ALENIA SPAZIO S.p.A.

PROGRAM : SHARAD

U S E R   M A N U A L

TITLE : **SHARAD - FLIGHT USER MANUAL**

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1 Introduction

1.1 Scope

This document presents the Flight User Manual (FUM) for the Mars Reconnaissance Orbiter payload instrument SHARAD (SHAllow RADar). It defines the mission objectives, physical and functional configuration and operational modes of the instrument. It also describes how the instrument can be controlled, utilized and monitored by ground operations.

1.2 Reference Documents

The following documents may be referred for further, more detailed, information regarding topics discussed in this document. These documents are available on request.

Id	***Document Number***	***Description***
[RD-01]	MRO-31-201	MRO Mission Plan
[RD-02]	RQS-SHR-0004-INF	SHARAD System Functional Req. Doc. (Issue 2)
[RD-03]	SPE-SHR-0027-ALS	SHARAD DES Requirements Spec. (Issue 3)
[RD-04]	RQS-SHR-0014-ALS	SHARAD On Board Processing Req. Spec. (Issue 3)
[RD-05]	SPE-SHR-0045-ALS	DCG Internal Interfaces Specification (Issue 2)
[RD-06]	RQS-SHR-0012-ALS	SHARAD RX Requirements Spec. (Issue 2)
[RD-07]	RQS-SHR-0011-ALS	SHARAD TFE Requirements Spec. (Issue 2)
[RD-08]	RQS-SHR-0030-ALS	SHARAD Antenna Requirements Spec.
[RD-09]	TL19749	DES Design Report (Issue 3)
[RD-10]	TL19844	DES HW/SW Interfaces (Issue 2)
[RD-11]	TL19769	TC/TM Packet Structure Definitions (Issue 7)
[RD-12]	TL19765	OST/PT/ODT Definitions (Issue 7)
[RD-13]	TL20340	SHARAD DES SW CIDL (Issue 8)
[RD-14]	MRO-01-0028	SHARAD to MRO ICD (Rev. C)
[RD-15]	0171-Telecomm-NJPL	JPL created SFDU structures

1.3 Annexed Documents

The following documents shall be considered, for the given issue of this manual, as an integral part of this document.

Id	*Document Number*	*Description*
[AD-01]	SPE-SHR-0045-ALS	DCG Internal Interfaces Specification (Issue 2)
[AD-02]	TL19769	TC/TM Packet Structure Definitions (Issue 7)
[AD-03]	TL19765	OST/PT/ODT Definitions (Issue 7)
[AD-04]		SHARAD Command Dictionary (from MRO Command Dictionary)
[AD-05]		SHARAD Telemetry Dictionary (from MRO Telemetry Dictionary)

1.4 Acronyms List

The intended meaning is given, hereafter, of the acronyms and abbreviations used in this document.

ADC	Analogue to Digital Converter
AIV	Assembly, Integration and Verification
ALS	Alenia Spazio
APID	Application Processor ID
ANT	Antenna (unit)
ASDC	ASI Science Data Center
ASI	Agenzia Spaziale Italiana – Italian Space Agency
ATLO	Assembly, Test and Launch Operations
BB	Bread Board (model)
C&C	Command and Control
C&DH	Command and Data Handling
CADM	Configuration And Data Management
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CFDP	CCSDS File Delivery Protocol
CLFP	Component-Level Fault Protection
CMD	Command (refers to a software command)
COG	Center Of Gravity
COTS	Commercial Off-The-Shelf
CPU	Central Processing Unit
DCG	Digital Chirp Generator
DDS	Direct Digital Synthesizer
DES	Digital Equipment Section (unit)
DMD	Data Monitoring Display
DPA	Destructive Physical Analysis
DSP	Digital Signal Processor
ECC	EGSE Control Computer
EEPROM	Electrically Erasable Programmable Read Only Memory
EGSE	Electrical Ground Support Equipment
EIDP	End Item Data Package

EM	Engineering Model
EOL	End Of Life
EOM	End Of Mission
FM	Flight Model
FMECA	Failure Mode Effect and Criticality Analysis
FPGA	Field Programmable Gate Array
FRD	Functional Requirements Document
FSW	Flight Software (typically refers to MRO C&DH SW)
FUM	Flight User Manual
GDS	Ground Data System
GSE	Ground Support Equipment (generic)
HK	HouseKeeping (Telemetry)
HLFP	High-Level Fault Protection
HMI	Human/Machine Interface (preferred to MMI)
HPF	High Pass Filter
HW	Hardware
I/F	Interface
ID	Interface Drawings or Interface control Document (depending on context)
ICD	Interface Control Document or Interface Control Drawing (depending on context)
IEM	Interface Engineering Model
IFL	Interactive File Load
IP	Internet Protocol
IPTF	Integrated Pointing and Targeting File
ITL	Integrated Targeting Load
JPL	Jet Propulsion Laboratory
LAN	Local Area Network
LPA	Low Pass Filter
LMA	Lockheed Martin Astronautics
LOA	Letter Of Agreement
LVDS	Low Voltage Differential Signalling
MEGS	Mars Echo Generator

MGSE	Mechanical Ground Support Equipment
MICD	Mechanical Interface Control Drawing
MMI	Man/Machine Interface (deprecated term, see HMI)
MO	Master Oscillator
MOS	Mission Operations System
MRO	Mars Reconnaissance Orbiter
MROCIP	MRO Commaind Interface Protocol
MROSP	MRO Science Protocol
MROSS	MRO Spacecraft Simulator
MSPS	MegaSample Per Second
N/A	Not Applicable
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NCO	Numerical Controlled Oscillator
NIFL	Not Interactive File Load
NIPC	Not Interactive Payload Command
OBS	On Board Software
OBT	On Board Time
ODT	Orbital Data Table
OFTR	Over Flight Temperature Range
OOL	Out Of Limits
ORR	Operational Readiness Review
OST	Operational Sequence Table
OTB	Orbiter Test Bed
P/L	PayLoad
PDR	Preliminary Design Review
PFCT	Payload Fit Check Template
PFM	Proto Flight Model
PIS	Payload Interface Simulator
PPC	Post Processing Computer
PRI	Pulse Repetition Interval (= 1/PRF)
PRF	Pulse Repetition Frequency (= 1/PRI)
PSA	Parts Stress Analysis
PT	Parameters Table or Product Telemetry (File)
PTF	Pointing and Targeting File

RAMS	Reliability, Availability, Maintainability and Safety
RDS	Receiver and Digital Section
RFFE	Radio Frequency Front End
RX	Receiver (unit)
S/C	Spacecraft
SASF	Spacecraft Activity Sequence File
SCET	SpaceCraft Elapsed Time
SDI	Science Data Interface
SEB	SHARAD Equipment Box
SFC	Spacecraft Flight Computer
SFDU	
SHARAD	SHAllow RADar
SI	Systeme International d'Unites (International System of Units)
SOPC	Science Operations and Planning Computer
SPF	Single Point of Failure
SRAM	Static Random Access Memory
SSR	Solid State Recorder
SW	Software
T/R	Transmit/Receive
TBC	To Be Confirmed
TBD	To Be Defined
TBS	To Be Specified
TBV	To Be Verified
TC	TeleCommand (refers to discrete telecommands)
TFE	Transmitter – Front End (unit)
TLM	Telemetry (refers to software telemetry)
TLP	Track Length Position
TLU	Track Length Unit
TM	TeleMetry (refers to discrete, or analog, telemetries)
TTL	Transistor-Transistor Logic
TRP	Temperature Reference Point
TRR	Test Readiness Review
TVT	Thermal Vacuum Test
TX	Transmitter
UDP	User Datagram Protocol
UUT	Unit Under Test

VC	Virtual Channel
WAN	Wide Area Network
WBS	Work Breakdown Structure
WCA	Worst Case Analysis
WPD	Work Package Description
WPF	Window Positioning Function
wrt	with reference to

2 General Description

2.1 Introduction

SHARAD is the sub-surface sounding radar provided by the Italian Space Agency (ASI) as a facility instrument to NASA's 2005 Mars Reconnaissance Orbiter.

SHARAD's goal is the detection of liquid water and the profiling of ice layers within the first few hundreds meters of the Martian subsurface. Even if Mars surface is not uniformly apt for radar sounding, it will however be possible to find favourable conditions, which may allow the identification from orbit of aqueous layers. SHARAD will also provide new scientific data about Martian soil, ground morphologies and overall geology.

SHARAD is expected to operate on the night side of the orbit, at least 4 times a day (that is during 4 orbits). Each operation will last roughly 30 minutes. A possibility exists for SHARAD to be operated also on the dayside depending from mission constraints and requirements.

Orbit characteristics, for the Primary Science Orbit, are as follows:

- Altitude: 255x320 km
- Inclination: 92.66°
- Sun-synchronous orbit: AN @ -10.7°, LMST 15:00h +/- 15'
- Period: 112.2 minutes
- Eclipse duration: min 30 minutes, max 39 minutes.

The Primary Science Phase last one Martian year, i.e. 687 days. Launch, interplanetary cruise and Mars orbit insertion will last about 210 days, aerobraking phase and primary science orbit attainment will last between 120 and 180 days.

2.2 Scientific Objectives

To summarise, the primary objective of the SHARAD investigation is to map, in selected locales, dielectric interfaces to depths of up to one kilometre in the Martian subsurface and to interpret these interfaces in terms of the occurrence and distribution of expected materials, including rock, regolith, water, and ice.

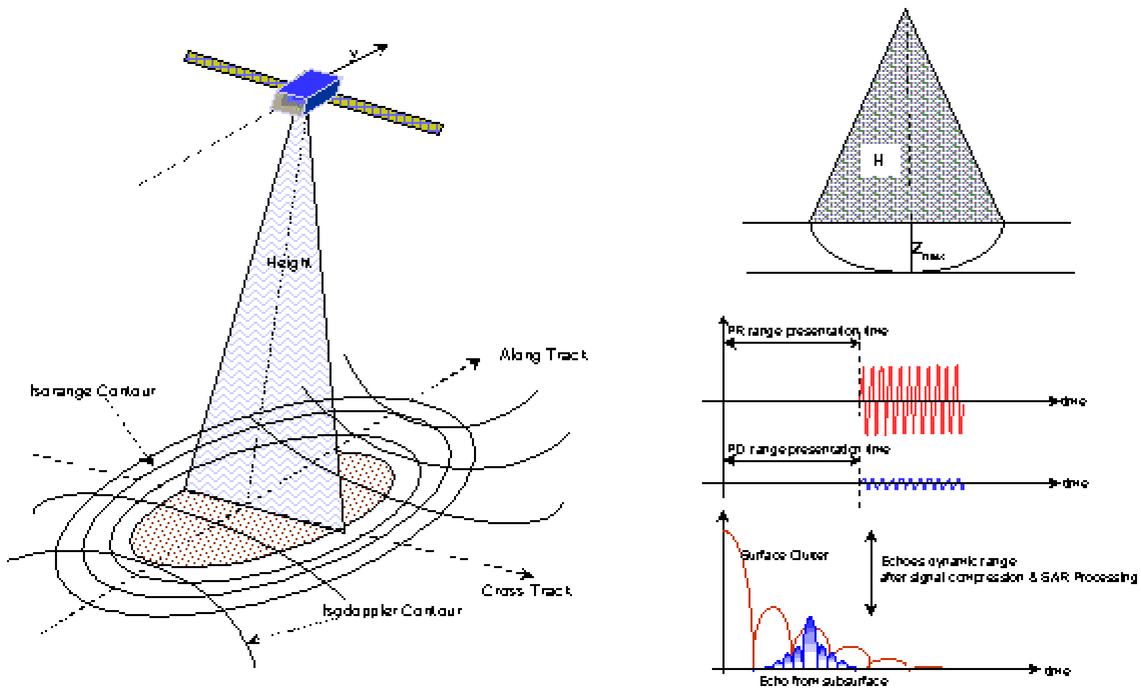
In particular, the SHARAD science objectives are:

- Map the distribution of water/brine and ice within the 1st kilometre of the subsurface in selected regions of Mars.
- Map the thickness, extent and continuity of the layers within the polar deposits.
- Map the thickness, extent and continuity of sedimentary layers.
- Map the distribution of shallow buried channels.
- Determine electromagnetic properties of the shallow subsurface.
- Identify regions on Mars for follow-up surface-based water/ice exploration.

2.3 Functional Objectives

SHARAD will be programmed upon need to perform radar measurements in different operating modes thus receiving commands and producing Science Data. To accomplish this SHARAD will interface with different S/C's resources (C&DH, SSR, Power).

Key elements for the radar design are represented by the identified centre frequency, 20 MHz, the bandwidth of the radar pulse equal to 10 MHz, and the requested spatial resolution which should be better that 1000 m in the along-track direction and 7000 m in the cross-track direction.



The radar shall be able to radiate, through its antenna, frequency modulated radar pulses of 85 microseconds in length. The resultant bandwidths will be around 10 MHz.

2.4 Instrument Overview

2.4.1 Design

The SHARAD instrument is functionally composed by two building blocks:

- The transceiver, composed by two units (named RDS and TFE) located in the SHARAD Electronic Box (SEB)
- The antenna (10 m foldable dipole)

The RDS implements both digital (including digital chirp generation) functions in the DES and the analogue, receiving functions in the RX.

A functional block diagram is provided in fig 2.3.1-1.

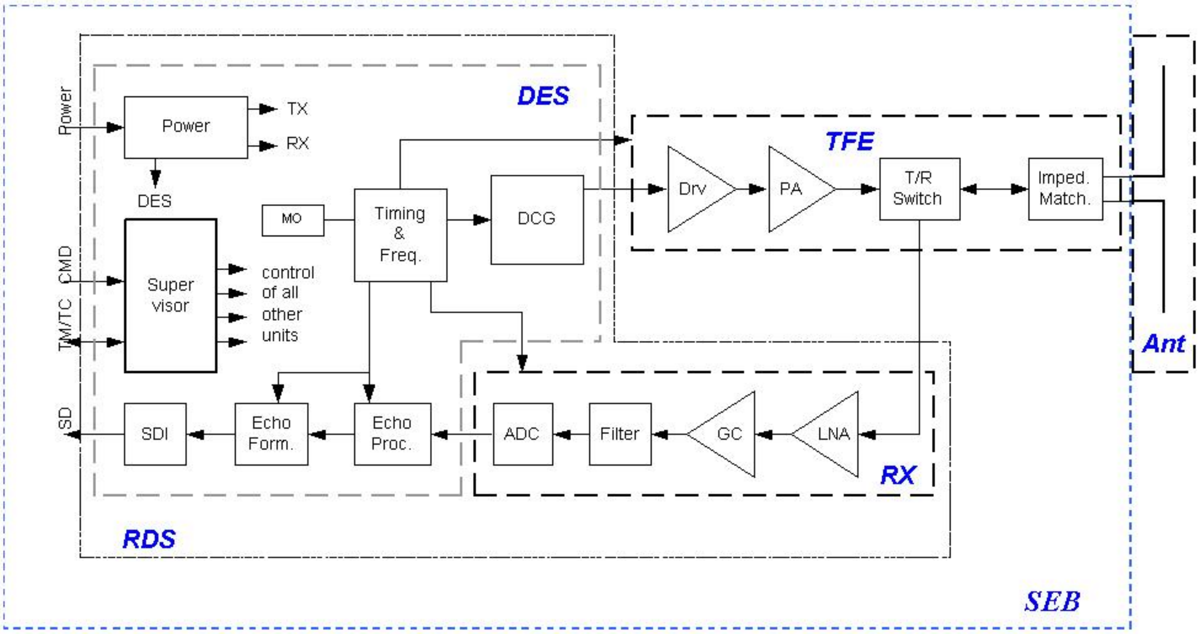


Figure 2.4-1: SHARAD Block Diagram.

2.4.1.1 Tx/Rx functions

The transmitting chain is composed by a digital chirp generator (DCG), located in the RDS/DES, that generates the transmitted chirp directly at RF (20 MHz +/- 5 MHz) using a stepped-phase Direct Digital Synthesizer (DDS).

This approach has been preferred versus the more flexible Memory ReadOut approach for its lower complexity. Compensation for hardware distortions (which can be introduced in the transmitted signal using an MRO approach) shall be (due to the tight distortions requirements) implemented on ground on the received data anyway, making the Memory ReadOut flexibility advantage useless. The DDS approach should also allow to easy change the transmitted pulse initial phase, which can be exploited for range-rate compensation.

The signal from the Digital Chirp Generator is boosted to suitable power level in the TFE, by means of a class C power amplifier.

The TFE contains also:

- the balun to provide a balanced feed to the antenna;
- the matching network required to ensure the optimum power transfer to/from the antenna;
- the T/R switch to provide duplexing between Tx and Rx functions.

The power amplifier works on 50 Ohm impedance and feed the T/R switch (implemented with an high power MOSFET). A low-pass, multicell matching network, followed by a balun match the 50 Ohm impedance seen on the T/R side to the high impedance, frequency dependant, balanced impedance of the antenna.

The antenna is a dipole, 10 m long, realised using 2 flexible dielectric tubes (one each arm) containing a wire which is, in fact, the effective antenna element.

The tubes are folded and tied together during launch and cruise and deployed by release of the tie-down brackets.

On receiving, the signal from the antenna follow the reverse path until the T/R, which route the signal to the TFE Rx output, connected to the receiver.

The receiver performs the following tasks:

- signal amplification
- bandpass filtering
- gain control (open loop, under control of the DES)
- analogue-to-digital conversion

The A/D converter, operating at the RF frequency (after up-conversion, if processing and down-conversion) performs an undersampling of the signal, acquiring, during the receive window, at a rate of 26.67 Msamples/sec, with a resolution of 8 bits. The sampling frequency has been selected in order to:

- allow unambiguous sampling of the received signal over the range 15-25 MHz
- simplify extraction of baseband I/Q components for later processing 8both on-board and on-ground)

The digitised data are then transferred to the DES section of the RDS, where they are buffered in a FIFO before being fed to the FPGA which is in charge of echo presumming and pre-formatting. The surface tracking function is software implemented by the DES Supervisor, which also schedule all the activities related to radar operations. The digitised and processed data are then packetised and sent to the Spacecraft.

2.4.1.2 Instrument Control function

The control of the instrument is also performed by the DES Supervisor (a TSC21020 DSP), by receiving Telecommands sent by the S/C and processing them according to its operational state. The DES Supervisor activities are monitored by means of Housekeeping Telemetries. Time-keeping services are also managed and synchronised to S/C OBT.

While Telecommands are received by the S/C C&DH (Command and Data Handling) computer, Telemetries are sent to the S/C SSR (Solid State Recorder) together with Science Data packets. S/C monitoring of the instrument is accomplished through 4 discrete TM signals, which provide status information to the S/C FSW (Flight Software). The S/C C&DH can disable activation of SHARAD TFE by means of a dedicated discrete TC.

2.4.2 Operations

SHARAD is designed to be kept, when not operating any of the science modes, in a minimum power state (STAND-BY) with only the digital electronics powered. In this state the instrument is able to receive commands from the S/C.

During the operational science modes, SHARAD does not respond to S/C commands and operates according to a pre-programmed sequence recorded in the **Operation Sequence Table** (OST), loaded during the STAND-BY mode, and triggered by an Enable OST command.

During these programmed operations, other two pre-loaded tables are used by SHARAD: the **Parameter Table** (PT) containg information about surface topography and required slope compensation, and the **Orbital Data Table** (ODT), containing predicted orbital data like spacecraft altitude and radial velocity. Also these tables are loaded while in STAND-BY state.

After completion of the OST sequence, SHARAD returns in STAND-BY state and is ready to be programmed for another science pass. SHARAD can be programmed only for one science pass at each time.

In case of anomalies, the instrument, as well as a science pass sequence, can be suddenly switched off without any concern for the instrument.

3 Instrument Design Description

3.1 Instrument Configuration

SHARAD is composed by two main physical elements, the SEB (SHARAD Electronic Box) and the Antenna.

The SEB includes all the transceiver electronics and the signal processing and control functions, and is made up from two separate electronic assemblies (RDS and TFE) mounted on a support structure which acts as radiator for the thermal control and which includes the heaters and temperature sensors.

The RDS - Receiver and Digital Section - (composed by several modules stacked together) is, in turn, divided into the DES (Digital Electronic Section), in charge of instrument control, communication with the S/C, timing generation and processing of the received data, and generation of the transmitted chirp signal, and by the Receiver (Rx) which amplifies, filter and digitise the received signal.

The TFE (Transmitter and Front End) provides amplification of transmitted signal, Tx/Rx duplexing, and includes the matching network required to interface the antenna.

The Antenna is a 10 m dipole made of two 5 m foldable tubes which, in stowed configuration, are kept in place by a system of cradles and, when released, will self-deploy thanks to its elastic properties. The Antenna interfaces electrically with the SEB (TFE). The antenna includes also its release mechanism and related thermal control.

The resultant hierarchical configuration is shown in next figure:

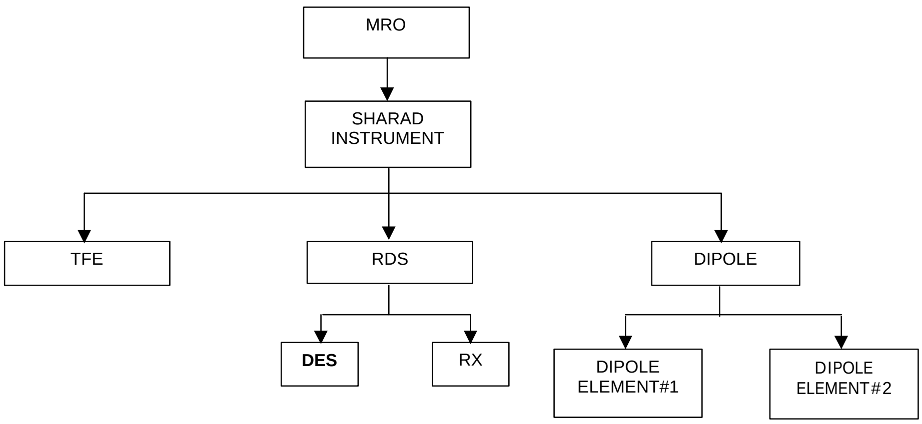


Figure 3.1-1: Instrument Hierarchical Configuration.

An overall view of the SEB is shown in next figure:

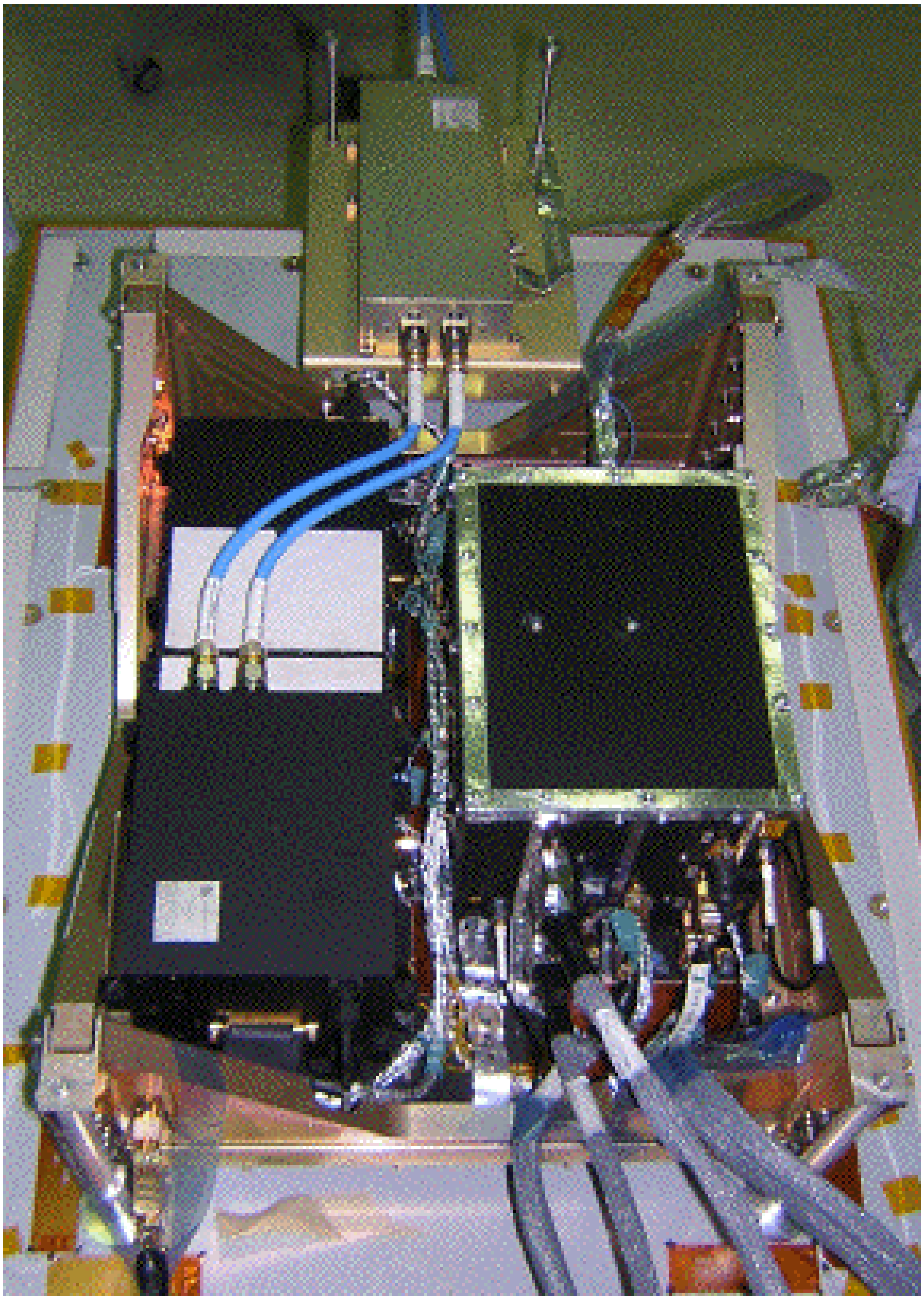


Figure 3.1-2: SEB Internal Layout (PFM during final integration)

3.2 Hardware Description

3.2.1 Digital Equipment Section

The Digital Electronics Section (DES) is the heart of SHARAD and concentrates many functions of the instrument, including command and control, low-power radar pulses generation, science data processing and formatting, timing. The DES provides all the hardware and software components in order to enable SHARAD operations. These components are used to perform the following functionalities:

- command and control capability (by way of S/C's C&DH);
- command and control capability of other SHARAD's units;
- formatting of Science Data and their transfer as Telemetry to the S/C's SSR;
- generation of Housekeeping Telemetry and its transfer to the S/C's SSR;
- generation of the radar chirp signal;
- processing of radar raw data;
- provision of a high-stability oscillator and generation of timekeeping and synchronisation signals for all SHARAD's units;
- power conditioning and distribution to the other SHARAD's units.

The DES is based on a modular design. The Receiver Section (RX) shares DES' same mechanical form factor and is joined to the DES to is also implemented as a self-standing module within the DES architecture.

The following picture shows DES functional architecture from a top-level design viewpoint:

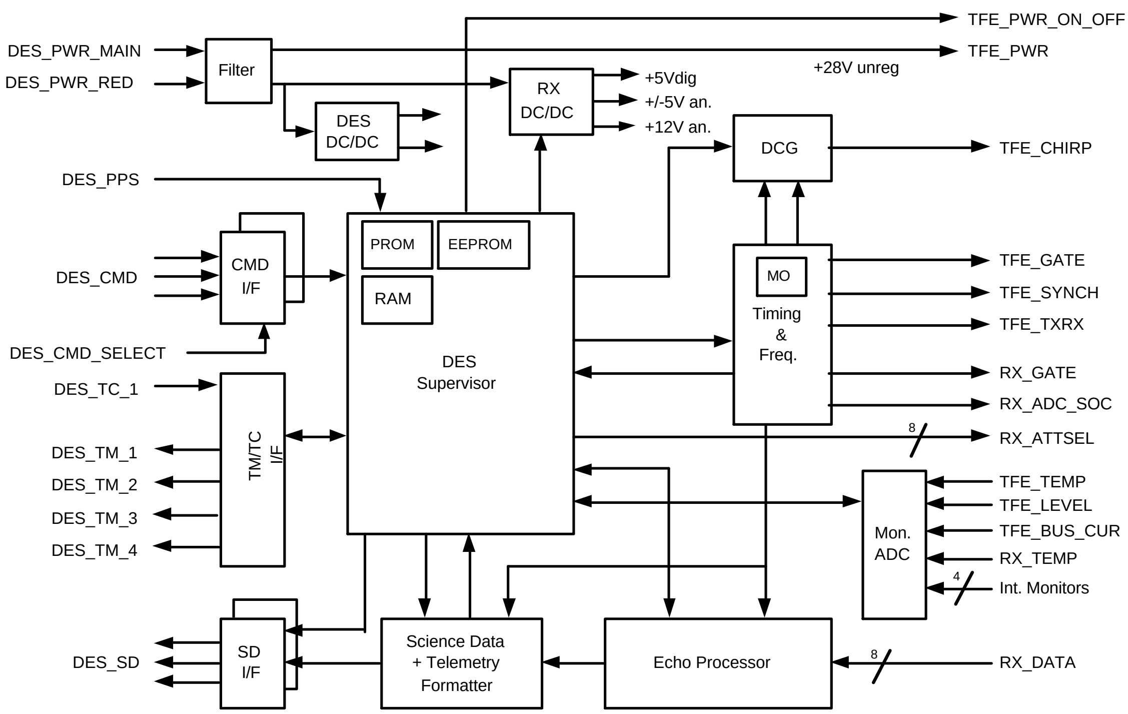


Figure 3.2.1-1: DES Functional Architecture

SHARAD's DES is constituted by the following items (see figure 3.2.1-2):

- DSP Module
- Service Module
- Digital Chirp Generator (DCG) Module
- Harness
- Mechanics

The DSP Module is constituted by the Command & Control Board and the Slave Board, which are mounted on the same mechanical frame.

The Service Module is constituted by the Timing Board and the DC/DC Converter Board, which are mounted on the same mechanical frame.

The Digital Chirp Generator Module is constituted by the DCG board enclosed in its own mechanical frame.

The boards are connected one to the other through the DES internal harness, which allows also the connections with the SHARAD Receiver (once mechanically joined to the DES to form the RDS).

DES block schematic is shown in Figure 3.2.1-3 while overall interconnections are depicted in Figure 3.2.1-3.

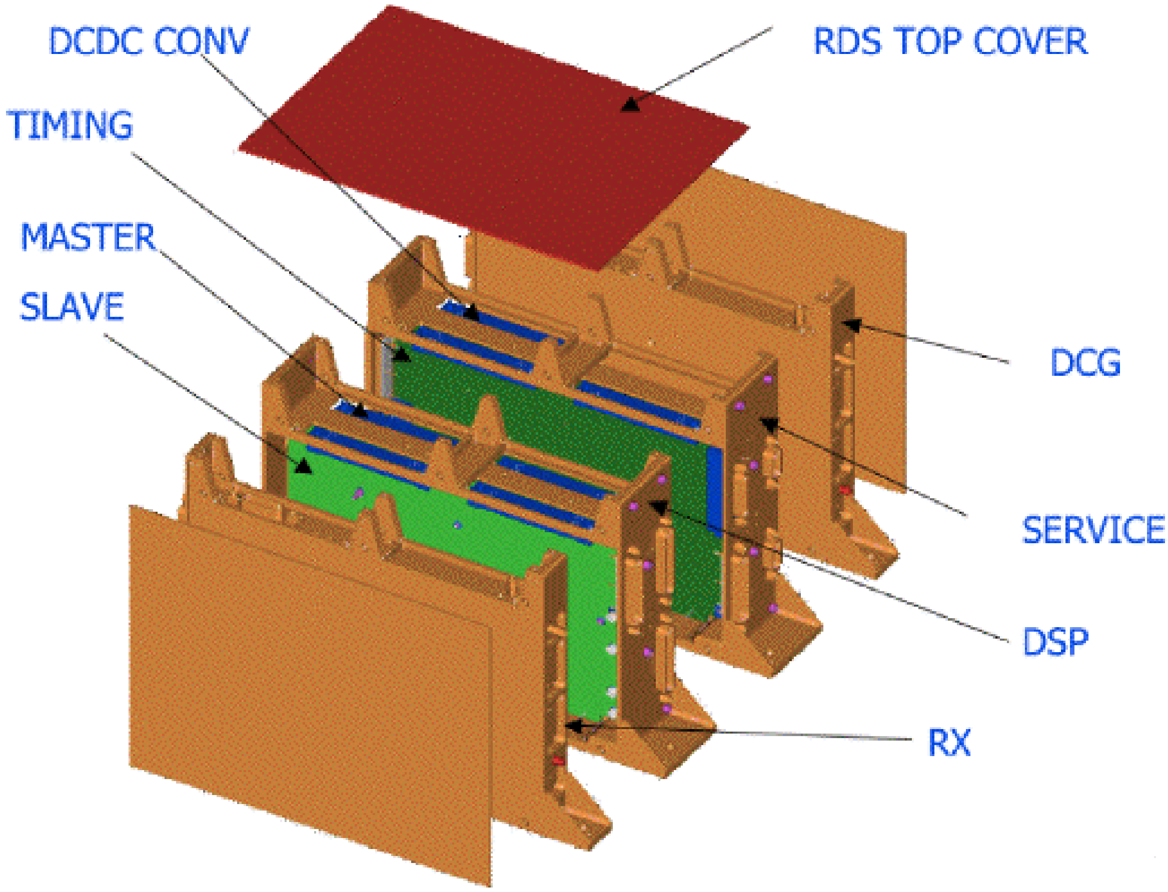


Figure 3.2.1-2: DES mechanical composition.

