ExoMars

EDL Demonstrator Module Surface Payload Experiment Proposal Information Package

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1 DOCUMENT SCOPE

This Experiment Proposal Information Package (E-PIP) defines all technical, managerial and programmatic data relevant to the Announcement of Opportunity (AO) for the Surface Payload (SPL) on the ExoMars EDL Demonstrator Module (EDM). It does not yet contain formally agreed requirements; however all stated parameter values and other data reflect the currently agreed baseline for the spacecraft, the mission, mission operations, product assurance, and managerial approach.

The nominal technical information contained in this document is the baseline for proposing in response to AO. Proposers should understand that evolution of the project may result in this information being modified.

Following selection of the SPL, the Experiment Interface Requirements Document (E-IRD) will be issued to define all the technical, managerial and programmatic requirements applicable to the surface payload's interfaces with the EDM Spacecraft and Mission.

The SPL shall at selection be compliant with this E-PIP. The E-PIP, in principle, reflects the contents of the to-be-issued E-IRD. The E-IRD shall then be considered as a baseline for the definition and update of the Surface Payload Experiment Interface Control Document (E-ICD) relevant to the payload through all phases of the ExoMars EDM development.

2 INTRODUCTION

2.1 Project Organisation

The ExoMars 2016 project is led by ESA, procuring from an industrial Prime Contractor (Thales Alenia Space Italy) the Trace Gas Orbiter (TGO) and the Entry, Descent and Landing Demonstrator Module (EDM). The ExoMars TGO payload was selected in conjunction with NASA, and NASA will also procure the launch. The EDM Surface Payload (SPL) will be managed by the ESA ExoMars Project team, supported by ESA's industrial partners. Under the ExoMars Project Manager, ESA's Project Scientist for the EDM will provide scientific co-ordination, while ESA's ExoMars Project payload team will provide technical support for the interface of the SPL to the EDM platform.

It is intended that the SPL will come under a single Principal Investigator, with a single organisation being responsible for providing a complete SPL, including a Common Electronics Unit and primary battery.

2.2 Document Structure

Chapters 3 to 6 provide essential information about the ExoMars EDM, its mission, and issues related to the potential surface payload. The contents reflect the requirements that will be part of the to-be-issued Experiment Interface Requirements Document (E-IRD).

Chapter 3 lists informative documents for this E-PIP.

Chapter 4 describes the ExoMars EDM, its mission and mission timeline, as well as a description of the ground segment, the operational concept and the basic data flow.

Chapter 5 gives all relevant information having a direct impact on the technical accommodation of the SPL, covering a wide spectrum of interface parameters.

Chapter 6 describes management, responsibilities, communications, schedule, reviews, configuration management and deliverables.

The appendix provides preliminary AIV requirements.

Note: 'Instrument' or 'payload' or 'experiment' shall be understood to mean the SPL.

3 REFERENCE DOCUMENTS

The documents listed here are available on request to the ExoMars Project Office.

3.1 Normative Documents

None.

3.2 Informative Documents

Informative References (IR) are applicable to this document only when specifically called up in the text with references to specific parts of the document that are to be applicable. Otherwise the documents below are listed for information and as an aid for understanding.
For the explicit, dated or versioned, references, subsequent amendments to, or revisions of, any of those references do not apply to this document.
Other Informative References are listed for information and as an aid for understanding.

Note: the documents marked [N] in the following list are expected to be among those to be Normative in the E-IRD.

3.2.1 ESA Documents

[IR 1] [N] ExoMars Product Assurance Requirements. EXM-MS-RS-ESA-00002 iss.4, rev. 0.
[IR 2] ExoMars Science Management Plan. EXM-MS-PL-ESA-00002 Issue 5, Rev. 4.
[IR 3] ExoMars 2016 and 2018 Missions Environmental Specification. EXM-MS-RS-ESA-00013, Issue 4.
[IR 4] ExoMars Planetary Protection Requirements. EXM-MS-RS-ESA-00005, Issue 4, Rev. 0.
[IR 5] ExoMars Assembly, Integration and Verification Requirements Document. EXM-MS-RS-ESA-00006, Issue 5, Rev. 0.
[IR 6] PPL Applicability Matrix for ExoMars Configuration Management Requirements – EXM-PL-MTX-ESA-00001 iss.2, rev.0.
[IR 7] ExoMars Configuration Management Requirements, EXM-MS-RS-ESA-00008, Issue 2, Rev. 0.

3.2.2 Standards Documents

Useful standards include the following cited in this document:

[IR 8] ECSS-Q-ST-70-02C, Thermal Vacuum Outgassing Test for the Screening of Space Materials.
[IR 9] ECSS-Q-ST-20C, Quality Assurance.
[IR 10] ECSS-E-ST-32C Rev. 1, Structural General Requirements.
[IR 11] ECSS-E-10-02A, Space Engineering – Verification.
[IR 12] ECSS-E-10-03A: Space Engineering – Testing.

3.2.3 Prime Contractor Documents

[IR 13] ExoMars Thermal Environment and Test Requirements Specification. EXM-MS-SSR-AI-0013, Issue 4.

[IR 14] ExoMars Thermal Modelling Requirements (for 2016 mission). EXM-MS-RQM-AI-0022, Issue 2.

[IR 15] ExoMars Mechanical Environment and Test Requirements Specification. EXM-MS-SSR-AI-0012, Issue 4.

[IR 16] ExoMars EMC and Power Quality Requirements. EXM-MS-SSR-AI-0002, Issue 9.

[IR 17] ExoMars Cleanliness and Contamination Control Requirements. EXM-MS-SSR-AI-0005, Issue 7.

[IR 18] [N] ExoMars Space Environment Requirements Specification. EXM-MS-SSR-AI-0014, Issue 3.

[IR 19] [N] ExoMars CAN Bus Specification, EXM-MS-RQM-AI-0021, Issue 3.

[IR 20] CAN Bus Implementation for the ExoMars Project, EXM-MS-TNO-AI-0115, Issue 1.

[IR 21] ExoMars Product Assurance Requirements for Subcontractors. EXM-MS-RQM-AI-0004, Issue 4.

[IR 22] ExoMars SW PA Requirements for Subcontractors. EXM-MS-RQM-AI-0010, Issue 5.

[IR 23] ExoMars Planetary Protection Implementation Requirements. EXM-MS-SSR-AI-0007, Issue 6.

[IR 24] [N] ExoMars EGSE CCS Communication Protocol Specification. EXM-MS-SSR-AI-0010, Issue 1.

4 EDM MISSION DESCRIPTION

The ExoMars programme has evolved into a scenario with two missions:

- One mission under ESA leadership, launched in 2016 by a US launcher including an ESA Trace Gas Orbiter with US and European Instruments, and an ESA EDL Demonstrator Module (EDM);
- Another mission under NASA leadership, launched in 2018 by a US launcher including an ESA Rover and a US Rover, both deployed by a US cruise stage and EDL system.

This chapter describes the objectives and concepts of the 2016 mission, in particular that of the EDM.

4.1 ExoMars 2016 Mission Objectives

The ExoMars Programme will demonstrate key flight and *in situ* enabling technologies in support of the European ambitions for future exploration missions, as outlined in the Aurora Declaration and will accomplish fundamental scientific investigations critical to fulfilling the next steps in the exploration of Mars.

Particularly, the ExoMars 2016 mission shall accomplish the following objectives:

- *Technological objective:* Entry, Descent and Landing (EDL) of a payload on the surface of Mars (addressed by the EDM);
- *Scientific objective:* to investigate Martian atmospheric trace gases and their sources (addressed by the Trace Gas Orbiter).
- The Trace Gas Orbiter will also serve the programmatic objective of providing communications capability for present and future ESA/NASA missions (2018-20).

4.1.1 Science Background and Objectives

The EDM constitutes primarily a technological development rather than a science platform, and the science payload shall be constructed in such a way as to guarantee no interference with the EDL aspect of the mission. The two main science opportunities of the mission (limited by the available resources) are:

- The engineering sensors included in the EDL system have as their main objectives to reconstruct the flown trajectory and measure the performance of the EDL subsystems (e.g. Heat Shield, Parachute, RCS). Data produced by these sensors may also be used to derive scientific information such as the atmospheric density profile along the entry trajectory, helping to improve understanding of the Martian atmosphere. It is reminded that these engineering sensors are under the responsibility of ESA with the contract to the ExoMars Prime Contractor, and are not covered by this document.
- The opportunity exists to accommodate a few, simple sensors (requiring no deployment and limited electrical power and data return) and a camera system that will operate independently (from the platform) and autonomously after landing on the Mars surface. Measurements could be conducted during the surface mission.

Scientific objectives of the EDM Surface Payload are discussed in the AO. The science activities on the surface will be on a best-efforts basis, linked to the available resources; these may change during the development phase, in particular when the EDM landing site will be finally defined.

4.2 ExoMars 2016 Mission Concept

ESA will design, build and integrate a large Spacecraft Composite consisting of the ExoMars Trace Gas Orbiter, which will carry the scientific trace gas payload instrumentation, and the EDL Demonstrator Module (EDM).

The Spacecraft Composite will be launched in early January 2016 by a NASA-provided Atlas V 431 class Launcher and will arrive at Mars approximately 9 months later, in mid-October of 2016. Prior to arrival at Mars, the EDM will be released from the Trace Gas Orbiter and will enter the Mars atmosphere from a hyperbolic arrival trajectory.

The release of the EDM will take place 3 days prior to the critical Mars Orbit Insertion (MOI) manoeuvre to be performed by the Trace Gas Orbiter. The sequence of manoeuvres following the separation will be designed to ensure a UHF telecommunication link between the TGO and the EDM during its Entry, Descent and Landing phase. After capture, the TGO will be in a 4-sol elliptical orbit around Mars that will be maintained for about 8 sols from landing, to provide an additional pass over the landing site for EDL data up-load sessions (potentially, depending on the insertion errors, a pass 4 sols after landing may be achieved). Subsequently, the TGO will begin a series of manoeuvres to change the orbit inclination to 74° and reduce the apoares using on-board fuel reserves, down to a 1 sol orbit. Further reductions of the apoares will be performed using aerobraking techniques over a period of about 6 to 9 months followed by a final circularisation manoeuvre to arrive at the science and communications orbit with an altitude in the range of 350 km to 420 km.

