraction lanyard is attached to one of the PJM spools. It is then attached to the stabilising drogue bag via the closure system of the Container Assembly.

4.8.1-5-2 External Interfaces

PDD to Upper Platform

The PDD interfaces with the probe upper platform via four M4 bolts which are located at each foot mounted on the PDD body.

Pilot Chute to Back cover

The pilot chute bridle is attached to the back cover using a clevis assembly. The bridle spool is attached to a clevis assembly mounted on the back cover via a 6 mm clevis pin .

Back Cover to Main Parachute

The main parachute extraction lanyard is attached to the back cover at the three pilot chute attachment points via three spools. It is then attached to the main parachute bag via the closure system of the Container Assembly.

Stabilising Drogue to Upper Platform

The stabilising drogue bridle interfaces to the upper platform of the probe at three locations. Each clevis assembly is fixed to the upper platform using two M4 bolts. The clevis assembly interfaces with the stabilising drogue bridle spool using a clevis pin.

Container Assembly to Upper Platform

The Container Assembly interfaces with the probe upper platform via eight M4 x 12 bolts which are located at each foot mounted on the container shell.

PJM to Upper Platform

The PJM body is attached to the upper platform by four M8 bolts.

4.8.1-6 TM/TC

4.8.1-6-1 Telecommand

Only Pyro Commands are involved in PDD and PJM.
See § 4.3.1-6 TM/TC PYRO in EPSS description.

4.8.1-6-2 Telemetry

TM REF	DESCRIPTION	TYPE	DESTIN.	MNEMO	HK PACKET
D5 003 T	Probe Temp. 3A (PJM A)	Temp.	CDMU A	PTEMP3A	HK2
D5 004 T	Probe Temp. 4A (PJM C)	Temp.	CDMU A	PTEMP4A	HK2
D5 015 T	Probe Temp. 3B (PJM B)	Temp.	CDMU B	PTEMP3B	HK2
D5 016 T	Probe Temp. 4B (PDD)	Temp.	CDMU B	PTEMP4B	HK2

See location of the Temperatures sensors in § 4.6 Figure 4.6.1-5-4.

4.8.1-7 Operational Constraints

The pilot must not inflate at Mach > 1.76 or Dynamic Pressure > 440Pa.

4.8.2 NOMINAL OPERATIONS

See MP01 in Doc n° HUY.AS/c.100.OP.0384 which describes the Pyro sequence during the Descent Phase.

4.8.3 BACK-UP OPERATIONS

During Descent Phase, as no TC can be sent, there is no possibility to have a Back-up of Pyro sequence.

4.8.4 CONTINGENCY OPERATIONS

No contingency can be foreseen as no TC can be sent.

5. INSTRUMENTS DESCRIPTION - OPERATIONS

Experiment User Manuals are provided by ESA/ESTEC in Annex 6.

6. TELEMETRY AND TELECOMMAND DATA

The main elements of the overall Telemetry and Telecommand paths are illustrated in Figure 6.1 (Note that the redundancy is not shown).

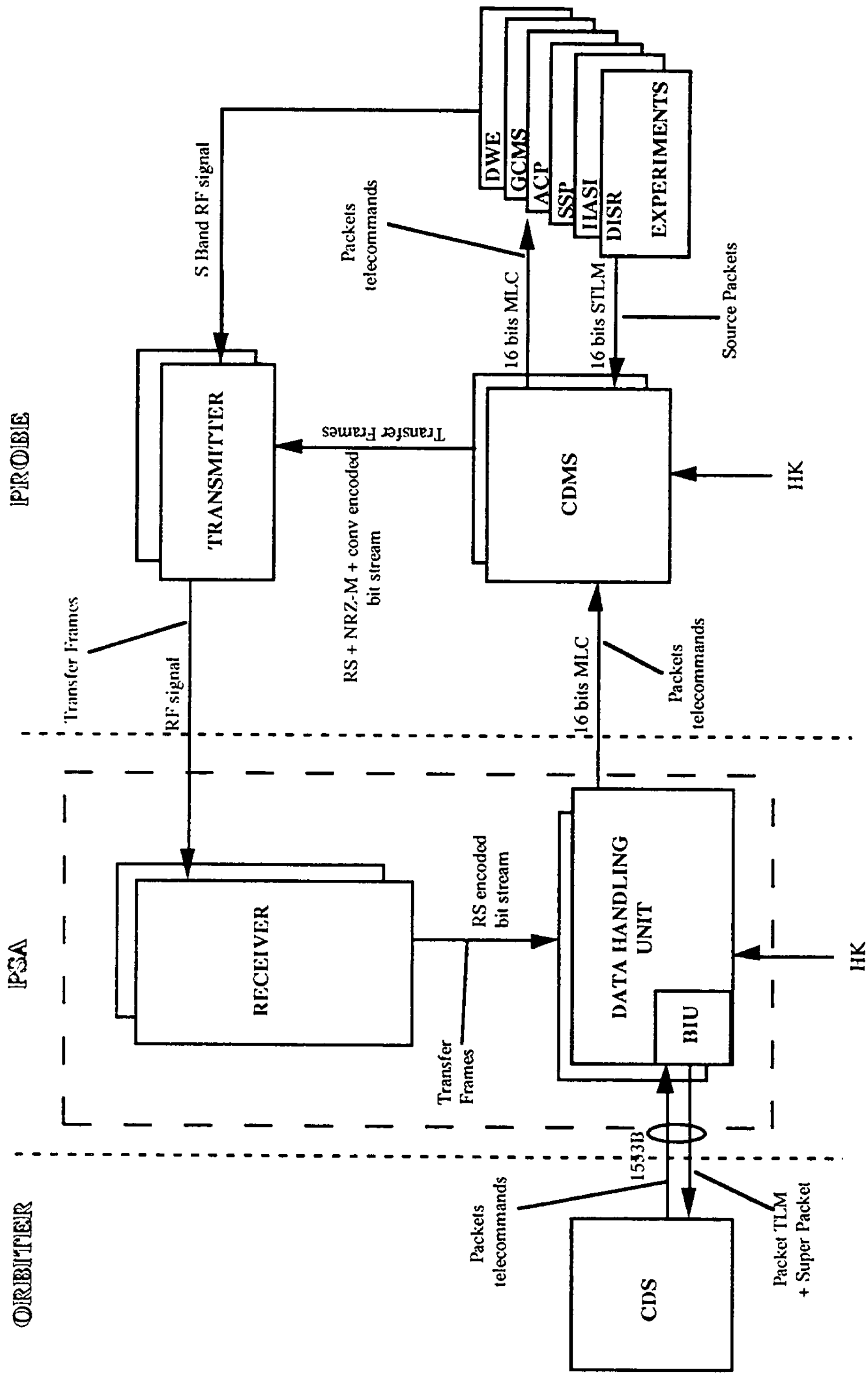


FIGURE 6.1 OVERALL DATA PATH

6.1 TELECOMMAND

6.1.1 Format Description

Commands formatted according to the ESA Packet Telecommand Standard (ESA PSS-04-107) are transmitted over a 1553 interface from the Orbiter Command and Data Subsystem (CDS) to a specific subaddress of the Bus Interface Unit (BIU), part of the PSA equipment.