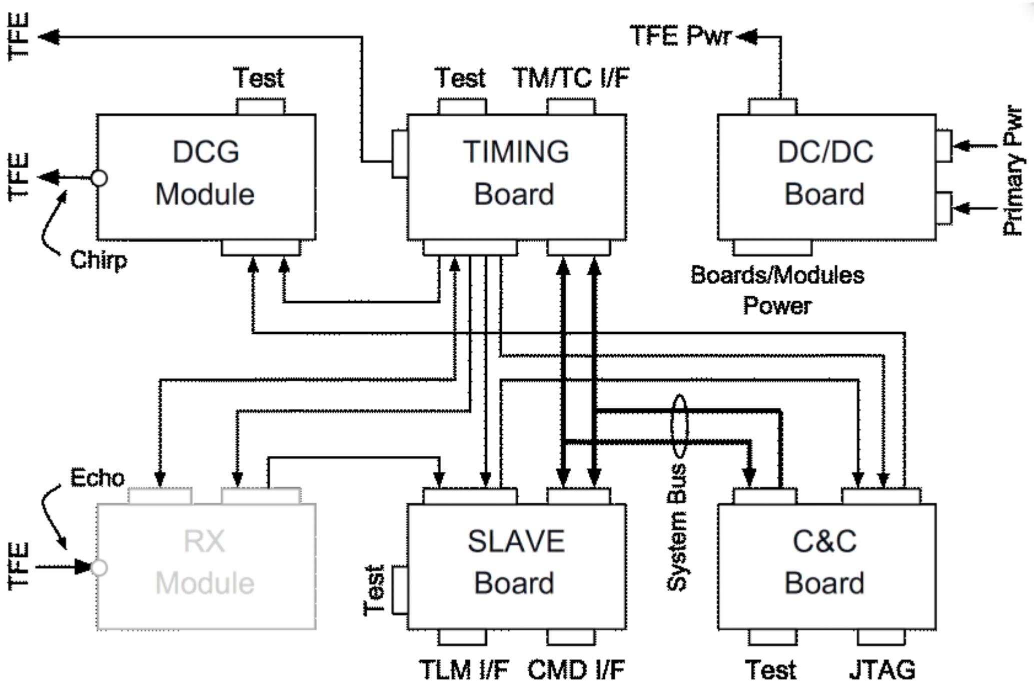


Figure 3.2.1-3: DES Block Schematic.

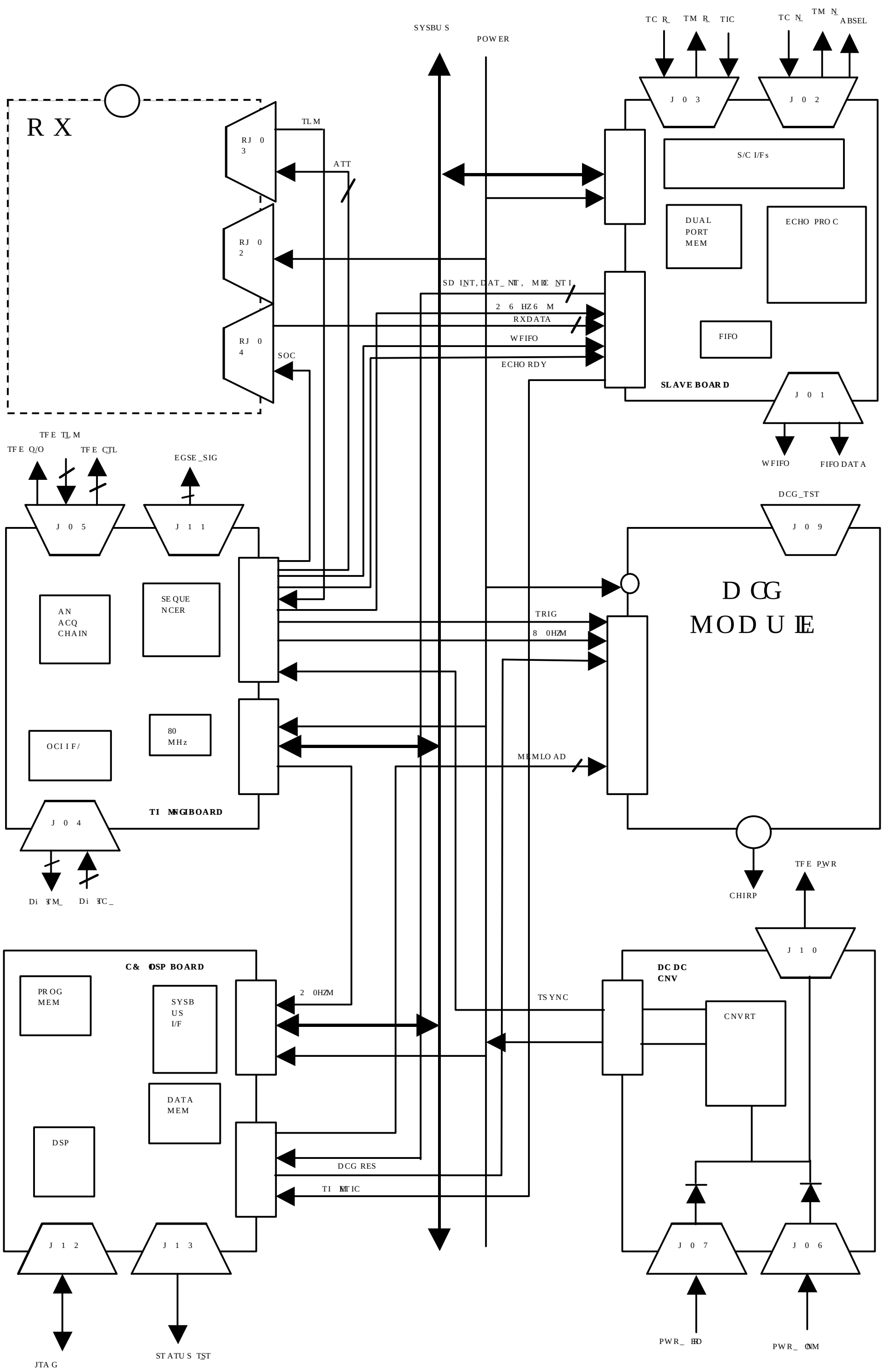


Figure 3.2.1-4: DES boards interconnections.

3.2.1.1 DC/DC Converter Board

SHARAD power distribution is managed by the DC/DC Converter Board, which also provides all the required supply voltages (according to the block schematic in Figure 3.2.1-4).

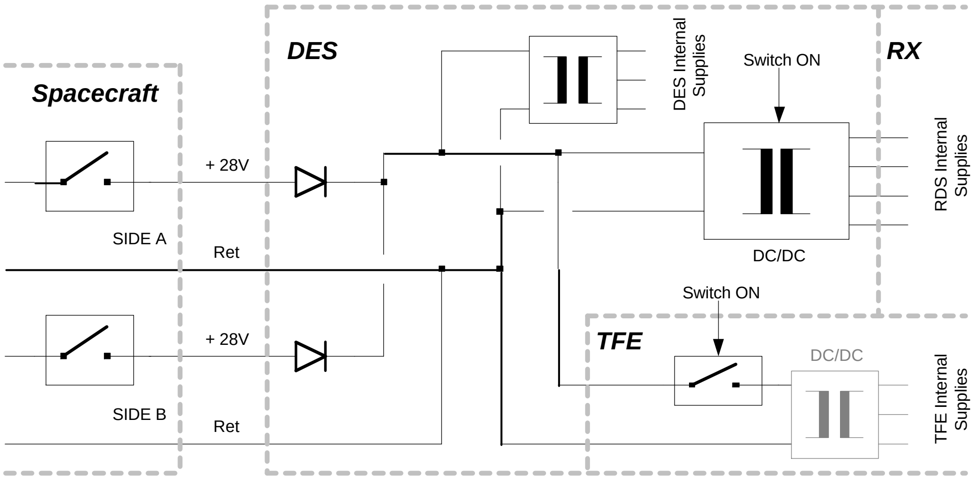


Figure 3.2.1-5: DES Power Distribution

The DES and the RX are powered by the same DC/DC converter.

The RX DC/DC converter can be switched ON with a bilevel signal under SW control.

The TFE DC/DC converter is located in the TFE, and can be switched ON/OFF under SW control through an optocoupled interface. The 28V for the TFE is the OR of the nominal and the redundant lines.

The DES and RX DC/DC converter is a free running one at 131KHz +-10% (which bears no correlation with any of SHARAd's PRF values) and provides synchronisation to the TFE DC/DC converter (which is slaved to DES DC/DC converter's frequency).

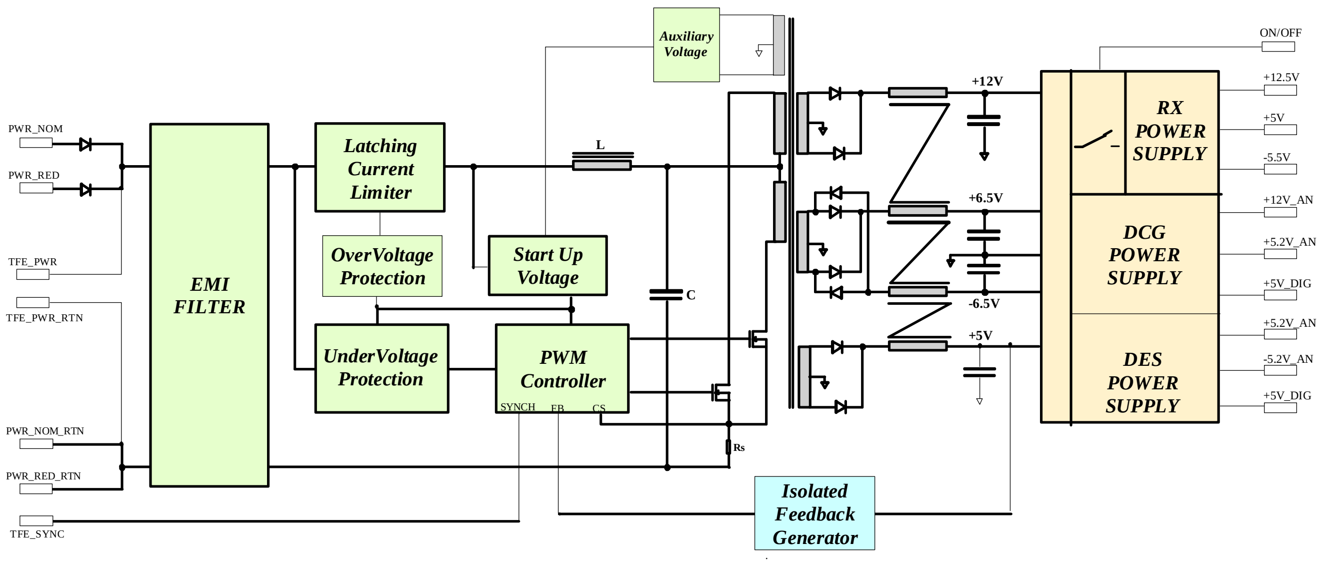


Figure 3.2.1-6: DC/DC Converter Board Block schematic

3.2.1.2 Command & Control Board

The command and control board design is derived from the one of MARSIS and is based on a ATMEL's Digital Signal Processor TSC21020F operating at 20 MHz. CPU clock is derived from the 80 MHz Master Oscillator on the Timing Board.

The DSP can access contemporarily two different memory buses:

- The Program memory bus, where two different banks of memories are mounted
- The Data memory bus, on which one memory bank and one FPGA are mounted

The Program memory is constituted by:

- 512K words on 48 bits Static RAM accessed at 0 wait states, for fast program execution;
- 128K words on 48 bits EEPROM accessed at 7 waits states, for code storage.

The first page of the EEPROM is write-protected, so that is appears as a PROM to the SW. Write protection is removable only when the external emulator is connected to the DES via the JTAG connector (J13), used also for program loading into EEPROM.

The data memory is constituted by a 512K 32-bit words SRAM bank, accessible at 0 wait states, on the first segment of data bus.

The FPGA implements all the functionalities that allow the processor to control the DES. These include:

- System Bus access (corresponding to 7 waits states for the DSP)
- On-Board Time management
- Interrupt controller
- Watchdog
- Reset circuitry
- PRI counter
- EEPROM protection
- DCG serial interface (memory load type)

The System Bus is a dedicated I/O bus (not a CPU bus) that connects all DES boards, but the DC/DC Converter one and the DCG. It allows to transfer 16 bit data every 350ns. Addressing capability is 8k addresses and 2 other bits are decoded on the board to select 4 other banks on the bus.

The HW Watchdog present on the board is periodically reset by SW. If 30 seconds elapse without reset, then the Watchdog will fire issuing a reset pulse to the DSP and to the other boards. If the 30 seconds timeout expires again (after the first timeout), then the Watchdog definitely resets the system putting it into a blocked state, and a Power Off – Power On cycle is required to restart the instrument.

3.2.1.3 Timing Board

The Timing Board implements three main functions:

- sequencing of the RADAR
- acquiring of the analogue monitors telemetries
- providing the optocoupled interfaces for the discretes TM and TC.

The Timing Board design is built around a FPGA that provides the following resources:

- the system bus interface;

- the RADAR sequencer programming registers;
- the analogue monitoring chain sequencer and storage;
- the I/O registers for the optocouplers.

The Timing Board hosts SHARAD's Master Oscillator, which provides the 80MHz clock to the system with the following characteristics.

Frequency	80MHz
Initial Accuracy	Settable to 0.1 ppm via external fixed resistor
Temperature stability	±1 ppm over –20°C to +70°C including hysteresis and perturbations.
Short-term stability (10s)	0.001 ppm, under constant and static conditions
Long term stability (30min)	0.01 ppm, under constant and static conditions
Frequency vs. supply	±0.5 ppm for a ±5% change
Aging	<1.5 ppm first year <1 ppm per year average thereafter

The FPGA derives all other needed clocks to sequence the radar with the following clock distribution concept:

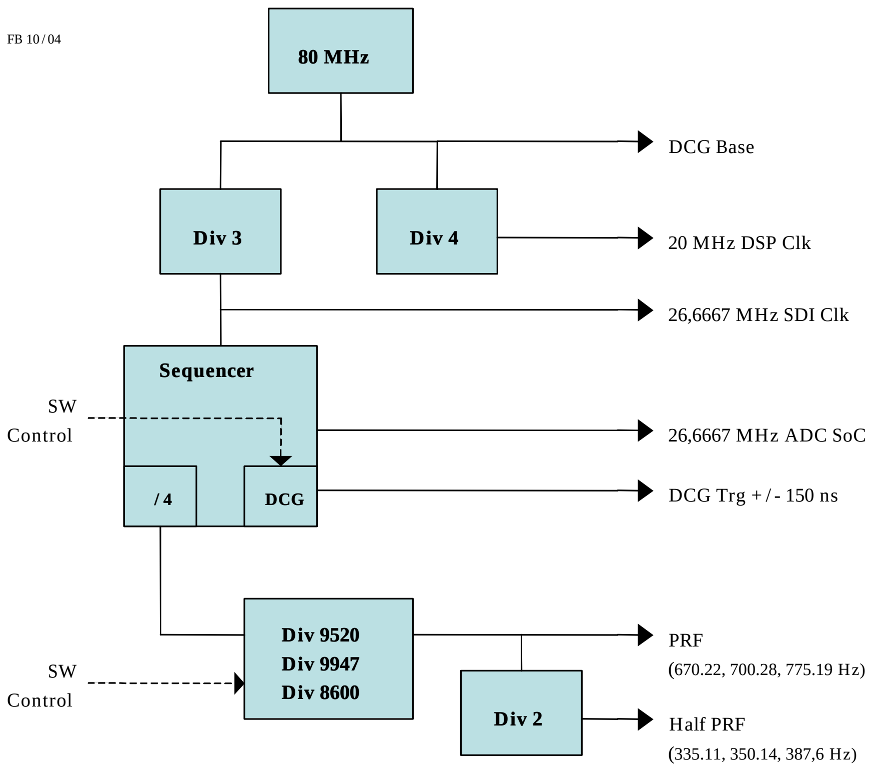


Figure 3.2.1-7: Timing Board Clock Distribution Concept

3.2.1.4 Slave Board

The Slave Board implements three main functions:

- reception and buffering of telecommands from the C&DH;
- buffering transmission of telemetries to the SSR;
- echo data buffering and processing (presumming and compression, followed by packet preparation).

The Slave board is built around a FPGA which interfaces:

- a FIFO memory (8k x 8bit) written by the Timing board with the data coming from the receiver;
- a Dual Port memory (4 IC 8k x 16bit each) which can be accessed by the system bus (i.e. the DSP) on the other port
- a pair of LVDS receivers, that interface with the C&DH
- a pair of LVDS drivers that interface with the SSR

The A/B Side Select optocoupled interface is also implemented on this board to select either the nominal or the redundant Command interface. The SSR Telemetry interface is, on the other hand, hot redundant (both drivers are always active and generating data).

The optocoupled Time_Tic signal is buffered to TTL levels and sent to the C&C for OBT management.

Commands received by the C&DH are sampled as 32 bits wide words. Each word generates an interrupt to the DSP, which in turn has 62 μsec to fetch the data.

Transmission of telemetries to the SSR is a process started by the DSP and automatically managed by the Slave Board, which makes a available up to 32K 16-bit words as telemetry buffer (in the DP memory). Compression is implemented while transmitting the data field of a science packet. Packet checksum is computed on the fly, and added to the packet while transmitting.

Processing mainly concerns the Pre-summing function which is implemented by storing interim pre-summed results in the DP memory.

Data exchanges with the C&C Board foresee that Tracking algorithm data are accessed at a relatively slow rate in order to avoid DP memory conflicts.

The two packet buffers shown in next figure are alternatively used in a ping-pong fashion. The DSP fills in the header (time tag) and auxiliary data before transmission to the SSR.

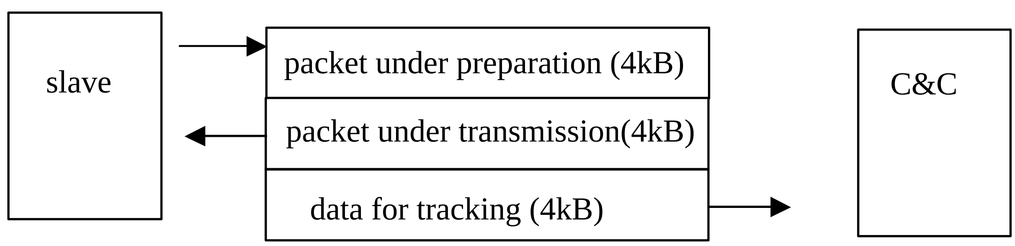


Figure 3.2.1-8: C&C and Slave science data exchanges.

The DP memory has a single, separate, buffer for HK Telemetry packets.

3.2.1.5 Digital Chirp Generator

The DCG is a module that synthesizes the Chirp signals in the Digital Electronic Section (DES). It has been designed using the Direct Digital Synthesis Technique, which consists in the generation of discrete samples of a sinewave and in the successive reconstruction at analog level.

A custom Numerical Controlled Oscillator has been employed to implement this technique. The NCO allows obtaining both surface area occupation and power consumption savings.

The DCG is a programmable signal generator. This characteristic permits to Shallow Radar to achieve an high flexibility and adaptability of use during the mission

The Digital Chirp Generator is built around a Numerical Controlled Oscillator (NCO). The main functional blocks of this architecture (see next figure) are:

- Command Interface
- ASIC:
    - o Chirp Parameter register
    - o NCO
- Look-up Table Prom
- Timing & Control Logic
- Digital to Analog Converter
- Low Pass Filter
- Output Amplifier
- Interface (for DCG signals and for test points)

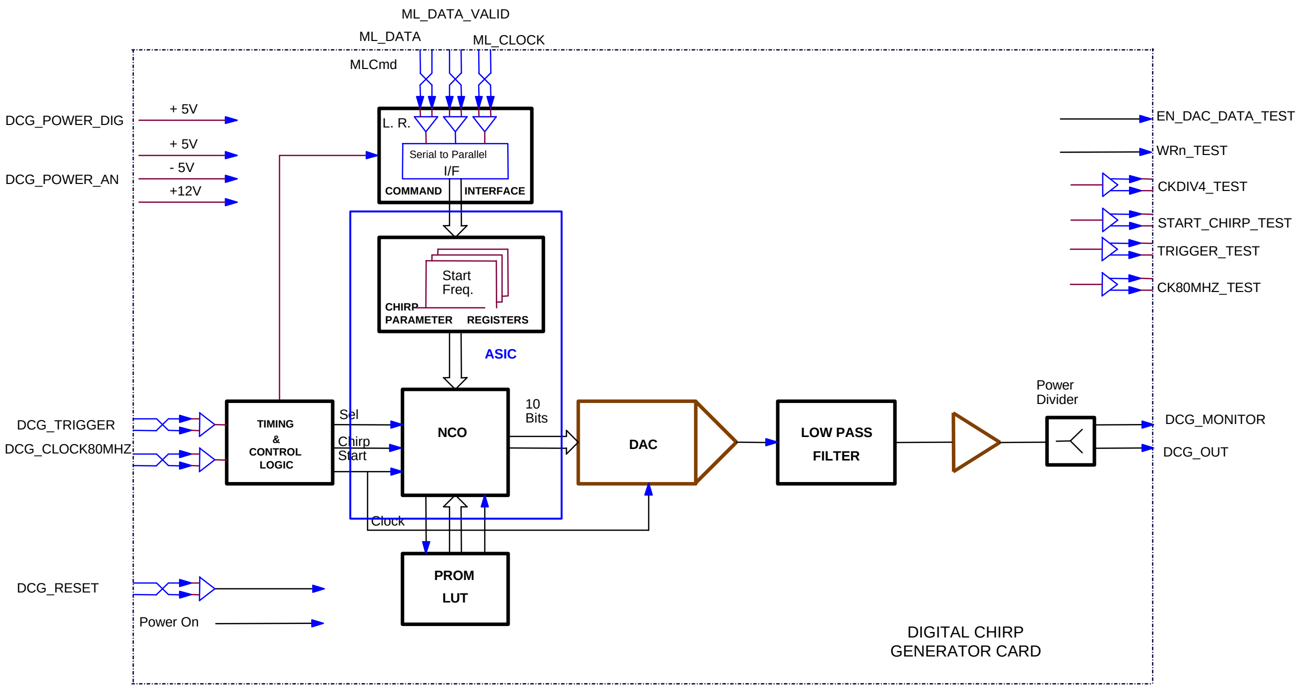


Figure 3.2.1-9: Digital Chirp Generator block schematic.

The principal tasks in the Chirp Generator are the following:

Command Interface

It allows to receive from DES Supervisor a serial Memory Load Command, through the which Start Frequency, Phase Compensation, Bandwidth and Pulse Duration of the chirp signal may be set.

Details about DCG commands and parameters are given in para. 3.4.2.

Timing & Control Logic

It performs all the timing functions required in the DCG.

It synchronizes the Start of the pulse generation with the External Trigger coming from the DES. It has the task to prevent the clock ambiguities that may cause jitter or indeterminate pulse starts.

In addition it provides all the specific signals necessary for the correct working of the NCO.

ASIC

The NCO (Numerical Controlled Oscillator) function is implemented on a single fully space qualified ASIC - developed by ALS in the frame of the activities for the SAR 2000 Program. The main features of the ALS NCO are listed below:

- Flexibility: all parameters are configurable(start freq,slope,phase comp,duration)
- Frequency Resolution: 32-bits (0.018 Hz @ 80 MHz clock)
- Wide Output Bandwidth: 0 to 32 MHz @ 80 MHz clock
- CW or Chirp Signal Gen.: 10 bit outputs
- Automatic Download of the External Look-up Table Prom content
- µProcessor Compatible input (16 bits BusAddress and 16 bits BusData)
- Low Power Dissipation: 520 mW @ 80 MHz (Core and I/O powered at 3.3V)
- Technology: ATMEL MH1 RT (0.35µm CMOS, Sea of gates, latch up immune, 200+ Krads total dose capability)

3.2.1.6 DES General Data Flow

During scientific processing, DES nominal operation are the following ones:

1. At the beginning of the operating mode, the SW knows from the OST line which is the PRF that must be programmed in the timing board sequencer, and sets it in the Timing Board registers.
2. The SW also programs the timing sequencer to samples the echo at a given Rxdist (RX Window opening time since PRI trigger).
3. The SW finally programs the Slave Board about where to store the results and prepares the headers of the scientific packet in the active packet buffer.
4. The Timing Board issues the PRF signal.
5. The PRF signal forces, in the C&C Board, the SW to program DCG, RX and TX parameters.
6. The Timing Board fires the DCG (already programmed with the correct phase) with the trigger.

7. After Rxdist interval has elapsed, the Timing Board commands the writing of data samples into the Slave Board FIFO.
8. After 3600 samples are written into the FIFO, the Timing Board triggers the Processing function in the Slave FPGA.
9. When the Processing function ends in the Slave Board a signal is sent to the C&C Board.
10. If the required Pre-summing value has been reached, the SW re-programs the Slave FPGA and triggers it to start Science telemetry transmission of the previously computed data. Otherwise another PRI cycle is programmed and newly sampled data will be summed to the previous ones stored in the DP buffer.
11. The SW keeps track of the PRI to computed the new phase of the DCG and be prepared to respond to the next PRF pulse.

HK telemetry packets are generated in an asynchronous way with respect to the PRI. They are prepared in the HK packet buffer of the Slave DP memory by the SW. HK packets, when ready, are transmitted between two scientific packets, when the opportunity occurs.

3.2.2 Receiver Section

From an architectural point of view, SHARAD's receiver has been designed without the need for frequency-conversion, the receiver's F.E. performs a band-pass filtering function, while the received signal is amplified to a level enough to A/D convert.

The SHARAD's receiver is based on band-pass sampling technique, so doing the sampling rate can be much lower than those required by sampling at two or more times the highest frequency content of the band-pass signal. In fact, to satisfy the Nyquist's theorem the sampling rate must be at least twice the bandwidth of interest, not necessarily twice the highest frequency component.

The choice of direct digitization of the RF input signal has, for this application, several advantages w.r.t. frequency-conversion configuration receiver.

Firstly, the most obvious reason regards the conversion mixer, which is used no longer. Secondly, we don't need a built-in LO for conversion any more.

The SHARAD's receiver unit, from a mechanical point of view, consists of a double-sided module that houses all the circuitry.

By looking at fig 3.2.2-1 (Receiver Electrical Block Diagram) a brief overview of the unit can be given.

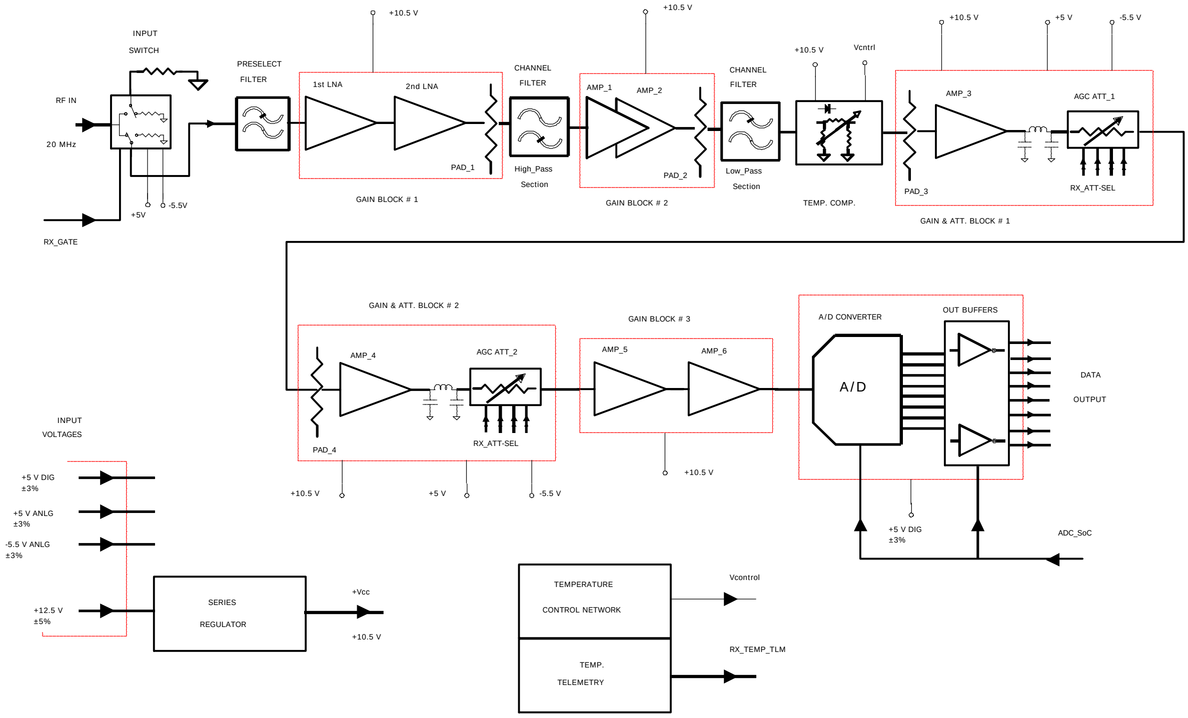


Figure 3.2.2-1: RX Section Block Schematic

The incoming signal, after having been filtered by a 5-pole Pre-select Low Pass Filter to cope with the electromagnetic environment, is sent to the LNA. The LNA consists of two cascaded SMD devices, where the the first stage is optimized for noise figure, while the second one is optimized for gain. The LNA is blanked, by the RX_gate CMD, which enables the Input Switch during transmission to route the input signal to a dummy load rather than to receiver's input.

The signal enters the Channel Band-shape Filter (Anti-aliasing Filter), which is split into two sections: High Pass and Low Pass section with a couple of amplifiers in between. This has been done to cope with the wide filter fractional bandwidth (50%) w.r.t. the 20 MHz center frequency. So doing we designed two filters: a 7-pole Cebicef HPF and an 11-pole Cebicef LPF. These filters are manufactured by using both wire-wound inductor (on a magnetic core) and ceramic SMD capacitors. A couple of SMD amplifiers is placed between the two filter sections. They provide about 13 dB gain along with 22 dB of isolation for decoupling the filter sections.

The signal emerging from the LPF is sent to a Temperature Compensating Network which compensates for the overall gain variation over –20°C to +65°C temperature range. It is based on a SMD device using a Pi configuration of PIN diodes. In fact, the PIN diode can be used as a current controlled variable resistor. The Pi configuration provides a very good match and very flat attenuation over an extremely wide band. Doing so, we can compensate for gain variation due to temperature up to ± 3 dB.

Going along the receiving chain we find two Gain & Attenuator Blocks, whose task is to amplify the signal and control the overall receiver gain. These two blocks rely on SMD amplifiers and on two 4-bit digital attenuators (1-dB step), which provide up to 30 dB of attenuation.

A couple of amplifiers provide the A/D Converter with a suitable signal for full scale. Moreover, they have a high third order intercept point.

The ADC converts the signal to digital form working at sampling rate of 26.6 MHz.

The AD 9042 is a high speed (41 MSPS min sample rate), high performance, low power monolithic 12-bit ADC (for SHARAD Receiver we need 8 bits only). All necessary functions, including track and hold and reference are included on chip to provide a complete conversion solution. This device has been specifically designed for communications systems, which must digitize a wide signal bandwidth.

Finally, after having been buffered the digital data are sent to User.

Up to now we have described the receiver chain in terms of signal flow, however the receiver unit relies on three other circuits as well. Namely, they are: the series regulator, the temperature compensation control network and the telemetry circuit.

The series regulator acts as an interface between the +12.5 V external power supply line, providing the RF circuits with a filtered and regulated voltage.