The EDM will provide Europe with the technology for landing on the surface of Mars with a controlled landing orientation and touchdown velocity. The total mass of the EDM is approximately 600 kg and the design maximises the use of technologies already in development within the ExoMars programme. These technologies include:

- Heat Shield based on ablative materials
- Supersonic Parachute System (Disk Gap Band canopy)
- Velocity and slant range measurement sensor (using a Radar Doppler Altimeter)
- Liquid propulsion controlled final braking
- Semi-soft landing

The configuration of the EDM is developed keeping in mind the scalability to future larger landers. Engineering sensors are incorporated into the design to assess the performance of the system throughout its EDL phase. The EDM will have a heatshield diameter of 2.4 m and will support entry from a hyperbolic trajectory. The system will be designed to survive the possibility of a severe dust storm since it will arrive during the Mars Global Dust Storm Season (around L_S = 244°), therefore with high probability of encountering high dust load. After entry the system will deploy a single-stage Disk Gap Band parachute and will complete its landing by using a closed-loop Guidance, Navigation and Control (GNC) system based on a Radar Doppler Altimeter sensor and on-board Inertial Measurement Units that will guide a liquid propulsion system by the actuation of 3 clusters of thrusters to be operated in pulsed on-off mode.

The ESP is designed to survive on the surface of Mars for a short time (8 sols) using the energy capacity of its primary batteries to guarantee at least one Trace Gas Orbiter UHF pass to recover the EDL data and SPL data.

It shall be underlined that the 8-sol lifetime of the ESP on the Mars surface is currently guaranteed for a landing site in the Meridiani Planum region. Mission launchability constraints may lead to an increase in the latitude of the landing site. This could result in a reduction of the lifetime of the EDM on the Mars Surface.

A set of scientific sensors will be embarked as a demonstration of surface science, within the mass and electrical (including radio-frequency) resources available in the EDL Demonstrator, without adding additional systems for solar power generation or for thermal control, such as Radioisotope Heater Units.

The nominal science operations period foreseen in the Meridiani Planum scenario is 4 sols.

The 2016 mission is led by ESA and the spacecraft operations will be performed by ESOC in Darmstadt including the EDL Demonstrator operations. Science planning, timeline preparation and telemetry monitoring for the SPL CEU will be managed by the SPL PI.

4.2.1 EDM Model Payload

A model payload was defined by the ExoMars Project for the purposes of facilitating EDM design work prior to payload selection. The model payload comprises two main elements:

1) A baseline configuration, providing resource allocations for payload units (common electronics, battery and 3 sensor units)
2) A set of accommodation test cases for a variety of sensor types with differing accommodation requirements.

This approach allowed an achievable baseline configuration to be established, while also ensuring that the EDM configuration can offer a range of other possible mounting locations for potential sensors. The test cases are thus framed only in terms of the requirements for mechanical accommodation (unit volume, attachment points, FoV, possibility for harness routing, etc.) rather than mass, power and data requirements. In both the baseline and the accommodation test cases, the sensors are supported by a common electronics unit, primary battery and harness. The baseline configuration is given in Table 1.

Table 1. Baseline units of the EDM Surface Model Payload.

Unit	**Brief Description and Accommodation**	**Envelope [mm] (L×W×H)**	**Mass /g incl. maturity margins**	**Downlinked data volume (TBC)**
External Environmental Sensors Unit	Sensors requiring exposure to the external environment and/or unobstructed wide-angle view of zenith; external unit on upper surface of EDM	125 × 125 × 50	180	1200 kbit/sol
Internal Environmental Sensors Unit	Sensors not requiring exposure to the external environment; sensor unit in warm compartment (with tube to exterior if needed)	65 × 50 × 20	48	97 kbit/sol
Camera System	Wide-angle camera viewing local environment; one camera head on EDM exterior	63 (along camera's optical axis) × 76 × 61	204	<44.8 Mbit total
		TBD calibration targets	15	
Common Electronics Unit	incl. PCBs, structure & attachment hardware. Internally mounted.	164 × 145 × 150	1130	3.3 kbit/sol
Instrument harness	Use of low mass (e.g. flex) cables assumed.	TBD	288	-
Payload primary battery	Energy for SPL operation (incl. thermal control) prior to relay 4 sols post-touchdown	150 × 110 × 110	1135	-
Totals			**3000**	**50 Mbit total**

The sensors for the accommodation test cases are given in Table 2. A set of achievable measurements was assumed for the purposes of choosing the example sensors.

Table 2. Sensors for the Surface Model Payload accommodation test cases for the EDM in Phase B2X2.

Designation	Brief Description	Envelope [mm] (L×W×H)
A1-4	Azimuthally-distributed array of external sensors needing contact with undisturbed atmospheric flow	30×10×30 (4 off)
B	Internal sensor unit needing tube to external atmosphere	62×50×17
C	External sensors needing contact with undisturbed atmosphere	Adjacent units: 93×28×8 and 14×15×30
D	External environmental sensing unit needing exposure to external environment and unobstructed wide-angle view of zenith	120 diameter × 45 height
E	External sensor needing unobstructed wide-angle view towards zenith	36×39×24
F	External sensor needing exposure to external environment	25×29×9
G	External sensor needing unobstructed wide-angle view of sky	75×50×12
H1,2	Imaging system needing views of surrounding landscape	63×76×61 for each (63 is along camera's optical axis) TBD calibration targets
I	Passive experiment needing wide-angle view of sky	50 diameter × 25 height

4.3 Mission Phases

The 2016 Mission phases are summarised in Table 3. For each phase, the main events are highlighted together with expected mission elapsed time. The provided information is based on available mission analysis simulations.

The reported epochs are indicative and assume a launch at the start of the launch window (LW). Precise epochs shall be tuned upon launch date. For a launch date at start of LW, i.e. 05/01/2016, arrival at Mars is expected on 14/10/2016. For a launch date at end of LW, i.e. 24/01/2016, arrival at Mars is expected on 27/10/2016.

Table 3. ExoMars 2016 Mission Phases Overview

MISSION EVENTS					
Phase	*Key events*	*Epoch*	*Mission elapsed time from launch*		*Remarks*
Launch	Launch with Atlas V 431 class launcher	Jan 2016	- -		Launch window from 05th to 24th January 2016
Early operations	Injection into escape trajectory	Jan 2016	1967 s		Spacecraft Composite Checkout Phase (incl. EDM SPL checkout) starts after injection into escape trajectory.
Interplanetary cruise	Trajectory correction manoeuvres (TCMs) #1,2,3 and Deep Space Manoeuvre (DSM)	Jan-May 2016	0.0274 - 0.3998 Years	10.0 - 146.0 Days	TCM #1 indicates the end of the Early Operations Phase and the transition to Interplanetary Cruise (T2 transfer). TCMs #2,3 and the DSM make the trajectory compatible with the selected landing site.
Mars approach	Start of increased orbit determination (OD) activities	Sep 2016	0.6517 years	237.8 days	Initiation of the intense orbit determination process including DDOR. Time between start of intense OD and arrival: 45.0 days.
	EDM pre-separation checkout	Sep 2016	TBD	TBD	Includes SPL checkout
	Trajectory correction manoeuvres (TCMs) #4,5	Sep & Oct 2016	0.7064 & 0.7571 Years	257.8 & 276.3 Days	Terminal TCMs 25.0 and 6.5 days before arrival
EDM separation	TGO - EDM separation	Oct 2016	0.7598 years	277.3 days	Time from separation to arrival between 2.5 and 5.5 days
EDL EVENTS					
Phase	*Key events*	*Epoch*	*Mission elapsed time from Orbiter Separation*		*Remarks*
Coasting	EDM enters hibernation mode	Oct 2016		1 h (TBC)	All EDM systems are OFF, except timers
	EDM exits from hibernation mode			71 h (TBC)	EDM systems are awaken in order to prepare for the EDL
Entry, Descent and Landing	EDM passes the Entry Interface Point (EIP)	Oct 2016		72 h	Entry of the EDM in Mars atmosphere and landing close to the target site.
Touchdown	ESP comes to rest and essential telemetry transmitted to TGO	Oct 2016		72 h	Ends a few minutes after touchdown. Local hour at landing site: 14.3.
SURFACE MISSION EVENTS					
Phase	*Key events*	*Epoch*	*Mission elapsed time from touchdown*		*Remarks*
Check-out before hibernation	Activation of surface payload and initiation of operation	Oct 2016		15 min (TBC)	
Hibernation	ESP enters hibernation mode	Oct 2016		15 min (TBC)	EDM systems are OFF except the timers. SPL operates autonomously
Communications pass #1	ESP exits hibernation mode	Oct 2016		4 sols	EDM systems are awaken, SPL data are retrieved and transmission of System and SPL data to the TGO is attempted (TGO pass cannot be guaranteed)
Hibernation	ESP enters hibernation mode	Oct 2016		4 sols	EDM systems are OFF except the timers. SPL operates autonomously if resources allow
Communications pass #2	ESP exits hibernation mode	Oct 2016		8 sols	EDM systems are awaken, SPL data are retrieved and transmission of System and SPL data to the TGO is performed
EDM End of Mission		Oct 2016		8 sols	EDM End of mission may be reduced after selection of the final landing site.

4.4 Description of EDL Demonstrator Module

The EDM is designed as a blunt-shape re-entry capsule and is launched on top of the Orbiter Module (OM) as shown in Figure 4-1. The EDM external overall dimensions are shown in Figure 4-2.