Then, depending upon the packet header identifier, the packetized commands are either operated locally within the PSA, or distributed to the Probe CDMS using Memory Load Commands. On receipt by the Probe CDMS, telecommand packets will again be operated upon locally within the Probe subsystems, or distributed, still in packet form, to the addressed experiment.

For obvious reasons of memory and processing limitations, and to permit the transmission of up to one packet each 125 ms (one POSW cycle duration), the telecommand packet size is limited: 128 words has been felt as convenient to support the foreseen check out operations such as the memory dump or the reprogrammation functions, without strong impacts on the memory and buffers dimensionning.

One word contains 16 bits, bit 15 is the most significant bit (msb) and is the first bit transmitted.

The Figure 6.1-1 summarizes the content of the telecommand Packet, consistent with the principle described above.

6.1.2 Types

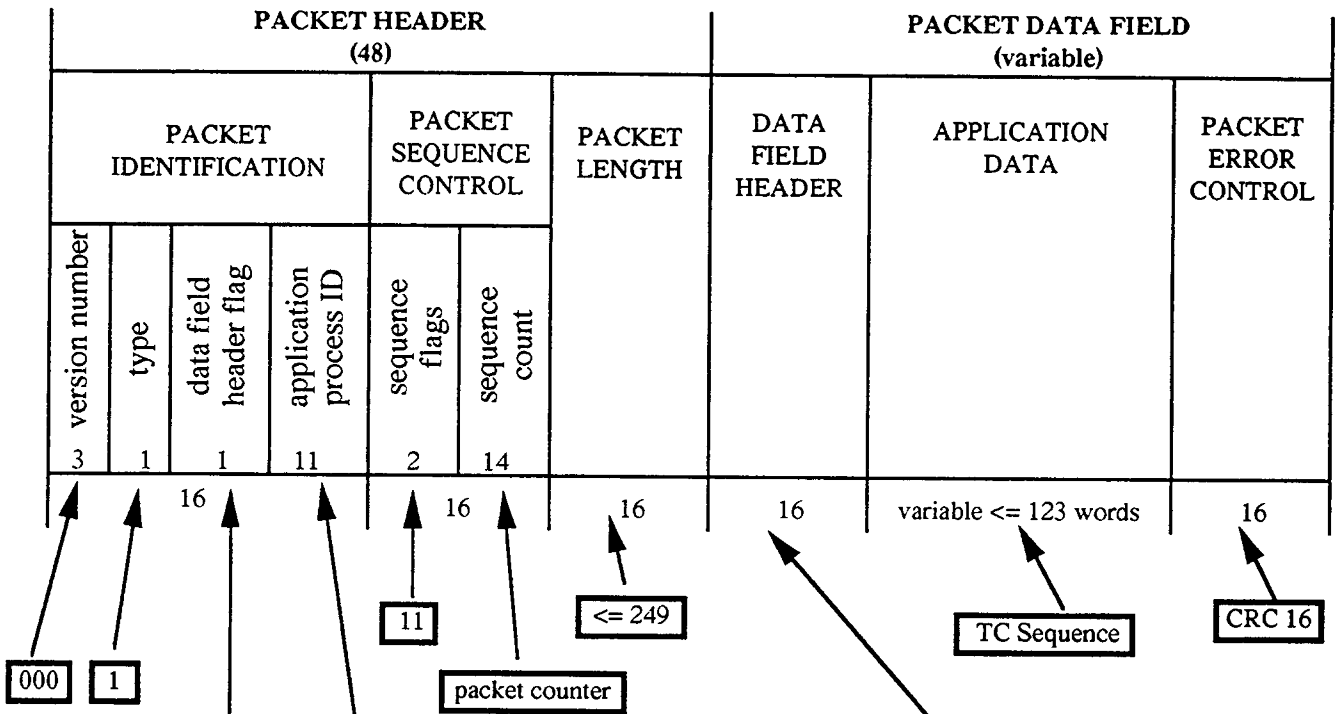
Table 6.1-1 shows the different types of TC which can be used. The operations related to these TCs are described in Doc n° HUY.AS/c.100.OP.0384.

TC Type	POSW Operation	SASW Operation
Dump	SP01	AP01
Patch	SP07/SP10	AP05
Direct	SP03/SP04	AP03
Inhibition	SP02	AP02
Alteration	SP06	AP04
Suspend/Resume	SP05	/
Load MTT	SP08	/
Experiments	SP09	/

TABLE 6.1-1 TC TYPES

Details on software data are given in § 4.4 (POSW) and § 4.5 (SASW).

List of Probe system TCs is given in Annex 2 TM/TC Data Tables.



	Unique Identifier for Packet Destination	
	Channel A	Channel B
ACP	783H	7A3H
DISR	792H	7B2H
GCMS	780H	7A0H
HASI	791H	7B1H
SSP	794H	7B4H
PROBE	785H	7A5H
PSE	78CH	7ACH

TC Type	Packet TC Identifier
0030H	Dump TC
0050H	Patch TC
0060H	Direct TC
0090H	Inhibition TC
00A0H	Alteration TC
00C0H	Suspend/Resume TC
00F0H	Load MTT TC
For Experiments: Command Header	

PROBE/PSE	1	secondary header in the PKT
EXPERIMENT	1	presence DISR, HASI, GCMS, SSP in the PKT Data Field
EXPERIMENT	0	absence ACP in the PKT Data Field

FIGURE 6.1-1 TELECOMMAND PACKET LAYOUT

6.1.3 TC Verification

At each TC reception, the software will verify the content of the packet identification, the packet length, the TC type, perform a CRC calculation and check.

If these checks are successful, the valid TC counter will be updated and the TC packet will be handled. If not, the invalid TC counter will be updated and the TC packet will be rejected.

If a Dump or Patch TC is being processed, any new TC will be rejected and the invalid TC counter will be updated.