The temperature compensation control network delivers to the PIN diode voltage controlled attenuator a voltage proportional to temperature. It consists of two sections: the amplifying section and the linearizing section. As a temperature sensor a monolithic transducer has been used, which provides a linear thermal voltage. Since the attenuation law of the thermal compensating attenuator departs significantly from a linear function, we have to linearize its characteristic by using non-linearity (diode breakpoints) in the feedback path of an Op. Amp.

The telemetry circuit provides a voltage proportional to the Receiver Unit temperature. It uses a well-proven temperature transducer that produces an output current proportional to absolute temperature (1μA/K).

3.2.3 Transmitter/Front-End Section

The Transmitter & Front End Unit (TFE) is a self-standing equipment, devoted to amplify the low level chirp signals coming from the DES unit and to couple them to the dipole antenna; the unit provides also for time division duplexing function, sharing the antenna between the transmitter and the receiver path.

The TFE includes internal DC/DC converter to supply all internal circuitry and to provide galvanic isolation from the power bus; the power supply assures high peak energy over the pulse duration while preventing both from excessive current transients on the main bus and from ripple on the secondary voltage rails.

The main feature of the TFE is the capability to handle wide bandwidth frequency modulated pulsed signals (15   25 MHz) maintaining as low amplitude/phase distortions over the pulse width as possible (consider that the antenna highly mismatched load causes significant amplitude and phase ripples over the useful bandwidth); nominal operation foresees 85 msec duration pulses with 700 Hz repetition frequency.

A TT&C section interfaces the DES unit, exchanging commands and telemetries; transmitted power level, main bus current and internal temperature are provided as analogue telemetry outputs.

The TFE performances, especially the output power, are very dependent on the impedance characteristics of the antenna which represents the output load of the equipment: a dummy load reproducing the antenna has been designed and implemented for testing purposes; all tuning and characterization activities on the TFE equipment are indeed carried out by GA with the TFE terminated on this antenna simulator.

The TFE is supplied by a 21 to 36V unregulated bus with the provision for external synchronization (both free running and synchronized operation is foreseen).

A functional block diagram for the TFE equipment is presented in figure 3.2.3-1, while figure 3.2.3-2 shows the unit's power interface.

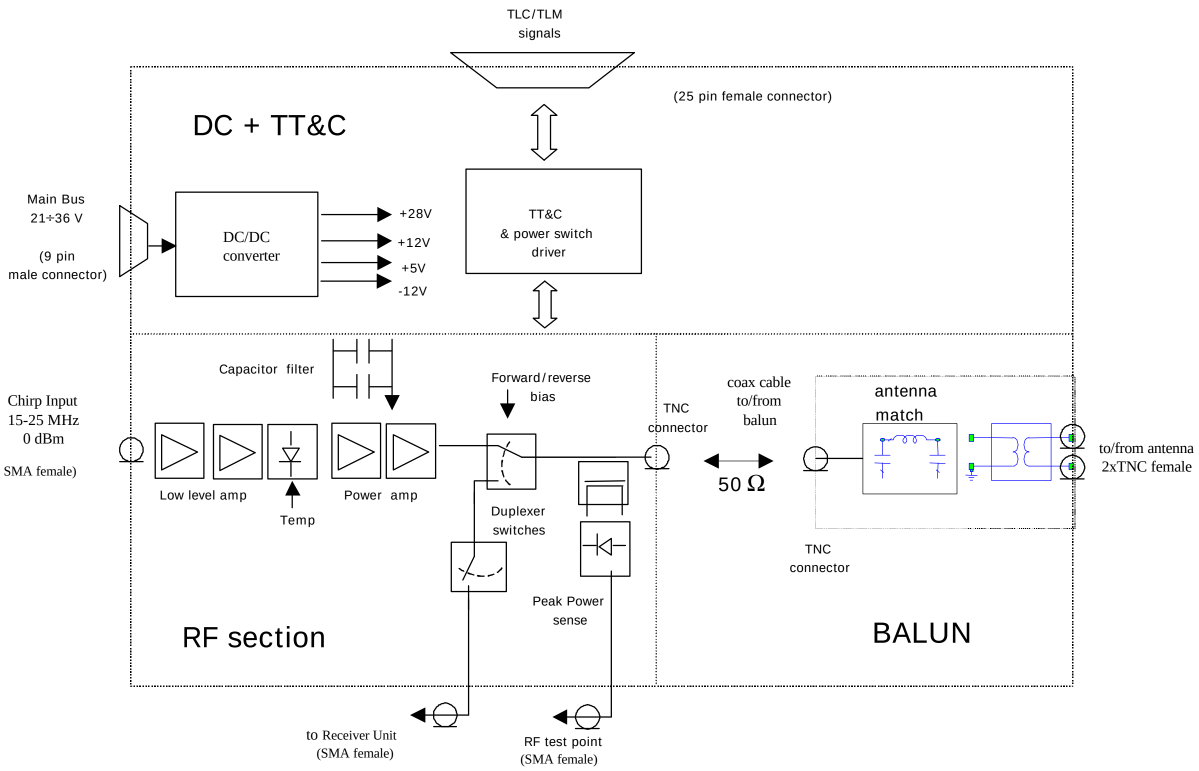


Figure 3.2.3-1: Transmitter & Front-End Block Schematic.

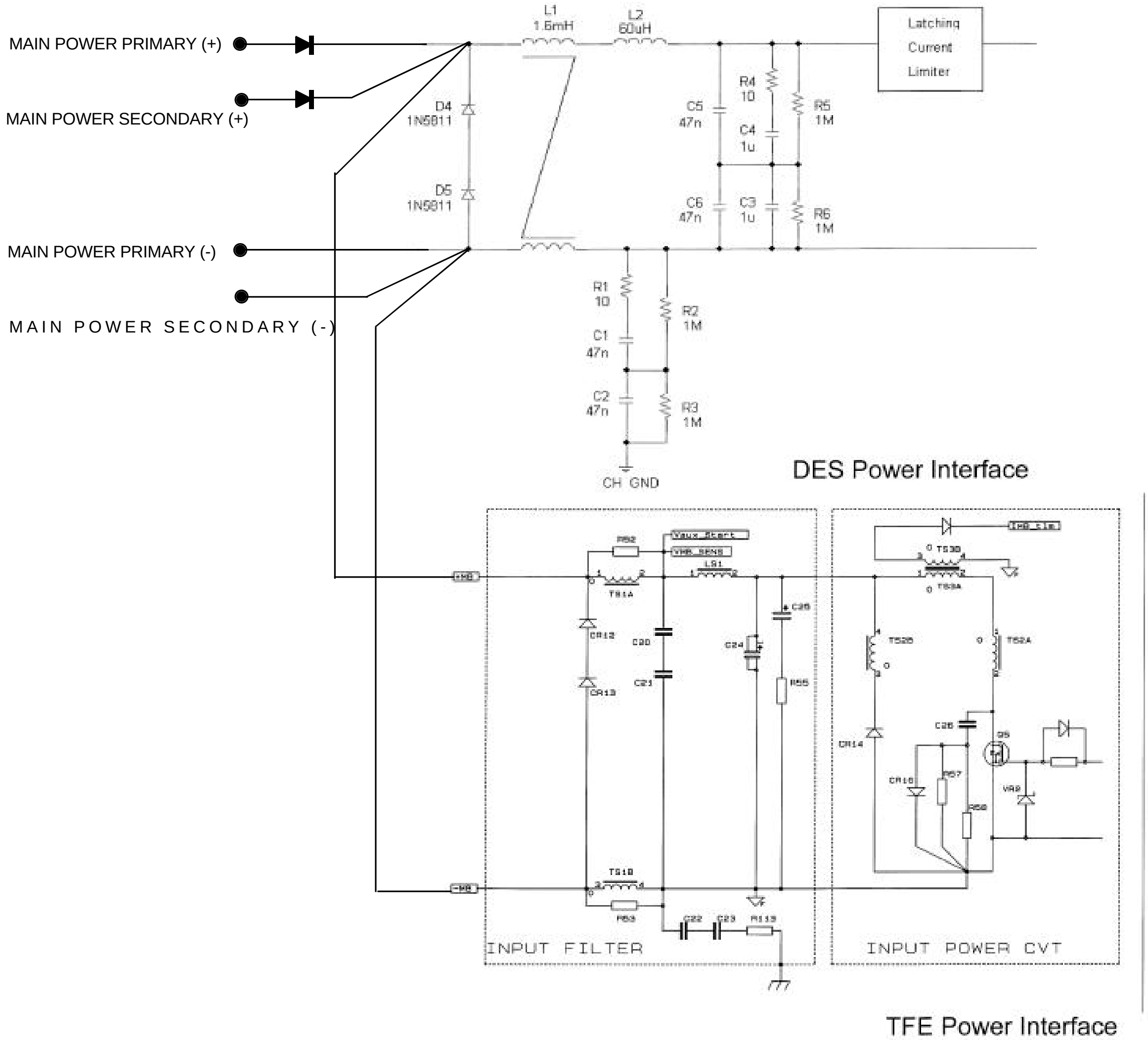


Figure 3.2.3-2: Transmitter & Front-End Power Interface.

3.2.4 Antenna

SHARAD'a Antenna is a 10 m dipole made of two 5 m foldable tubes, which, in stowed configuration, are kept in place by a system of cradles and, when released, will self-deploy thanks to its elastic properties.

Electrically, the Antenna is fed at the centre, interfacing the SEB by means of two wires (one for each dipole). The connection wires together form a balanced connection line. The line itself has no controlled impedance, (the antenna not having any matching network) and the load seen on the TFE side is therefore frequency dependant (thus requiring a dedicated matching network within the TFE).

The connection cables interface the TFE with 2 TNC connectors.

The Antenna includes also its release mechanism (two solenoid controlled actuators to release the right and left dipoles). During deployment operations, heaters installed on the Spacecraft panel will heat antenna cradle hinges in order to keep the actuator mechanism within a suitable temperature range.

3.3 Hardware Interfaces

3.3.1 Electrical Interfaces

The following diagram summarizes all SHARAD electrical interfaces.

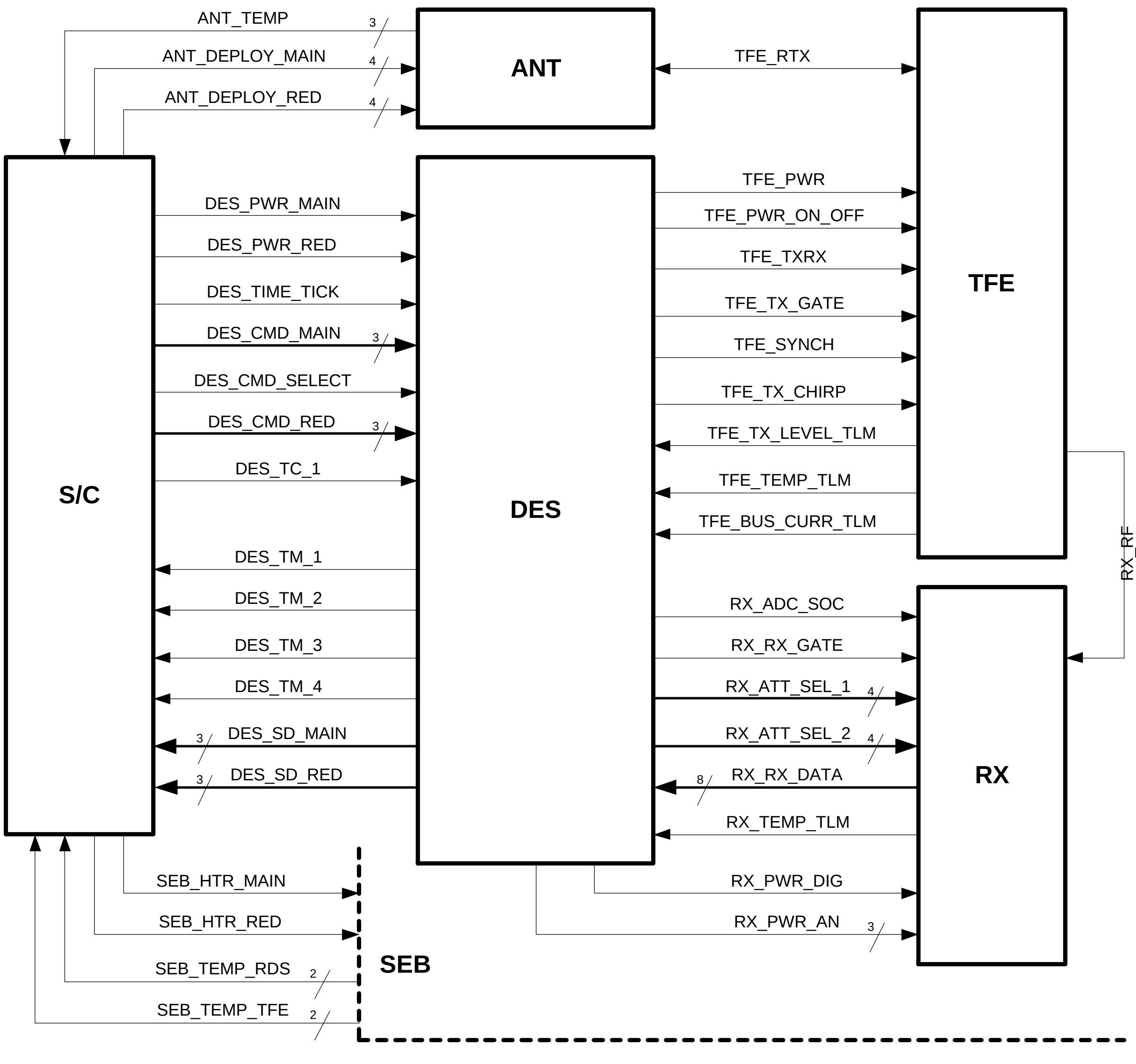


Figure 3.3.1-1: SHARAD Interfaces.

From the grounding viewpoint, SHARAD follows the Distributed Single Point Ground (DSPG) approach, i.e., it is forbidden to use the structure ground as an intentional return path.

For this reason, all the interface to the S/C and between RDS and TFE (interface internal to RDS, i.e. DES <-> Rx are excluded, being part of the same box) are differential in nature, while the DC /DC converters in RDS and TFE are isolated on the primary side (grounded on S/C side only).

A sketch of the grounding concept is provided in fig 3.3.1-2

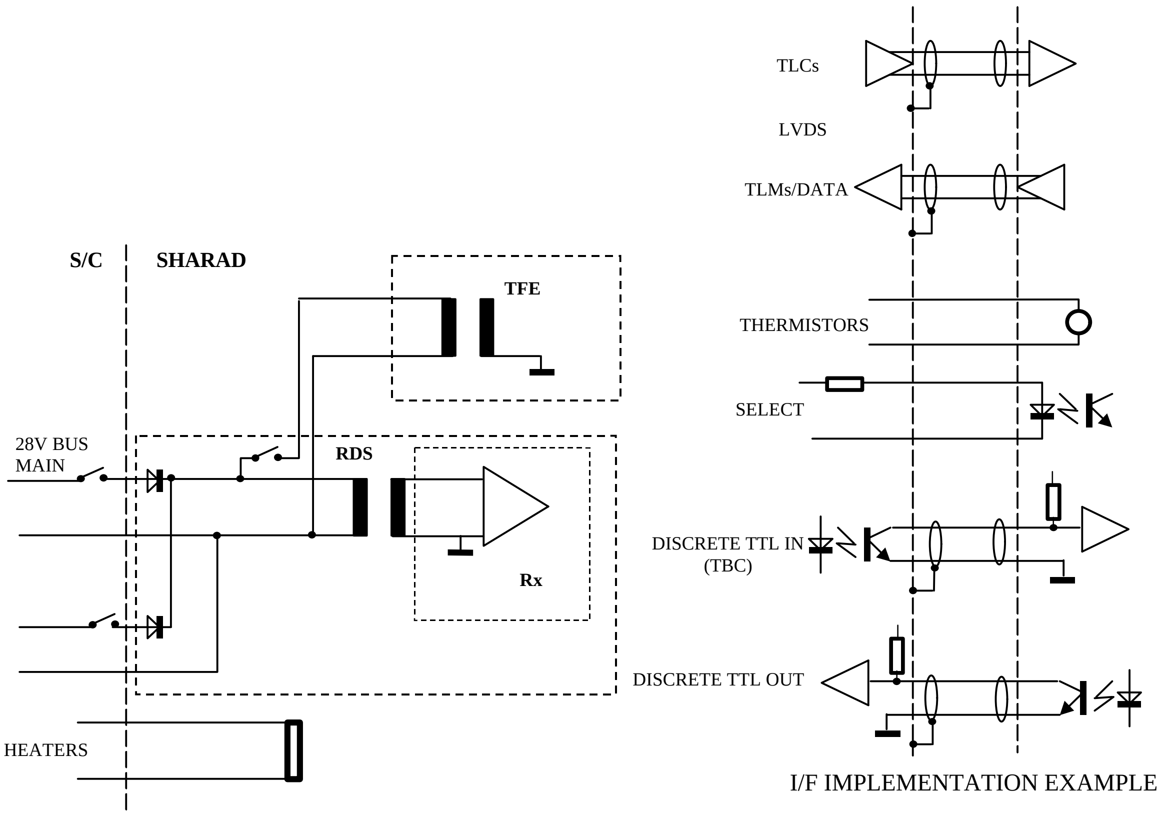


Figure 3.3.1-2: SHARAD Grounding Diagram (concept).

The following discussion partitions the electrical interfaces in Internal ones (shared between instrument units/sections) and External ones, those between SHARAD and S/C.

3.3.1.1 Internal Interfaces – DES to RX

RX Data Port

A/D converter output interface implementation is depicted in figure 3.3.1-3.

Conversion is started on rising edge of “Start of Conversion” (ADC_SoC) signal. This signal will be continuously active.

Signal name:	**RX_DATA**
Description:	ADC Digital data output, from Rx to DES
Signal type:	TTL
Number of bits:	8
Data representation:	2’s complement

Sampling rate:	Through ADC_SoC signal: - 26.67 MHz, nominal - 30 MHz max

Signal name:	**ADC_SoC**
Description:	ADC Sampling/Latching signal
Signal type:	LVDS
Sampling edge:	Rising (Positive) Edge
Sampling rate:	Rising edge every 37.5 nsec

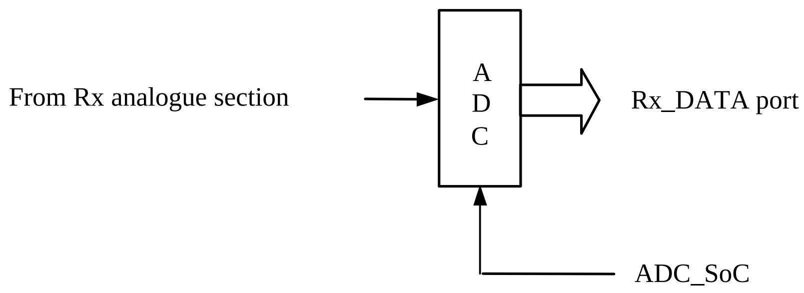


Figure 3.3.1-3: A/D Converter data interface

DES Telecommands to Rx

Command name:	**RX_GATE**
Description:	Control blanking of LNA for receiver protection
Number of bits:	1
Signal Type:	TTL
Control logic:	a) Logic Level Low = Rx ON b) Logic Level High = Rx blanked c) Switching time: <=2 µsec

Command name:	**ATT_SEL_1**
Description:	Select gain control setting of Rx
Number of bits:	4
Signal Type:	TTL
Control logic:	- Inserted attenuation = 0 to15 dB (step 1 dB) - Bit 0=LSB, Bit 3=MSB - plain binary
Notes:	Upstream attenuator (to be inserted first)

Command name:	**ATT_SEL_2**
Description:	Select gain control setting of Rx

Number of bits:	4
Signal Type:	TTL
Control logic:	- Inserted attenuation = 0 to15 dB (step 1 dB) - Bit 0=LSB, Bit 3=MSB - plain binary
Notes:	Downstream attenuator (to be inserted last)

Rx Telemetry to DES

Telemetry name:	**TEMP_TLM**
Description:	Hot spot temperature of Rx
Signal Type:	DEA
Range:	-35°C ÷ +70°C

Rx Power

Signal name:	**PWR_DIG**
Description:	+5 V power line for digital circuits (live line + return)
Signal Type:	Power
Voltage:	+5 V +/- 3% V
Max Current:	260 mA
Ripple:	< 50 mVpp (0 to 50 MHz)

Signal name:	**PWR_AN**
Description:	Power lines for analogue circuits (3 live lines + common return)
Signal Type:	Power
Voltage:	+ 5 V +/- 3% - 5.5V +/- 3% +12.5 V +/- 5%
Max Current:	30 mA 30 mA 300 mA
Ripple:	< 20 mVpp (0 to 50 MHz)

3.3.1.2 Internal Interfaces – DES to TFE

TX Chirp Port

Signal name:	**TX Chirp**
Description:	Chirp signal from DES to TFE
Connector type:	SMA, female

Nominal impedance:	50 Ohm
Signal Type:	Linear frequency modulated (chirp) pulse
Centre frequency:	20 MHz
Signal bandwidth:	10 MHz
Pulsewidth:	85 μsec, nominal
Power level:	0 dBm (+/- 0.5 dB)

<u>DES Telecommands to TFE</u>

Command name:	**PWR_ON_OFF**
Description:	Enable/disable DC/DC converter operation
Number of bits:	1
Signal Type:	OPTO
Control logic:	OC ON = TFE ON, OC OFF = TFE OFF

Command name:	**TX_RX**
Description:	Control the T/R switch and enable the transmitter.
Number of bits:	1
Signal Type:	DIF
Control logic:	LL Low = Tx, LL High = Rx

Command name:	**TX_GATE**
Description:	Enable Transmission
Number of bits:	1
Signal Type:	DIF
Control logic:	LL 0= ON, LL1=OFF

<u>TFE Telemetry to DES</u>

Telemetry name:	**TX_LEVEL_TLM**
Description:	Analogue telemetry of output power.
Signal Type:	DEA
Range:	+30 dBm to Max Pout
Notes:	Type of info: peak detected output power: - ripple due to decay (at min PRF): <= 1% pp - Settling time from power application: <= 1 sec within 3% of final value

Telemetry name:	**BUS_CURR_TLM**
Description:	Absorbed current from Tx_PWR line
Signal Type:	DEA
Range:	0 to 1A

Telemetry name:	**TEMP_TLM**
Description:	Hot spot temperature of TFE
Signal Type:	DEA
Range:	-30°C ÷ +80°C

Synchronisation signals

Signal name:	**SYNC**
Description:	Synchronisation signal for the DC/DC converter
Signal Type:	DIF
Frequency:	131 KHz +/- 10%

TFE Power

Signal name:	**PWR_AN**
Description:	+ power line for TFE (live line + return)
Signal Type:	Power
Voltage:	Unregulated bus 21-36 V
Max Current:	18 W max (10 W no transmission, i.e. no input signal, TxRx on Rx, Tx gate OFF)

3.3.1.3 Internal Interfaces – TFE to ANT

RTX Port

Signal name:	**TFE_RTX**
Description:	RF balanced connection to/from antenna (each connector carrying one polarity)
Connector type:	2 x TNC (balanced), female
Nominal impedance:	TFE output impedance shall maximise power transfer vs antenna load
Power level (Tx):	+40 (+/- 1.5) dBm
Max VSWR no damage (Tx/Rx):	Any phase

3.3.1.4 Internal Interfaces – TFE to RX

RX Port

Signal name:	**RX_RF**
Description:	Received signal from TFE to Rx
Connector type:	SMA, female
Nominal impedance:	50 Ohm
Signal Type:	Linear frequency modulated (chirp) pulse
Centre frequency:	20 MHz
Signal bandwidth:	10 MHz
Pulsewidth:	85 μsec, nominal
Notes:	Active switching performed within TFE. Power to TFE required to obtain a valid signal at RX input.

3.3.1.5 External Interfaces - Power

The power interface is constituted by two (primary and secondary) primary power lines at 22 to 36 V (28V nominal). The two lines corresponds to S/C sides A (primary) and B (secondary) and go directly to DES connectors, respectively, J06 and J07.

Inside the DES, the two primary power lines are OR-ed together and distributed to the users, RDS DC/DC and TFE. The latter is internally switched.

Interface design is such that **only one** of the two primary power lines shall be active at any time.

For power consumption, see section 3.6.1

3.3.1.6 External Interfaces – Thermal Control

The thermal control interface (which is physically implemented by the SEB J101 connector) is made by:

- two (primary and secondary) heater channels controlled by the S/C at a nominal voltage of 28V (22 to 36V), with a total heater resistance (for each channel) of 19 +/- 1 Ohm;
- four (with redounded connections) temperature sensors lines, 2 connected to the thermal reference point of the RDS and two to the TRP of the TFE, of type AD 590 (unconditioned).
-

3.3.1.7 External Interfaces - Command and Control

SHARAD receives commands frames from the S/C C&DH computer via a redundant LVDS interface. The nominal interface is associated to S/C Side A. The redundant interface is associated to Side B. Only one interface shall be active at any time. The Side_Select discrete signal provide indication about which interface is active at any time.

Signal name:	**CMD_Data**
Description:	NRZ Command Data frame
Signal Type:	LVDS
Notes:	Data frames are multiple of 32-bits

Signal name:	**CMD_Valid**
Description:	Identification of a CMD_Data frame
Signal Type:	LVDS
Notes:	Signal active low when data are to be sampled

Signal name:	**CMD_Clock**
Description:	Clock signal to sample CMD_Data
Signal Type:	LVDS
Frequency:	515.625 Khz +/- 5%
Notes:	Sampling performed at negative-going edge.

Signal name:	**Side_Select**
Description:	Enables S/C selection of the Command Interface redundancy.
Signal Type:	OPTO
Control logic:	DES_CMD_SELECT High (LED On) => SIDE A Active – CMD I/F MAIN DES_CMD_SELECT Low (LED Off) => SIDE B Active – CMD I/F RED
Notes:	It is expected that side selection will be performed by S/C before SHARAD is switched on

Command protocol layering and frame layouts are provided in Section 4.

3.3.1.8 External Interfaces - Science Data

SHARAD sends telemetry packets (both Housekeeping and Science Data ones) to the S/C SSR via a hot-redundant LVDS interface. The nominal interfaces is associated to S/C Side A. The redundant interface is associated to Side B. Both interfaces are active and the related data clock is generated since DES power on.

Signal name:	**TLM_Data**
Description:	NRZ Telemetry Data frame
Signal Type:	LVDS
Notes:	Data frames are multiple of 32-bits

Signal name:	**TLM_Valid**
Description:	Identification of a TLM_Data frame
Signal Type:	LVDS
Notes:	Signal active low when data are to be sampled

Signal name:	**TLM_Clock**
Description:	Clock signal to sample TLM_Data
Signal Type:	LVDS
Frequency:	26.666667 Mhz +/- 5% (max. 30 MHz).
Notes:	Sampling performed at negative-going edge.

Telemetry protocol layering and frame layouts are provided in Section 4.

3.3.1.9 External Interfaces – Discretes

Discrete TMs

When the DES is switched off all signals are “high” (OC LED is Off).

Signal name:	**SHR_Running**
Description:	Provides indication that SHARAD is powered on and that the CPU is running.
Signal Type:	OPTO
Control logic:	OC ON = SHARAD Running, OC OFF = SHARAD Not Running
Notes:	

Signal name:	**SHR_Alive**
Description:	Provides a pulsed indication that SHARAD software is running.
Signal Type:	OPTO
Control logic:	Not applicable
Timing:	The signal toggles state every 5 seconds.
Notes:	The signal starts toggling when DES enters Stand By state.

Signal name:	**SHR_Operating**
Description:	Provides indication that SHARAD is performing measurements.
Signal Type:	OPTO
Control logic:	OC ON = SHARAD Operating, OC OFF = SHARAD Not Operating
Notes:	The signal is active when DES leaves Stand By mode.

Signal name:	**SHR_Safe**
Description:	Provides indication of a serious anomaly (like an Out Of Limit or a not-recoverable SW event).
Signal Type:	OPTO
Control logic:	OC ON = SHARAD in Safe/Idle, OC OFF = SHARAD Not in Safe/Idle
Notes:	The signal is active when DES goes into Safe/Idle State.

Note that the four TM discrete signals are used in a not conventional way during the Boot phase (which lasts about 28 seconds from Power On). During this phase the meaning of the signal is overridden and their status is used to provide indications of critical anomalies during execution of the Boot code.

Additional details are available in section 3.4.

<u>Discrete TCs</u>

Signal name:	**TX_Enable**
Description:	Driven by S/C to control the activation of SHARAD's TFE
Signal Type:	OPTO
Control logic:	OC ON = TFE ON, OC OFF = TFE OFF
Notes:	For TFE control the signal is sampled at the transition from Warm Up 1 State to Warm Up 2 State.

Note that the TX_Enable signal has another role during the Boot process. At Power On Reset the signal is sampled and its status is used to select the active EEPROM from which the subsequent Boot phase will be executed. After the Power On Reset the signal resumes its conventional meaning.

Additional details are provided in section 3.4.

Signal name:	**Time_Tic**
Description:	Used by S/C to provide a timing reference after a TIME UPDATE Command.
Signal Type:	OPTO
Control logic:	The active edge is the positive going (rising) one.
Timing	- period is 1 second +/- 1msec - duty cycle is 50% +/- 10%. - maximum rise time is less than 50 nsec.
Notes:	See the synchronisation diagram below.

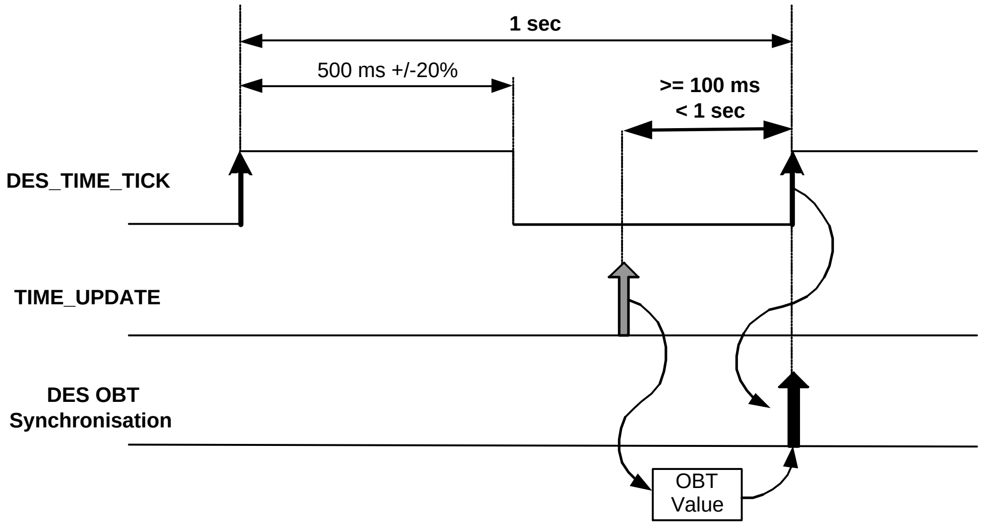


Figure 3.3.1-4: DES OBT Synchronisation Timings

3.3.1.10 Connectors list

The following table provides basic details about SHARAD connectors.

Conn.	To	On	Type	No of pins	Used pins	Used for
J01	EGSE	DES	DBM-25S-NMB-1A7N	25	11	Slave DSP FIFO test connector
J02	S/C	DES	DBM-25S-NMB-1A7N	25	16	Nom. SDI, Nom. MCMD, MCMD_SEL
J03	S/C	DES	DBM-25S-NMB-1A7N	25	16	Red. SDI, Red. MCMD, Time_tick
J04	S/C	DES	DBM-25P-NMB-1A7N	25	10	Discrete_TM, Discrete-TC
J05	S/C	DES	DBM-25P-NMB-1A7N	25	21	Analogue monitors
J06	S/C	DES	DEM-9P-NMB-1A7N	9	5	RDS nominal primary power
J07	S/C	DES	DEM-9P-NMB-1A7N	9	5	RDS redundant primary power
J08	TX	DES	SMA RADIALL R125414001	1	1	DCG_out
J09	EGSE	DES	DAMA-15S	15	15	DCG test signals
J10	TX	DES	DEM-9S-NMB-1A7N	9	5	TXFE primary power
J11	EGSE	DES	DBM-25S-NMB-1A7N	25	21	EGSE test signals
J12	EMU	DES	DBM-25S-NMB-1A7N	25	18	DES status test signals
J13	EGSE	DES	DBM-25S-NMB-1A7N	25	23	Master DSP test connector
J101	SEB	SEB	DBM-25S-NMB-1A7N	25	12	SEB Thermal Control
J201	ANT	ANT				
J202	ANT	ANT				

3.3.2 Mechanical Interfaces

SHARAD's SEB is mounted, backward-looking, to the S/C engine deck by means of four M4 type screws (one for each "leg" of the SEB structure).