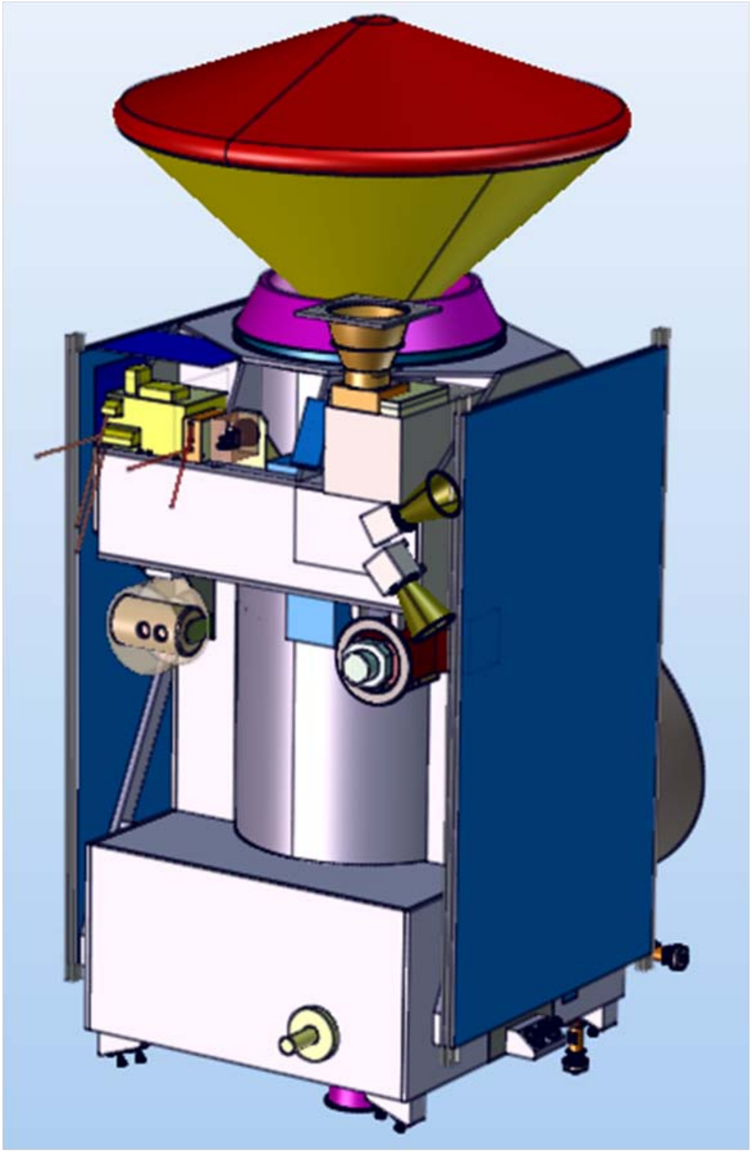

Figure 4-1. Conceptual spacecraft composite configuration in launch configuration

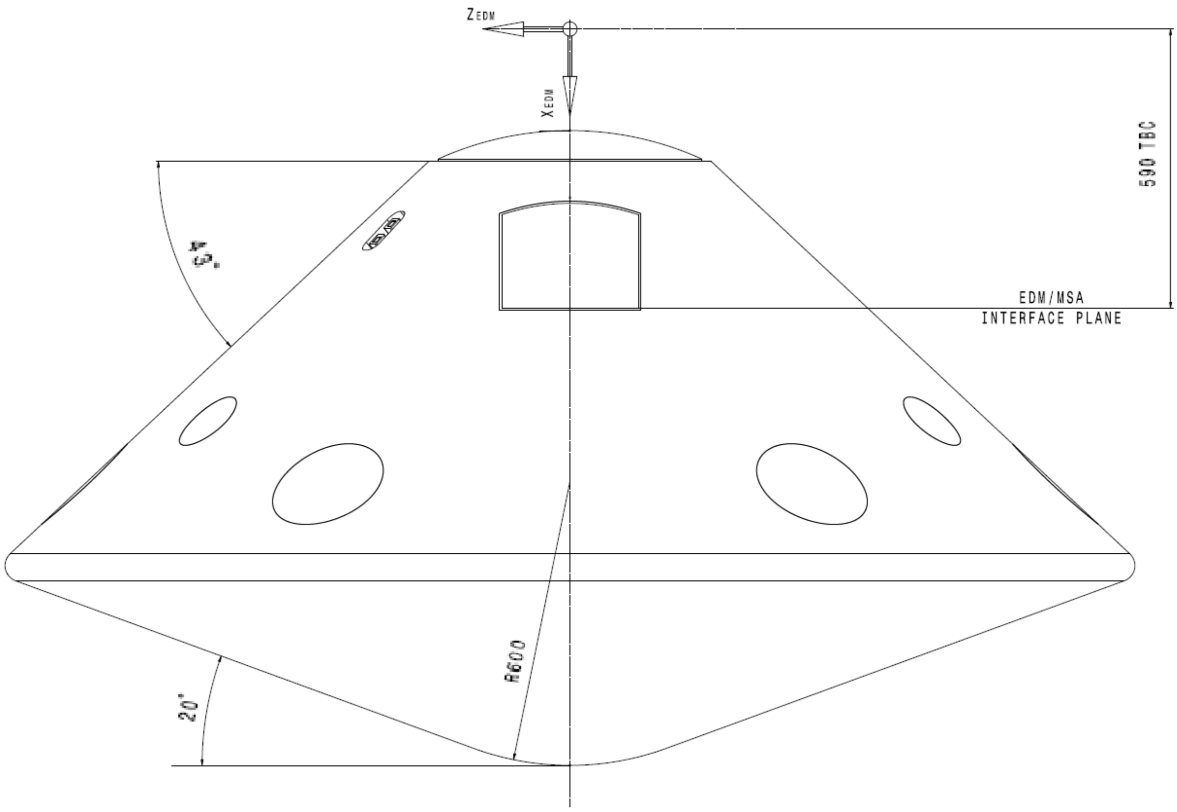

Figure 4-2. EDM external overall dimensions. The diameter is 2.4 m.

The EDM is launched attached on the top of the Orbiter Module (OM) until approaching Mars. It is then released from the incoming hyperbola, on a trajectory targeted to allow its landing on Mars surface in the daylight and at the selected landing site.

During cruise the EDM will be nominally OFF except the thermal control function that is permanently ON. During interplanetary trip to Mars, EDM health check-out session and software patches down to subsystem/equipment level, including Surface Payload is possible via ground-originated command dispatched by Trace Gas Orbiter.

The release of the EDM will take place 3 days prior to the Mars Orbit Insertion manoeuvre. Shortly after separation, the EDM will enter into hibernation mode to minimise the electrical energy demand from its primary battery modules. All units will then be OFF, with the exception of triple redundant timers that will awaken the EDM about 1 hour prior to Mars atmosphere entry.

The EDL phase will be automatically detected when the EDM passes by the Entry Interface Point (EIP), conventionally 120 km above Mars surface and will end with touchdown on the Martian surface. The duration of the whole EDL phase is about 400 s. The sequence of TGO manoeuvres following the separation will be designed to ensure a UHF telecommunication link between the TGO and the EDM during its Coast, Entry Descent and Landing phases.

During the EDL phases, the sub-modules will be separated and jettisoned such that the EDM Surface Platform (ESP) can land safely on Mars.

An exploded view of the EDM sub-modules is given in Figure 4-3.

- **Back Shell (BSH)** is the EDM sub-module constituted of the Back Cover plus all EDM items physically installed, including the DM-OM separation mechanism, the ablative thermal protection material and the parachute system.
- **Front Shield (FS)** that sustains the maximum mechanical and thermal loads at entry.
- **Surface Platform (SP)** that consists of a primary structure accommodating among others the EDM propulsion system, the Central Terminal Power Unit (CTPU), batteries, the Surface Payload plus crushable material to ensure the platform structural integrity at touchdown on Mars terrain.

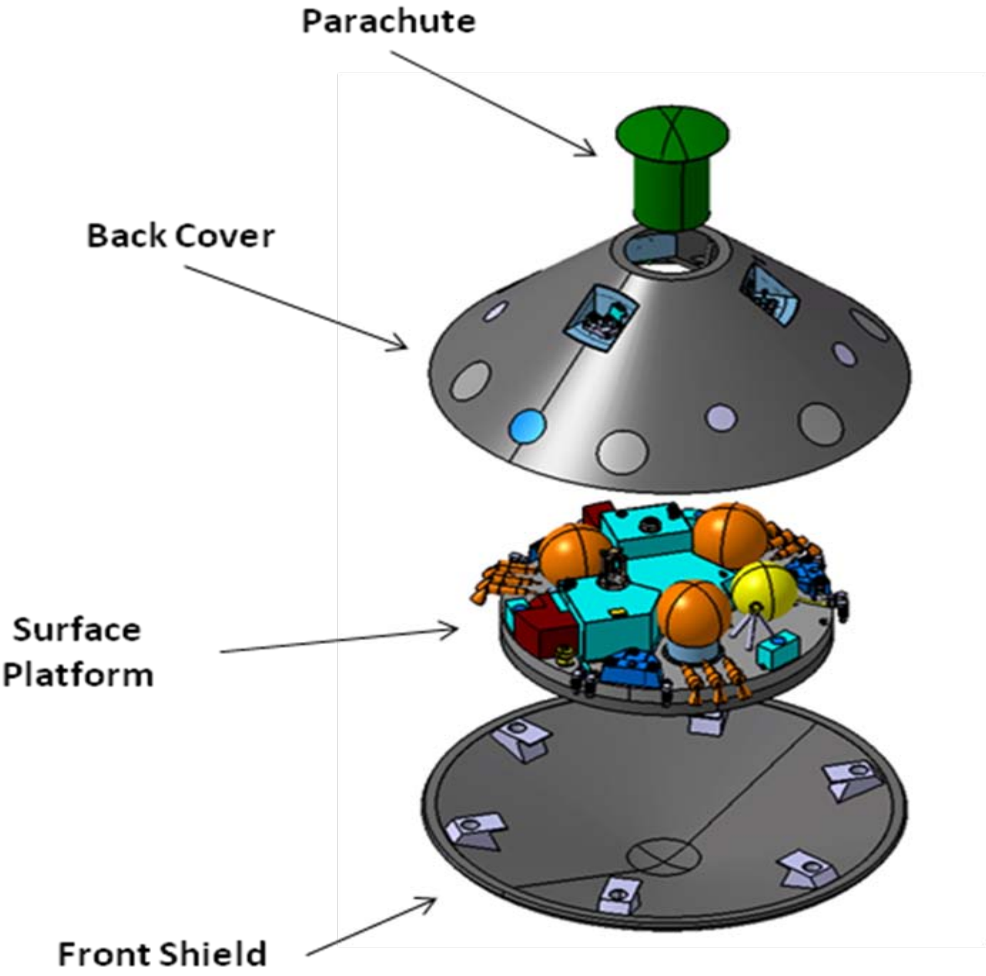

Figure 4-3. EDM Exploded View

The EDL phases are described in Figure 4-4, Figure 4-5 and Figure 4-6.