If a resume TC on pre-To MTT occurs when the POSW is processing the post-To MTT, this TC will be rejected and the invalid TC counter will be updated.

TC counter is reported in HK parameters.

See details in Operations mentioned in Table 6.1-1.

6.1.4 TC Operational Contraints

- Telecommanding is only possible before separation.

- SASW (POSW) will accept TCs only 15 seconds after PSA (CDMU) are powered ON, except "Inhibition TC" which has to be sent between 6.5 s and 9.5 s after PSA (CDMU) are powered ON.

- See SASW Operational Constraints in § 4.5.3-5.

- See POSW ON/OFF command timing constraints in § 4.4.3-4-1.

- See POSW Dump TC constraints in § 4.4.3-4-3.

- See POSW constraints on TC during start-up in § 4.4.3-4-5.

- It is required to send TC at a maximum rate of 1 TC/second/chain.

6.2 TELEMETRY

6.2.1 Format Description

The data acquisition processes involve both the CDMS and the PDRS (Probe and PSA) subsystems.

During the Probe Mission and Checkout phases, the experiments generate source Packets according to the Packet Telemetry Standard (ESA PSS-04-106) to be acquired by the Probe CDMS following a polling scheme implemented within the POSW.

The Probe CDMS take these science data source packets along with locally generated Housekeeping source packets, encapsulate them in transfer frames, and produce differential, Reed-Solomon and convolutional encoding of the Frames before sending them to the Transmitter.

The Transmitter sends the Transfer Frames to the Receiver via one of two routes, namely:

- prior to separation the route between the transmitter and the receiver is hardwired (umbilical link) and taken before the high gain amplification stage

- during Probe Descent the route is via the S-band link.

The PSA receiver decodes the convolutional and differential encoding and passes the RS encoded Transfer Frames to the PSA data handling section. This one takes these Frames and, through the Support Avionics Software (SASW), turns them into "Super Packets" by removing the synchronising bits (SYNC MARKER) and adding a header and Orbiter time before it transfers it to the Orbiter CDS via the Bus Interface Unit (BIU).

Local to the PSA, housekeeping Source Packets are also produced.

Two distinct BIU subaddresses are utilized for the transmission of Super Packets and PSA housekeeping Source Packets.

The Figure 6.2-1 presents the baseline TM packets arrangement:

- the source Packets size applicable to the telemetry produced on the Probe is 126 bytes. This packet size allows 7 source packets to be inserted in each of the CCSDS, 1 kbytes, transfer frames transmitted over the Probe Relay Link.

- the selected Source Packets size applicable to the telemetry produced on the PSA is 182 bytes.

The Figure 6.2-2 (a) defines the Super Packet and PSA Source Packet headers and the figure 6.2-2 (b) defines the Probe Source Packets headers, both in accordance with the principles described above.

One word contains 16 bits, bit 15 is the most significant bit (msb) and is the first bit transmitted.