Four similar attachment points are used for each antenna hinge (8 total).

For a detail of the SHARAD to MRO mechanical interface, refer to MICD available in [**RD-14**].

3.3.3 Thermal Interfaces

SHARAD elements are thermally decoupled from the Spacecraft and have autonomous thermal control devices managed by S/C.

Both the SEB and the Antenna are mounted on the MRO engine deck using thermal insulating washers to prevent heat exchange with the spacecraft.

SEB thermal control is then achieved by means of:

- <u>radiative exchange</u>: the outer side of the SEB structure is partially painted with white paint (with high emissivity in the infrared region) to provide a radiative exchange path to the space in order to dissipate the heat produced during operation. The rest of the SEB is covered by a thermal blanket for insulation purpose.
- <u>survival heaters</u>: to prevent the SEB from going at too low temperature when in OFF mode, two series of heaters (primary and redundant) can be switched by the spacecraft according to the readings of four active temperature sensors (AD590) placed near the temperature reference points of the RDS and TFE.

The thermal control of the antenna (which does not dissipate significant amounts of heat during operation) is instead passive, with the exception of the release actuator mechanism. Heaters are located on the S/C panel below the antenna and are used to increase the temperature of the antenna hinges within the temperature operating range of the deployment actuators. They are used only before the antenna deployment.

The stowed antenna is surrounded by a Germanium-Kapton thermal shield, which has the main purpose to prevent overheating during the aerobraking phase.

3.4 Software Description

This section provides additional hardware details for items that are strictly related to SW functions and/or resources.

Due to their operational importance, some SW design topics are given a dedicated paragraph in the follow of this section.

3.4.1 SW Architecture

3.4.1.1 SW Overall Design

SHARAD SW requirements are mapped in the following Use Cases diagram, while Figure 3.4.1-2 shows DES SW decomposition in components/modules.

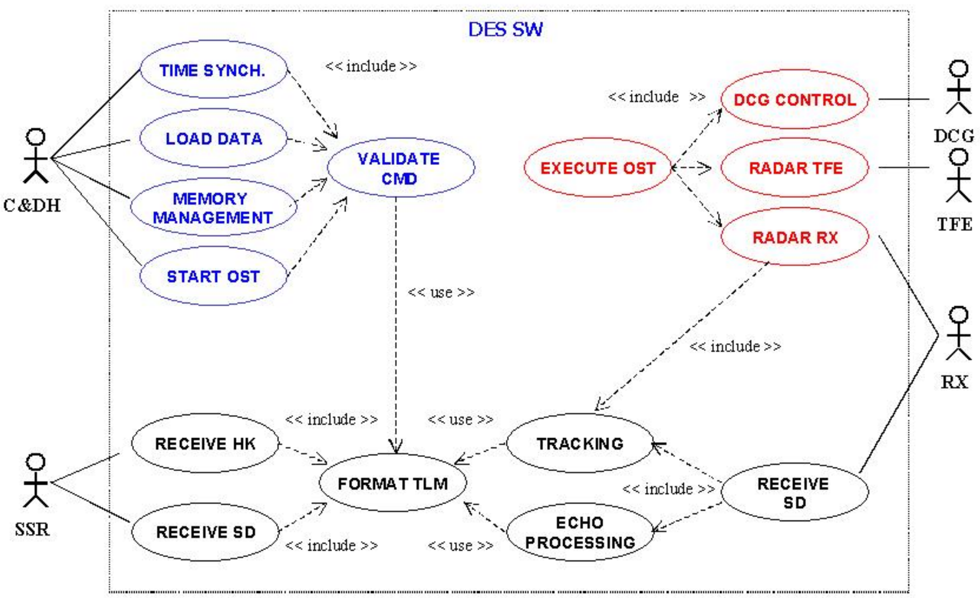


Figure 3.4.1-1: DES SW Use Cases

All components/modules are implemented over the Virtuoso Real-Time Executive, but for the Boot (or Boot/Loader) module, which is a stand-alone application written only in assembly language. All other components/modules are written mainly in C Language, while many HW interfaces are written ADSP21020 assembly language.

Ten different blocks are depicted, some of them can be logically grouped in two macro modules:

- The Command and Control module, which is in charge of managing the System and its interfaces with spacecraft. It is composed by:
  - o Command Handler
  - o Telemetry Handler
  - o Mode Transition Handler

- Built in Test
- Boot functionalities
- Background auxiliary activities (like Watchdog reset)
- Discrete Telemetry lines functionalities

▪ The Radar Sequencer, which includes:
  - Parameter Table access functionalities
  - Radar HW programming
  - Basic Data Processing, using polynomial interpolation of Mars surface as defined by [AD2]
  - Tracking processing, implementing tracking algorithm as defined by [AD2]

Additional descriptions to be provided in next issue.

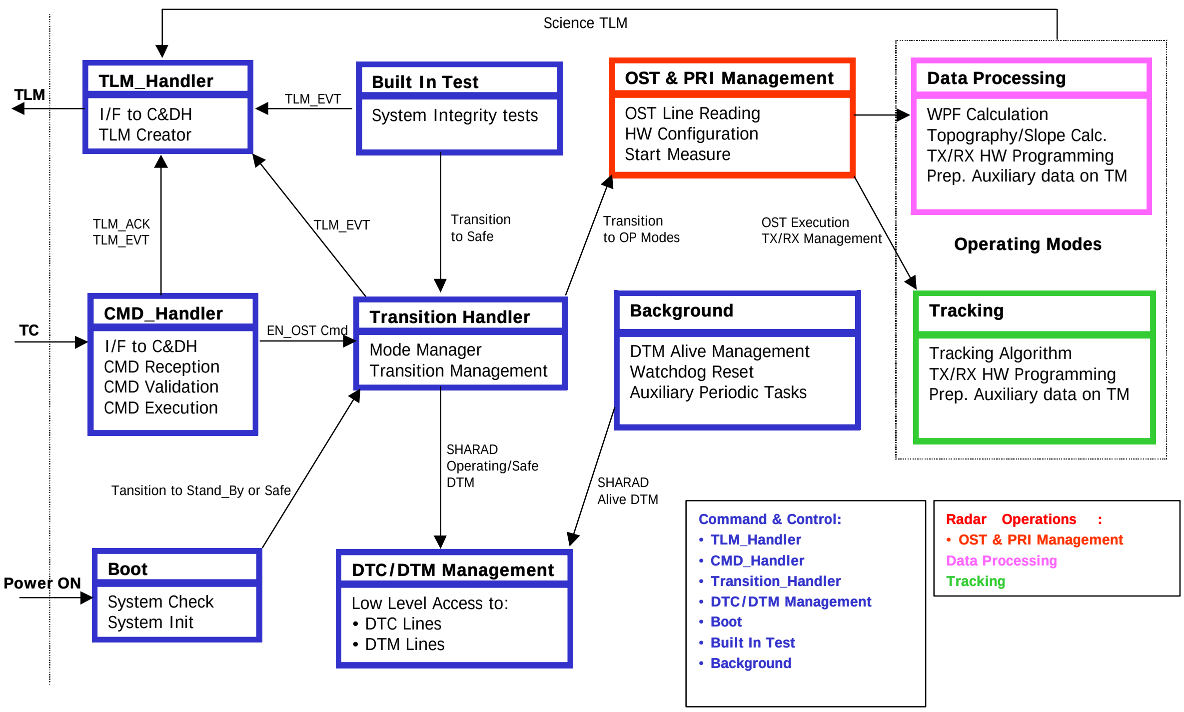


Figure 3.4.1-1: DES SW Components

Software processes running in DES SW are listed as instanced OS modules tasks in the following table:

Module	Process Name
TLM_HANDLER	TM_Science_Creator TM_HK_TLM_CMD_Task TM_HK_TLM_ENG_Task TM_end_DMA_hdl_Task TM_Send TIMEOUTs_Handler
CMD_Handler	TC_Validation TC_Exec_Handler TC_Reception Suspend_TC_Reception
OST & PRI Management	PRI_Handler
BUILT IN TEST	BIT_Handler
Transition Handler	Transition_Handler
Background	Background

3.4.1.2 SW Release History

The following releases have been used for the development of SHARAD EM:

- **Rel. 1.1** First formal release.
- **Rel. 1.2** Used to support functional tests in LABEN.
- **Rel. 1.3** Used to support instrument integration tests in ALS.
- **Rel. 1.4** Delivered for integration in the OTB.

The following releases have been developed for SHARAD PFM:

- **Rel. 2.1** Derived from 1.4, including post OTB integration changes and new configuration changes.
- **Rel. 2.2** Used to support DES Functional and Environmental tests in LABEN
- **Rel. 2.3** Installed in DES PFM for SHARAD integration testing in Alenia (Tracking module present but not operational, dummy data only).
- **Rel. 2.4** Software qualification release (full Tracking Module capability and rel. 2.3 SPR's resolution) installed on PFM for delivery.

  This SW release has also been retrofitted to the EM in the OTB.
- **Rel. 2.5** Future release, if required.

A formal declaration of the release status is available in [**RD-13**].

3.4.2 HW/SW Interfaces

Not considering DSP CPU internal configuration registers, the DES architecture contains a number of configuration registers implemented in the three FPGA used in the design. These are called DES Internal Registers and are accessed (read-only, write-only or read-write) as memory mapped registers through the DES system bus.

The DCG offers a series of internal registers used to store its operating parameters. Some of these parameters are set at startup, others are re-programmed during the PRI cycles. These are called DCG Registers and are accessed (write-only) by means of the serial DCG memory load interface.

3.4.2.1 DES Internal Registers

Details about DES Internal Registers and the inner working of each DES board are available in [**RD-10**].

3.4.2.2 DCG Registers

Details about DCG Internal Registers are available in [**RD-09**].

3.4.3 Memory allocation

The DSP on board of DES has an Harvard architecture, that means that two indipendent memory spaces are implemented, as shown in Figure 3.4.4-1:

- The Program Memory, divided into program EEPROM and program RAM
- The Data memory

EEPROM memory is hardware partitioned in two 64 Kword banks, or Partitions, (by toggling the highest order address bit of the EEPROM chips). This arrangement has been required to increase the redundancy of Boot/Loader code. The resultant organisation of EEPROM banks is shown in Figure 3.4.3-2.

Selection of EEPROM is performed by means of the TX_ENABLE discrete TC signal. The signal is sampled at Power On Reset and its status, latched in a FPGA register, is used to determine the active EEPROM partition. There exist a SW capability to alter the status of the controlling bit thus implementing access to the not active partition for particular purposes (EEPROM Patch/Dump or EEPROM Re-write function).

At Power On Reset	Status	EPROM Boot Partition	Mem. Segm. Field (HK TLM)
TX_ENABLE = 0V	Not Active	A	0x00
TX_ENABLE = 5V	Active	B	0x01

According to Flight Rules, a nominal boot requires the TX_ENABLE signal to be not active (to prevent accidental TFE activation). The following definitions therefore apply:

- **Nominal Boot**: EEPROM Partition A
- **Alternate Boot** : EEPROM Partition B

Additional details on the management of the two memory partitions are given in the following paragraphs.

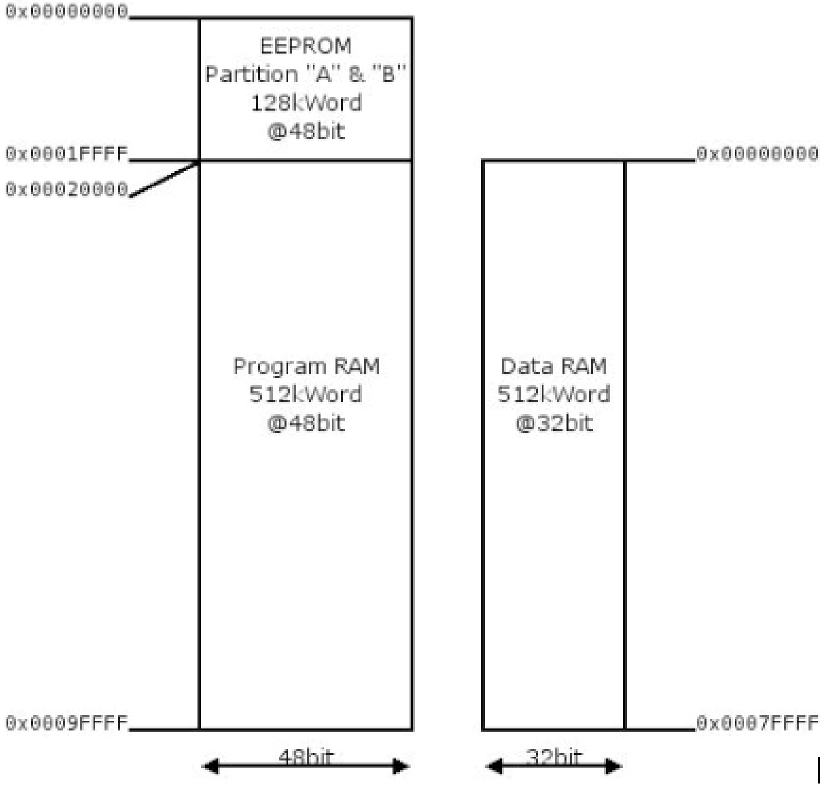


Figure 3.4.3-1: DES Memory Organisation.

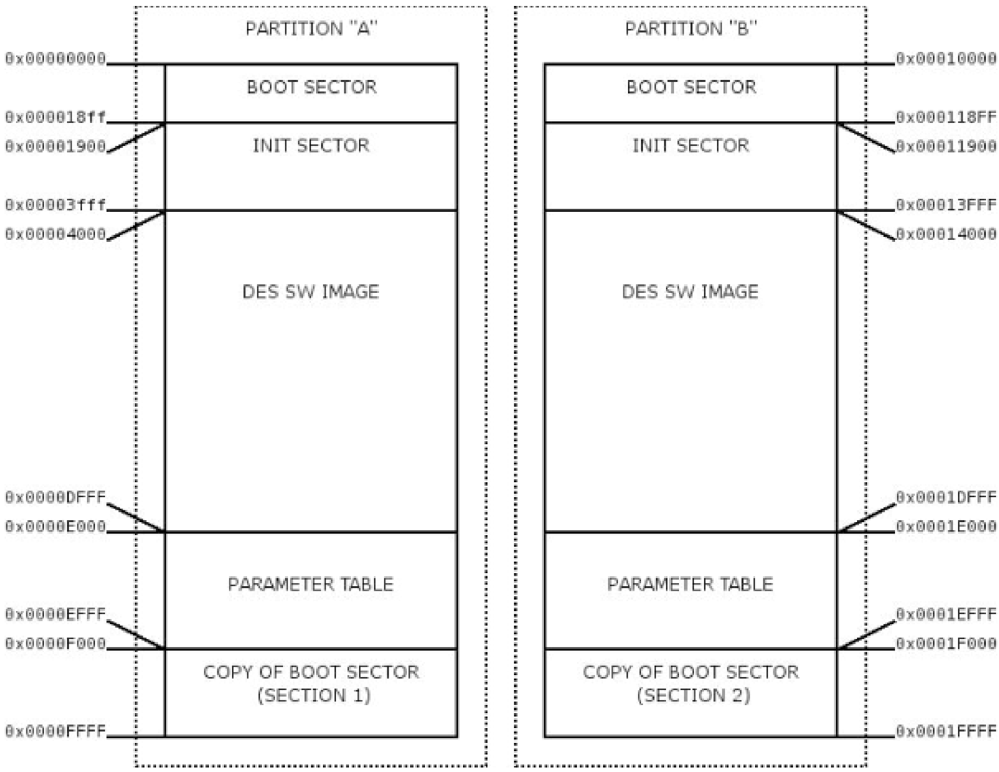


Figure 3.4.3-2: DES EEPROM Memory Organisation.

3.4.3.1 Program Memory Map

The following table summarizes the 48-bit wide Program Memory addressing space map.

Type and location size	Address			
	Start	End	Description	Patchable?
EEPROM "A" 48bit	0x00000000	0x000018FE	Boot Sector	N
	0x000018FF	0X000018FF	Boot crc	N
	0x00001900	0x00003FFE	Init Sector	Y
	0x00003FFF	0x00003FFF	Init crc	Y
	0x00004000	0x0000DFFE	DES SW Image	Y
	0x0000DFFF	0x0000DFFF	DES SW crc	Y
	0x0000E000	0x0000EFFF	PT Defaults	Y
	0x0000F000	0x0000FFFF	Boot Copy (part 1)	N
EEPROM "B" 48bit	0x00010000	0x000118FE	Boot Sector	N
	0x000118FF	0X000118FF	Boot crc	N
	0x00011900	0x00013FFE	Init Sector	Y
	0x00013FFF	0x00013FFF	Init crc	Y
	0x00014000	0x0001DFFE	DES SW Image	Y
	0x0001DFFF	0x0001DFFF	DES SW crc	Y
	0x0001E000	0x0001EFFF	PT Defaults	Y
	0x0001F000	0x0001FFFF	Boot Copy (part 2)	N
Static RAM 48bit	0x00020000	0x000200FF	RTOS reserved	Y
	0x00020100	0x00029FFF	DES SW (runtime)	Y
	0x0002A000	0x0009FFFF	DES SW Program data	Y

Note that the first three sectors of the EEPROM include a dedicated checksum for the given section. The checksum value is used to verify memory integrity during Boot and BIT phases.

All the CRC sectors (i.e. Boot, Init and DES SW) store their checksum values in the following format:

0x0000CCCC0000

where CCCC is the relevant checksum value.

EEPROM Boot Sector

The Boot Sector contains minimal, highly optimized code to perform:

- integrity tests
- dedicated CMDs reception in order to reload code during power on phase
- HW setup routines
- RTOS setup routines

The interrupt vector table is also contained in this sector.

The Boot Sector is write protected by SW, i.e. a Patch CMD at location between 0x00000000 and 0x000018FF (or 0x00010000 and 0x000118FF for partition "B") is always rejected. The only way the SW can write into boot sector is by means of the EEPROM Rewrite CMD.

<u>EEPROM Init Sector</u>

The Init Sector acts as a kind of bridge between boot code and real application SW. It contains a SW “bridge” to remap the interrupt vector table from EEPROM to RAM and RTOS runtime libraries (such as mathematical libraries for floating point operations, FFTs, etc.).

<u>EEPROM DES SW Image</u>

The DES SW Image is the copy of the application SW (as well as that of some required variables). This image is copied into RAM during RTOS initialization.

<u>EEPROM Parameter Table Defaults</u>

The Parameter Table Defaults Sector contains a partial copy of the PT that is to be stored in RAM during DES SW start-up. DES SW uses only the PT copied in RAM for its operations.

The PT Image stored in EEPROM contains all the PT values (starting from 0) excluding the 4096 complex points of the reference function used by the tracking algorithm (these values are generated at runtime generated during DES SW start-up, either at Power On or in case of warm restart).

<u>EEPROM Boot Sector Copy</u>

The last segment of each EEPROM partition contains a partial copy (roughly half) of the Boot Sector. The two portions can be assembled together to obtain a complete copy of the Boot Sector (the B part shall be appended to the A part).

This copy of the Boot Sector is used for the automatic recovery of unexpected corruptions of Boot Sector due to external causes (like SEUs or component failures). See EEPROM Rewrite in next paragraph for further details.

<u>RAM</u>

The Program RAM mainly contains the runtime DES SW Image copied from the EEPROM and some data structure used by the RTOS.

3.4.3.2 Data Memory Map

The following table summarizes the 32-bit wide Data Memory addressing space map.

Type and location size	Address			
	Start	End	Description	Patchable?
Data RAM 32bit	0x00000000	0x000011FF	RTOS reserved	Y
	0x00001200	0X00025FFF	DES SW data	Y
	0x00026000	0X0002CFFF	Parameter Table	Y
	0x0002D000	0X0007FFFF	RTOS reserved	Y

Data RAM is a 32bit addressable space that contains:

- RTOS data structure (for instance: stack and heap segment, system variables etc.);
- DES SW variables;
- Runtime Parameter Table.

3.4.4 Memory Management

3.4.4.1 Patch and Dump operations

DES memories can be patched and dumped by means of dedicated Comands (PATCH_MEMORY and DUMP_MEMORY).

Patches operations are permitted for all memory addressing ranges excepting the critical areas of the Boot Sectors and the Boot Sector Copies.

Tables in paragraphs 3.4.3.1 and 3.4.3.2 show the patchable addressing ranges.

Dump operations are allowed for all memory addressing ranges, even including not existing locations. This feature has been inserted in order to obtain system flexibility. A dump from a not existent location will yield 0xFFFFFFFF (or 0xFFFFFFFFFFFF) value for the addressed location.

3.4.4.2 Full SW re-load

The Boot/Loader code provides the capability to perform a full SW re-load by providing a complete, contiguous, image of the Init, DES SW Image and PT Defaults EEPROM sectors.

This capability is exercised by sending a LOAD_REQUEST command to the DES during a 15 seconds window marked by the SHR_Alive signal being low during the Boot phase.

When the command is received, the Loader is activated and, without further timing criticalities, LOAD_DATA commands can be sent to compose the whole image.

The new image loading ends with a LOAD_CHECKSUM command which provide a checksum value for the entire image (sector checksums are embedded in the image data). After this command is received the Loader copies the image (temporarily stored in RAM) into the active EEPROM partition and a full re-start from EEPROM is performed.

Additional details will be provided in next issue.

3.4.4.3 EEPROM Re-write function

The EEPROM Rewrite function (activated with the RESTART EEPROM Re-write Command) performs a refresh of all DES EEPROM locations, including the Boot Sectors.

This feature has been implemented due to an issue concerning a bit toggling detected on the same EEPROM component on board a previous NASA mission. Reasons for this issue are still under investigation. For safety purposes, a system to recover an EEPROM corruption, based on the Majority Voting algorithm, as therefore been implemented in SHARAD's DES.

The EEPROM Re-write, originally meant to be periodically run as a background task, as been assigned a dedicated command for "manual" execution due to the extremely criticality of its operations (so critical that during the function, all the DES nominal operations are suspended).

The EEPROM Re-Write function is activated by the RESTART EEPROM Re-Write command, which includes selection of the EEPROM partition to be targeted. The following steps are then performed:

1. The EEPROM TOGGLE register is saved in order to recover nominal operation at the end of sequence.

2. For each memory segment on the selected partition, the following operation are performed:
    1. All interrupts are disabled to put the RTOS kernel in a freeze state and to ensure that any task cannot interfere with the re-write operations. Note that this also implies that the SHR_Alive TM signal will stop toggling.
    2. EEPROM is put in Write enable condition.
    3. For each location of the segment:
        A. The location is read.
        B. The location is written with value previously read.
    4. The EEPROM is put back in Write protected condition.
3. Interrupts are re-enabled, the RTOS awakes and ALIVE signal returns to toggle.
4. In case the re-write is concerning the Boot Sector, then the following extra actions are performed:
    1. For each location in the boot sector:
        A. The location is read and stored apart
        B. The corresponding location in the other partition is read and stored apart
        C. The corresponding location in the Boot Copy Sector is read and stored apart
        D. Let’s call the three values A, B and C. These values are compared according with the following algorithm (expressed in pseudo-code):

```
if  (A <> B) then
    if (A = C) then
        recover location B
    else if (B = C)
        recover location A
    else
        // all three location are different
        do nothing
else if (B <> C) then
    recover location C
```

where the operation “Recover location x” consists in the following steps:

1. Enable EEPROM writing
2. Disable interrupts
3. Write corrupted location with the contents of the other two not corrupted location
4. Disable EEPROM writing
5. Re-enable interrupts

5. At the end of the Rewrite sequence, the starting partition is retrieved.

3.4.5 Boot Sequence

3.4.5.1 Nominal Boot

The Boot Sequence starts when S/C powers on the DES, or as result of a RESTART From EEPROM command. The Sequence nominally extends to RTOS start-up and DES SW activation and ends when DES enters into STANDBY State.

Boot Sequence steps:

1. All the HW registers (both DPS and FPGAs ones) are properly reset. This includes also the four TM discrete signals. After this, the SHR_Running TM is asserted.
2. All OBT register are cleared (set to 0), i.e. the resulting OBT is 01/01/1980-00:00:00.0.
3. If the reset has been caused by the Watchdog, then a flag is set to make visible the reset condition to the user by means of HK Engineering TLM.
4. Verify Boot Sector checksum: in case a CRC error is detected, the system halts its operation (idling) and the SHR_Running TM is de-asserted while SHR_Safe TM is asserted.
5. Perform Program RAM integrity tests, which includes:
    - Write an incremental test pattern into the Program RAM.
    - Check the pattern written into the Program RAM. If an error is found, then a Boot Report TLM format is generated reporting the wrong location and SHR_Operating TM is asserted while the system halts its operation (idling).
    - Fill the Program RAM with an all zeroes pattern.
6. Perform Data RAM integrity tests, which includes:
    - Write an incremental test pattern into the Data RAM
    - Check the pattern written into the Data RAM. If an error is found, then a Boot Report TLM format is generated reporting the wrong location and SHR_Operating TM is asserted while the system halts its operation (idling).
    - Fill the Data RAM with an all zeroes pattern.
7. Perform a 15 seconds delay as a window for Loader invocation by means of a LOAD_REQUEST command and subsequent LOAD_DATA/LOAD_CHECKSUM commands. No other command may be sent, including TIME_UPDATE. During this time interval the SHR_Alive TC is asserted.
8. At the end of the 15 seconds delay SHR_Alive is de-asserted.
9. Verify Init Sector checksum: in case a CRC error is detected, the system halts its operation (idling) and the SHR_Running TM is de-asserted while SHR_Safe TM is asserted.
10. Verify DES SW Image checksum: in case a CRC error is detected, the system halts its operation (idling) and the SHR_Running TM is de-asserted while SHR_Safe TM is asserted.
11. Copy the DES SW Image stored in EEPROM to RAM.
12. Copy the PT from EEPROM to RAM.
13. Transfer control to the RTOS (here the Boot Sector code ends).
14. The RTOS is initialized.
15. The DES SW is started and performs the following steps:

- Generates the Complex Reference Function, needed by the Tracking algorithm, using parameters stored in PT as reference. (In order to optimize performances the required 4096 complex points stored in PT are the FFT squared-module of the Reference Function).
- Resets HK counters for Telemetries and Telecommands.
- Read from PT the required default HK generation configuration, i.e. which telemetry formats are to be enabled and whether the internal buffer is to be enabled (no TLM output) or disabled (TLM packets immediately available).

16. All SW task are spawned, SHR_Running TM is kept asserted while SHR_Alive TM starts toggling with a period defined by a PT value (default 10 seconds).

3.4.5.2 Not Nominal Boot

The following table shows TM discrete signals and DES SW status after Power On:

Condition	**Discrete Telemetries**				**SW Status**
	Running	Alive	Safe	Operating	
Nominal condition	ON	Toggling	OFF	OFF	Running
Boot CRC error	OFF	OFF	ON	OFF	Idling
Init CRC error	OFF	OFF	ON	OFF	Idling
DES SW CRC error	OFF	OFF	ON	OFF	Idling
DES RAM Errors	OFF	OFF	ON	ON	Idling

Note that in the column SW Status, the label “Idling” identifies an internal DSP condition (which means that SW is altogether stopped). This is not to be confused with the Safe/Idle State.

Although different error conditions have the same TM status, it is underlined that they are presented in different time. Analysis of a not nominal boot condition shall consider that:

- Boot CRC and Init CRC errors appears after a few seconds from Power On
- SW CRC error appears only after the end of the 15 seconds SW re-load window

Figure 3.4.5-1 shows the behavior, as seen on J04 connector, of TM discrete signals during a nominal Boot. Note that signals are used with negative logic (i.e., active low).

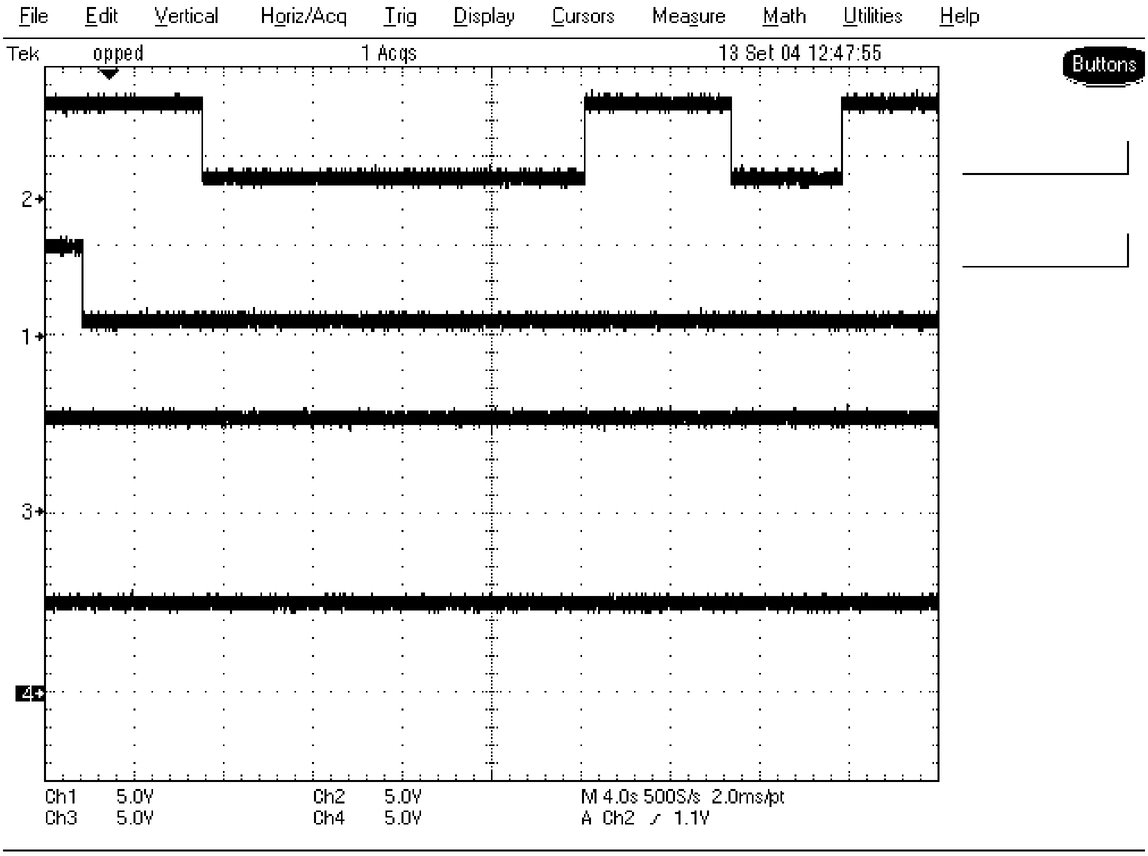


Figure 3.4.5-1: Nominal Boot TM Discrete Signals Behavior.

3.4.6 Time Management

SHARAD's DES implements two different counters to keep track of time:

- the On Board Time (OBT) Counter.
- the High Resolution Time (HRT) Counter;

The clock for both counters is necessarily derived from the 80 MHz TCXO Master Oscillator.

3.4.6.1 Counters description

The OBT counter (48 bits) is managed so that it counts integer seconds (32 bits) and fractional seconds (16 bits). Its least significant bit toggles every 2^{-16} seconds. This would require a clock input frequency of 65536 Hz for the binary counter a value which cannot be obtained exactly from an 80 MHz clock. The 48-bits format provides a resolution of about 15.259 microseconds.

48 bit	
Number of seconds	**Fractional seconds**
32 bit	16 bit

The actual implementation is therefore based on a clock divider that gives a clock frequency slightly higher than the one required. Thus the OBT Counter has a drift which is taken case of by resetting its value to the value provide by the periodical TIME_UPDATE command sent by the C&DH. TIME_UPDATE command period is set to 60 seconds to have a good margin against the possible error of 1/2 LSB in the time count (it will occur after a few minutes from the last update).

However, since commanding is disabled during science modes, and since these modes may last for many minutes (up to 30 minutes), the accumulation of drift errors in the OBT increases and produces errors in time tagging of telemetries.

In order to correct the reading of the OBT Counter, another counter, the HRT, has been implemented.

The HRT is a 40 bits counter clocked with a 10 MHz clock, so that the least significant bit toggles every 100ns.

The HRT counter content is latched in the FROZEN_HRT registers at the arrival of each PRF pulse (from the Timing Board). This means that the latching period is not fixed through the orbit but varies with the PRF programmed in the OST. When not in science modes, the HRT is still active and the PRF supplied is the nominal, ambiguous, one.

Test results shows that the HRT as a small error compared to “real-time” (a sort of jitter which does not accumulate in time) but the extent of the error is below the accuracy requirements to be met.

The HRT Counter value is included in telemetry formats to provide a more accurate indication of time, particularly during the execution of science modes.