Figure 4-4. EDM entry configuration.

Figure 4-5. EDM Parachute opening, Front Shield separation and Surface Platform release.

Figure 4-6. EDM Surface Platform final braking, control and impact on crushable structure.

The Entry Interface Point is detected when the filtered value of acceleration in symmetry axis overcomes a prescribed threshold. In the first few minutes (from 2 to 3 minutes), the Heat Shield (front and back shields) sustains the aerothermodynamics loads and guarantees the EDM stability. At the suitable Mach/Altitude/Dynamic Pressure range, the Parachute deployment is triggered by on-board accelerometer measurement logic to increase probe braking. The Front Shield is then jettisoned on the basis of a timer-based trigger. Shortly after, the Radar Doppler is activated for internal checks and monitoring but still not included in the GNC loop. At an altitude of about 3000 m the Radar Doppler becomes able to measure the distance from the terrain along the capsule symmetry axis and the velocity in body axes. The Radar Doppler differentiated measurements are validated against the IMU measurements. For a combination of vertical velocity and altitude (< 1400 m) encountering the descent profile, the active control is enabled just before EDM Surface Platform (ESP) is separated from the back-shell. Given the lower descent landing mass to about 300 kg, the final braking and attitude control is obtained through modulation of pulsed engines installed on the Surface Platform. The GNC applies a *g*-turn strategy by imposing a thrust vector opposite to the velocity vector modulated in such way to follow the descent profile. At approximately 1.5 m altitude with a nominal null velocity, the RCS thrusters are switched off and the ESP drops in free fall to the Mars surface, landing on crushable structures.

During EDL, all meaningful data (especially relevant to trajectory reconstruction and EDM subsystem performances) are recorded on the CTPU's non-volatile memory, for download to ground via the TGO after touchdown. A subset of data is also transmitted 'live' during EDL and recorded by the TGO UHF transceiver. Immediately after touchdown, while transmitting data to the TGO for the remaining few minutes of coverage guaranteed by the TGO's trajectory, the CTPU activates the SPL for its autonomous surface operation and then enters hibernation.

Once on the Martian surface, data transmission to the TGO can only be performed during a periares pass, i.e. every 4 sols. Due to the trajectory errors resulting from the very large Mars Orbit Insertion manoeuvre, it cannot be guaranteed that the link will be possible at the first TGO pass, i.e. 4 sols after landing. Nevertheless, thanks to Orbit Determination and Correction campaigns, the link is guaranteed during the pass that will occur 8 sols after landing. This pass will be used to upload flight measurements and house-keeping data generated during the EDM mission and data generated by the Surface Payload, with data from the EDL phase taking priority over SPL data from the surface phase.

The ESP is designed to survive on the surface of Mars by using the energy capacity of its primary batteries.

4.4.1 EDM Surface Platform (ESP)

The Surface Platform (Figure 4-7) concept consists of a structure allowing the mounting of the propellant and pressurant tanks, the different propulsion components, secondary structures for implementation of thruster clusters and avionics equipment, including computer (CTPU), periphery unit for power and data management (RTPU), GNC sensors, UHF transponders, batteries, and Surface Payload.

All equipments are installed on the upper surface of the Main Panel with the exception of the RTPU and Radar Doppler Altimeter, located beneath the Main Panel.

The **Crushable Structure** is fixed on the lower surface of the Main Panel facing the conical shape of the Front Shield. A cut-out in the centre accommodates the Radar Doppler that needs a 40° free field of view. Below the Radar Doppler and fixed to the Main Panel there is the RTPU.

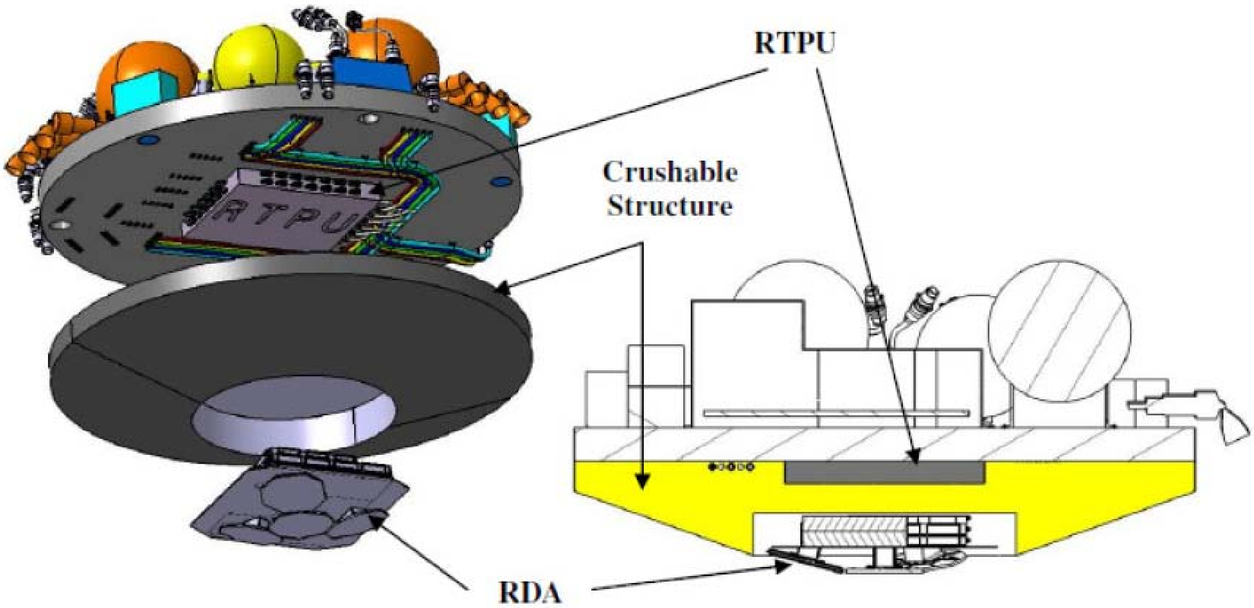

Figure 4-7. ESP Configuration views. The diameter of the surface platform is 1.65 m.

The ESP Central Bay (CB) will be designed as a warm compartment thermally sealed from the external environment to minimize the thermal energy needed to maintain the inner electrical equipment to be operated on Mars surface in the specified temperature range: i.e. the CTPU, the UHF transceiver and one ESP primary battery (Figure 4-8). Equipment will be fixed on an inner aluminium sandwich panel with aluminium skins, supported by thermally insulating stand-offs for decoupling from the main structural panel (Figure 4-9). Hosting within this warm zone of SPL units (common electronics and battery) has required the enlargement of the Central Bay. An SPL internal environmental sensors unit can be accommodated within the warm zone and an external environmental sensors unit mounted externally.

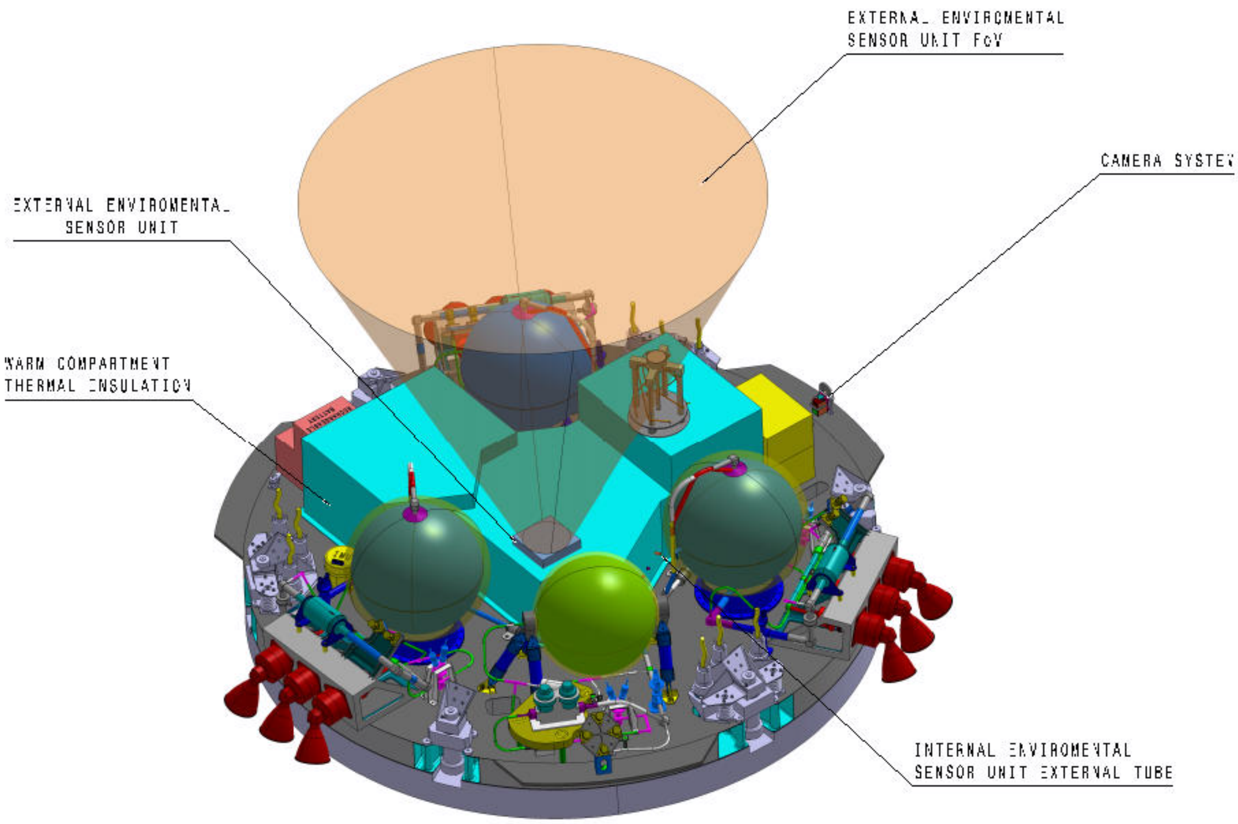

Figure 4-8. Surface Platform, on which is mounted the warm compartment, showing the baseline configuration of the model payload.