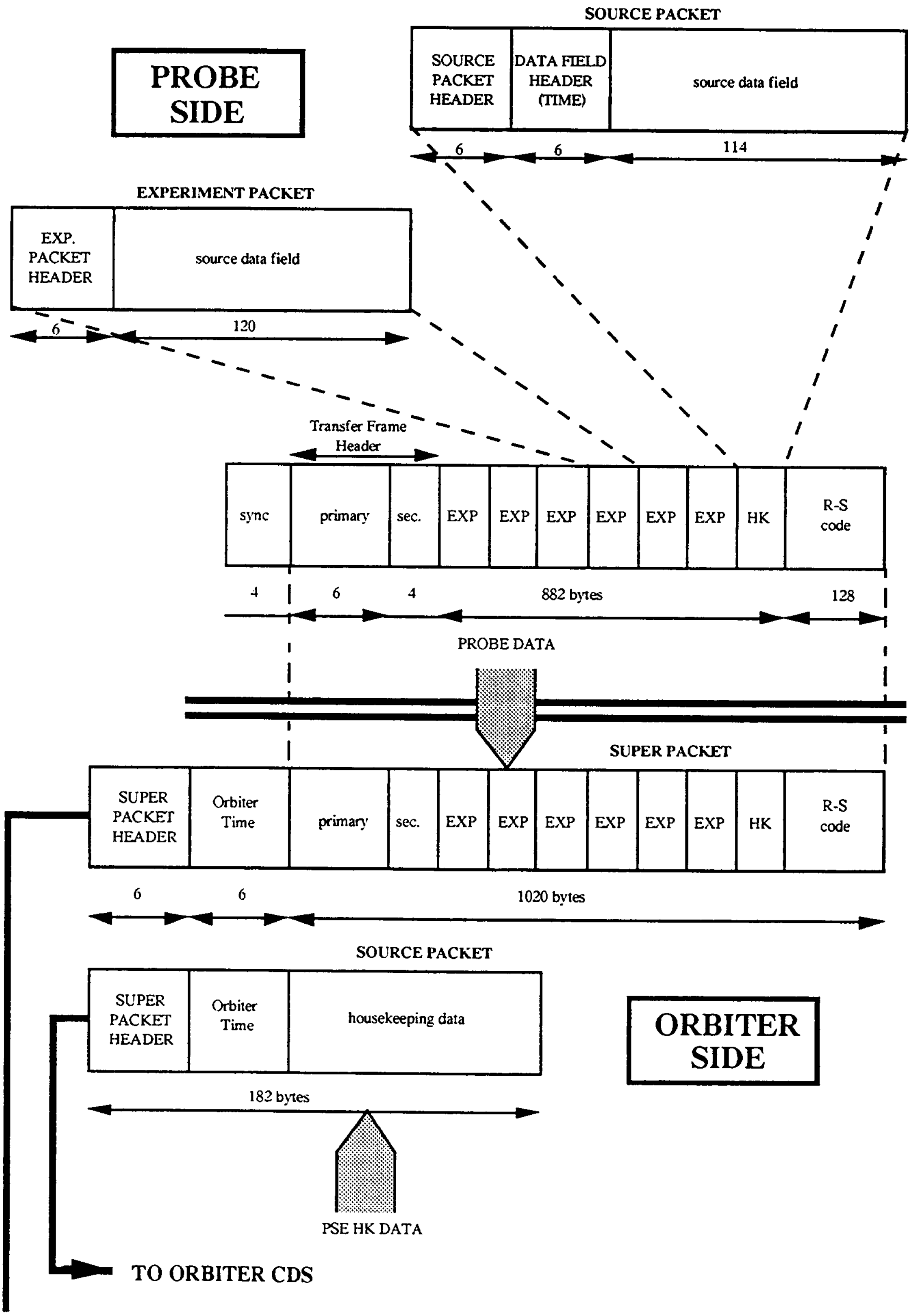
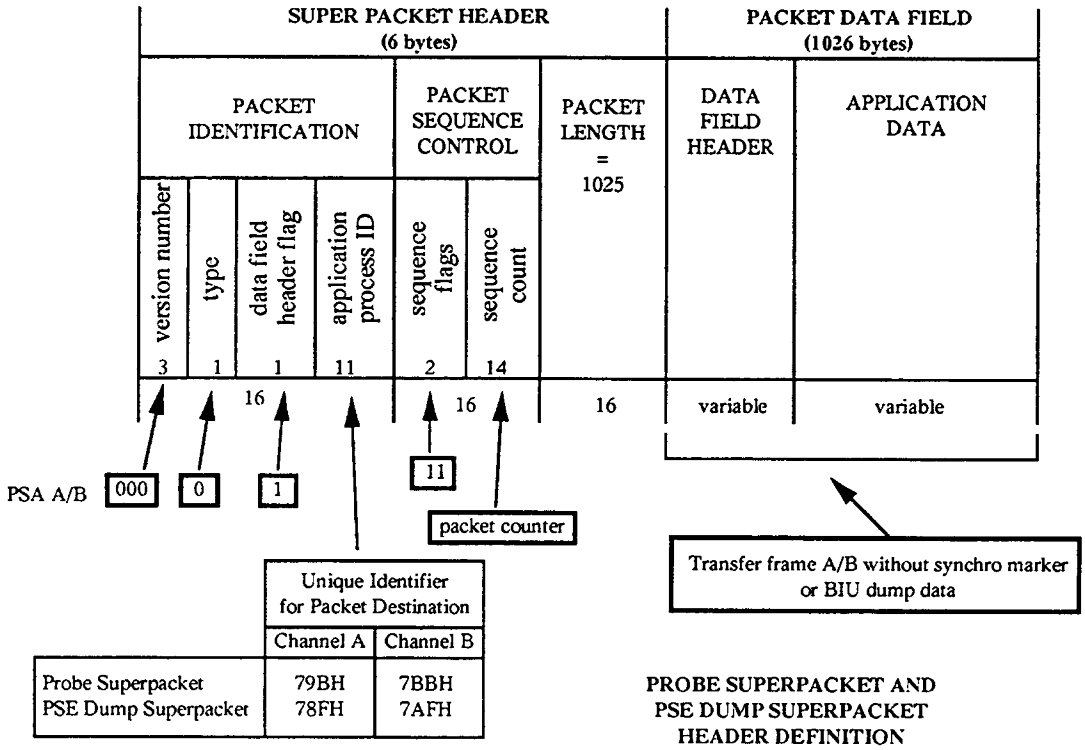
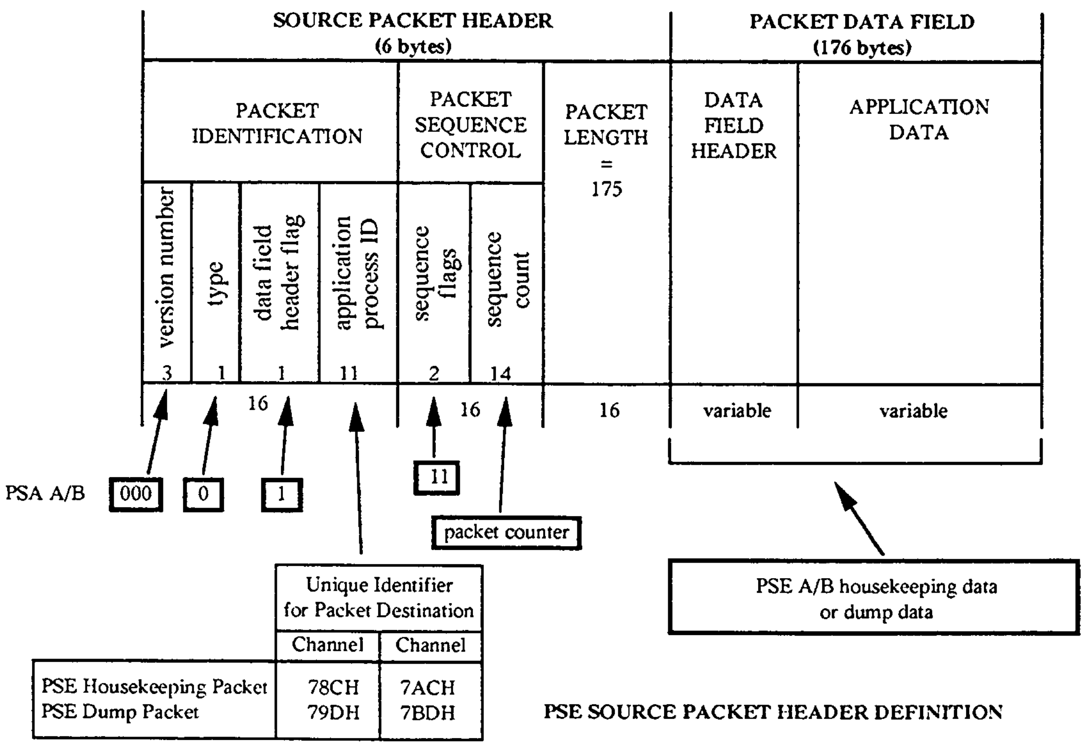