3.4.6.2 Counters management

OBT Counter

The OBT counter is written using the following procedure.

At the arrival of the TIME_UPDATE Command, the OBT Registers are loaded with the new OBT value provided within the command.

The OBT Registers content are then copied in the OBT Counter at the instant the TIME_TIC pulse is generated by S/C and, since then, it starts counting.

Without any further TIME_UPDATE, the OBT Counter, after 1 hour, will read 360ms more than the true value of the OBT.

HRT Counter

The HRT counter can be loaded with any value and the loading has effect at the arrival of the first PRF pulse.

After the OBT counter has been updated correctly (i.e. the Time_Update TC has been successfully executed), at the first next PRF pulse (“FIRST_NEXT_PRF”), the OBT value is read and frozen in memory as a VARIABLE, FROZEN_OBT(0).

At each n-th PRF pulse (interrupt), the SW reads the FROZEN_HRT value, F(n), subtracts the previous one F(n-1), thus obtaining the number of “100ns” elapsed and the difference _F(n) converted into OBT units _F’(n).

This increment must be added to the OBT value, for example, FROZEN_OBT(1) = FROZEN_OBT(0) + _F’(0), and at the n-th PRI the time will be:

FROZEN_OBT(n) = FROZEN_OBT(n-1) + _F’(n).

The OBT is expressed in different units from the HRT (i.e., 2^{-16} sec instead of $100*10^{-9}$ sec”), therefore the HRT must be multiplied by 152.587890625 before adding it to the OBT.

SW also takes care of HRT overflow when the FFFFFFFFFF value is reached, performing some binary arithmetic.

Note that the CURRENT_OBT value is read only once after each TIME_UPDATE Command: since then the FROZEN_HRT counter is used to update the variable FROZEN_OBT.

The variable FROZEN_OBT is used as the instrument OBT after the “FIRST NEXT PRF” pulse and before the next TIME_UPDATE command.

3.4.7 Monitoring

The DES monitors eight analogue channels assigned as follows:

Channel	Meaning
1	DES Temperature
2	DES 5V
3	DES 12V
4	DES 2.5V
5	RX Temperature
6	TFE Temperature
7	TFE TX Level
8	TFE BUS Current

These channels are acquired as 8 bit values and are HW sampled every second. Values are stored dedicated registers and are reported in HK Engineering telemetry as raw values.

DES Monitoring is managed by a OS task which starts its operations when the DES enters in STANDBY State. Within this task, channels are periodically checked for out of range condition. The checking period is defined by a PT value (PT_MON_SAMPLE).

For a given channel N, its value is verified against two limits assigned to the channel: PT_CHn_ULIM (Upper Limit) and PT_CHn_LLIM (Lower Limit). If an Out Of Limits (OOL) is found for three consecutive times on the same channel, then an Out Of Limits SW event condition is generated, which produces:

- A HK Log telemetry indicating the out of range channel and its value.
- A transition to SAFE/IDLE State.

The Upper and Lower Limit for all channels are stored in Parameter Table.

Note that the Out of limit test is not inclusive, e.g. a channel is in out of range when its value is greater than parameter, not greater or equal the parameter.

Monitoring of RX and TFE parameters is subject to the condition that those units are switched on (because the temperature sensors are active, AD590 type, ones). Therefore, when the DES is in State for which the RX and/or the TFE are switched off, related channels are not monitored and are reported with a 0x00 value in HK Engineering telemetry.

When running, the monitoring task is always active, there being no command to disable it. In case it were necessary to disable the monitoring of a given channel, it is possible to alter the corresponding Out Of Limits values in Parameter Table in such a way that any measured value cannot produce an OOL condition. To achieve this result it is sufficient to set the relevant PT_CHn_ULIM paramter value to 0xFF and “the PT_CHn_LLIM value to 0x00 (where n is 1 to 8 according to the given channel).

3.4.8 Built In Test

The DES SW implements a Built In Test feature to periodically verify DES memory integrity. The BIT is awaken every hour (3600 s) and it calculates checksums for the following memory segments:

- Boot sector of EEPROM partition in use
- Init sector of EEPROM partition in use
- DES SW Image of EEPROM partition in use
- Program RAM

Each computed checksum is verified with the corresponding value stored with the relevant segment. If a mismatch is found:

- a HK Log telemetry will report the identification of the corrupted segment, and the computed and expected checksum values;
- a transition to SAFE/IDLE mode will be performed.

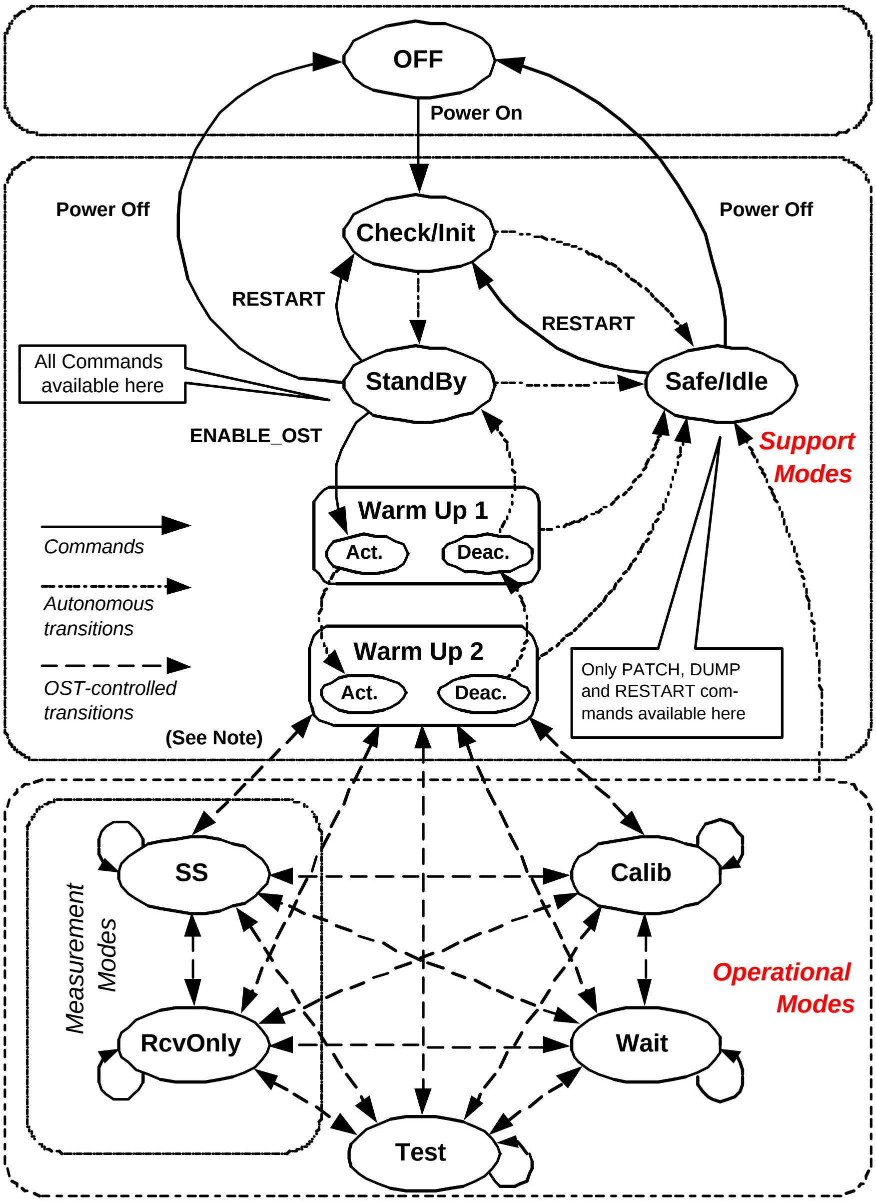
The BIT is executed for the first time immediately after RTOS initialization, that is at the end of the CHECK/INIT State.

Although the BIT is always running (even during DES operative modes) it is spawned by RTOS as a very low priority task in order to avoid interferences with other DES operations.

3.5 Functional Description

3.5.1 Instrument States/Modes

The DES, and SHARAD, perform different tasks within their operational sequence, such as power-up, initialisation, transmission and science operations. Consequently different states (and modes) can be identified.



Note: *The first transition to an Operational Mode (from Warm Up 2 Act.) is performed when the OST Time Tag expires and OST processing begins. The transition back to Warm Up 2 (Deac.) is performed when OST processing ends.*

Figure 3.5-1: States/Modes Diagram

The following definitions apply:

- A "State" is considered as a specific configuration of the hardware and software used to perform a specific task.
- An “operating mission mode” (or “Mode”) is considered as one of the specific mission task required by the mission as store data or downlink data. Mode availability depends on States.

The **Boot Sequence** is not considered as a State but a transitory condition between Power Off State and Check/Init State. See Check/Init State for more details.

3.5.1.1 Power Off State

In Power Off State, the DES is not powered. The DES can be made to transition to Power Off State, by switching it off, while being in any other State/Mode.

3.5.1.2 Check/Init State

Check/Init State is nominally entered, after applying power to the DES, at the end of the Boot Sequence which loads the main SHARAD SW code into RAM. In case of an unsuccessful Boot Sequence, a Boot Report is generated using the appropriate telemetry format.

This State may be also entered as result of some applications of the RESTART Command.

While in this State, the HW and SW initialisation of the DES is performed and commands cannot be received, neither Science Data nor Telemetry are generated and monitoring is not performed.

In this State the RX and the TFE are OFF.

At the end of a successful initialisation this State is automatically exited with a transition to Stand By State. In case of errors, this State is exited with an automatic transition to Safe/Idle State.

3.5.1.3 Stand By State

Stand By State is automatically entered as result of a successful DES initialisation or at the end of the processing of an Operational Sequence Table. While in this State, the DES receives and interprets Commands, generates housekeeping Telemetry and monitoring is enabled. No Science Data are generated.

In this State the RX and the TFE are OFF.

This State is nominally exited after reception of a valid ENABLE OST Command, which starts the processing of the Operational Sequence Table, switches ON the RX and performs an autonomous transition to Warm Up 1 State.

In case of errors or anomalies, excluding the reception of incomprehensible or invalid Commands but including the detection of an out of limits condition for monitored parameter, a transition is performed to Safe/Idle State.

3.5.1.4 Warm Up 1 State - activation

Warm Up 1 State is automatically entered as a first preliminary step toward the execution of an Operational Sequence Table.

In this State the RX is switched ON and a warm up delay is waited. The TFE is, and remains, OFF.

Reception of Commands is disabled, and any Command received while in this State shall be logged and discarded. Telemetry is generated and monitoring is active. No Science Data are generated.

This State is nominally exited, at the end of the RX Power Up (or Activation) Delay, by switching ON the TFE and autonomously transitioning to Warm Up 2 State.

The actual switching ON of the transmitter depends on the state of the TX_ENABLE signal (DES_TC_1). If the signal is not active at the beginning of the state transition, the transmitter will not be switched ON but the rest of the State behaviour shall not be altered.

In case of an anomaly, that is the detection of out of limits condition for monitored parameters, a transition is performed to Safe/Idle State thus ending the processing of the OST.

3.5.1.5 Warm Up 2 State - activation

Warm Up 2 State is automatically entered as a second preliminary step in the execution of an Operational Sequence Table.

In this State the RX and the TFE are switched ON and a warm up delay is waited.

Reception of Commands is disabled, and any Command received while in this State shall be logged and discarded. Telemetry is generated and monitoring is active. No Science Data are generated.

At the end of the TFE Power Up (or Activation) Delay the DES remains idling, waiting for the expiration of the OST Time Tag (which marks the beginning of the first operational mode programmed into the Table). Therefore, this State is nominally exited, as soon as the OST Time Tag expires, with an autonomous transition to the Mode specified by the first OST entry.

In case of an anomaly, that is the detection of out of limits condition for monitored parameters, a transition is performed to Safe/Idle State thus ending the processing of the OST. If the OST Time Tag is already expired at the end of the TFE delay a transition back to Warm Up 1, and then to Stand By, is performed.

3.5.1.6 Safe/Idle State

Safe/Idle State is automatically entered whenever a not nominal condition is encountered in any other State/Mode. In this State the RX and the TFE, if ON, are switched immediately OFF at the end of the transition.

In Safe/Idle the DES is able to receive and interpret a limited set of Commands including PATCH_MEMORY, DUMP_MEMORY and RESTART. Telemetry is generated and monitoring is active. No Science Data are generated.

The State is exited by an explicit Power OFF, performed by S/C, or by means of a RESTART Command. In the latter case the exit will produce a transition to the Check/Init State (with the software restarted directly from RAM or fully re-loaded from EEPROM).

3.5.1.7 Warm Up 2 State - deactivation

Warm Up 2 State is automatically re-entered at the end of the execution of the last entry of the Operational Sequence Table. In this State the RX and the TFE are, and remains, ON, while a brief TFE Power Off (or De-Activation) Delay is waited.

Reception of Commands is disabled, and any Command received while in this State shall be logged and discarded. Telemetry is generated and monitoring is active. No Science Data are generated.

This State is nominally exited, at the end of the Power Off Delay, by switching OFF the TFE and autonomously transitioning back to Warm Up 1 State.

In case of an anomaly, that is the detection of out of limits condition for monitored parameters, a transition is performed to Safe/Idle State.

3.5.1.8 Warm Up 1 State - deactivation

Warm Up 1 State is automatically entered after Warm Up 2, during the deactivation process after the end of the processing of an Operational Sequence Table. In this State the TFE is OFF and the RX is ON and remains, ON, while a brief RX Power Off (or De-Activation) Delay is waited.

Reception of Commands is disabled, and any Command received while in this State shall be logged and discarded. Telemetry is generated and monitoring is active. No Science Data are generated.

This State is nominally exited, at the end of the power off delay, by switching OFF the RX and autonomously transitioning back to Stand By State.

In case of an anomaly, that is the detection of out of limits condition for monitored parameters, a transition is performed to Safe/Idle State.

3.5.1.9 Operational Modes

Operational modes nominally see SHARAD configured with both the TFE and the RX switched ON regardless of the modes to be executed. However, if while transitioning through Warm Up 1 – Activation, the TX_ENABLE (DES_TC_1) was not active, then the TFE will not be switched ON. In this not nominal condition (used only for safe testing of the instrument) all operational modes are executed nominally.

Operational (or Measurement) Modes corresponds to the different actions that the DES may perform under the guidance of OST entries. Each OST entry specifies details for the transition to, and the execution of, a given Operational Mode. After the last Mode a transition is automatically performed to Warm Up 2 State.

Telemetry is always be generated during Operational Modes and monitoring is active. Commanding of the instrument is disabled and the DES will report a software anomaly in case commanding is attempted, without interrupting the OST processing.

In case of other error or anomalies during Operational Modes processing, an automatic transition is performed to Safe/Idle State.

Subsurface Sounding (SS) Mode

Subsurface Sounding Mode is the main measurement mode for SHARAD. In this Mode the DES shall perform scientific measurements by transmitting radar pulses and collecting, processing and formatting received echoes. PRI and duration are variable depending on parameters specified in each OST entry. A variable Science Data rate will be produced in this Mode depending on the specific processing parameters.

Receive Only (Rcv Only) Mode

Receive Only Mode is used to perform passive measurements mainly during the on-orbit phase, but can also be used to check the performances of the instrument during the cruise phase (even with the antenna folded). The TFE is ON but no transmissions will be performed. A variable Science Data rate will be produced in this Mode depending on the specific processing parameters.

Calibration (Calib) Mode

Calibration Mode is used to perform instrument calibrations during the on-orbit phase. A variable Science Data rate will be produced in this Mode depending on the specific processing parameters.

Wait Mode

Wait Mode is an idle mode used to introduce gaps in the measurement phase of an active orbit. Both the RX and the TFE are ON but no transmissions will be performed. No Science Data will be produced.

Test Mode

Test Mode is a debug mode used to generate a stream of science data simulating an instrument operational mode exercising all DES internal functions. A static pattern of data is also generated occasionally. Both the RX and the TFE are ON.

In current SW release (2.4) the Test Mode perform an SS Mode and therefore the TFE will transmit radar pulses. A future SW release may request to change this behaviour in order to have the Test Mode perform a RO Mode thus permitting to switch on the TFE without any danger in case the antenna has not yet been deployed.

3.5.1.10 States/Modes Indentification

DES States/Modes are identified by a unique numerical code, and are reported in every HK telemetry packet. The following table shows relevant identification values:

Sharad Mode	ID
CHECK/INIT	0x0
STANDBY	0x1
WARMUP1 Activation	0x2
WARMUP2 Activation	0x3
IDLE	0x4
SS	0x5
RECEIVE ONLY	0x6
WAIT	0x7
CALIBRATION	0x8
WARMUP1 Deactivation	0x9
WARMUP2 Deactivation	0xA
TEST	0xB

3.5.1.11 Allowed Transitions

The following table shows DES allowed mode transition (blank cells means transition not allowed):

		Final State/Mode											
		CHECK / INIT	STAND BY	WU1 ACT	WU2 ACT	SAFE/ IDLE	SS	REC ONLY	WAIT	CALIB	TEST	WU1 DEA	WU2 DEA
Start State/Mode	CHECK /INIT	YES	YES			YES							
	STANDBY	YES	YES	YES		YES							
	WM1ACT			YES	YES	YES							
	WM2ACT				YES	YES	YES	YES	YES	YES	YES		YES
	SAFE/IDLE	YES				YES							
	SS					YES	YES	YES	YES	YES	YES		YES
	REC_ONLY					YES	YES	YES	YES	YES	YES		YES
	WAIT					YES	YES	YES	YES	YES	YES		YES
	CALIB					YES	YES	YES	YES	YES	YES		YES
	WM1DEA		YES			YES						YES	
	WM2DEA					YES						YES	YES
	TEST					YES	YES	YES	YES	YES	YES		YES

Note that a transition to the same mode is always allowed.

The SAFE/IDLE State is a safety state that is entered whenever an unexpected event occurs or a potentially dangerous situation is detected.

There are four conditions that can force the DES into SAFE/IDLE State:

- On Monitoring OOL event occurrence;
- On Built In Test (BIT) failure;
- On certain Time Update failures;
- When an OST is found corrupted before starting science operations.

3.5.2 Science Observation Programming Model

3.5.2.1 Overview

The following definitions will apply:

Data Block: a Data Block is a set of Science Data, generated by SHARAD, which contains echoes averaged from one or more PRIs.

Data Take: a Data Take is the set of Data Blocks generated within the same Measurement Mode (a Measurement Mode corresponds to the execution of one OST line).

Every orbit, SHARAD executes a timeline of observations defined as a succession of Operational Modes each one specified by an entry in the Operational Sequence Table. According to the definitions given above, each Operational Mode produces therefore one Data Take. The whole result of an active pass (all the modes specified by the relevant OST load) is a series of Data Takes stored in the S/C SSR. Figure 3.5.2-1 shows the relationship between OST line, Data Block and Data Take.

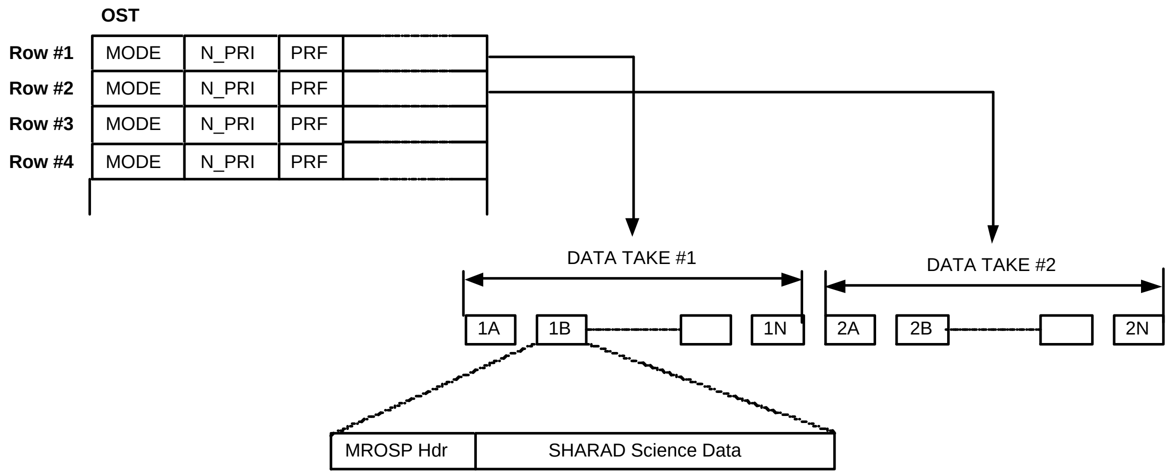


Figure 3.5.2-1: Relationship between OST, Data Takes and Data Blocks

Operating parameters that affect the entire observation pass are stored in the Parameter Table, which is used also to store engineering and functional parameters of SHARAD. Namely, those operational parameters are mainly the polynomial coefficients used to estimate the topographical characteristics of the ground track.

To perform internal estimation of the distance from the sub-satellite point, SHARAD SW needs, for each observation, orbital data, to be stored in the Orbital Data Table.

3.5.2.2 Instrument Timeline

The basic instrument timeline foresees that, before each observation is performed, three data sets (corresponding tot he three above-mentioned tables) are loaded and, then, the observation is commanded for execution at a given reference time tag.

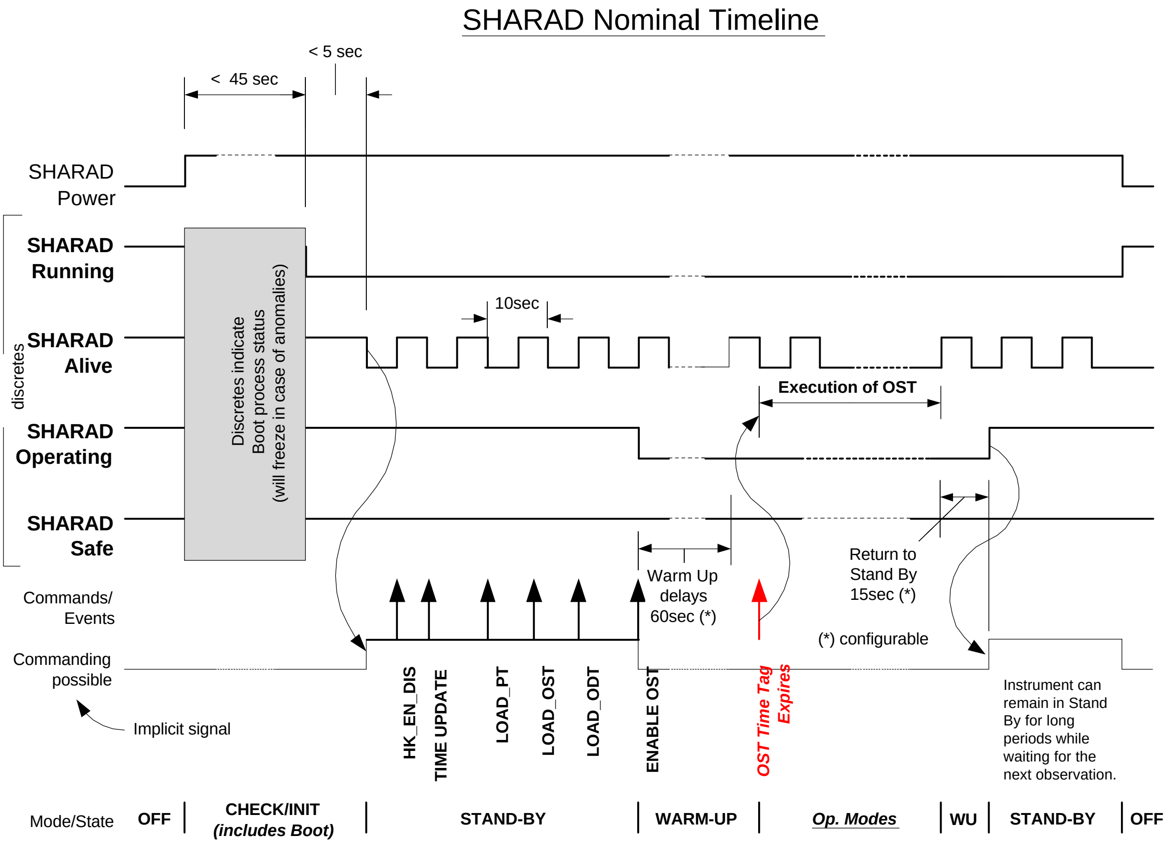


Figure 3.5.2-2: Instrument Timeline.

During observation processing SHARAD cannot be further commanded and the only way to interrupt an observation is that to power off the instrument. At the end of the observation, SHARAD transitions back into Stand By State where commanding can resume.

3.5.3 SHARAD Commands

The DES accepts the following commands:

Command Name	Cmd_ID	Description
TIME_UPDATE	0x01 (*)	Used to provide a new OBT value.
HK_EN_DIS	0x10	Used to configure the generation of HK telemetries and to enable/disable the internal HK buffer.
LOAD_OST	0x14	Used to load a new OST for next science pass.
LOAD_PT	0x15	Used to update the PT stored in RAM, in particular for setting new polynomial coefficients for the next science pass.
LOAD_ODT	0x16	Used to load a new ODT for the next science pass.

ENABLE_OST	0x11	Used to start the execution of a newly loaded OST, providing its starting Time Tag.
PATCH_MEMORY	0x12	Used to patch any not-write-protected memory location.
DUMP_MEMORY	0x13	Used to dump any memory location.
RESTART	0x30	Used to reboot the instrument from EEPROM or from RAM or to perform an EEPROM re-write or to re-load PT defaults.
LOAD_REQUEST	0x12 (**)	Used to start the Loader for a full SW load.
LOAD_DATA	0x12 (**)	Used to load a memory image.
LOAD_CHECKSUM	0x12 (**)	Used to provide the checksum for a newly loaded memory image and start EEPROM programming.

(*) Cmd_ID for TIME_UPDATE is not required (this is a S/C defined command). However, for SW tracing purposes, a Cmd_ID value is assigned.

(**) These commands share the same Cmd_ID of the PATCH_MEMORY command because they are based on the same format. However, since they are interpreted by a different SW (the Boot/Loader), no ambiguity exists.

Additional details may be temporarily found in [**AD-02**] and in section 5.1.

3.5.3.1 Commands Eligibility

The table below shows CMDs elegibility, blank locations means CMD not allowed for the mode.

		DES Mode		
		STAND BY	SAFE/IDLE	OP MODES
Command	Patch	YES	YES	
	Dump	YES	YES	
	EEPROM Rewrite	YES	YES	
	Time Update	YES		
	Enable OST	YES		
	Restart	YES	YES	
	HK Enable/Disable	YES	YES	
	Load OST	YES		
	Load PT	YES		
	Load ODT	YES		

3.5.4 SHARAD Telemetries

The DES generates two types of telemetry packets:

- Housekeeping (HK) packets.
- Science Data (SD) packets.

Telemetry packets share the same overall layout and are internally specialized. Housekeeping packets are not segmented.

Additional details for both formats may be temporarily found in [**AD-03**] and in section 5.2.

3.5.4.1 Housekeeping Telemetries

There are 6 types of HK Telemetry packets:

TLM Format	TLM_ID	TLM Type	Description
TLM_ENG	0xE	Engineering	Generated at regular intervals (configurable) to provide instrument status with a set of parameters related to HW and SW conditions.
TLM_ACK	0xA	Command Acknowledge	
TLM_LOG	0xF	Event/Error Log	
TLM_DMP	0xD	Memory Dump	
TLM_CMD	0xC	Command Log	
TLM_BTR	0xB	Boot Report	

3.5.4.2 Science Data Telemetries

Science Data Telemetries share the same TLM_ID, value 0x0.

Science Data packets are subject to segmentation in order to identify all the packets which belong to the same operating mode.

There are two types of Science Data Telemetry packets:

Science Data packets, which contain data processed from sampling the RX output.

Tracking Data packets, which contains a portion of the RX data processed by the Tracking algorithm.

The two types of packets are distinguishable from a flag embedded in the Auxiliary Data Header.

3.5.5 Radar Operations and Science Data Processing

3.5.5.1 Instrument Timing Diagram

The timing of SHARAD Radar operations is driven by the need to allocate the radar echoes from Mars surface (and sub-surface) in a suitable time frame between transmission pulses, covering the range variability due to Mars topography (assumed +20 Km/-10 Km wrt nominal radius) and Spacecraft orbit with a single PRF (i.e., SHARAD does not change its PRF in an adaptive way in relation to the target range).

This goal has been achieved for the orbit range foreseen for the MRO Nominal Science Phase (255 – 320 Km). To cope with the extended orbit variability expected in the extended and contingency mission (230 – 407 Km), two additional PRF values, slightly lower (670.22) and higher (775.19 Hz) than the nominal, have been added. PRF selection is pre-programmed in the Operational Sequence Table.

The resulting operations timing, depicted in the upper part of figure 3.5.5-1 foresees a nominal PRF value of 700.28 Hz, such to allocate the return echo range in the second-time-around window (i.e., the echo of the transmitted pulse N is located between the transmitted pulses N+1 and N+2). Received signals are acquired during an Rx window of 135 µsec. This duration accounts for:

- Pulse width: +85 µsec
- Useful range from surface (time window of subsurface echoes): +20 µsec
- Margin for Rx window positioning error: +/- 10 µsec
- Margin for ionospheric delay: +5 µsec

Therefore, the Rx window shall be opened 10 µsec before the predicted surface echoes delay to account for the positioning margin.

PRF: 700.28 Hz

PRF: 350.14 Hz

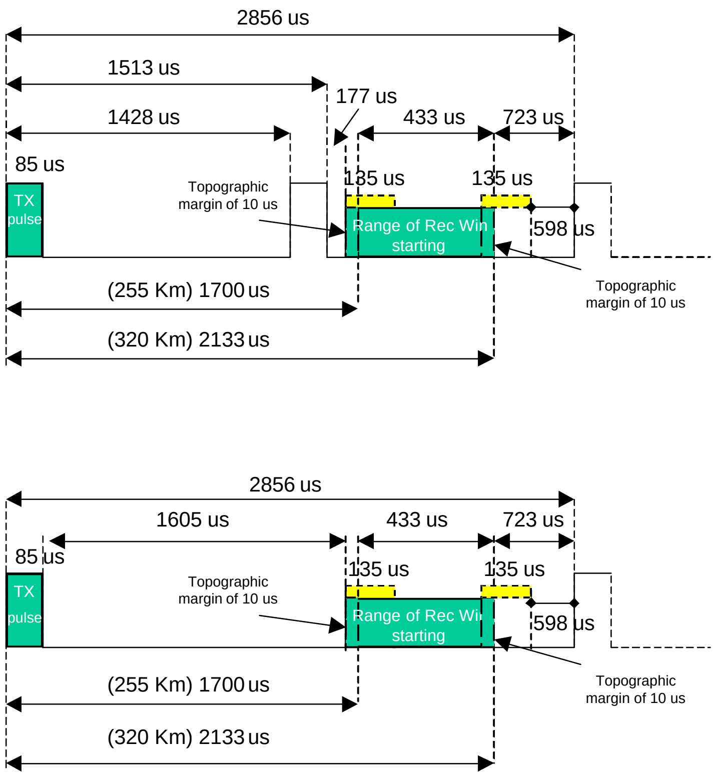


Figure 3.5.5-1: General Radar Timing

To avoid possible ambiguities due to triple-time-around echoes from points of the surface far from nadir (which are not regarded as likely but which may anyway occur at least in some scenarios) SHARAD foresees also the possibility to operate at half the PRF (thus avoiding ambiguities from odd-order returns).

The relevant operation in depicted in the lower part of Figure 3.5.5-1.

The detailed radar operation timing, derived from the above general operations, is given in Figure 3.5.5-3. This is applicable to both normal, or “ambiguous”, operations and to "non ambiguous" (1/2 PRF) operations, considering that the latter case can be viewed as a normal (ambiguous) operation with one PRI having only Tx and the other only Rx.

The reference clock for the timing generation is derived from the 80 MHz master clock. All events use a time quantisation of 1/12 of the 80 MHz clock, in order to be synchronous both with 26.6667 MHz (80MHz/3) and the processor clock (80MHz/4).

The master reference mark in the timing is the PRI Trigger, which marks the start of the operation sequence for each PRI. The actual transmission takes place, with the generation of the chirp pulse by the chirp generator, 15 usec later. This time is used to open two gates:

- the "Tx gate", which activate the bias of the TFE final stage, starting 15 μsec in anticipation of the chirp (simultaneous to the PRI trigger), in order to allow thermal stabilisation of the stage;
- the Tx/Rx control, which connects the TFE output to the antenna by way of the diplexer switch (by default, it is kept in the Rx position).

On the receive side, the signal is continuously sampled by the AD converter present in the Rx, driven by the 26.6667 MHz clock. The sample is stable, at the output of the Rx, 2.5 cycles after the relevant "start of conversion" positive edge from the DES, and it is re-sampled on the negative edge of the 26.6667 MHz.