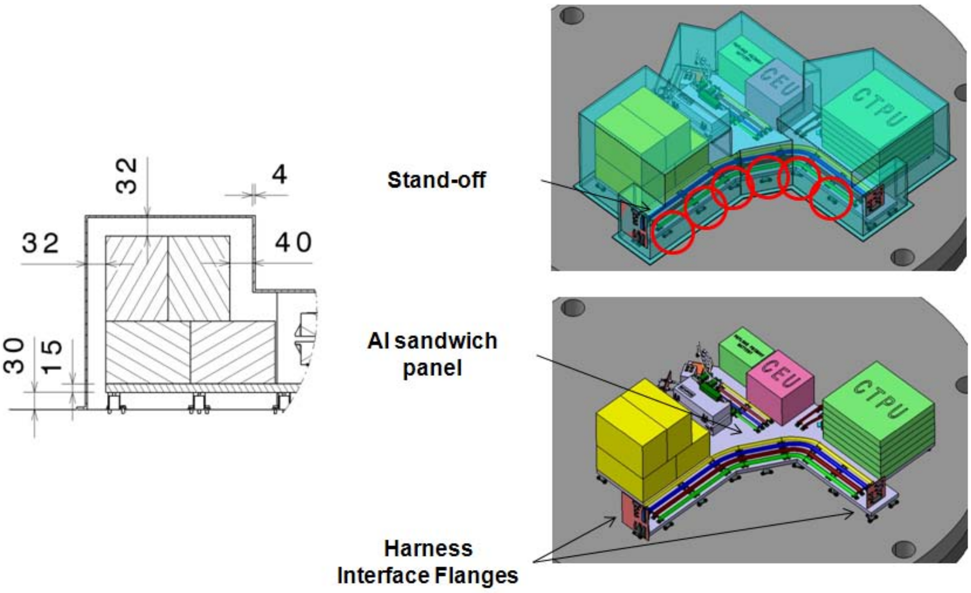

Figure 4-9. Central Bay supporting structure

4.4.2 Surface Payload Accommodation Concept

The Surface Payload will consist of instrumentation/sensors, service subsystems (primary battery and Common Electronic Unit (CEU)), harness, mechanical fittings and thermal insulators as necessary. Sensors are accommodated on the ESP Propulsion Bay while the service subsystems remain within the warm compartment of the ESP Central Bay. The SPL CEU will be connected to the various sensors by means of harness properly insulated passing through dedicated cavities of the warm compartment wall (Figure 4-10). Power lines are provided from the CTPU to the CEU for use during checkouts only.

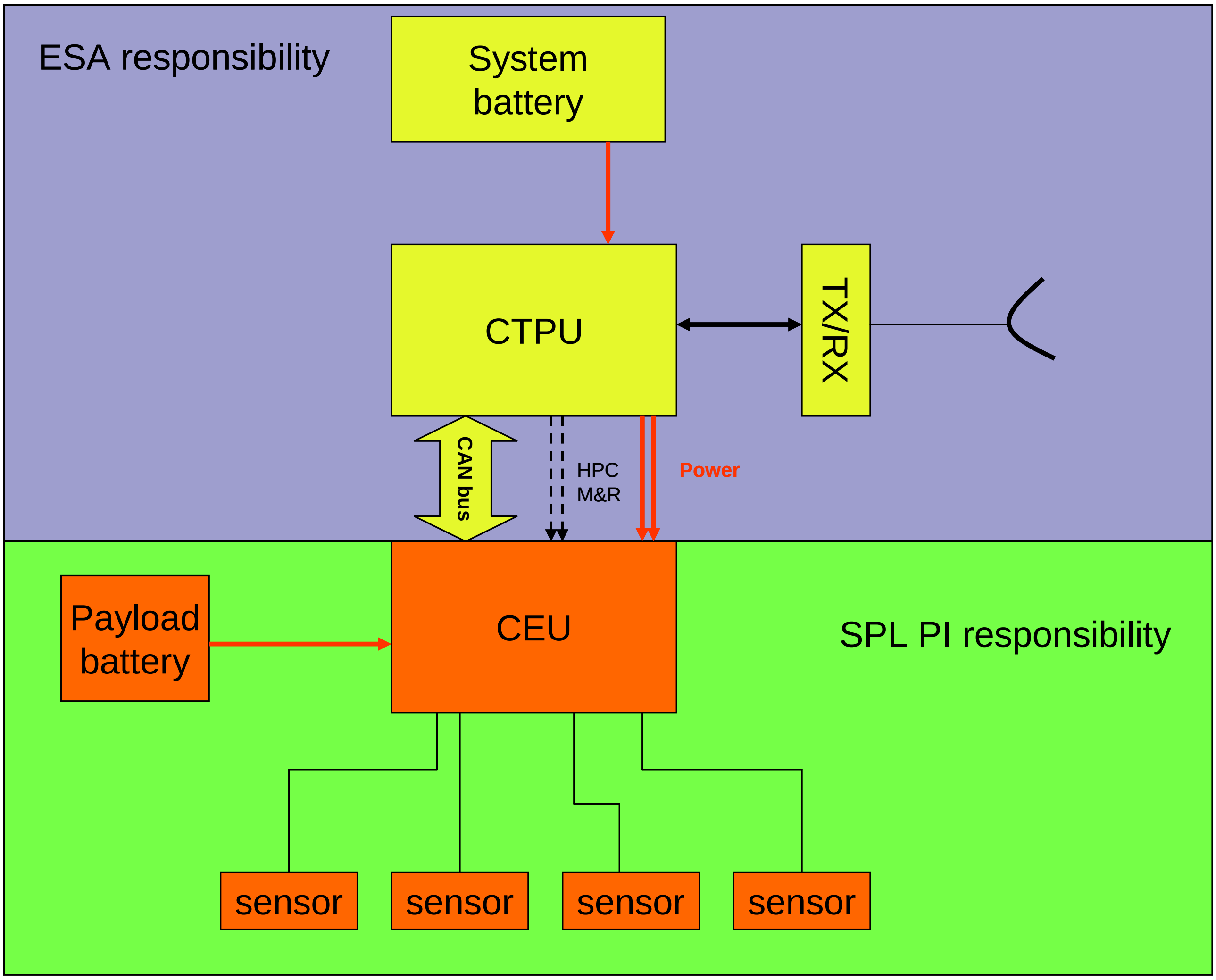

Figure 4-10. Surface Payload: Functional I/F Concept

4.5 Landing Site

The EDM Landing sites are identified by the ExoMars Project as a Reference Landing Site and an Alternative Landing Site to fulfil the overall mission needs and the EDL technology objective. The technical drivers for the landing sites are the performance of Entry, Descent and Landing (EDL) missions when interacting with the Mars environment, but also the overall mission launchability constraints.

The EDM design, as with all Mars landing missions, is sensitive to specific Mars features. Concerning atmospheric characteristics, very important parameters for final EDL performance are the atmospheric density as well as the horizontal and vertical winds in the first kilometres above the surface. Regarding surface terrain, important parameters to consider are slopes, rock distribution and size, radar reflectivity, thermal inertia and albedo. It is therefore crucial to know the characteristics of the atmosphere and terrain for the landing.

The current reference landing ellipse (of approximately 100 km major axis, 3-sigma) has been preliminarily centred around **6.1 W and 1.9 S**, in the Meridiani Planum area. The alternative landing site will be preliminarily positioned upon completion of PDR. It shall be noted that the reference landing site may be modified as a result of mission launchability constraints and may be located at higher latitudes. This could result in a reduction of the lifetime of the EDM on the Mars surface.

Information on the environments to be encountered by the EDM can be found in [IR 3], [IR 16] and [IR 21].

4.6 Surface Payload Mission Operations

The Surface Payload shall be autonomous, i.e. it will have to rely on its own common battery and electronics unit and shall operate according to a pre-planned timeline. Once it has been activated by the EDM a few minutes after landing, it shall start acquiring scientific data according to a pre-defined timeline. The acquired data shall be recorded on local memory on the common payload electronics unit.

Before the first TGO potential passage (landing + 4 sols), the acquired data will be transferred to the EDM system and this will conclude the nominal surface payload mission. The EDM will then take care to establish the link to the TGO and to uplink the data. If the EDM data uplink to the TGO is not successful during the first passage, the EDM shall be able to re-transmit all the data from the first passage to the TGO during the second passage (landing + 8 sols).

If resource availability allows the nominal surface payload mission to be extended, this shall be detected autonomously by the payload and it shall continue data acquisition and storage as long as resources are available. The payload shall autonomously switch itself off while leaving enough energy to be switched on again by the EDM for final data transfer to the EDM system before the second TGO pass (landing + 8 sols).

If all or part of the data is successfully uplinked during the first passage, the EDM shall allow further science data to be received from the payload. It shall during the second passage first re-transmit the lost data and then allow the newly received science data to be uplinked, as far as EDM resources and capabilities allow. For this, the EDM shall be able to connect to the payload CEU at a pre-planned time.

The operational sequence of the surface payload is to be kept as simple as possible, conforming to a pre-planned timeline. This includes Camera images, which are to be obtained according to that timeline. The SPL CEU shall be capable of receiving an updated timeline prior to EDM separation from the Orbiter Module.

Surface payload operations will alternate between ‘day’ and ‘night’ modes, according to whether the subset of sensors that require illumination is sampled.

The ExoMars 2016 mission operations will be performed from the MOC, located at ESOC in Darmstadt, Germany, from Launch to End of Mission (EoM). Key characteristics of the operations systems are described in this section. This information should be considered preliminary at this point and will be updated following selection of the SPL.

4.6.1 Ground Segment Architecture

The main components of the ExoMars 2016 EDM Ground Segment architecture consist of:

- The Ground Stations, being shared between ESA (ESTRACK) and NASA (DSN);
- The Mission Operations Centre (MOC), located in ESOC, Darmstadt, in charge of the overall mission operations planning, execution, monitoring and control, including EDM operations;
- The EDM SPL PI, being in charge of generating the SPL timeline and monitoring and analysing the technical and scientific TM from the SPL.