FIGURE 6.2-1 TM PACKETS ARRANGEMENT



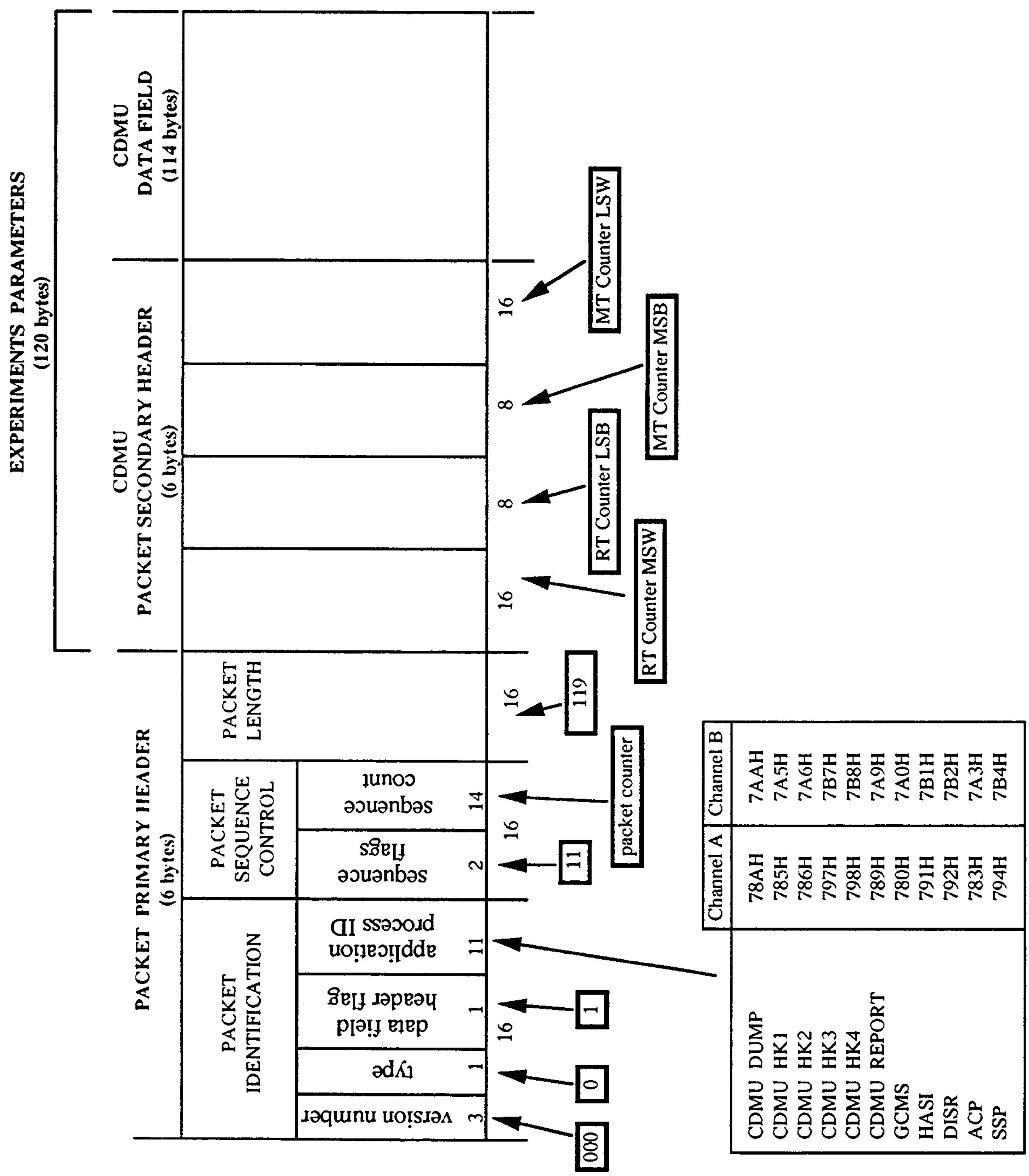
PROBE SUPERPACKET AND
PSE DUMP SUPERPACKET
HEADER DEFINITION



PSE SOURCE PACKET HEADER DEFINITION

FIGURE 6.2-2 (a) TELEMETRY PACKETS HEADERS

D9



MD-P

FIGURE 6.2-2 (b) PROBE TELEMETRY PACKETS HEADERS

6.2.2 Types

There are six types of TM source packets:

- Experiment TM
- Probe dump TM
- Probe HK TM
- Probe report TM
- PSA dump TM
- PSA HK TM.

The three first words of the TM packets (Packet Header) are the following:

- the first word is the TM packet identifier
- the second word is the packet counter
- the third word indicates the packet length in bytes.

Each Probe TM packet is constituted by 63 words.

The seventh word of the Probe dump TM packet gives the address of the first dumped word of the dumped area then the other 56 words are the dumped words.

The fourth to sixth words of the Probe HK and report TM packets give the RT counter and MT counter values then the other 57 words are parameters completed by zeros if needed.

There are four HK TM packets which differ by the parameter contents.

Each PSA TM packet is constituted by 91 words, the fourth to seventh words give the BIU time and the RT counter value.
The other 84 words of the PSA HK TM packet contains PSA parameters and software data.

The eighth word of the PSA dump TM packet gives the address of the first dumped word of the dumped area their the other 83 words are the dumped words.

Details on HK TM contents and TM list are given in Annex 2 TM/TC Data Tables.
Details on software data are given in § 4.4 (POSW) and § 4.5 (SASW)
Details on Experiment TM are given in Annex 3 Experiments TM/TC Data Tables.

6.2.3 Experiment Data Acquisition

PSA Source Packets are exclusively composed of locally generated housekeeping, while Super Packets, basically encapsulating the Probe Transfer Frames are more complex. They comprise both Experiment Source Packets and Housekeeping Source Packets.

The exact distribution of Experiment and HK Packets within a Frame is POSW driven, and follows the Polling Sequence Table in Table 6.2-1.

001: EXP	002: EXP	003: EXP	004: EXP	005: EXP	006: EXP	007: *HK1*	008: NULL
009: EXP	010: EXP	011: EXP	012: EXP	013: EXP	014: EXP	015: EXP	016: NULL
017: EXP	018: EXP	019: EXP	020: EXP	021: EXP	022: EXP	023: EXP	024: NULL
025: EXP	026: EXP	027: EXP	028: EXP	029: EXP	030: EXP	031: EXP	032: NULL
033: EXP	034: EXP	035: EXP	036: EXP	037: EXP	038: EXP	039: *HK2*	040: NULL
041: EXP	042: EXP	043: EXP	044: EXP	045: EXP	046: EXP	047: EXP	048: NULL
049: EXP	050: EXP	051: EXP	052: EXP	053: EXP	054: EXP	055: EXP	056: NULL
057: EXP	058: EXP	059: EXP	060: EXP	061: EXP	062: EXP	063: EXP	064: NULL
065: EXP	066: EXP	067: EXP	068: EXP	069: EXP	070: EXP	071: *HK3*	072: NULL
073: EXP	074: EXP	075: EXP	076: EXP	077: EXP	078: EXP	079: EXP	080: NULL
081: EXP	082: EXP	083: EXP	084: EXP	085: EXP	086: EXP	087: EXP	088: NULL
089: EXP	090: EXP	091: EXP	092: EXP	093: EXP	094: EXP	095: EXP	096: NULL
097: EXP	098: EXP	099: EXP	100: EXP	101: EXP	102: EXP	103: *HK4*	104: NULL
105: EXP	106: EXP	107: EXP	108: EXP	109: EXP	110: EXP	111: EXP	112: NULL
113: EXP	114: EXP	115: EXP	116: EXP	117: EXP	118: EXP	119: EXP	120: NULL
121: EXP	122: EXP	123: EXP	124: EXP	125: EXP	126: EXP	127: EXP	128: NULL

Legend:

"EXP": to indicate that the frame slot is to be loaded with an Experiment packet

"*HK1*": to indicate that the frame slot is to be loaded with a HK type 1 packet

"*HK2*": to indicate that the frame slot is to be loaded with a HK type 2 packet

"*HK3*": to indicate that the frame slot is to be loaded with a HK type 3 packet

"*HK4*": to indicate that the frame slot is to be loaded with a HK type 4 packet

"NULL": no packet acquisition - This time slot corresponds to the insertion by the CDMUs of the Reed-Solomon code block (128 bytes)

Note : - each slot represents 125ms
- The Major polling Cycle consists in the whole table (128 slots), and represents 16s.