Only 3600 samples per PRI (corresponding to a receive window of 135 μsec) are actually acquired by the DES and stored in the FIFO. The start of the receive window is generated with a delay from the PRI trigger which can be computed from ODT and PT data or provided by the tracking function.

The "Rx gate" signal enables the operation of the receiver, which is kept normally blanked to protect it from transmission leakage or other unwanted signals coming from the antenna.

It is worth noting that, to cope with the operation on second-order return, in the first PRI of an acquisition block (corresponding to one entry in the OST), the return signal is NOT acquired (return from the first transmitted pulse will arrive in the 2nd PRI). In the same way, the last PRI of a block is receive only (no Rx) being the radar still receiving echoes from the former transmitted pulse. This does not apply when DES operates with PRF/2 values.

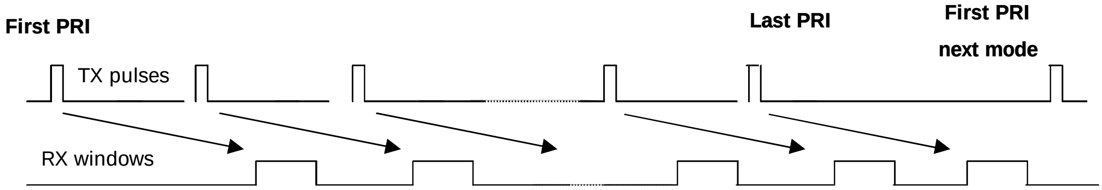


Figure 3.5.5-3: Handling of Second Order Returns

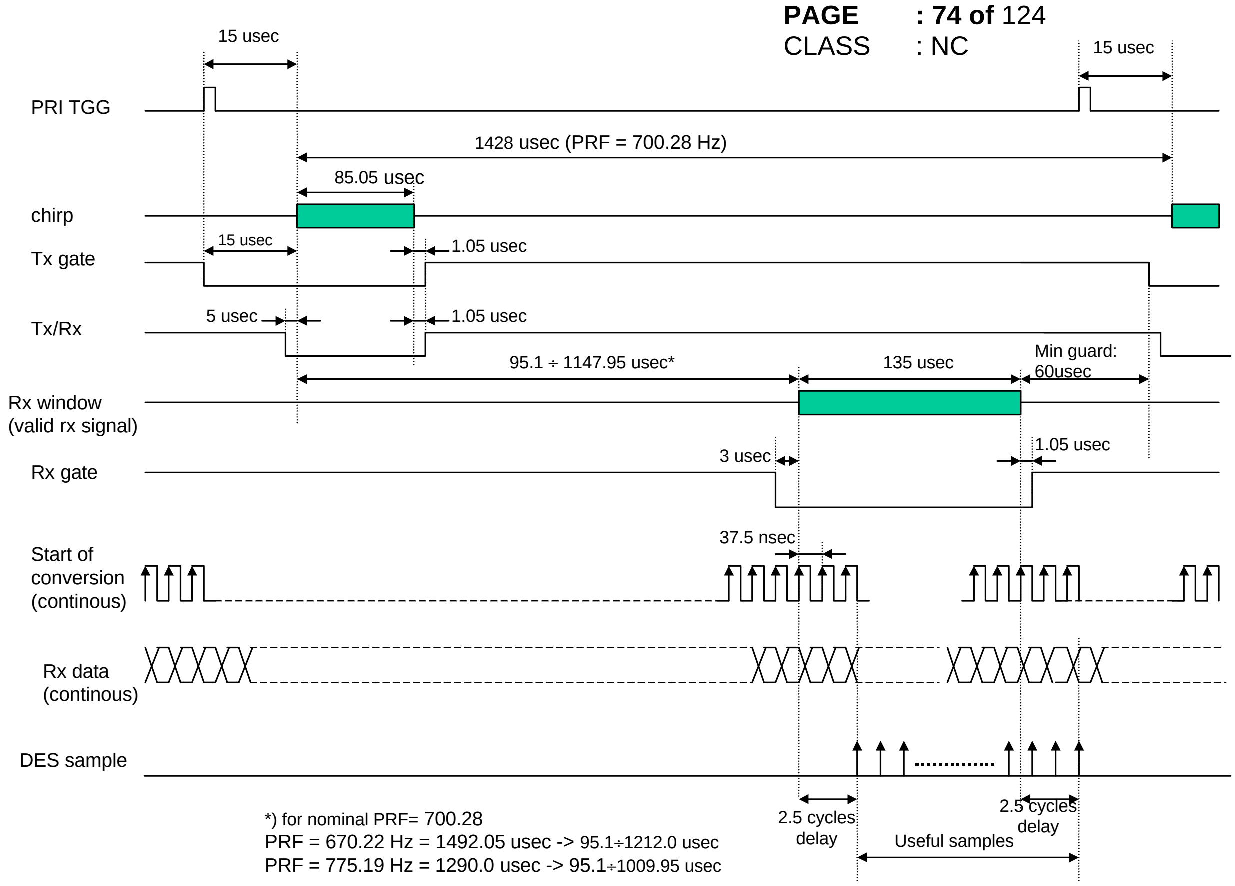


Figure 3.5.5-4: Complete Radar Timing Diagram

3.5.5.2 Operational Sequence Table

The Operational Sequence Table, OST, contains SHARAD measurement modes programming for the active portion of an orbit. The execution of the OST coincides with performing radar operations.

Once the OST has been loaded into the instrument by means of a LOAD_OST Command, its execution (and thus the programmed measurements) are initiated by an ENABLE_OST Command and, thence, will proceed autonomously by means of automatic mode transitions following the timeline listed in the Table.

Each line of the OST defines a single Operational Mode, its duration and the required parameters to permit its execution.

The basic Operational Sequence Table layout is represented in Figure 3.5.5-3.

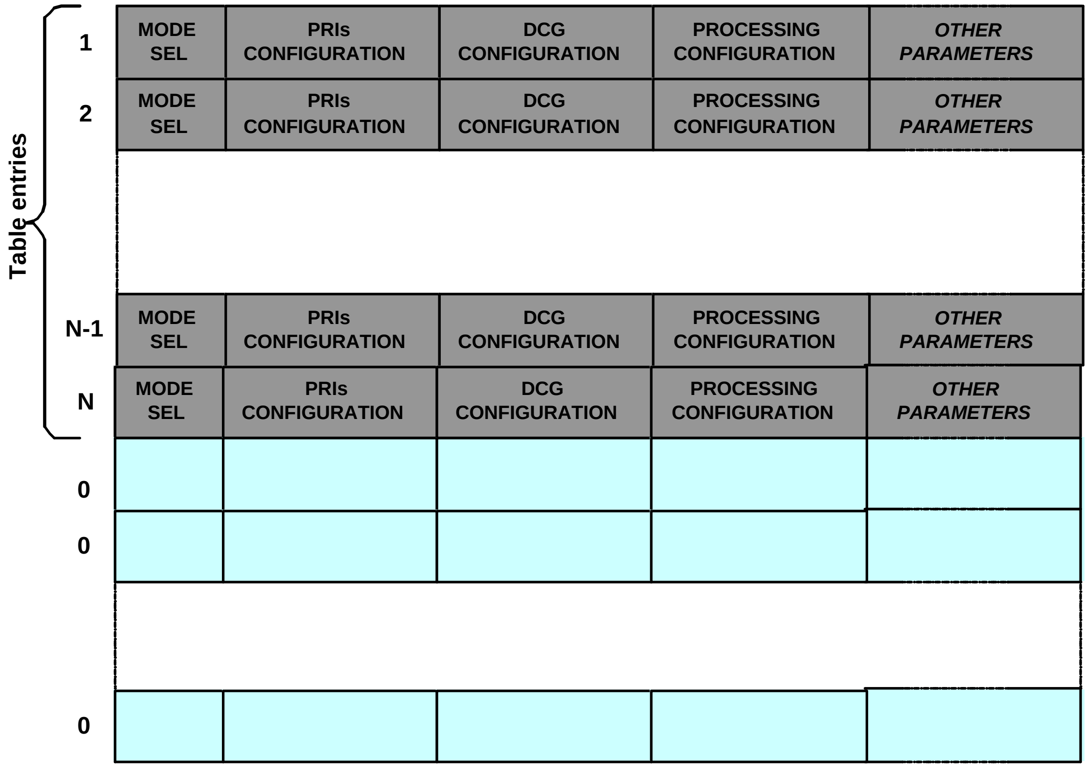


Figure 3.5.5-5: OST Generic Layout.

The OST is default loaded with 0's and is reset at the end of each observation. If an OST has not been loaded, a request to start a observation will produce a SW event report.

Details about usage of the OST for programming Measurement Modes are provided in Section 6.

3.5.5.3 Parameter Table

The Parameters Table contain all SHARAD's operational and engineering parameters organised for a random access. Each parameter is identified by an identification number and has associated one value. Value types are of different type but are all stored in a single 32-bits word.

Parameters contained in the Parameters Table may be associated to three main categories:

- Instrument Configuration Parameters, that should not require any update (e.g., Speed of Light or PRF values).
- Instrument Calibration Parameters, that once set (after ground testing first, and after orbital commissioning) should not require any update (e.g., closed-loop tracking algorithm parameters).
- Instrument Operating Parameters, that shall be set before every execution of a sequence of measurement modes.

The Parameters Table has the following basic structure:

Parameter's Location		Usage	Number of Locations
From	To		
0	59	System initialization parameters	60
60	1020	Polynomial Coefficient Tables	961
1021	1033	DCG Configuration Table	13
1034	1094	Tracking Parameters	61
1095	5190	Tracking Reference Function	4096

- System initialization parameters contain values related to DES SW behaviour, such as the Engineering HK Telemetry period, the SHR_Alive discrete signal period, the Monitoring limits, etc.
- Polynomial Coefficient Tables contains the values of the coefficients used for Mars topographical characteristics interpolation performed by Radar Processing. These values are Instrument Operating Parameters.
- DCG Configuration Table contains registers' values used by Radar processing to initialize and perform PRI-based DCG programming
- Tracking Parameters and Tracking Reference Function are used by Tracking algorithm.

Note that the Parameter's Location is an offset from the beginning address of the PT stored in memory (that is, the physical address of a Parameter's value is the referred PT base address plus its location).

A copy of the default value for the first 1095 PT locations is stored inside both Program EEPROM partitions (i.e., the Reference Function values are not stored in EEPROM).

During DES Power On sequence, the PT stored in EEPROM is copied into Data RAM and from there it will be referred by DES SW. At the end of the copy process (using 4 values in PT) the 2048 complex points FFT of the Tracking Reference Function are computed and stored in the dedicated portion of the PT in RAM, thus completing the whole PT. Note that the Reference Function values are generated not only during the during power on phase (EEPROM re-boot), but also when a warm restart command is executed.

Each Parameters Table location is defined as a 32 bits wide value. When in Data RAM each parameter occupies naturally a 32bit word. Since the EEPROM is a 48 bits wide memory, the PT default values stored there occupy a 48 bit word each. Values are left aligned (e.g., if a parameter as value 42 decimal, than its representation in PT RAM is 0x0000002A while its representation in PT EEPROM is 0x0000002A0000).

Note that in case a parameter is a signed integer, the sign must be propagated through 32bit. That is, to write the decimal value -1 as a 32 bits parameter, the correct translation is 0xFFFFFFFF, not 0x00000FFF or similar values.

Values in PT RAM can be modified via LOAD_PT Commands, or even via PATCH_MEMORY Commands. The only way to change the default value of a parameter is that to use a PATCH_MEMORY Command targeting the EEPROM. Users should take care in patching default PT values, since a wrong patch could affect SW behaviour. care shall be taken also to respect the correct value alignment in the 48 bits word as described above.

Details about usage of the OST for programming Measurement Modes are provided in Section 6.

3.5.5.4 Orbital Data Table

The Orbital Data Table contains orbit-related parameters required for the open-loop tracking of the radar sounding process (and for the initialisation of the closed-loop tracking algorithm). Data for the ODT are generated on Ground and provided to the instrument as part of the programming for each active orbital pass.

ODT data include two separate values for the ODT Step (time interval between ODT lines) and for the definition of an early starting point (ODT Start) of the ODT (referred to the OST Time Tag being used for the observation).

T_0:	ODT_START	S:	ODT_STEP

$T_0 + S = T_1$:	TLP	RADIUS	RAD_RATE	VEL_TAN
$T_0 + 2S = T_2$:	TLP	RADIUS	RAD_RATE	VEL_TAN
$T_0 + 3S = T_3$:	TLP	RADIUS	RAD_RATE	VEL_TAN
$T_0 + NS = T_N$:	TLP	RADIUS	RAD_RATE	VEL_TAN

Figure 3.5.5-6: ODT Generic layout

Once the ODT has been loaded and the OST is being executed, the ODT provides the relationship between the On Board Time and the sub-satellite point being observed.

The ODT is default loaded with 0's. If an observation is started without having previously loaded an ODT, unpredictable science results will be obtained.

Details about programming the ODT in order to perform measurements are provided in Section 6.

3.5.5.5 PRI Management

As baseline, all the nominal operations of the instrument will use the 700.28 Hz PRF ("nominal PRF"): in the case that problems due to third-order are detected, the PRF of 350.14 Hz ("nominal 1/2") can be used (it must by noted that at this PRF the transmitted total energy is halved, with 3 dB decrease of the S/N after processing).

For use during the extended operation phase, a higher and a lower PRF are available (together with the corresponding 1/2 PRF mode) to be used in the lower and higher part of the orbit respectively.

The orbit ranges covered by the 3 available PRFs are the following:

PRF Summary				
Ambiguous PRFs	Freq.	Period	Range	Orbit
Nominal PRF	700.28 Hz	1428 μsec	230-400 km	250-390 km
High PRF	775.19 Hz	1290 μsec	210-360 km	230-350 km
Low PRF	670.22 Hz	1492.05 μsec	240-419 km	260-409 km
Not Ambiguous PRFs	Freq.	Period	Range	Orbit
Nominal PRF	350.14 Hz	2856 μsec	230-400 km	250-390 km
High PRF	387.595 Hz	2580 μsec	210-360 km	230-350 km
Low PRF	335.11 Hz	2984.1 μsec	240-419 km	260-409 km

PRFs are selected by the SHARAD SS mode parameter in the Operation Sequence Table. The wide overlap existing between the orbit coverage of the 3 PRFs makes the time of the PRF switching not critical.

3.5.5.6 Science Data Processing

Data processing performed on-board is very limited to simplify instrument operations, and consists mainly in a coherent pre-summing of the received data. According to the operating scenario, several levels of pre-summing can be selected, i.e.: pre-summing 1 (i.e, no pre-summing), 2, 4, 8, 16, 28, 32. The average data relevant to the N PRIs are referred to as a **data block**.

When pre-summing "N" is selected, the samples from N sequential PRIs are averaged sample-by-sample, thus reducing the data rate by a factor N.

The data are represented in fixed point, 2's complement notation, and the averaging operation is performed by adding and scaling the data of sequential PRIs.

Two kinds of scaling are possible:

- fixed scaling: data are scaled by log2(N)
- dynamic scaling: this is equivalent to a fast automatic gain control performed at digital level. For each data block, the minimum scaling factor, which prevent data overflow, is automatically selected in order to best exploit the available data transmission dynamic range. The scaling factor is then included in the data block ancillary data.

Selection between these two operations is performed by a dedicated parameter of the operating mode selected by the Operation Sequence Table.

In order to allow proper synthetic aperture forming on ground, when pre-summing is used, the pulse-to-pulse phase shift induced by Doppler effect due to spacecraft radial velocity shall be compensated for. To compensate for the Doppler shift the signal should be phase shifted in steps in relation to the radial velocity value.

Additionally, when an off-nadir pointing is desired (e.g., over sloped surfaces), a linear phase term shall be added within a data block to allow proper aperture forming, compensating for a pseudo Doppler proportional to effects due to tangential velocity and slope.

In both cases, it is required to add a linearly increasing/decreasing phase shift in the received signal. For practical purposes, this is not performed acting on the receive chain, but acting on the transmit chain. In fact, the digital chirp generator enables to program the starting phase of the chirp pulse: this feature allows implementing this compensation without additional hardware and just by properly setting the Tx chirp pulse on each PRI.

The information about S/C radial velocity and slope compensation are included in the ODT and PT, respectively. They are combined to compute the overall frequency shift required for the compensation and, consequently, the phase increment steps to be applied. The phase is always programmed as zero for the first transmitted chirp of a data block, and is linearly increased (decreased) in the subsequent pulses. Phase is reset to zero for the new data block.

It is noted that the scope of the on-board compensation is only to avoid losses due to target de-correlation in the pre-summing process, not to perform the overall compensation, which will be performed on-ground during the aperture synthesis processing. This is the reason for the compensation to be re-initialized at the start of each data block.

Radial velocity and "slope" compensation can be individually enabled by specific parameters in the OST.

3.5.5.7 Tracking Processing

Proper operations of SHARAD require knowledge of the spacecraft/surface range in order to correctly position the receive window within the PRI. This can be accomplished by two different methods:

- derive surface range from an “a priori” knowledge of surface topography and spacecraft orbit ("open loop" tracking)
- autonomously generate the range information from onboard processing of the received echo itself ("closed loop" tracking).

The open loop tracking uses two sets of data, one relevant to the Mars elevation profile along the predicted ground track, and the other relevant to S/C predicted altitude along the orbit, stored in the Parameter Table (PT) and in the Orbital Data Table (ODT) respectively.

Elevation data in the PT is stored in the form of polynomial coefficients: profiles segment relevant to a ground track corresponding to 30 sec of flight, are reconstructed by interpolating a 6th order polynomial provided in the PT, obtaining the radius of the surface (relevant to the Mars centre) in km as a function of the "Track Lenght Position" (TLP).

The ODT contains position along the ground track (Track Lenght Position, TLP) and spacecraft altitude data (Mars radius in km) in a form of a table, as a function of on-board time, at variable interval (typical, 1 sec).

The TLP is expressed in arbitrary units, named TLUs (Track Lenght Unit) indicating the walk along the S/C ground track referred to the TLP origin

Refer to Section 6 for details of the generation of ground profiles for PT and their correlation with the ODT data.

The ODT contains also the Radius Rate (in m/sec) and the Tangential Velocity (in m/sec), also as a function of on-board-time. They are used, together with the Surface Slope compensation profile (also in polynomial form, 7th order) provided by the PT, to compute the phase compensation parameters.

An overview of the parameter reconstruction process is provided in fig 3.5.5-5. The current time is used as input to look in the ODT data, linearly interpolating, if needed, the ODT discrete value, to fetch the corresponding TLU, radius, radius rate and tangential velocity.

The TLU value is used to expand the appropriate polynomial of the PT data to derive the corresponding values for topography and slope compensation.

Topography and S/C radius are then combined to derive the Rx window position, while surface slope, radius rate and tangential velocity are used to generate the phase compensation information.

The avoid ambiguities, the S/C location (TLP) is expressed as progress relevant to the track start point, in suitable length units (TLU)

Note also that, instead of having the time as an entry in the ODT, the information of the start time and time step is included in the relevant PT.

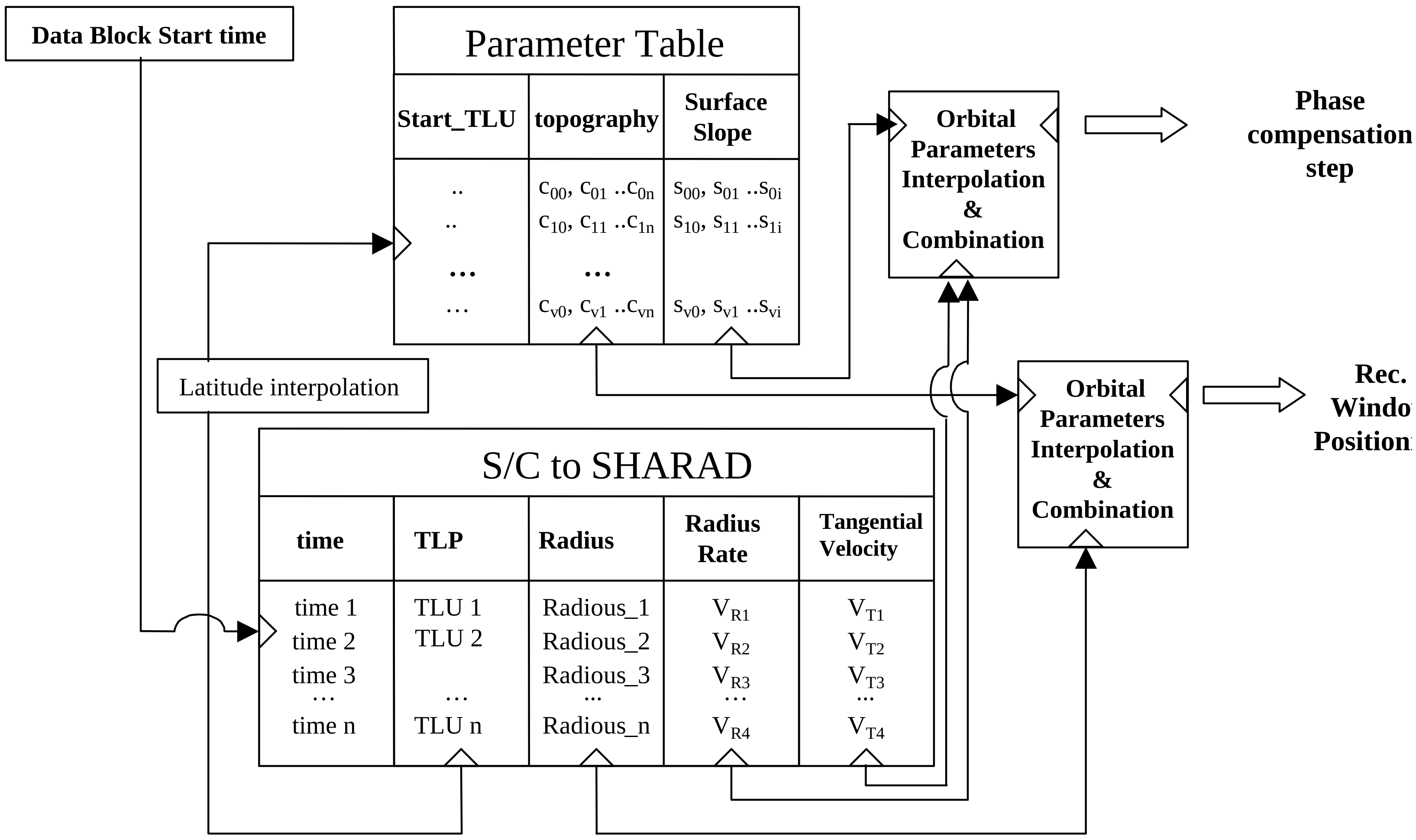


Figure 3.5.5-7: On-board Parameters Reconstruction Process

Closed loop tracking, on the other hand, makes use of autonomously derived information.

Acquired echoes after presumming are:

- further presummed to increase the S/N ratio (amount of additional presumming is programmable by the OST)
- decimated (not all the acquired data are submitted to further processing: this because the range compression is a computational intensive task, and of the need of limiting the processor load)
- range compressed, to exploit the range resolution relevant to the 10 MHz signal bandwidth and to increase the S/N ratio

Following these steps, the proper tracking algorithm is applied.

Initial data for the tracking are derived from the same ODT-PT combined information used for the open-loop tracking. The signal centre of gravity is computed, and assumed as the surface echo position. Difference between centre of gravity and reference (desired) position is fed to an alpha-beta filter which, in turns, control the window positioning.

When positive confirmation of tracking is achieved, the window over which the centre of gravity is estimated is gradually narrowed. Tracking is confirmed if the peak signal within the range window exceeds a threshold computed from value outside the window (or selected from the PT)

If tracking is lost, the process is started again.

Radial and tangential velocity, and slope information, are still derived from PT-ODT data and not derived from the tracking.

Other parameters affecting tracking performances are:

- amount of presumming before range compression
- Automatic/Manual threshold selection
- Manual threshold values.

3.6 Performances and Budgets

3.6.1 Power Budget

SHARAD power consumption per mode, at nominal, minimum and maximum Vbus, is summarised in the table below (as measured on PFM).

	Power Demand (W)			**Current Absorption (A)**		
MODE	**36V**	**28V**	**22V**	**36V**	**28V**	**22V**
STAND-BY	12.4	12.1	12.0	0.34	0.43	0.55
WA-1	15.5	15.4	15.4	0.43	0.55	0.70
WA-2	20.9	20.4	20.3	0.58	0.73	0.92
SS/CALIBRATION/TEST	27.5	26.9	26.9	0.76	0.96	1.22
RxONLY	22.0	21.5	21.61	0.61	0.77	0.98

Table 3.6-1: SHARAD Power Consumption.

3.6.2 Command and Control Timings

Boot timing

DES Boot sequence duration lasts about 28 seconds (at the end of which the DES is in Stand By State).

This applies to both a power cycling and a full restart from EEPROM.

In case of a warm restart from RAM the boot time is less than 5 seconds.

Back to back commanding

As an operational margin, commands shall be sent not faster than a command every 2 seconds. The DES is guaranteed to process a command every second, but some commands require a negligible execution time.

This margin does not take into consideration the time required to perform long operations that might have been started by a given command (like ENABL_OST or MEMORY_DUMP).

When the TLM_CMD format is enabled (the format provides a dump of each command received as a HK Telemetry packet) DES SW performances in processing commands are not guaranteed anymore and the above margin shall be brought to a command every 5 seconds.

Engineering HK Telemetry Rate

The rate at which Engineering HK packets are generated has a default value of 10 seconds (that is, an Engineering packet is generated every 10 seconds regardless of the operating condition of the DES).

This value is a good compromise between SHARAD observability during operations and during the long periods in Stand By between active passes.

In case of trouble-shooting activities it is suggested to increase the rate of generation by means of the HK_EN_DIS Command.

Full SW Reload

A full SW reload is a timing critical operation which must start in a well defined timing window set for this purpose during the Boot sequence (see para. 3.4.4.2 for more details).

The sequence of steps defined is listed as follows:

1) Power on SHARAD (from either S/C side) selecting a convenient EEPROM Partition, that is not necessarily the one which is to be targeted by the reload operation.
2) Perform any required reference memory dump.
3) Set the TX_Enable discrete to address the EEPROM Partition targeted by the reload operation.
4) Reboot SHARAD from the EEPROM Partition targeted by the reload operation using a RESTART Command.
5) Wait 10 seconds.
6) Send a LOAD_REQUEST Command.
7) Wait 5 seconds.
8) Send the required sequence of LOAD_DATA Commands built with the memory image to be loaded. Use a 5 seconds interval between each command.
9) Send the LOAD_CHECKSUM Command containing the checksum value for the memory image being loaded.
10) Monitor the correct reboot of the instrument from the reloaded partition.

Updates to this procedure may be provided in next issue of this document.

3.6.3 Operations Timing

Science passes are UTC time tagged in coincidence of the overfly of the latitude relative to the ground track to be observed. After the start of the observation the timing will be set in terms of radar Pulse Repetition Intervals.

In order to program SHARAD correctly it is required that the Warm Up 1 Activation and Warm Up 2 Activation delays are respected.

In particular, the loading of the three tables, OST, PT and ODT, and the issuing of the ENABLE_OST command (carrying, in nominal conditions, the Time Tag of the observation) shall be performed in such advance as to take care of the need of the DES to go through the two delays before starting the first mode in the OST.

Default values for the Warm Up 1 Activation and Warm Up 2 Activation delays are, respectively, **20 and 40 seconds**. Therefore the ENABLE_OST Command shall be issued at least **60 seconds** before the observation Time Tag and the three LOAD Commands shall be issued even earlier.

In case the observation Time Tag expires before the end of the Warm Up 2 Activation delay, the entire observation will be lost with a SW Event report in telemetry.

Section 4 provides guidelines for a typical observation timeline.

3.6.4 Science Data Volume

This paragraph is TBD and will be provided in next issue of this manual.

It will include a summary of Science Data sizes and a quick reference guide to estimate volumes of data produced by observations.

4 SHARAD Operations

4.1 Introduction

4.1.1 Overview

4.1.1.1 Uplink

SHARAD receives commands to be interpreted and processed immediately. Commands are sent to SHARAD by the S/C C&DH (through the Command Interface), which acts after instructions sent from Ground. In order to be able to manage autonomously more than one orbit of operations, the S/C's C&DH will perform commands queuing on behalf of SHARAD. There is a clear distinction between commands sent to SHARAD's via the C&DH and commands that the C&DH sends to SHARAD.

The firsts are called **Ground Commands** and in their set are included those commands that produce S/C actions related to SHARAD (like switching the instrument on).

The seconds are called **Interface Commands** and include all those commands built according to SHARAD's commands formats and that SHARAD's DES can interpret and execute.

It is not possible to send a "SHARAD Command", or Interface Command, from ground up to the instrument. The required command shall be built by the C&DH and activated by a Ground Command.

The relationship between Interface Commands and Ground Commands is 1 to N (with N being at least 1) because the same Interface Command format may be used to perform different actions (see for example the HK_EN_DIS Command and the relevant two Ground Commands). In this respect we may consider Ground Commands as "instantiations" of SHARAD's Interface Commands.

Interface Commands are built by the C&D in four ways:

- Direct Command generation (no parameters involved).
- Command generation depending on one, or more, parameters.
- Command generation depending on a file previously uploaded to the C&DH and containing a portion of the Command itself.
- Command generation, by a combination of the latter two ways.

For instance, loading one of the operational tables in SHARAD means providing part of the relevant LOAD command as a file that shall be uplink to the S/C before invoking the Ground Command that will build the LOAD one. The format of these files is clearly defined.

The S/C C&DH has also defined sequences of Ground Commands, called **Blocks**, which are used to perform repetitive tasks. A dedicated Block, the "Targeting" one, is defined, for instance, to program SHARAD and perform a science pass. Other Blocks are defined to power the instrument On and Off, as well as to manage the Fault Protection scheme.

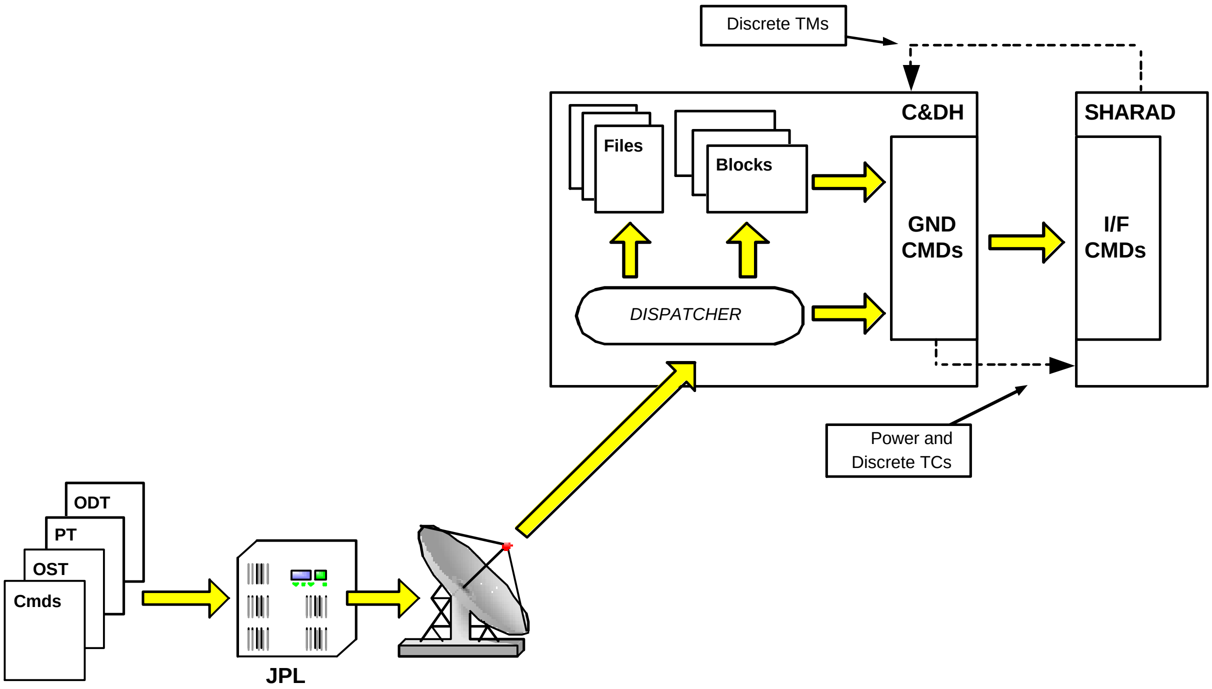


Figure 4.1.1-1: SHARAD Uplink Model

4.1.1.2 Downlink

SHARAD produces both Science Data and HK Telemetry over the same interface (Science Data Interface), which is connected to the S/C's SSR. Given also the typical mission constraints (distance, availability of DSN, etc.) these data may not be available on Ground in real-time.