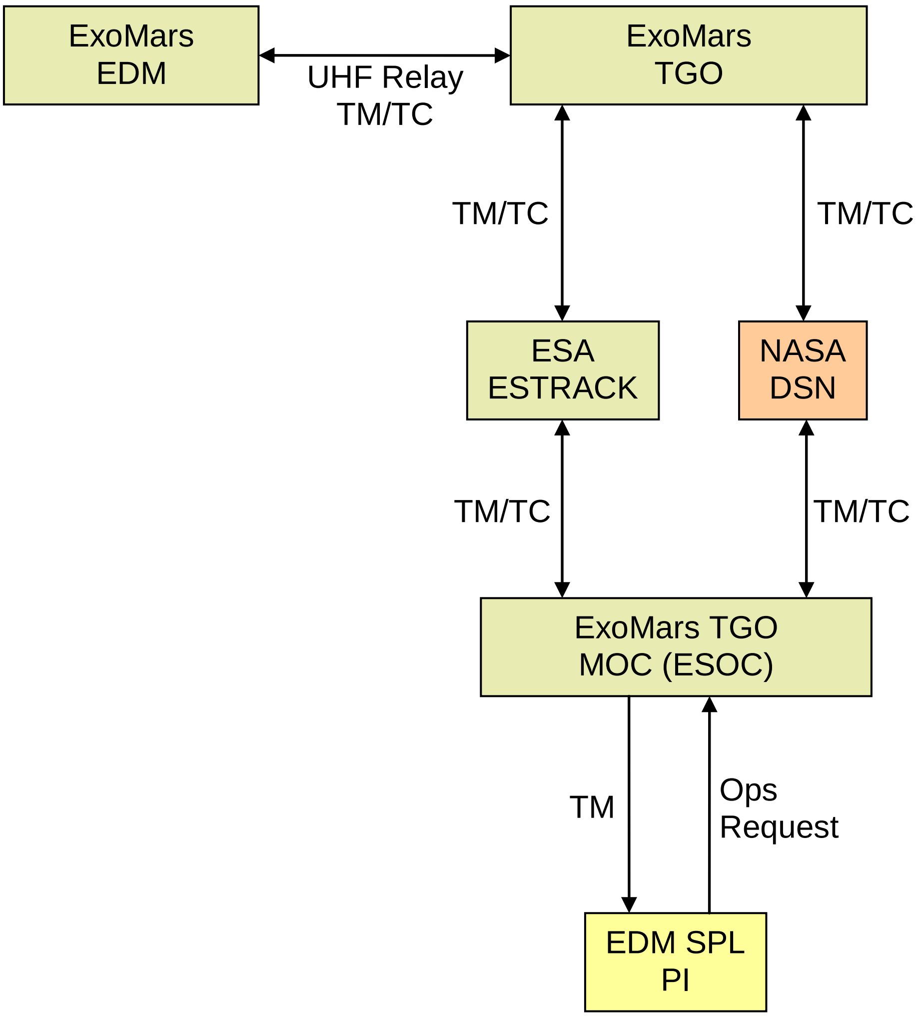

Figure 4-11. ExoMars 2016 EDM Ground Segment Architecture.

The SPL PI shall interface directly with the MOC. ExoMars EDM SPL data received via the ground stations will be stored at ESOC at the ExoMars Mission Operation Centre

(MOC) and made available to the EDM SPL PI via the MOC Data Distribution System (DDS).

It is assumed that SPL anomalies detected during cruise checkout will be observed by the PI once he receives the data, and not by the MOC.

The Surface Payload shall be autonomous, relying on its own battery and common electronics unit, and shall operate according to its own pre-planned timeline. This SPL CEU timeline is part of the CEU flight software, which shall be provided by the SPL PI and loaded onto the CEU before launch.

The only SPL operations foreseen prior to separation from the TGO are the following:

- checkouts of the SPL (one during the Spacecraft Composite Checkout Phase and one before the EDM separation preparation (TBC)) and
- reload of the complete CEU timeline.

For these operations the SPL PI will have to forward a formal Payload Operations Request (POR) to the ExoMars MOC, which then takes care to uplink the related request via the TGO/EDM. The SPL checkout and execution timeline reload operations shall be developed and validated by the PI and shall be executed autonomously by the SPL and shall not assume interactive ground control while performing these operations.

4.6.2 Operations Activities

All SPL operations shall be described in the SPL User Manual.

Before launch, ESOC will test flight operations sequences and commands in simulation campaigns and System Validation Tests (SVT). For those in which payload functions are involved, the SPL PI will be expected to participate.

During Spacecraft Composite Checkout Phase, there will be daily ground station passes of 10 h each in which spacecraft subsystems, EDL Demonstrator Module (EDM) and payload instrument health checks and in-flight calibrations will be carried out. ESOC will document any payload operations planned during this mission phase in dedicated procedures in the Flight Operations Plan (FOP). Flight teams at ESOC, the spacecraft contractor site, and PI sites will jointly conduct these activities. During this checkout phase, PIs are invited to participate from the ESOC PI Support Area (PISA) to allow short reaction times and close collaboration with the TGO flight control team.

During Cruise phase, there will be 3 ground station passes per week of 4 h each, allowing only non-interactive operations. The phase is primarily dedicated to navigation operations. One non-interactive payload checkout can be performed on a non interfering basis in a dedicated, pre-agreed slot. Scheduling of an EDM SPL checkout is coordinated by the MOC (within the TGO constraints) and will be uploaded to the spacecraft for execution outside of ground station passes. When the data is downlinked during subsequent ground station contacts, it can be accessed and evaluated offline by the SPL PI from their home institute.

During the EDM Surface Mission Phase, the SPL will be OFF until a few minutes after landing, when it will be activated by the EDM CTPU. The SPL will then perform its activities autonomously.

4.6.3 Telemetry Processing and Mission Products

All SPL raw telemetry data and auxiliary data will be made available to the SPL PI via the MOC. The following shall be noted:

1. All telemetry packets received at the MOC shall be stored as raw data and made available to all mission users. Upon delivery of raw data to external users, additional information such as quality data and packet timing are provided to enable the users to time correlate the data with UTC.
2. Decompression of data compressed by the SPL itself is not supported by ESOC. These packets shall be delivered as received.
3. ESOC shall not perform any processing of science telemetry packets, neither for calibration nor for instrument monitoring purposes.

4.7 Long Term Raw Data Archiving

Processed scientific and auxiliary data shall be archived according to the EDM Data Archive Plan. Following a period of six months from the date when the measurements are obtained, all data sets, calibration information, and any necessary software tools and information to use the data, shall be made public to the international scientific community by delivery by the SPL PI to the ESA Planetary Science Archive.

5 EDM SURFACE PAYLOAD ACCOMMODATION CONSTRAINTS

5.1 Payload Activities by Mission Phase

The surface payload will be basically OFF for the whole cruise and EDL phase, apart from a few identified periods in which it will be subjected to commissioning or health-check activities. The following table outlines surface payload status and operations against mission phases:

- LEOP → The surface payload is OFF.
- Interplanetary Cruise → Nominally the SPL is off.

  The SPL is switched on for Check-Out (check-out slots are currently planned after LEOP and after DSM) and possibly for timeline reload. The SPL check-out will be an automatic sequence triggered upon EDM command but fully run and managed by SPL electronics. The definition of the check-out procedure is under the SPL PI's responsibility. During the check-out, the SPL shall transmit to EDM computer the test progress status and the test results. The SPL check-out shall not last longer than 1 hour.

  When switched on during cruise, the SPL is supplied on external power provided by the EDM (however it will be possible to exercise the SPL battery in the frame of the check-out if deemed necessary). The EDM power is supplied by the TGO during the Cruise phase.
- Mars Proximity & EDM separation → While approaching Mars, the SPL will undergo a final Check-Out. It will be also possible to upload an updated measurement timeline, if needed. For these activities the SPL is supplied on external power provided by the EDM (EDM power supplied by the TGO). During operations preparatory to separation, the SPL will be off.
- Coasting → The surface payload is OFF.
- Entry, Descent and Landing → The surface payload is OFF.
- Surface Mission: Touchdown → Immediately after touchdown, the SPL will be activated according to the following sequence:
  - The SPL computer will be powered on;
  - The SPL will switchover to internal power (provided by the SPL battery);
  - The SPL will perform an overall health check (not longer than 60s) and will transmit the result to

		the EDM computer.; • The SPL will activate its operational timeline. Finally, the EDM will enter hibernation. From this point on, the SPL shall perform its scientific mission without relying on any EDM/ESP resources with the exception of data relay to Ground.
➢ Surface Mission: Data Relay	➔	Respectively 4 (TBC following successful MOI with minimum error) and 8 sols after touchdown, the TGO is expected to perform data relay for the EDM Surface Platform (ESP). Before this happens, the ESP will awaken from hibernation with a suitable time margin and the SPL data recorded over the last 4 sols will be transferred to the ESP memory to be transmitted to ground via the TGO.

5.2 Mass

The total maximum mass allocated for the surface payload is 3 kg NTE, inclusive of maturity margins, which shall be applied as follows:

- 5% of the current best estimate for available sub-assemblies (that do not need any modification)
- 10% of the current best estimate for modified sub-assemblies
- 20% of the current best estimate for new sub-assemblies

The relevant categorisation (available, modified, new) shall be justified in the mass breakdown description of the proposal.

The SPL mass budget shall include:

- sensor heads and their attachment hardware (bolts, screws, washers, bonding straps, support brackets,…),
- Common Electronics Unit (including bolts, screws, bonding strap,…),
- harness between sensors and CEU (cables, connectors, fixation and insulation means,…),
- thermal hardware (e.g.: radiators, coolers, heaters, thermal blanket / MLI, thermostats,…),
- primary battery for the surface payload (including common electronics) (including bolts, screws, bonding strap,…), and
- harness between battery and CEU (cable, connectors fixation means).

5.3 Accommodation Envelopes

Envelopes inside the EDM central bay (warm compartment) have been defined for accommodation of the SPL model payload CEU and battery (see Table 1 for dimensions). Mounting locations have been identified for SPL sensors in three general locations, as described in Table 4.

Table 4. Mounting locations for SPL units. See Table 1 and Table 2 for dimensions of units from the model payload baseline and accommodation test cases, respectively.