TABLE 6.2-1 POLLING SEQUENCE TABLE

6.2.3-1 Experiment Packets Acquisition and Report

The design of the data acquisition interface and its operation is such that an adequate supply of data is collected in order to maintain a constant output data rate to the Probe transmitter. The design also ensures that the quantity of data collected from the Experiments does not exceed the output rate hence avoiding buffer memory overflows in the CDMS.

To this end the CDMS and the POSW are protected themselves against failure modes in the Experiments which could affect their data production rates. Each experiment is guaranteed to be given opportunity to supply data at, as a minimum, its nominal data rate.

The availability of a source packet from an experiment is indicated by a status line generated by the experiment, called "Packet Ready".

The CDMS through the POSW establishes the availability of scientific data packet by monitoring this Packet Ready line from each experiment. Valid status results in the data being collected from the experiment by the POSW via the CDMS.

Each experiment is polled on a **16 s repeat cycle basis**, software driven, at a rate which ensures the collection of all scientific data generated in accordance with the EID part A allocation, without exceeding the Relay Link transmission capability.

In order to optimize the data return, the polling scheme, controlled by the POSW, automatically reallocates the resource available due to the absence of a Packet Ready status flag when expected to the next experiment in the Experiment Polling Table in use.

Additionally, in order to minimize the risk of experiments failure in permanent "Ready Status" they are requested to reset the Packet Ready flag after having been polled and in any case before the next software cycle start (Broadcast Pulse occurrence).

The polling scheme actually consists in 3 tables, the Experiments Polling Tables (EPT), the swap from one EPT to the other one being driven by the time. These tables, presented in Tables 6.2-2 to 6.2-4, define the order of priority for the polling of the experiments.

In case no experiment is able to provide a Science Packet while they are requested for by the EPT, a Probe Housekeeping Packet is put in place of the missing science (Note that this configuration is nominal at mission start, before the first Experiment is powered on).

The overall process is illustrated in Figure 6.2-3.

Finally, an important consideration is that experiments source packets are reported in the telemetry frame in the same order than their acquisition one. Also, no buffering is performed inside the POSW or the CDMU, so that the time delay between a packet acquisition and its transmission to the PSA is 1second.

It is clear however that this statement does not consider the 6s buffering applied to the chain B for the overall data return to cope with a limited relay link "black out".

D9

001=>DISR	002=>HASI	003=>SSP	004=>DISR	005=>DISR	006=>DISR	
007=>DISR	008=>GCMS	009=>HASI	010=>DISR	011=>DISR	012=>DISR	013=>DISR
014=>DISR	015=>GCMS	016=>HASI	017=>DISR	018=>DISR	019=>DISR	020=>DISR
021=>DISR	022=>GCMS	023=>HASI	024=>DISR	025=>DISR	026=>DISR	027=>DISR
028=>DISR	029=>GCMS	030=>HASI	031=>DISR	032=>DISR	033=>DISR	
034=>DISR	035=>DISR	036=>GCMS	037=>HASI	038=>DISR	039=>SSP	040=>DISR
041=>DISR	042=>DISR	043=>GCMS	044=>HASI	045=>DISR	046=>DISR	047=>DISR
048=>DISR	049=>DISR	050=>GCMS	051=>HASI	052=>DISR	053=>DISR	054=>DISR
055=>DISR	056=>DISR	057=>GCMS	058=>HASI	059=>DISR	060=>DISR	
061=>DISR	062=>DISR	063=>DISR	064=>GCMS	065=>HASI	066=>DISR	067=>DISR
068=>DISR	069=>DISR	070=>DISR	071=>GCMS	072=>HASI	073=>DISR	074=>DISR
075=>SSP	076=>DISR	077=>DISR	078=>GCMS	079=>HASI	080=>DISR	081=>DISR
082=>DISR	083=>DISR	084=>DISR	085=>GCMS	086=>HASI	087=>DISR	
088=>DISR	089=>DISR	090=>DISR	091=>DISR	092=>GCMS	093=>HASI	094=>DISR
095=>DISR	096=>DISR	097=>DISR	098=>DISR	099=>GCMS	100=>ACP	101=>DISR
102=>DISR	103=>DISR	104=>DISR	105=>DISR	106=>DISR	107=>DISR	108=>GCMS