The SSR is partitioned between different MRO's instruments. The partition allocated to SHARAD, called the Raw Space, is managed like a circular buffer. During the mission, the S/C C&DH perform a lower priority task to extract data in the Raw Space and packetize it for subsequent transmission to Ground. Packetized data are stored in the SSR Framed Space.

Packetisation is performed according to CCSDS formats and protocol. In particularm, CFDP (Common File Delivery Protocol) is used to transfer so-called Product Telemetry files containing a collection of instrument telemetries fetched from the SSR.

Since there is no direct connection from SHARAD's back to the C&DH, no SHARAD's HK Telemetry data is available for inclusion in the S/C's own telemetry downlink. To improve the latency time with which HK Telemetry is available on Ground, HK packets are copied from the SSR storage and downlinked on a separate, higher priority, channel.

The two different types of downlink data produced by SHARAD (Housekeeping alone and Science Data plus Housekeeping) will be distinguished by means of APID values. Two other APIDs will be used to specify a downlink using equipment working on another RF band, and for collections of unrecognized packets.

The only information available to the C&DH to assess SHARAD's health and status are the four TM discrete signals defined in Section 3. The C&DH monitors these lines and act on SHARAD according to their status. The status of the four discrete lines, as well as a number of engineering parameters related to SHARAD (including voltages, currents and temperatures) are available on the Ground as part of the S/C telemetry.

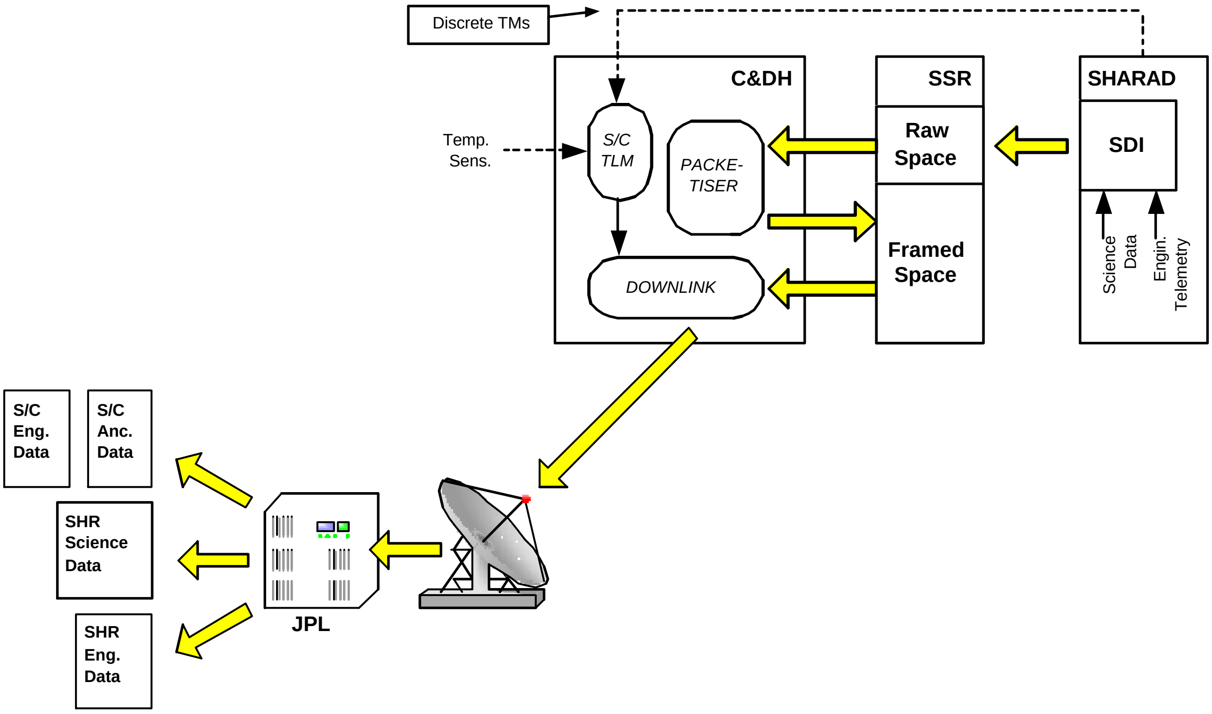


Figure 4.1.1-2: SHARAD Downlink Model

4.1.2 Operational Phases

The following operational phases have been identified:

- <u>ATLO – Assembly, Test and Launch Operations</u>

  All SHARAD PFM testing will be performed in flight-like conditions. All tests will be rehearsed using SHARAD EM in the Orbiter Test Bed (OTB).

  This phase includes the definition of System Verification Tests. While instruments are excluded by the S/C critical operations tests (e.g., Lauch or Aerobraking), dedicated Mapping SVT will be defined and repeated at critical milestones during ATLO operations.

- <u>Launch</u>

  No instrument activity is foreseen well after Launch, and subsequent S/C commissioning activities, have been performed. The instrument will be always switched off. The first engineering checkout will be performed without powering on the TFE.

- <u>Cruise</u>

  During cruise it is expected that a periodic engineering checkout will be run to assess instrument health status, without powering on the TFE. Other than for these checkouts the instrument will be always switched off.

- <u>Aerobraking</u>

  During aerobraking the instrument will always be switched off.

A dedicated engineering test, without powering on the TFE, is recommended at the end of the aerobraking phase or whenever higher than expected thermal peaks are measured.

- Antenna Deployment

  The antenna deployment phase foresee a special sequence of operations to be run before, during and after antenna arms deployment to assess, from noise level measurements, the correct deployment.

  After a successful deployment it will be possible to perform the first full engineering checkout including an active TFE.

- Commissioning

  During the commissioning phase all instrument calibrations will be performed.

  Details will be included in a dedicated commissioning plan.

- Science Ops

  At the end of the commissioning phase SHARAD will be ready for routine science observation. From then on it is expected that SHARAD will be left on for most of the time running in Stand By State. HK Telemetries will be collected and sent to ground even during long periods of science inactivity.

4.2 S/C Interaction

4.2.1 SSR Management

All SHARAD Telemetries are sent to the SSR for immediate storage in SHARAD dedicated Raw Space partition (size 2Gbytes, TBC).

Depending on SHARAD operating status, two conditions are identified:

- **SHARAD is not operating**, that is SHARAD is in Stand By State (or in Safe/Idle State) and only HK Telemetry packets are generated. The SHR_Operating discrete signal is not active.
- **SHARAD is operating**, that is SHARAD has been programmed to perform an observation and it is not in Stand By State (it is in a Warm Up State or in an Operating Mode). In this condition Science Data packets, interleaved by HK Telemetry packets, are generated. The SHR_Operating discrete signal is active.

SHARAD not operating condition

When SHARAD is not operating a C&DH process awakes every 120 seconds (TBC, configurable) and fetches data from the SSR (before doing that SHARAD generation of HK Telemetries is suspended by activating temporarily its internal buffer).

Data fetched are scanned and sent to ground on a dedicated Virtual Channel (VC). These data are “channelized” data and are de-commutated on ground for display on SHARAD-dedicated Data Monitoring Display.

SHARAD operating condition

When SHARAD is operating, the previous process is suspended (C&DH FSW is able to do so because the generation of an ENABLE_OST Interface Command is the trigger which switch the instrument condition). Data are let accumulate in the SSR until the SHR_Operating discrete is not seen to de-activate.

Upon SHR_Operating de-activation, telemetries are fetched from the SSR in portions 100 Mbytes (or less) in size. Each portion is considered a Product Telemetry file and it is named including the Product ID provided in the PTF/ITL. The value will be incremented by 1 (starting from a 0 increment) for every file produced within the same observation session.

One implication of the above.described scheme is that there is no “real-time” downlink of SHARAD HK telemetries while the instrument is operating.

Care shall be taken programming instrument observation not to incur in a SSR partition full state. In this state additional data will be discarded and not written to the SSR.

4.2.2 Ground Commands

Details about SHARAD-related Ground Commands are available in [**AD-04**].

4.2.3 Product Telemetries

4.2.3.1 Housekeeping Telemetries

Housekeeping Telemetry packets read from the SSR stream while SHARAD is not operating are available on a dedicated downlink channel with a separate APID.

These packets are collected on the ground and distributed as SFDU-formatted files. Every packet is encapsulated by a complex structure whose details are provided in [**RD-15**].

4.2.3.2 Science Data Telemetries

Science Data Telemetry packets are fetched from the SSR together with any HK packet interleaved within them in portions 100 Mbytes in size (less if data are not available). The fetching process starts at the end of instrument science operations. Packets structures which happen to be at the end of a portion, are not preserved (i.e., they are cut if needed, and the rest will be available in next file).

Each portion of data constitutes a Product Telemetry File and it is downlink using CFDP. On the ground each file is associated a file name which will embed the Product ID value provided with the SHR_ENABLE_OST Ground Command. The value will be incremented by 1 for each file belonging to the same observation.

Details about the Product Telemetry format will be provided in next issue of this manual.

4.2.3.3 APIDs

Four (4) APID values have been assigned to SHARAD. Assignments are as follows:

APID XXX Nominal Science Data downlink in X-Band.

APID XXX Alternative Science Data downlink in Ka Band.

APID XXX Housekeeping Telemetries dedicated downlink.

APID XXX Unrecognized data (data fetched from the SSR not recognized as telemetry packets by the process which read the HK packets from the data stream).

Note: APID values will be provided in next issue of this manual.

The selection of the Nominal or Alternative band for Science Data downlink is performed by means of the SHR_ENABLE_OST Ground Command. The choice is governed by the greater data rate obtained with the Alternative downlink at the expense of an increase in the bit error rate.

4.2.4 Thermal Control

SHARAD does not perform any active thermal control. Passive thermal control is achieved by SEB design characteristics, applied reflective paint and multi-layer insulation.

SHARAD provides heaters and temperature sensors (AD-590) for active thermal control to be implemented by S/C. See para. 3.3.3 for more details.

Instrument temperature ranges are as follows:

	Min Temperature [°C]	Max Temperature [°C]
Operating	-10(*)	+50(*)
Not Operating	-40	+75
Start-up	-35(**)	NA

(*) Tested with +/- 10 °C qualification margin, i.e. -20 to +60 °C

(**) DES section only. Rx can be switched ON from -30°C

4.3 Nominal Timeline

This paragraph describes the nominal sequence of steps to program and instrument observation.

The sequence is TBC and may be updated in next issue of this manual, pending result of Mapping SVT exercises.

Phase	Delta	Step/Event	Notes
Programming an active pass	**0**	LOAD OST	
	5 sec	LOAD PT (partial)	The number of parameters updated depends from the operations to be performed
	5 sec	LOAD ODT	
	5 sec	ENABLE OST	SHARAD leaves Stand By and HK fetching is suspended. TIME_UPDATE service suspended as well.
Performing an active pass	**60 sec**	End of Warm Up Delays	RX and TFE activation
	30 sec		OST Time Tag expires here.
	Depends on modes programming	Succession of modes controlled by the OST	Up to 100 Modes
	15 sec	End of Warm Up Delays	TFE and RX de-activation
		SHARAD in Stand By	

This sequence is implemented by SHARAD Target Block.

Details of SHARAD Target Block will be included in next issue of this manual.

4.4 Anomalies detection and management

4.4.1 Contingency Features

4.4.1.1 Component-Level Fault Protection

MRO implements a CLFP scheme based on the following definitions.

For every fault conditions two entities may be defined:

- Detection
- Response

Each entity may be separately enabled/disabled by means of flag bits pairs corresponding to each possible fault condition. The selection of the flag bits state is performed in Instrument Configuration File.

Detection of a fault is independent from sampling (see [RD-14] fro more details).

If Response is disabled, then counter and messages are still updated/generated but no notification is performed to High level Fault protection (HLFP).

A value of Persistence is associated to Response. Persistence (value start from 1) identifies hwo many consecutive detections are needed before the relevant response is activated.

In case of SHARAD two fault conditions have been considered so far:

- Safe indications (SHR_Safe becoming active).
- Lost aliveness (SHR_Alive stops toggling).

The respective Persistence values are 1 and 3.

The result of Response is marking the Instrument Condition as FAILED instead of GOOD (as reported on DMD).

4.4.1.2 High-Level Fault Protection

MRO implements a HLFP scheme based on the following definitions.

HLFP has a separate enable/disable flag bit and monitors the Instrument Condition.

If the Instrument is found FAILED the HLFP will run the Instrument Safing Sequence defined as a dedicated Block.

SHARAD has a dedicated Block, the Safing Block, defined for this purpose. The main behaviour of this block is that to switch off SHARAD, regardless of its state, after waiting 120 seconds (TBC) to collect some HK telemetry packets that may be useful for trouble-shooting activities.

4.4.2 Hardware Failures

This paragraph will be provided in next issue of this manual.

Refer to [**AD-02**] for details on possible HW failure conditions reported in HK Telemetry packets.

4.4.3 Software Events

This paragraph includes:

- Instrument events due S/C anomalies
- Instrument events due to internal causes
- Instrument events related to failure to operate properly due to programming errors

The paragraph will be provided in next issue of this manual.

Refer to [**AD-02**] for details on possible HW failure conditions reported in HK Telemetry packets.

4.5 Instrument Checkout

4.5.1 On-Ground Checkout

4.5.1.1 PFM Test Categories

This paragraph will be provided in next issue of this manual.

4.5.1.2 PFM Integration Test Categories

This paragraph will be provided in next issue of this manual.

4.5.1.3 Mapping SVT Content

This paragraph will be provided in next issue of this manual.

4.5.2 In-Flight Checkout

This paragraph will describe the On-Flight Checkout procedure that will be performed before antenna deployment.

This paragraph will be provided in next issue of this manual.

4.6 SHARAD Ground Data System

A summarized description will be provided in next issue of this document.

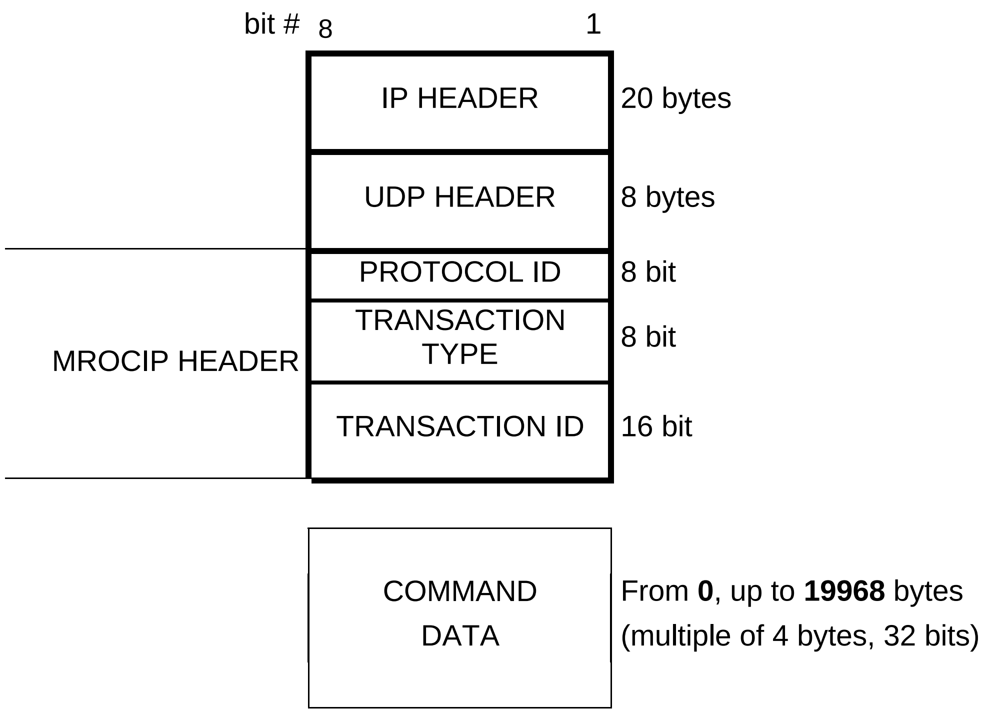
5 SHARAD Operational Data

5.1 Commands

5.1.1 SHARAD Commands

5.1.1.1 SHARAD Commands Protocol Layering

SHARAD Commands are embedded by the S/C C&DH in a multiple protocol frame outlined as follows.



The IP HEADER conforms to Internet Protocol formats. Additional details are to be found in [**AD-02**]. This header includes a checksum for verifying its own integrity and the overall command frame length.

The UDP HEADER conforms to User Datagram Protocol formats. Additional details are to be found in [**AD-02**]. This header includes a checksum for verifying the integrity of the header itself and of the command data it carries.

The MROCIP HEADER constitutes an MRO proprietary protocol defined as follows:

PROTOCOL ID	This field is used to identify the MROCIP protocol. [Value = 0xF0 hex]
TRANSACTION TYPE	This field identify the type of MROCIP message. [Value = 0x01 hex, C&DH Command

0x02 hex, SHARAD Command]

TRANSACTION ID — This field is used, for messages sent to the instrument, to provide a rolling sequence number that uniquely identifies the message. This value will be used in replies or acknowledges.

[Value = Variable]

The overall size of a SHARAD Command, including all the above-mentioned headers, shall not exceed **20000 bytes**.

5.1.1.2 SHARAD Commands Layout

SHARAD Commands are defined according to the following layout, which applies when the Transaction Type in the MROCIP Header is set to value 0x02 (in other cases the format will be detailed in the following):

Command HEADER	START OF CMD	8 bit
	CMD ID	8 bit
	COMMAND DATA	From **0**, up to **19964** bytes (multiple of 4 bytes)
Command TRAILER	END OF CMD	16 bit

The fields of the SHARAD Commands format shall be used as follows:

START OF CMD — Fixed bit pattern

[Value 0x7E].

CMD ID — Identification of Command.

COMMAND DATA — Command data, from 0 up to 19964 bytes.

This field shall be padded with 0's to always be multiple of 32 bits in length.

END OF CMD — Fixed bit pattern

[Value 0xFF7E].

Command validation and verification data (i.e., lengths and/or checksums) are already provided as part of the IP and UDP layers.

Detailed information about SHARAD Commands (layout and usage) is available in [**AD-02**].

5.1.2 SHARAD-related MRO Ground Commands

SHARAD-related MRO Ground Commands are mainly built as instantiations of SHARAD Commands.

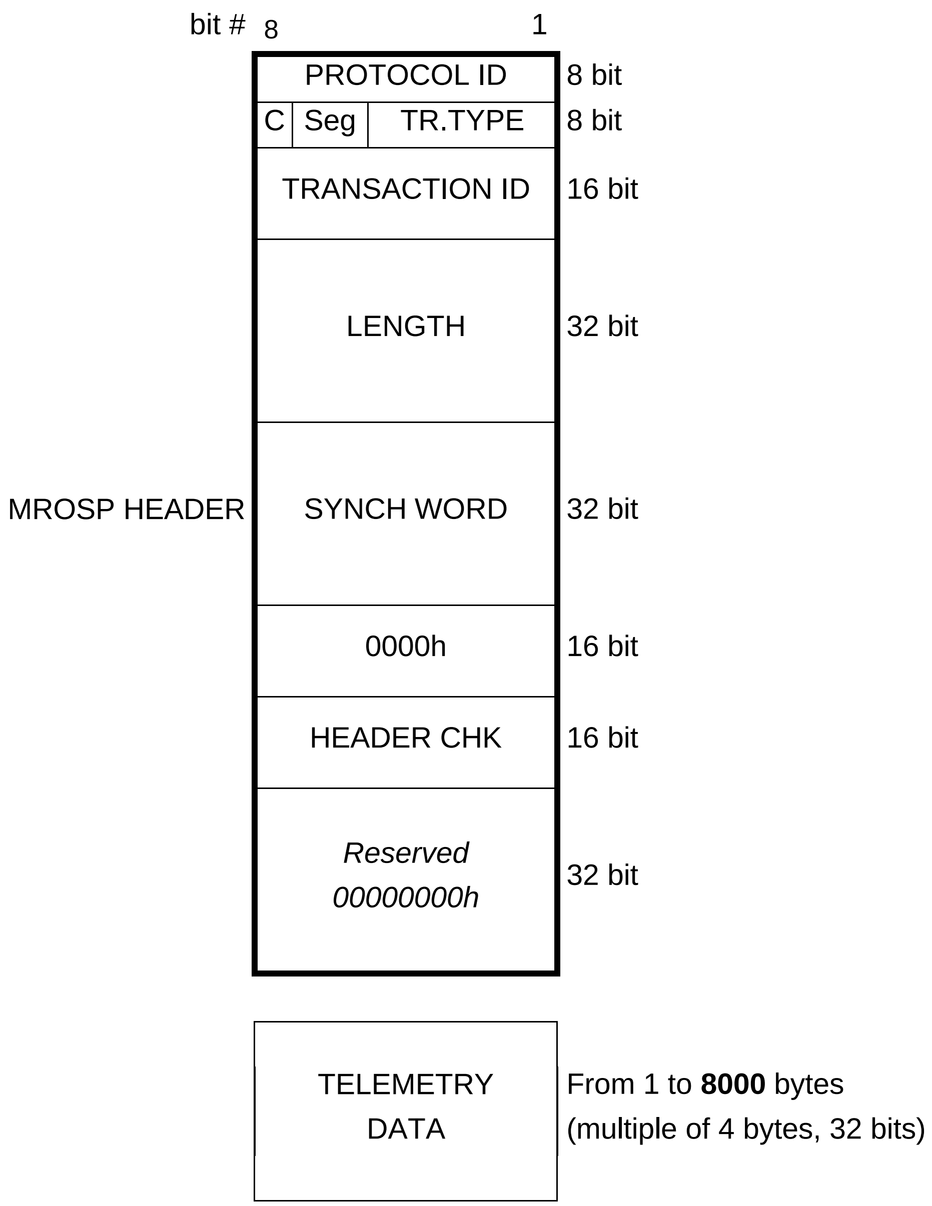
Full details of MRO Ground Commands are available in [**AD-04**].

5.2 Telemetries

5.2.1 SHARAD Telemetries

5.2.1.1 SHARAD Telemetries Protocol Layering

SHARAD Telemetries are sent to the SSR embedded in a protocol frame outlined as follows:



The MROSP HEADER constitutes an MRO proprietary protocol defined as follows:

PROTOCOL ID — This field is used to identify the MROSP protocol.
[Value = 0xFF hex]

COMPRESSION	Not applicable to SHARAD. [Value = 0 dec. (fixed for SHARAD)]
Seg, SEGMENTATION	This field is used to relate one MROSP packet to the next. SHARAD shall use segmentation only for Science Data (for Housekeeping data it shall be fixed to 0). [Value = 0 dec., No Segmentation 1 dec., Segmentation Start (First pkt) 2 dec., Segmentation Middle 3 dec., Segmentation End (Last pkt)]
TRANSACTION TYPE	This field indicates the type of data contained in the packet. [Value = 1 dec., Science Data packet 2 dec., Housekeeping data packet]
TRANSACTION ID	This field may replicate commands sequencing information (see para. 5.1.1.1) to permit relating commands to telemetries. [Value = Variable]
LENGTH	This field provides the length in number of octets (bytes) of the MROSP packet, including the header. [Value = Variable, min. 20]
SYNC WORD	This field provide a value useful to synchronize with the packet header. [Value = 0xFED4AFEE]
HEADER CHECKSUM	This field provides a checksum value computed over all MROSP header bytes, assuming a value of 0x0000 for the Header Checksum field. [Value = Variable, computed like the IP Header Checksum]

The overall size of a SHARAD Telemetry, including MROSP header, shall not exceed **8000 bytes**.

5.2.1.2 SHARAD Housekeeping Telemetries Layout

SHARAD Housekeeping Telemetries are defined according to the following generalised layout:

The second byte of the MROSP Header is configured as follows:

COMPRESSION 0

SEGMENTATION 0

TRANSACTION TYPE 2

The resultant 8 bits pattern is 0 00 00010, that is 0x02.

bit #	8	1	
Telemetry HEADER	START OF TLM		8 bit
	FMT ID	S/M ID	8 bit

	TLM SECONDS	32 bit	TLM Time Tag
	TLM FRACTIONS	16 bit	
	TLM COUNTER	32 bit	
	FMT LENGTH	16 bit	
	0000h	16 bit	
	HK FORMAT	From 0 to **7980** bytes (multiple of 4 bytes)	
Telemetry TRAILER	CHECKSUM	16 bit	
	END OF TLM	16 bit	

The fields of the SHARAD Telemetry format for HK packets shall be used as follows:

START OF TLM — Fixed bit pattern.
[Value = 0x7E]

FMT ID — Identification of SHARAD HK Telemetry format.
[Value = 0xE, Engineering,
0xA, Acknowledge,
0xF, Log,
0xD, Memory Dump,
0xC, Command Dump,
0xB, Boot Report]

S/M ID — Identification of DES' State, or Mode, at the moment of TLM generation.
[Value = see para. 3.5.1.10]

TLM SECONDS — Integer seconds part of the Time Tag associated to the format.
[Value = Variable]

TLM FRACTIONS — Fractional seconds part of the Time Tag associated to the format.
[Value = Variable]

TLM COUNTER — Sequential counter value of the HK Telemetry formats generated.

	[Value = Variable]
FMT LENGTH	Length of format (Header and Trailer not included).
	[Value = Variable, min 20]
CHECKSUM	16 bit checksum of the whole HK Telemetry format (Header included, Trailer and MROSP Header not included)
	[Value = Variable]
END OF TLM	Fixed bit pattern
	[Value 0xFF7E]

Detailed information about SHARAD Housekeeping Telemetries (layout, usage and calibration values) is available in [**AD-03**].

5.2.1.3 SHARAD Science Data Telemetries Layout

SHARAD Science Data Telemetries are defined according to the following generalised layout:

The second byte of the MROSP Header is configured as follows:

COMPRESSION 0

SEGMENTATION XX (1, 2 or 3)

TRANSACTION TYPE 1

The resultant 8 bits patterns are:

0 01 00001, that is 0x21 = First packet in mode

0 10 00001, that is 0x41 = Middle packet in mode

0 11 00001, that is 0x61 = Last packet in mode

bit #	8	1		
Telemetry HEADER	START OF TLM		8 bit	
	FMT ID	S/M ID	8 bit	
	TLM SECONDS		32 bit	TLM Time Tag
	TLM FRACTIONS		16 bit	
	TLM COUNTER		32 bit	
	FMT LENGTH		16 bit	

	0000h	16 bit
	SD FORMAT	From 0 to **7980** bytes (multiple of 4 bytes)
Telemetry TRAILER	CHECKSUM	16 bit
	END OF TLM	16 bit

Fields definition are as in the Housekeeping packets layout.

The content of the SD Format is further divided as follows:

HEADER SECTION	AUXILIARY DATA HEADER	32 bytes
	AUXILIARY DATA	140 bytes
DATA SECTION	SCIENCE DATA	Variable bytes (multiple of 4 bytes)

The Header section provides additional information, called Auxiliary Data, for each Data Block generated by SHARAD. This information includes time references, orbital parameters, processing parameters, etc., which are needed in order to perform relevant data processing on Ground.

The Data section contains the result of the sampling and processing performed by the DES.

There are two possible usages for this format:

- Science Data
- Tracking Data

Detailed information about SHARAD Science Data Telemetries (layout, usage and calibration values) is available in [**AD-03**].

5.2.2 SHARAD-related MRO Telemetry Data

There are two types of SHARAD-related MRO Telemetry Data:

- Data generated by MRO C&DH which are of interest to SHARAD operations
- Data extracted from SHARAD HK packets read from the SSR stream during the transfer from the Raw Space to the Framed Space.

SHARAD-related MRO Telemetry data are available in [**AD-05**].

5.2.3 MRO Data Monitoring Display

5.2.3.1 DMD Limitations

DMD displays present the user with a synoptic representation of telemetry values as soon as they are processed on the ground. These displays are meant for operational use and do not provide freeze, step or history functions.

SHARAD HK parameters are fetched while reading Raw SSR data and are sent to ground on a separate downlink APID (as well as being processed for Product Telemetry, if required).

An entire observation pass will be most likely received as a single stream that the DMD display will “play” as fast as possible. For this reason the DMD display will only show, in a stable way, the last HK values of a given stream.

For what pertains other S/C originated data the display will hold its value and will present the status of parameters according to the rate they are generated by the S/C (plus the current propagation and processing time latency).

5.2.3.2 DMD Layout

The layout of SHARAD DMD display is under review.

Details will be added in the next edition of this document.

5.3 Procedures

5.3.1 Nominal Procedures

Procedure considered, and being tested, so far include:

- SHARAD Power On (S/C Side A)
- SHARAD Power On (S/C Side B)
- SHARAD Power Off (S/C Side A)
- SHARAD Power Off (S/C Side B)
- SHARAD Science Target
- SHARAD EEPROM Re-write (Partition A)
- SHARAD EEPROM Re-write (Partition B)

Details of these procedures will be provided in next issue of this manual.

Other operational requirements are met by means of Not Interactive Payload Commands (NIPC) and no procedures are foreseen for them. This include:

- Memory Dump operations
- Enabling TLM_CMD format.
- Disabling TLM_CMD format.
- Performing a stand-alone PT Reload
- Other TBD.

Details on the execution of these commands will be defined nevertheless in terms of procedures (despite no sequences will be defined) and will be provided in next issue of this manual.

5.3.2 Contingency Procedures

Procedure considered so far include:

- SHARAD Full SW Load
- SHARAD EEPROM Memory Patch
- SHARAD RAM Memory Patch
- SHARAD EEPROM Restart
- SHARAD RAM Restart

Details of these procedures, in terms of sequences or NIPC, will be provided in next issue of this manual.

5.4 Operational Constraints

5.4.1 Instrument Constraints

Additional constraints are TBD.

5.4.1.1 TFE Operations

The TFE shall not be operated in transmission if the antenna is not deployed.

In practical terms this constraint suggest to always keep the TFE disabled (using the relevant command discrete signal) during all SHARAD checkouts.

During ground testing, the RF-FEE is connected in place of the antenna. This permits TFE transmit operations.

Never operate SHARAD with the TFE not connected to a load.

5.4.1.2 RX Operations

Noise and signal measurements require the TFE to be switched on in order to provide power to the TX/RX duplexer. Care shall be taken not to transmit if the antenna is not connected (se previous paragraph).

5.4.1.3 Antenna temperature during deployment

During the antenna deployment, the antenna release mechanism shall be kept within TBD °C and TBD °C using the antenna heaters and monitoring the relevant temperature sensors.

5.4.1.4 S/C attitude during data acquisition

During SHARAD data acquisition, the attitude of the spacecraft shall be controlled within TBD degrees in pitch and TBD degrees in roll to preserve science data accuracy.

5.4.2 S/C Constraints

Additional constraints are TBD.

5.4.2.1 Interaction with S/C systems

SHARAD shall not operate during S/C manoeuvres due to the possibility that gases released by engine deck attitude thrusters may induce multipaction (arcing) phenomena.

5.4.2.2 Interaction with other instruments

SHARAD shall not be switched on when Electra is operating. (TBC)

5.4.3 Mission Constraints

5.4.3.1 Required Orbit Prediction Accuracy

This paragraph will be provided in next issue of this manual.

5.4.3.2 Required End to End Timing Accuracy

This paragraph will be provided in next issue of this manual.

6 Appendices

6.1 OST Generation

Each Operational Sequence Table entry (line) shall adhere to the following 128 bits format:

32 bits				32 bits									
8 bits		24 bits		8 bits	8 bits	8 bits						8 bits			
PRI	**PH**	*Sp.*	**LENGTH**	**MODE**	**MGC**	**CS**	**TR**	**TS**	**T_PRE**	**TR_L**	**TH_L**	**N_SAM**	*Sp.*	**A_B**	**RB**
4	***4***	*2*	***22***	***8***	***8***	***1***	***1***	***1***	***3***	***1***	***1***	***4***	*1*	***2***	***1***

32 bits							32 bits	
16 bits		16 bits					32 bits	
THRE	**INC_THR**	*Sp.*	**EC_INI**	**D_EC**	**D_LT**	**D_RT**	**TOPO_VAL**	**SLOPE**
8	***8***	*4*	***3***	***3***	***3***	***3***	***16***	***16***

Spare bits shall always be set to 0's. The same applies to bits whenever their usage is not applicable.