Location	Mounting Surface	Examples from Model Payload	Figure
Inside the warm compartment	on the supporting structure, close to the SPL CEU and battery	Internal environmental sensors unit of the baseline model payload	Figure 5-2
		Sensor B of the model payload test cases	Figure 5-4
On top of the warm compartment	on internal units of the warm enclosure, via stand-offs penetrating through the thermal insulation	External environmental sensors unit of the baseline model payload	Figure 5-1
		Sensors D, E, G and I of the model payload test cases	Figure 5-3
On the exterior	around the edge of the surface platform	Camera system of the baseline model payload	Figure 5-1
		Camera system and sensors A, C, F and H of the model payload test cases	Figure 5-3

The current EDM design does not foresee to offer mounting locations that would bring sensors into direct contact with the martian ground.

In terms of accommodation of proposed units for the SPL, the following guidelines apply:

- Units of dimensions similar to (or smaller than) those of the model payload units may be proposed for one or more of the mounting locations illustrated here, and it may be assumed that the EDM will be able to satisfy the sensor's unit envelope requirement.
- Sensor units exceeding the model payload sensor envelope may be proposed for any of these locations but it cannot be assumed that the EDM will be able to satisfy the sensor's unit envelope requirement. The feasibility of their accommodation will, however, be evaluated against the current EDM design.

In particular, system units and harness restrict the available footprints for sensors, while equipment in the EDM Back Shell restricts the available height.

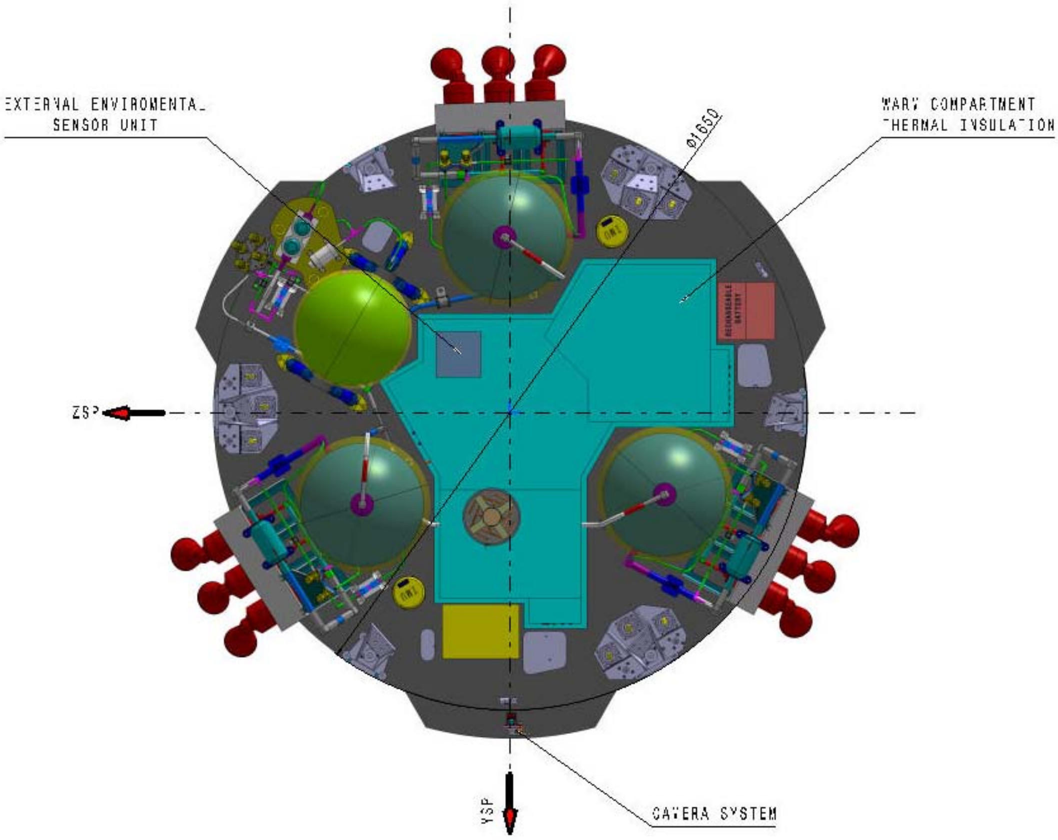

Figure 5-1. EDM Surface Platform, showing warm compartment and accommodation of baseline sensors of the model payload.

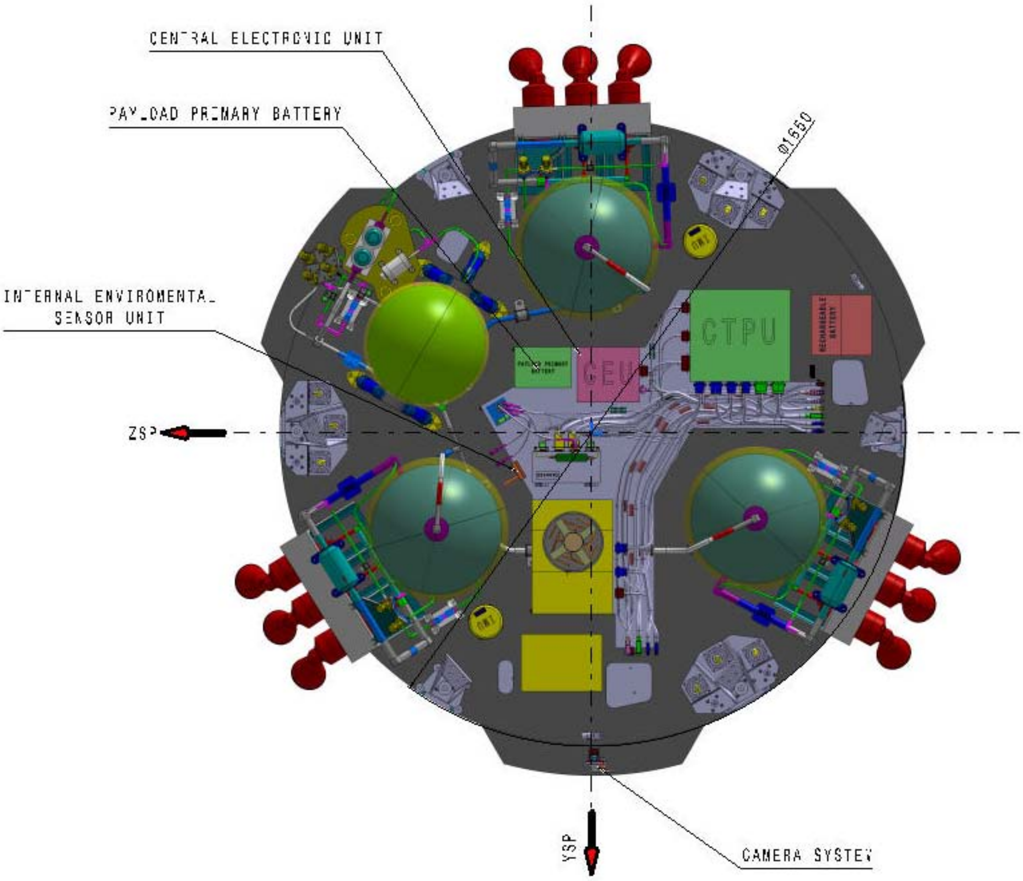

Figure 5-2. EDM Surface Platform with accommodation of baseline sensors of the model payload, without showing the warm enclosure. The SPL CEU, battery and internal environmental sensors unit are revealed.

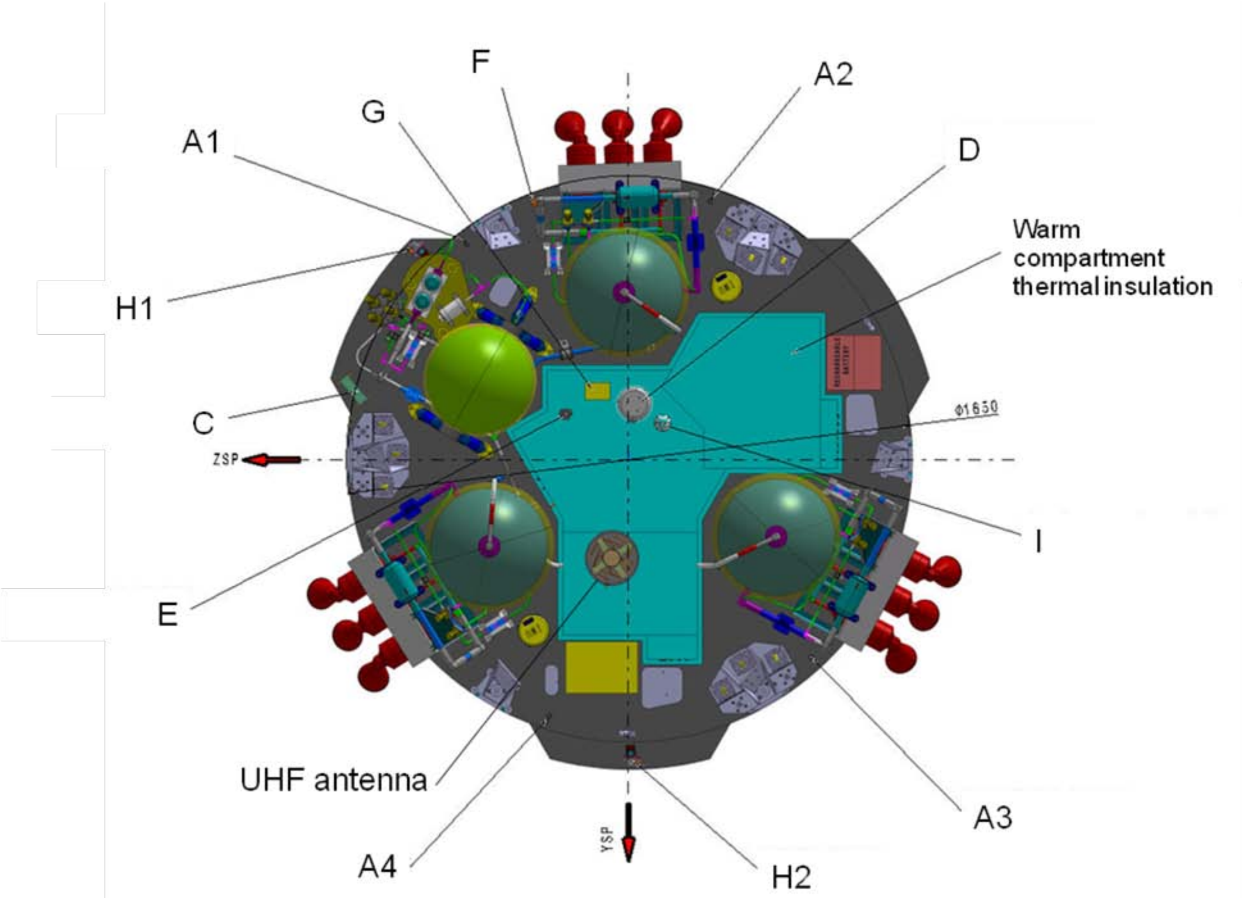

Figure 5-3. EDM Surface Platform with accommodation test cases for SPL sensors, with warm enclosure.