TABLE 6.2-2 EXPERIMENT POLLING TABLE 1

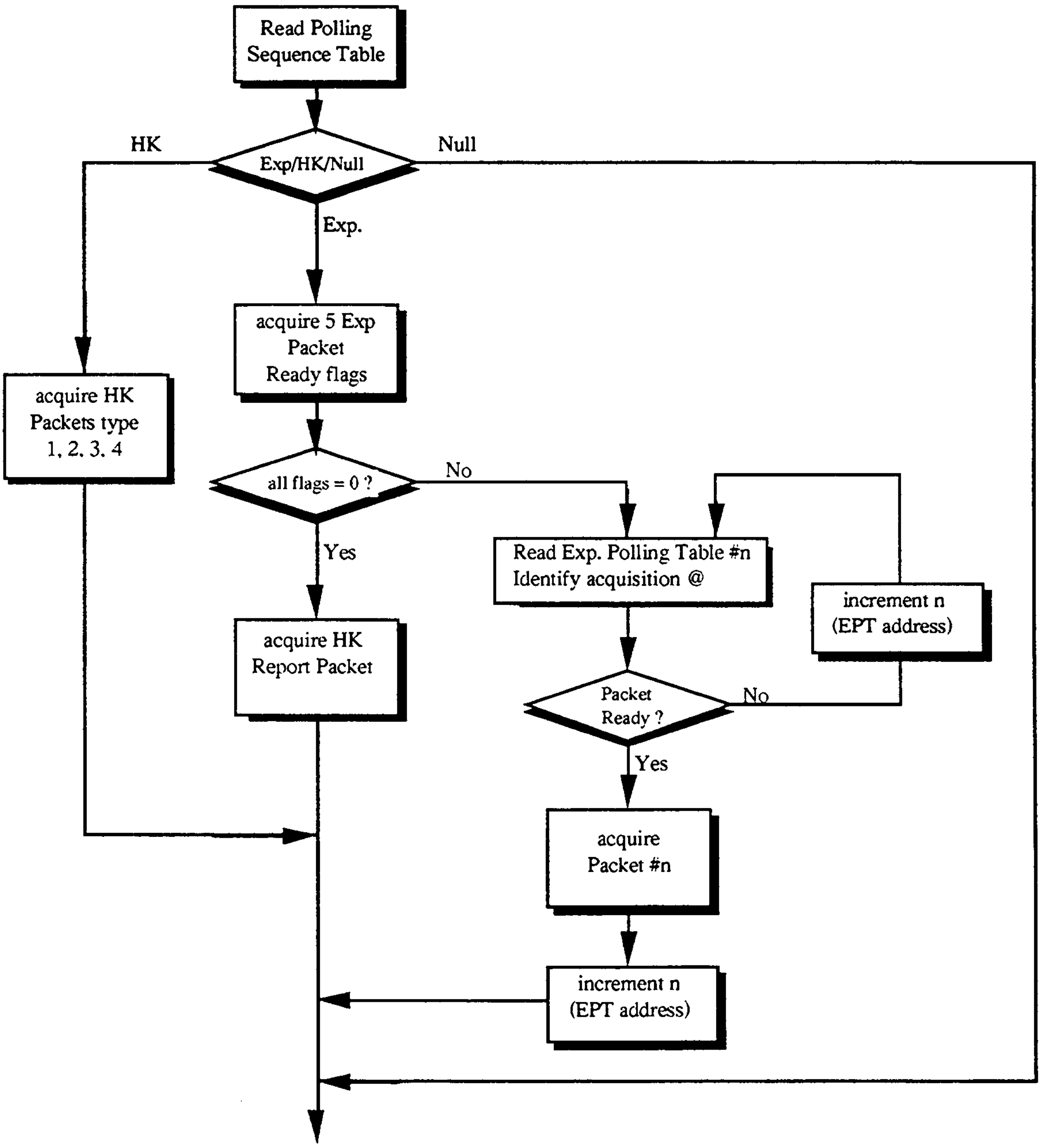
001=>GCMS	002=>HASI	003=>DISR	004=>SSP	005=>DISR	006=>ACP	
007=>DISR	008=>GCMS	009=>DISR	010=>DISR	011=>DISR	012=>DISR	013=>DISR
014=>HASI	015=>GCMS	016=>DISR	017=>SSP	018=>DISR	019=>DISR	020=>DISR
021=>DISR	022=>GCMS	023=>DISR	024=>DISR	025=>DISR	026=>HASI	027=>DISR
028=>DISR	029=>GCMS	030=>SSP	031=>DISR	032=>DISR	033=>DISR	
034=>DISR	035=>DISR	036=>GCMS	037=>DISR	038=>HASI	039=>DISR	040=>DISR
041=>DISR	042=>DISR	043=>GCMS	044=>SSP	045=>DISR	046=>DISR	047=>DISR
048=>DISR	049=>DISR	050=>HASI	051=>GCMS	052=>DISR	053=>DISR	054=>DISR
055=>DISR	056=>DISR	057=>SSP	058=>GCMS	059=>DISR	060=>ACP	
061=>DISR	062=>HASI	063=>DISR	064=>DISR	065=>GCMS	066=>DISR	067=>DISR
068=>DISR	069=>DISR	070=>SSP	071=>DISR	072=>GCMS	073=>DISR	074=>HASI
075=>DISR	076=>DISR	077=>DISR	078=>DISR	079=>GCMS	080=>DISR	081=>DISR
082=>DISR	083=>SSP	084=>DISR	085=>DISR	086=>HASI	087=>GCMS	
088=>DISR	089=>DISR	090=>DISR	091=>DISR	092=>DISR	093=>DISR	094=>GCMS
095=>DISR	096=>SSP	097=>DISR	098=>HASI	099=>DISR	100=>DISR	101=>GCMS
102=>DISR	103=>DISR	104=>DISR	105=>DISR	106=>DISR	107=>DISR	108=>DISR

TABLE 6.2-3 EXPERIMENT POLLING TABLE 2

D9

001=>GCMS	002=>HASI	003=>DISR	004=>DISR	005=>DISR	006=>ACP	
007=>DISR	008=>GCMS	009=>DISR	010=>DISR	011=>DISR	012=>SSP	013=>DISR
014=>HASI	015=>GCMS	016=>DISR	017=>DISR	018=>DISR	019=>DISR	020=>DISR
021=>SSP	022=>GCMS	023=>DISR	024=>DISR	025=>DISR	026=>HASI	027=>DISR
028=>DISR	029=>GCMS	030=>SSP	031=>DISR	032=>DISR	033=>DISR	
034=>DISR	035=>DISR	036=>GCMS	037=>DISR	038=>HASI	039=>SSP	040=>DISR
041=>DISR	042=>DISR	043=>GCMS	044=>DISR	045=>DISR	046=>DISR	047=>DISR
048=>SSP	049=>DISR	050=>HASI	051=>GCMS	052=>DISR	053=>DISR	054=>DISR
055=>DISR	056=>DISR	057=>SSP	058=>GCMS	059=>DISR	060=>ACP	
061=>DISR	062=>HASI	063=>DISR	064=>DISR	065=>GCMS	066=>SSP	067=>DISR
068=>DISR	069=>DISR	070=>DISR	071=>DISR	072=>GCMS	073=>DISR	074=>HASI
075=>SSP	076=>DISR	077=>DISR	078=>DISR	079=>GCMS	080=>DISR	081=>DISR
082=>DISR	083=>DISR	084=>SSP	085=>DISR	086=>HASI	087=>GCMS	
088=>DISR	089=>DISR	090=>DISR	091=>DISR	092=>DISR	093=>SSP	094=>GCMS
095=>DISR	096=>DISR	097=>DISR	098=>HASI	099=>DISR	100=>DISR	101=>GCMS
102=>SSP	103=>DISR	104=>DISR	105=>DISR	106=>DISR	107=>DISR	108=>DISR

TABLE 6.2-4 EXPERIMENT POLLING TABLE 3



MD-P

FIGURE 6.2-3 PACKET ACQUISITION PROCESS

6.2.3-2 Housekeeping Packets Acquisition and Report

As described through the Polling Sequence Table (see Table 6.2-1), 4 main types of Housekeeping Packets are identified : HK1, HK2, HK3 and HK4. Each of them is sent in a regular manner, every 4s. The housekeeping repetition cycle is therefore 16s.