Each entry's field is described in the following table:

FIELD ID	DEFINITION	SIZE bits	RANGE	DESCRIPTION
PRI	Pulse Repetition Interval	**4**	0001 => 1428 µs 0010 => 1492 µs 0011 => 1290 µs 0100 => 2856 µs 0101 => 2984 µs 0110 => 2580 µs	PRI = 1 / PRF to be used for the entire duration of the selected Mode. Applies also to Test Mode depending on different sub-cases.
PH	Phase Compensa-tion	**4**	0000 = No compensation 0001 = Radial velocity comp. 0010 = Surface Slope comp. 0011 = Radial velocity & Surface slope compensation	To select the DCG initial phase correction, according to the estimated surface slope and the satellite radial velocity.
LENGTH	Data Take Length	**22**	Value shall be an integer (> 0) multiple of the Pre-summing value.	Mode Duration in terms of number of PRI's. This value, multiplied by the PRI value, establishes the duration on the selected Mode.

MODE	Operational Mode	**8**	**000** 00000 = Wait Mode **001** 00001 = SS Mode sub #1 … **001** 10101 = SS Mode sub #21 **010** 00001 = Cal Mode sub #1 … **010** 10101 = Cal Mode sub #21 **011** 00001 = Rcv Mode sub #1 … **011** 10101 = Rcv Mode sub #21 **1XX** XXXXX = Test Modes	To select the operational Mode/Sub-Mode combination. See additional tables for sub-modes details (which include pre-summing and compression selections).
MGC	Manual Gain Control	**8**	0x00 - 0xFF	Manual Gain Control, used to select the RX attenuation.
CS	Compression Selection	**1**	0 = Static Compression 1 = Dynamic Compression	Bit Compression Algorithm selection
TR	Closed-loop Tracking	**1**	0 = disabled 1 = enabled	To enable or disable the Closed-loop Tracking
TS	Tracking Data Storage	**1**	0 = disabled 1 = enabled	To enable or disable the Closed-loop Tracking data packets acquisition
T_PRE	Tracking Pre-Summing	**3**	000 = 1 001 = 2 010 = 3 011 = 4 100 = 8 101 = 16 110 = 32 111 = 64	Number of pre-summed blocks to be summed before a Tracking algorithm iteration.
TR_LOG	Tracking Logic Selection	**1**	0 = Logic based in threshold overshooting 1 = Logic based on COG	Selection of the logic for the range tracker discriminator.
TH_LOG	Threshold Logic Selection	**1**	0 = Threshold evaluated on board 1 = Threshold programmed from ground	Selection of the logic for the tracker threshold determination.
N_SMPL	Samples Number	**4**	0000 = 1 0001 = 2 … 1111 = 16	Number of the samples that shall overshoot the tracker threshold.
A_B	Alpha and Beta	**2**	00, 01, 10, 11	Selection of one out of four coefficient sets for Alfa/Beta filter. (Values are stored in PT).
REF_BIT	Reference Bit	**1**	0 = Start with value from the previous mode 1 = Start from a new value	Bit to select the refresh logic of the tracking.
THRE	Threshold	**8**	0x00 … 0xFF	First order linear coefficient for the threshold value. (Values are stored in PT).

INC_THR	Threshold Increment	**8**	0x00 … 0xFF	First order linear coefficient for the Increment for the threshold value. (Values are stored in PT).
EC_INIT	Initial Echo Value	**3**	000 … 111	First order linear coefficient for the correction for the initial prediction of the first echo. (Values are stored in PT).
D_ECHO	Expected Echo Shift	**3**	000 … 111	First order linear coefficient for the value to shift the echo position. (Values are stored in PT).
D_LEFT	Window Left Shift	**3**	000 … 111	First order linear coefficient for the value to shift the left side of the tracking window. (Values are stored in PT).
D_RIGHT	Window Right Shift	**3**	000 … 111	First order linear coefficient for the value to shift the right side of the tracking window. (Values are stored in PT).
TOPO_V	Topography polynomial coefficients validity	**16**	0x00000 = all operative modes 0x00001 = … … 0x40000 =	Validity of the polynomial coefficient necessary to the WPF. 0x00000 allows using the same coefficients for the entire Mode: it may be especially used when WPF is not utilized to determine S/C to surface distance.
SLOPE_V	Slope polynomial coefficients validity	**16**	0x00000 = all operative modes 0x00001 = … … 0x40000 =	Validity of the polynomial coefficient necessary to the WPF. 0x00000 allows using the same coefficients for the entire Mode: it may be especially used when WPF is not utilized to determine S/C to surface distance.

The following sub-modes have been identified. For Modes concerning Radar Operations, (SS, RECEIVE ONLY, CALIBRATION, WAIT and TEST, also called Measurement Modes), two extra parameters are needed for proper HW configuration. These parameters are:

- the Pre-summing rate for acquired data
- the Compression factor for the Science Data to be packetised.

The available combinations of three parameters (Mode, Pre-summing and Compression) are identified inside the OST by a unique code shown in the table below.

Non Measurement modes (WAIT, TEST) have Pre-summing and Compression values both set to 0 since these parameters are not applicable.

OST Mode Code	Mode	Presumming	Compression	Nominal Mode Name
0x21	SS	32	8	SS#1
0x22	SS	28	6	SS#2
0x23	SS	16	4	SS#3
0x24	SS	8	8	SS#4
0x25	SS	4	6	SS#5
0x26	SS	2	4	SS#6
0x27	SS	1	8	SS#7

0x28	SS	32	6	SS#8
0x29	SS	28	4	SS#9
0x2A	SS	16	8	SS#10
0x2B	SS	8	6	SS#11
0x2C	SS	4	4	SS#12
0x2D	SS	2	8	SS#13
0x2E	SS	1	6	SS#14
0x2F	SS	32	4	SS#15
0x30	SS	28	8	SS#16
0x31	SS	16	6	SS#17
0x32	SS	8	4	SS#18
0x33	SS	4	8	SS#19
0x34	SS	2	6	SS#20
0x35	SS	1	4	SS#21

0x41	CALIBRATION	32	8	CALIBRATION#1
0x42	CALIBRATION	28	6	CALIBRATION#2
0x43	CALIBRATION	16	4	CALIBRATION#3
0x44	CALIBRATION	8	8	CALIBRATION#4
0x45	CALIBRATION	4	6	CALIBRATION#5
0x46	CALIBRATION	2	4	CALIBRATION#6
0x47	CALIBRATION	1	8	CALIBRATION#7
0x48	CALIBRATION	32	6	CALIBRATION#8
0x49	CALIBRATION	28	4	CALIBRATION#9
0x4A	CALIBRATION	16	8	CALIBRATION#10
0x4B	CALIBRATION	8	6	CALIBRATION#11
0x4C	CALIBRATION	4	4	CALIBRATION#12
0x4D	CALIBRATION	2	8	CALIBRATION#13
0x4E	CALIBRATION	1	6	CALIBRATION#14
0x4F	CALIBRATION	32	4	CALIBRATION#15
0x50	CALIBRATION	28	8	CALIBRATION#16
0x51	CALIBRATION	16	6	CALIBRATION#17
0x52	CALIBRATION	8	4	CALIBRATION#18
0x53	CALIBRATION	4	8	CALIBRATION#19
0x54	CALIBRATION	2	6	CALIBRATION#20
0x55	CALIBRATION	1	4	CALIBRATION#21

0x61	RECEIVE ONLY	32	8	RECEIVE ONLY#1
0x62	RECEIVE ONLY	28	6	RECEIVE ONLY#2
0x63	RECEIVE ONLY	16	4	RECEIVE ONLY#3
0x64	RECEIVE ONLY	8	8	RECEIVE ONLY#4
0x65	RECEIVE ONLY	4	6	RECEIVE ONLY#5
0x66	RECEIVE ONLY	2	4	RECEIVE ONLY#6
0x67	RECEIVE ONLY	1	8	RECEIVE ONLY#7
0x68	RECEIVE ONLY	32	6	RECEIVE ONLY#8
0x69	RECEIVE ONLY	28	4	RECEIVE ONLY#9
0x6A	RECEIVE ONLY	16	8	RECEIVE ONLY#10
0x6B	RECEIVE ONLY	8	6	RECEIVE ONLY#11
0x6C	RECEIVE ONLY	4	4	RECEIVE ONLY#12
0x6D	RECEIVE ONLY	2	8	RECEIVE ONLY#13
0x6E	RECEIVE ONLY	1	6	RECEIVE ONLY#14
0x6F	RECEIVE ONLY	32	4	RECEIVE ONLY#15
0x70	RECEIVE ONLY	28	8	RECEIVE ONLY#16
0x71	RECEIVE ONLY	16	6	RECEIVE ONLY#17
0x72	RECEIVE ONLY	8	4	RECEIVE ONLY#18
0x73	RECEIVE ONLY	4	8	RECEIVE ONLY#19

0x74	RECEIVE ONLY	2	6	RECEIVE ONLY#20
0x75	RECEIVE ONLY	1	4	RECEIVE ONLY#21

0x7F	WAIT	1	8	WAIT

0xE1	TEST	32	8	TEST#1
0xE2	TEST	28	6	TEST#2
0xE3	TEST	16	4	TEST#3
0xE4	TEST	8	8	TEST#4
0xE5	TEST	4	6	TEST#5
0xE6	TEST	2	4	TEST#6
0xE7	TEST	1	8	TEST#7
0xE8	TEST	32	6	TEST#8
0xE9	TEST	28	4	TEST#9
0xEA	TEST	16	8	TEST#10
0xEB	TEST	8	6	TEST#11
0xEC	TEST	4	4	TEST#12
0xED	TEST	2	8	TEST#13
0xEE	TEST	1	6	TEST#14
0xEF	TEST	32	4	TEST#15
0xF0	TEST	28	8	TEST#16
0xF1	TEST	16	6	TEST#17
0xF2	TEST	8	4	TEST#18
0xF3	TEST	4	8	TEST#19
0xF4	TEST	2	6	TEST#20
0xF5	TEST	1	4	TEST#21
0xFF	TEST	1	8	TEST#22

Notes:

- TEST#22 is equal to TEST#7 and is often referred as TEST.
- In order to maintain SW consistency, the WAIT mode have a pre-summing value and a compression value, even if it does not apply (because in Wait mode the RADAR does not Transmit or Receive).
- Test mode acts exactly as an SS mode, the only difference being that the RX window is fixed at 452ms, with ambiguous PRFs and at 2303ms for not ambiguous ones. Thus both RX and TFE are operated.
- Radar Operations computations (polynomial or tracking processing) is always done also during Test Mode.

6.2 ODT Generation

The Orbital Data table has the following organisation in memory:

PT

ODT_START
48 bit

ODT_STEP
8 bit

ORBITAL DATA TABLE			
TLP	**RADIUS**	**RADIUS_RATE**	**TANG_VEL**
TLP	**RADIUS**	**RADIUS_RATE**	**TANG_VEL**
TLP	**RADIUS**	**RADIUS_RATE**	**TANG_VEL**
TLP	**RADIUS**	**RADIUS_RATE**	**TANG_VEL**
TLP	**RADIUS**	**RADIUS_RATE**	**TANG_VEL**
TLP	**RADIUS**	**RADIUS_RATE**	**TANG_VEL**

…	…	…	…
32 bit	*32 bit*	*32 bit*	*32 bit*

The Orbital Data Table shall contain the following 32 bit floating point values:

- S/C Track Length Position (TLP)
- S/C Radius (distance from Mars' centre in Kilometres)
- S/C Radius Rate (Radial velocity in metres/second)
- S/C Tangential Velocity (in metres/second)

Track Length Position (TLP) is an equivalent measure of the Spacecraft position along the ground track, in an arbitrary unit named Track Length Unit (TLU). The TLU must be coherent with the polynomial coefficients definition. The choice for TLU is still TBD according to the following options.

The TLP reference point (=0 TLP) shall correspond to the "Start_OST" coordinates. The suitable choices of the TLU can be:

- In Km, lenght of ground track, projected on the Mars reference ellipsoid (or spheroid, according to MOLA data reference)
- In milliradians: angular walk (in latitude) referred to the Mars reference ellipsoid (or spheroid, according to MOLA data reference)

Each value of the ODT is defined as function of time. In particular ODT_START is the initial reference time, while ODT_STEP is the fixed step between two consecutive lines, measured in seconds.

6.3 PT Generation

6.3.1 Table Description

The Parameter Table provides an index based storage space for the parameters listed in the following table. Other parameters are also available but they are not included in the following list because they are not of interest to instrument observation programming.

Id	Parameter name	Default	Range	Type	Description	For users
0	PT_OSTSTARTSEC	0	0 : FFFFFFFF	U32	OST starting time tag (seconds)	User definable in nominal condition
1	PT_OSTSTARTFRCT	0	0 : FFFF	U16	OST starting time tag (fractions)	User definable in nominal condition
2	PT_ODTSTARTSEC	0	0 : FFFFFFFF	U32	ODT beginning time tag.	Parameter assigned by LOAD_ODT
3	PT_ODTSTARTFRCT	0	0 : FFFF	U16	ODT beginning time tag.	Parameter assigned by LOAD_ODT
4	PT_ODTSTEP	1	0 : FF	U8	Time interval in seconds between subsequent ODT values.	Parameter assigned by LOAD_ODT
5	PT_ALIVE_PERIOD	5	0 : FF	U8	SHARAD ALIVE discrete TC period	User definable in not nominal condition

Id	Parameter name	Default	Range	Type	Description	For users
6	PT_MONSAMPLE	1	0 : FF	U8	Time interval in seconds for monitoring the engineering parameters (the modification is applied after restart).	Don't touch
7	PT_ENGTLM	5	0 : FF	U8	Time interval in seconds for generating ENG_TLM frames toward the SSR.	Don't touch
8	PT_SPARE					
9	PT_HKTLM	0x8F	NA	BF	Enabled HK TM Bit 0: TLM_ENG Bit 2: TLM_LOG Bit 3: TLM_DMP Bit 4: CMD_LOG Bit 4 to 6: Unused Bit 7: TLM_BUFFER (1=Enabled, 0=Disabled)	
10	PT_MAXOST	100	0 : FF	U8	Maximum number of OST lines	User definable in not nominal condition
11	PT_MAX_TIMEJUMP	60	0 : FFFFFFFF	U32	Maximum time jump for Time Update CMD	Don't touch
12	PT_CH1LLIM	0x08	0 : FF	U8	Lower monitoring limit for ch. 1	Don't touch
13	PT_CH1ULIM	0x7F	0 : FF	U8	Upper monitoring limit for ch. 1	Don't touch
14	PT_CH2LLIM	0x70	0 : FF	U8	Lower monitoring limit for ch. 2	Don't touch
15	PT_CH2ULIM	0x8F	0 : FF	U8	Upper monitoring limit for ch. 2	Don't touch
16	PT_CH3LLIM	0x8F	0 : FF	U8	Lower monitoring limit for ch. 3	Don't touch
17	PT_CH3ULIM	0xAA	0 : FF	U8	Upper monitoring limit for ch. 3	Don't touch
18	PT_CH4LLIM	0x75	0 : FF	U8	Lower monitoring limit for ch. 4	Don't touch
19	PT_CH4ULIM	0xAC	0 : FF	U8	Upper monitoring limit for ch. 4	Don't touch
20	PT_CH5LLIM	0x19	0 : FF	U8	Lower monitoring limit for ch. 5	Don't touch
21	PT_CH5ULIM	0xFF	0 : FF	U8	Upper monitoring limit for ch. 5	Don't touch
22	PT_CH6LLIM	0x0F	0 : FF	U8	Lower monitoring limit for ch. 6	Don't touch
23	PT_CH6ULIM	0xF6	0 : FF	U8	Upper monitoring limit for ch. 6	Don't touch
24	PT_CH7LLIM	0x00	0 : FF	U8	Lower monitoring limit for ch. 7	Don't touch
25	PT_CH7ULIM	0xFF	0 : FF	U8	Upper monitoring limit for ch. 7	Don't touch
26	PT_CH8LLIM	0x00	0 : FF	U8	Lower monitoring limit for ch. 8	Don't touch
27	PT_CH8ULIM	0xE5	0 : FF	U8	Upper monitoring limit for ch. 8	Don't touch
28	PT_WU1ACTDEL	20	0 : 0x418937	U32	Warm Up 1 activation delay [s]	Don't touch
29	PT_WU1DEACTDEL	5	0 : 0x418937	U32	Warm Up 1 de-	Don't touch

Id	Parameter name	Default	Range	Type	Description	For users
					activation delay [s]	
30	PT_WU2ACTDEL	40	0 : 0x418937	U32	Warm Up 2 activation delay [s]	Don't touch
31	PT_WU2DEACTDEL	10	0 : 0x418937	U32	Warm Up 2 de-activation delay [s]	Don't touch
32	PT_SPARE					
33	PT_F_CONV	26666667	1 : 0xFFFFFFFF	U32	Conversion Factor [Hz]	Don't touch
34	PT_PRF_1	1/1428e-6		F	Nominal_1 PRF [Hz]	Don't touch
35	PT_PRF_2	1/1492e-6		F	Nominal_2 PRF [Hz]	Don't touch
36	PT_PRF_3	1/1290e-6		F	Nominal_3 PRF [Hz]	Don't touch
37	PT_SPARE					
38	PT_PRF_HALF_1	1/2856e-6		F	Nominal_Half_1 PRF [Hz]	Don't touch
39	PT_PRF_HALF_2	1/2984e-6		F	Nominal_Half_2 PRF [Hz]	Don't touch
40	PT_PRF_HALF_3	1/2580e-6		F	Nominal_Half_3 PRF [Hz]	Don't touch
41	PT_SPARE					
42	PT_WPF_VALUE	64		F	NWpf	Don't touch
43	PT_T0	1e-5		F	Correction [s]	Don't touch
44	PT_C	299792.458		F	Light Speed [km/s]	Don't touch
45	PT_LAMBDA_20M	14.99		F	Wave length [m]	Don't touch
46	PT_SPARE					
47	PT_RX_MIN_N1	105e-6		F	RX window Lower Limit for Nominal_1 PRF [s]	Don't touch
48	PT_RX_MAX_N1	1243e-6		F	RX window Upper Limit for Nominal_1 PRF [s]	Don't touch
49	PT_RX_MIN_N2	105e-6		F	RX window Lower Limit for Nominal_2 PRF [s]	Don't touch
50	PT_RX_MAX_N2	1307e-6		F	RX window Upper Limit for Nominal_2 PRF [s]	Don't touch
51	PT_RX_MIN_N3	105e-6		F	RX window Lower Limit for Nominal_3 PRF [s]	Don't touch
52	PT_RX_MAX_N3	1105e-6		F	RX window Upper Limit for Nominal_3 PRF [s]	Don't touch
53	PT_RX_MIN_N4	1523e-6		F	RX window Lower Limit for Nominal_Half_1 PRF [s]	Don't touch
54	PT_RX_MAX_N4	2671e-6		F	RX window Upper Limit for Nominal_ Half_1 PRF [s]	Don't touch
55	PT_RX_MIN_N5	1587e-6		F	RX window Lower Limit for Nominal_ Half_2 PRF [s]	Don't touch
56	PT_RX_MAX_N5	2799e-6		F	RX window Upper Limit for Nominal_ Half_2 PRF [s]	Don't touch
57	PT_RX_MIN_N6	1385e-6		F	RX window Lower Limit for Nominal_ Half_3 PRF [s]	Don't touch
58	PT_RX_MAX_N6	2395e-6		F	RX window Upper Limit for Nominal_ Half_3 PRF [s]	Don't touch

Id	Parameter name	Default	Range	Type	Description	For users
59	PT_SPARE					
60	PT_START_TLP			F	First data set used for data processing (first of 60 copies). PT_START_TLP shall be expressed coherently with the TLP fields in ODT.	User definable in nominal condition
61	PT_S0			F		User definable in nominal condition
62	PT_S1			F		‘’
63	PT_S2			F		‘’
64	PT_S3			F		‘’
65	PT_S4			F		‘’
66	PT_S5			F		‘’
67	PT_S6			F		‘’
68	PT_S7			F		‘’
69	PT_TOP0			F		‘’
70	PT_TOP1			F		‘’
71	PT_TOP2			F		‘’
72	PT_TOP3			F		‘’
73	PT_TOP4			F		‘’
74	PT_TOP5			F		‘’
75	PT_TOP6			F		‘’
76					From second to 60th data set used for data processing	‘’
…				F		‘’
1019						User definable in nominal condition
1020	PT_SPARE					
1021	PT_WAVEFORM_MODE_DCG	0x00000000		U32	DCG Configuration parameters	User definable in not nominal condition
1022	PT_INITIAL_WAVEFORM_DCG	0x00800000		U32		‘’
1023	PT_WAVEFORM_NUMBER_DCG		0x00400000		U32	
1024	PT_WAVEFORM_CONTROL_DCG	0x00C2C000		U32		‘’
1025	PT_DITHERING_CONTROL_DCG	0x00D20000		U32		‘’
1026	PT_START_FREQ_MSW_DCG	0x00D8000A		U32		‘’
1027	PT_START_FREQ_LSW_DCG	0x00C80000		U32		‘’
1028	PT_SLOPE_MSW_DCG	0x00D07FFF		U32		‘’
1029	PT_SLOPE_LSW_DCG	0x00C019D3		U32		‘’
1030	PT_DURATION_MSW_DCG	0x00DC0000		U32		‘’
1031	PT_DURATION_LSW_DCG	0x00CC2560		U32		‘’
1032	PT_PHASE_MSW_DCG	0x00D40000		U32		‘’
1033	PT_PHASE_LSW_DCG	0x00C40000		U32		User definable in not nominal condition
1034	PT_TRK_NTRK_1	0x41A		U32	Closed Loop Tracking step for Nominal_1 PRF ##SHR-PROC-3.1.9-0010	User definable in not nominal condition

Id	Parameter name	Default	Range	Type	Description	For users
1035	PT_TRK_NTRK_2	0x3ED		U32	Closed Loop Tracking step for Nominal_2 PRF	‘’
1036	PT_TRK_NTRK_3	0x48A		U32	Closed Loop Tracking step for Nominal_3 PRF	‘’
1037	PT_TRK_NTRK_4	0x20D		U32	Closed Loop Tracking step for Nominal_Half_1 PRF	‘’
1038	PT_TRK_NTRK_5	0X1F6		U32	Closed Loop Tracking step for Nominal_Half_2 PRF	‘’
1039	PT_TRK_NTRK_6	0x245		U32	Closed Loop Tracking step for Nominal_Half_3 PRF	User definable in not nominal condition
1040	PT_TRK_C_LOL_INI	-6		I32	Initial value for C_lol parameter .This counter shall be increased when the tracking is not ok. In particular when C_lol becomes zero the tracking is lost.	
1041	PT_TRK_S_M	1024	0 : 2047	U16	Initial Offset position ##SHR-PROC-3.1.9-0020	‘’
1042	PT_TRK_EC_INI_0	0	-2047 : 2046	I32	Initialization Value for echo correction 0	‘’
1043	PT_TRK_EC_INI_1	-4	-2047 : 2046		Initialization Value for echo correction 1	
1044	PT_TRK_FS	(80E6)/3		F	Sampling Frequency. Type float [Hz]	‘’
1045	PT_TRK_LWIND_INI	530		U32	Initialised value for the left shift of the Rx Window.	‘’
1046	PT_TRK_RWIND_INI	530		U32	Initialised value for the right shift of the Rx Window.	‘’
1047	PT_SPARE					
1048	PT_TRK_MIN_WIND	0	0 : 2047	U16	Value defining the initial index of the window range used for the OCOG and threshold evaluation.	‘’
1049	PT_TRK_MAX_WIND	2047	0 : 2047	U16	Value defining the last index of the window range used for the OCOG and threshold evaluation.	User definable in not nominal condition
1050	PT_ALPHA00	0.56		F	Alpha filter coefficient, set 00	Don’t touch
1051	PT_BETA00	0.09		F	Beta filter coefficient, set 00	Don’t touch
1052	PT_ALPHA01	1		F	Alpha filter coefficient, set 01	Don’t touch
1053	PT_BETA01	0		F	Beta filter coefficient, set 01	Don’t touch
1054	PT_ALPHA10	0.4		F	Alpha filter coefficient, set 10	Don’t touch
1055	PT_BETA10	0.2		F	Beta filter	Don’t touch

Id	Parameter name	Default	Range	Type	Description	For users
					coefficient, set 10	
1056	PT_ALPHA11	0.3		F	Alpha filter coefficient, set 11	Don't touch
1057	PT_BETA11	0.3		F	Beta filter coefficient, set 11	Don't touch
1058	PT_TRK_INC_THR_0	0		F	#SHR-PROC-3.1.9.1-0020.	
Used for imposing a threshold value.						
1059	PT_TRK_INC_THR_1	10		F	Used for imposing a threshold value.	User definable in not nominal condition
1060	PT_TRK_TH_0	0		F	Used for imposing a threshold value.	User definable in not nominal condition
1061	PT_TRK_TH_1	0		F	Used for imposing a threshold value.	User definable in not nominal condition
1062	PT_TRK_CO_W_TH	0		I32	Used in case of threshold calculated on board. From this parameter depends the extreme position of the window (min_win_th) used for the threshold evaluation.	‘’
1063	PT_TRK_AD_W_TH	1300		I32	Used in case of threshold calculated on board. From this parameter depends the extreme position of the window (min_win_th) used for the threshold evaluation.	‘’
1064	PT_TRK_DI_W_TH	250		I32	Used in case of threshold calculated on board. From this parameter depends the extreme position of the window (max_win_th) used for the threshold evaluation.	‘’
1065	PT_SPARE					
1066	PT_SPARE					
1067	PT_SPARE					
1068	PT_SPARE					
1069	PT_SPARE					
1070	PT_TRK_MAX_W_TH	1800		I32	Used in case of threshold calculated on board. From this parameter depends the extreme position of the window (max_win_th) used for the threshold evaluation	
1071	PT_TRK_MIN_W_TH	650		I32	Used in case of	‘’

Id	Parameter name	Default	Range	Type	Description	For users
					threshold calculated on board. From this parameter depends the extreme position of the window (min_win_th) used for the threshold evaluation.	
1072	PT_TRK_DEL_EC_0	0		I32	Used during the upgrading of the echo position.	
1073	PT_TRK_DEL_EC_1	20		I32	Used during the upgrading of the echo position	‘’
1074	PT_TRK_DEL_L_0	0		I32	This parameter sets the left shift of the numeric window.	‘’
1075	PT_TRK_DEL_L_1	75		I32	This parameter sets the left shift of the numeric window.	‘’
1076	PT_TRK_LEFT_MIN	130		I32	LEFT_MIN is the minimum acceptable value, in samples, of the left part of the numeric window.	‘’
1077	PT_TRK_DEL_R_0	0		I32	This parameter sets the right shift of the numeric window.	‘’
1078	PT_TRK_DEL_R_1	75		I32	This parameter sets the right shift of the numeric window.	‘’
1079	PT_TRK_RIGHT_MIN	130		I32	RIGHT_MIN is the minimum acceptable value, in samples, of the right part of the numeric window.	‘’
1080	PT_SPARE					
1081	PT_TRK_LEFT_MAX	600		I32	LEFT_MAX is the maximum acceptable value, in samples, of the left part of the numeric window.	‘’
1082	PT_TRK_RIGHT_MAX	600		I32	RIGHT_MAX is the maximum acceptable value, in samples, of the right part of the numeric window.	‘’
1083	PT_TRK_DEL_LOL	2		I32	DEL_LOL increases the C_lol counter in case of tracking not ok.	‘’
1084	PT_TRK-_MAX_POS	60		I32	Maximum acceptable value, in samples, for the expected position of the echo in the numeric window.	‘’
1085	PT_TRK-_MIN_POS	900		I32	Minimum acceptable value, in samples, for the expected position of the echo in the numeric window.	‘’

Id	Parameter name	Default	Range	Type	Description	For users
1086	PT_SPARE					
1087	PT_TRK_DEL_OCOG_MAX	66.6666		F	Maximum acceptable value of the delay time, in samples, between the OCOG position and the estimated position of the echo.	‘’
1088	PT_TRK_N_T_DATA	0			If the tracking data field is set to one in the OST, compressed data, after the range compression, used for tracking, shall be formatted and sent to SSR, otherwise the data shall be deleted.Only a part of the numeric window, compatibly with the hardware constraints, shall be sent to SSR. This number is N_T_DATA.	
1089	PT_SPARE					
1090	PT_TRK_REF_A1	1		F	Coefficient A1 for Reference Function generation	Don’t touch
1091	PT_TRK_REF_A2	-3.6960e11		F	Coefficient A2 for Reference Function generation	Don’t touch
1092	PT_TRK_REF_A3	7.5e-8		F	Coefficient A3 for Reference Function generation	Don’t touch
1093	PT_TRK_REF_TAU0	566.66667		F	Coefficient TAU0 for Reference Function generation	Don’t touch
1094	PT_SPARE					
1095	PT_TRK_REF_R0			F	Run Time Generated array for reference function, Real part	Don’t touch
1096	PT_TRK_REF_R1			F		‘’
…				F		‘’
3143	PT_TRK_REF_R2047			F		‘’
3144	PT_TRK_REF_I0			F	Run Time Generated array for reference function, Imaginary part	‘’
3145	PT_TRK_REF_I1			F		‘’
…				F		‘’
5191	PT_TRK_REF_I2047			F		Don’t touch
5192						
5200						
1450						

Type Meaning
U8 Unsigned int 8 bit

U16	Unsigned int 16 bit
U32	Unsigned int 32 bit
I32	Signed int 32 bit
I16	Signed int 16 bit
F	Float 32 bit
BF	Bit field

When Closed-Loop tracking is disabled, parameters affecting the on board processing are stored from address 60 to address 1019, as follows:

- PT_START_TLP;
- PT_T0,…, PT_T6 (topography coefficients);
- PT_S0,…, PT_S7 (slope coefficients).

This sequence repeats for each pair of coefficient sets.

When Closed-Loop tracking is enabled, only the topography coefficients are used. These coefficients have an influence on the initialisation of the tracking.

In addition, all the parameters whose address is within the range 1034-1093 take part in the processing.

6.3.2 Programming Polynomial Coefficients

Topography and slope coefficients must be generated in the following way (see Fig.6.3-1):

- Dividing the surface profile into zones of suitable lenght (typical value = 30 sec);
- Appling for each zone a polynomial fitting (6th order for topography, 7th order for other parameters) respect to the relative interval [0,Dn], for n=1,…,N (i.e.: x=0 is the starting point of each segment).

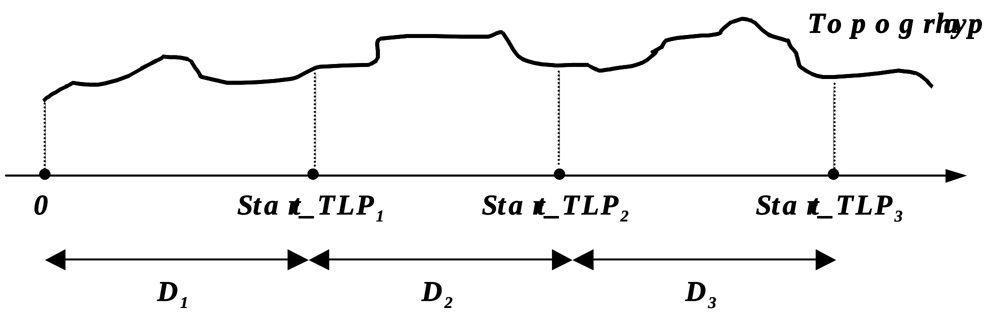


Figure 6.3-1: Polynomial Coefficients Model

6.4 Commanding Files Formats

Highlighted fields shall be included in the relevant file.

Details about the files for Memory Management purposes (Patches and Loads) will be provided in next issue of this document.

LOAD_OST

7Eh	8 bit
14h	8 bit
00h	8 bit
N_ENTRIES	8 bit
ENTRY (1st)	16x8 bit
ENTRY (2nd)	16x8 bit
ENTRY (Nth)	16x8 bit
Padding	16 bit
FF7Eh	16 bit

OST File (Generated by SHARAD GS)

LOAD_PT

	Field	Size	
	7Eh	8 bit	
	15h	8 bit	
	N_BLOCKS	16 bit	**PT File** (Generated by SHARAD GS)
Values Block	START_LOC	16 bit	
	N_VALUES	16 bit	
	VALUES	Sequence of N x 32 bit values	
	Other Values Blocks	48 bits + N x 32 bits	
	Padding	16 bit (0 or 1 time)	
	FF7Eh	16 bit	

LOAD_ODT

7Eh	8 bit	
20h	8 bit	
00h	8 bit	**ODT File** (Generated from PTF/ITL values)
DELTA_T	8 bit	
SECONDS (ODT Start Time)	32 bit	
FRACTIONAL SECONDS	16 bit	
N_LINES	16 bit	
DATA_LINE (1st)	128 bit	
DATA_LINE (2nd)	128 bit	
DATA_LINE (Nth)	128 bit	
Padding	16 bit	
FF7Eh	16 bit	

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