Each of them reports specific parameters and has the following characteristics :

- HK1 mainly contains parameters relevant to the operation of the CDMU (control port, init status) and of the POSW (command counters, software status). It also reports the Probe relays and bi-level status.
  46 bytes are spare.

- HK2 contains parameters mainly relevant to PCDU operation, and the temperature measured on board the Probe. It also includes the radial accelerometers measurements.
  4 bytes are spare.

- HK3 reports the data sent to the experiments in the frame of the Descent Data Broadcast, the experiments Packet Ready flags, and the altitude acquired by the Proximity Sensors.
  18 bytes are spare.

- HK4 is exclusively devoted to the report of the central accelerometers measures.
  66 bytes are spare.

The acquisition of housekeeping parameters is spread over the 16s major cycle, according to the CHAT described in § 4.4 POSW. In order to maintain a constant processor load, an average of 3 parameters per software cycle (125ms) is acquired.

This acquisition is not synchronized with the building and emission of the packets through the transfer frames; this means that there can be up to 16s delay between a parameter acquisition and its transmission inside a source packet.

An exception to this rule is HK4. The data it reports, indeed, is the measured deceleration during the Entry phase of the Probe. Although this information is of the highest interest, the relay link between Huygens and Cassini, at that time, will not be established. Consequently, in order to guarantee that the whole entry profile is available for ground analysis, the insertion of HK4 in the transfer frame is delayed by 24 major cycles, i. e. 6.4mn. It must be pointed out that the entire packet structure is delayed, not just the acceleration data inside.

Nevertheless, the first 24 HK4 following POSW initialization, are not delayed but transmitted similarily to HK1, 2 & 3 (this means that the first 24 HK4 packets are sent twice, with an identical header).

Another telemetry packet type is the "Report Packet". It aims at replacing Experiment Packets slots in the Polling Sequence Table, when no experiment is ready to deliver data. It simply contains Batteries voltage, Tx and HPA supply voltages

The last telemetry packet type is the "Dump Packet", sent in response to the "Dump TC". The number of "Dump Packets" corresponding to the requested dump size is sent in place of consecutive Experiment - or Report- packets.

6.2.4 TM Operational Constraints

• Before separation TM is transmitted via umbilical link while after separation, TM is transmitted via the radio link.

• SASW (POSW) will deliver TMs only 15 seconds after PSA (CDMU) are powered ON.

• The acquisition of HK parameters is not synchronized with the building and emission of the packets through the transfer frames; this means that there can be up to 16s delay between a parameter acquisition and its transmission inside a source packet.
An exception to this rule is HK4; the insertion of HK4 in the transfer frame is delayed by 24 major cycles, i. e. 6.4mn. Nevertheless, the first 24 HK4 following POSW initialization, are not delayed but transmitted similarily to HK1, 2 & 3 (this means that the first 24 HK4 packets are sent twice, with an identical header).

• In case no experiment is able to provide a Science Packet while they are requested for by the EPT, a Probe Housekeeping Packet is put in place of the missing science (Note that this configuration is nominal at mission start, before the first Experiment is powered on).

• Probe Chain B Transfer Frames are delayed by 6s w.r.t. Probe Chain A Transfer Frames.

6.3 ORBITER COMMANDS

The Orbiter commands which may be scheduled by the Huygens Flight Control Team are:

COMMAND	DESCRIPTION
80PS_PROBE_PWR	Turns ON or OFF the Probe Power Inputs (See PP01 in Doc n° HUY.AS/c.100.OP.0384)
80PS_PSA_PWR	Turns ON or OFF the PSA-A or PSA-B (See RP01 in Doc n° HUY.AS/c.100.OP.0384)
80PSA_A	To deliver a Probe Telecommand Packet to PSA_A
80PSA_B	To deliver a Probe Telecommand Packet to PSA_B
80RT_RESET_PSAA	Reset PSA-A microprocessor
80RT_RESET_PSAB	Reset PSA-B microprocessor
80RT_RTDT_PSAA	Reload PSA-A RTDT
80RT_RTDT_PSAB	Reload PSA-B RTDT
80RT_WDTERR_PSAA	Enable/Disable the Watchdog Timer Expired Flag in PSA-A BIU
80RT_WDTERR_PSAB	Enable/Disable the Watchdog Timer Expired Flag in PSA-B BIU
80RT_WPERR_PSAA	Clear/Set the Write Protect Violation Flag in PSA-A BIU
80RT_WPERR_PSAB	Clear/Set the Write Protect Violation Flag in PSA-B BIU
80RT_WPFNC_PSAA	Enable/Disable the Write Protect Function in PSA-A BIU
80RT_WPFNC_PSAB	Enable/Disable the Write Protect Function in PSA-B BIU

The following commands may be issued only by the Cassini spacecraft controllers; they are given for information:

COMMAND	DESCRIPTION
80CE_PRB_SEP	Enable Orbiter-Probe Separation pyro command
80PY_PRB_SEP	Issue Orbiter-Probe Separation pyro Fire command
80PS_RFE_HTR	Turns ON/OFF the RFE Replacement Heater A or B

6.4 ORBITER TM PARAMETERS

Some probe TM parameters are only sent to Orbiter. They are:

- SEPS temperature 1 to 4: M1001T to M1004T; see § 4.7.1-6-2 of § 4.7 and § 4.6.1-5-2 in § 4.6
- Input relay loop: P5001R; see § 4.3.1-6-2-a in § 4.3
- Timer relay loop: P5082R; see § 4.3.1-6-2-b in § 4.3
- LNAs temperature: R3003T and R4003T; see § 4.2.1-6-2 in § 4.2 and § 4.6.1-5-2 in § 4.6
- PSAs temperature: R5011T and R6011T; see § 4.2.1-6-2 in § 4.2 and § 4.6.1-5-2 in § 4.6
- Probe temperature 1 (bracket Batt 1a): T001T; see § 4.3.1-6-2-g in § 4.3 and § 4.6.1-5-2 in § 4.6
- Probe temperature 2 (PCDU box): T002T; see § 4.3.1-6-2-g in § 4.3 and § 4.6.1-5-2 in § 4.6
- Probe 1553 TM A and B used to transfer Probe TM to Orbiter.