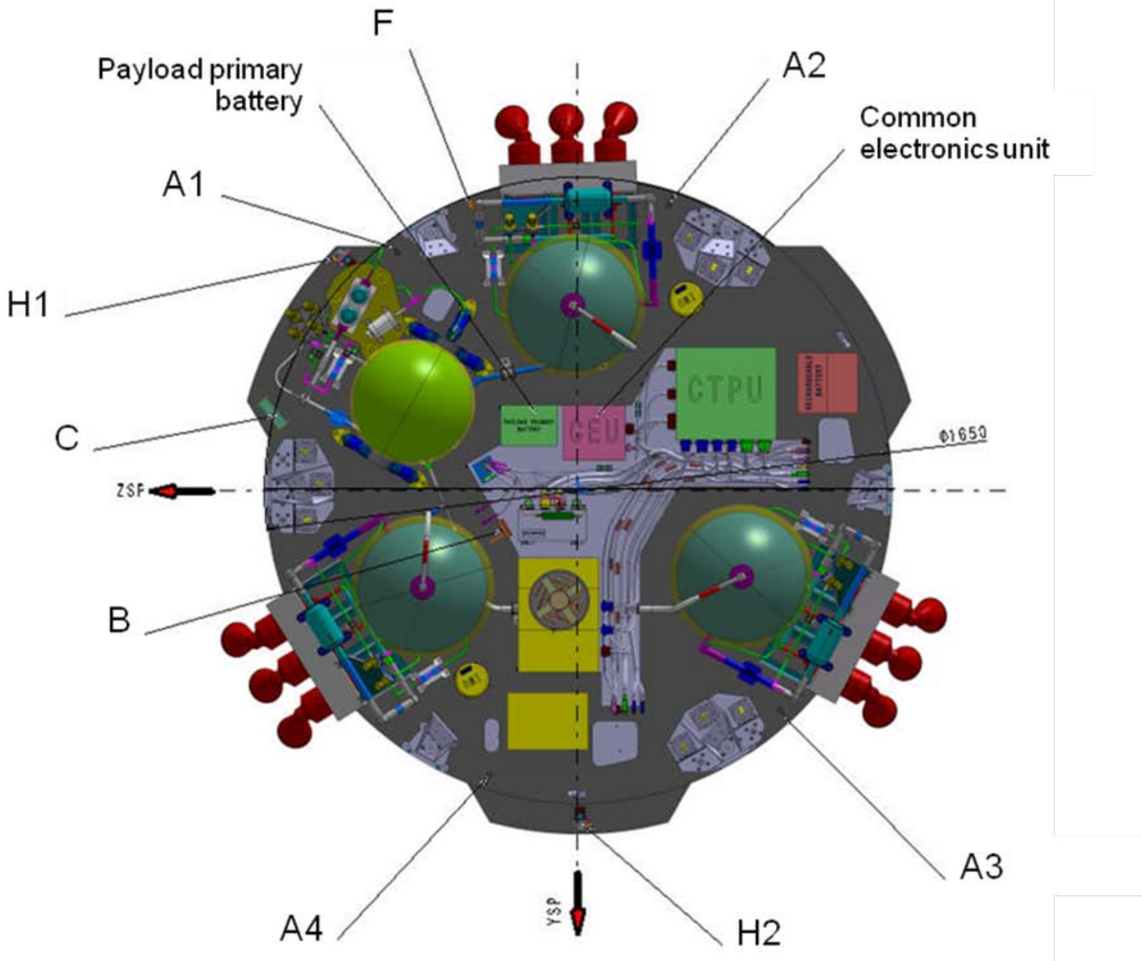

Figure 5-4. EDM Surface Platform with accommodation test cases for SPL sensors, without warm enclosure.

Figure 5-5 and Figure 5-6 show in close-up how external sensor units may be accommodated on top of the warm compartment, mounted to the CEU and battery via stand-offs penetrating through the thermal insulation.

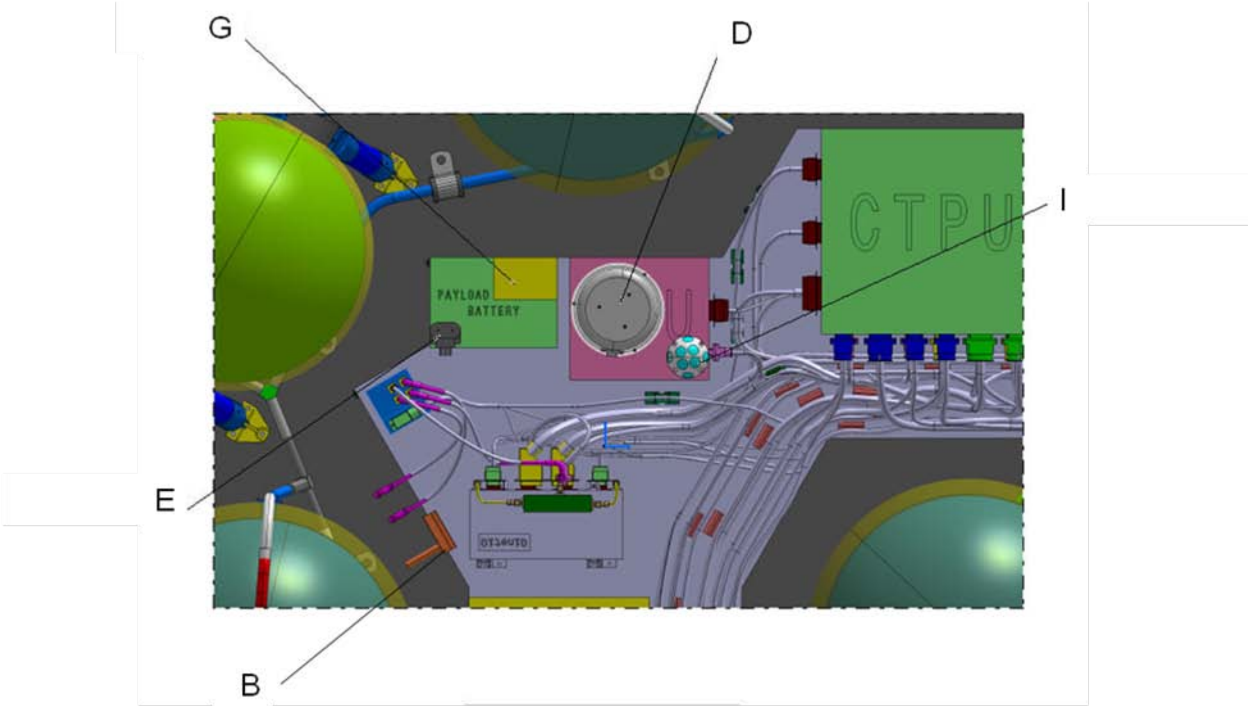

Figure 5-5. Close-up of arrangement of several SPL accommodation test case sensors, with warm enclosure invisible to illustrate mounting of sensor units on stand-offs protruding through the warm enclosure insulation.

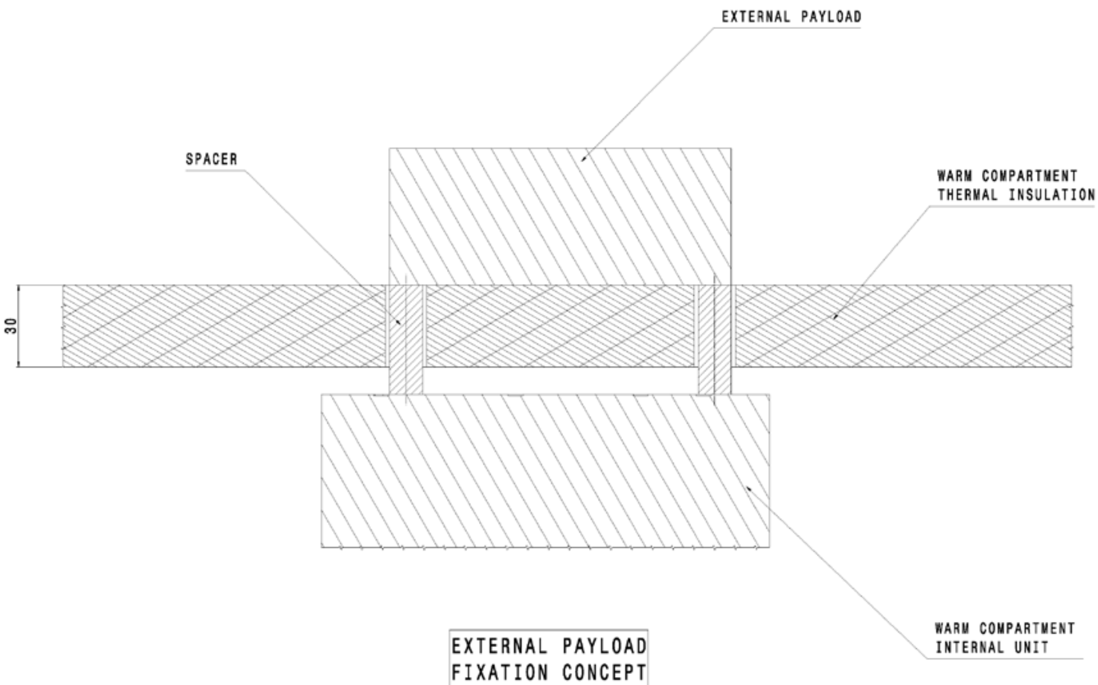

Figure 5-6. Scheme for mounting of external SPL sensor units on stand-offs mounted to units of the internal, warm compartment.

Figure 5-7 shows how external locations on top of the warm compartment above the SPL units may accommodate sensor units needing wide-angle fields of view. The tallest items in proximity to this area are the propellant and pressurant tanks of the RCS, and the UHF antenna.

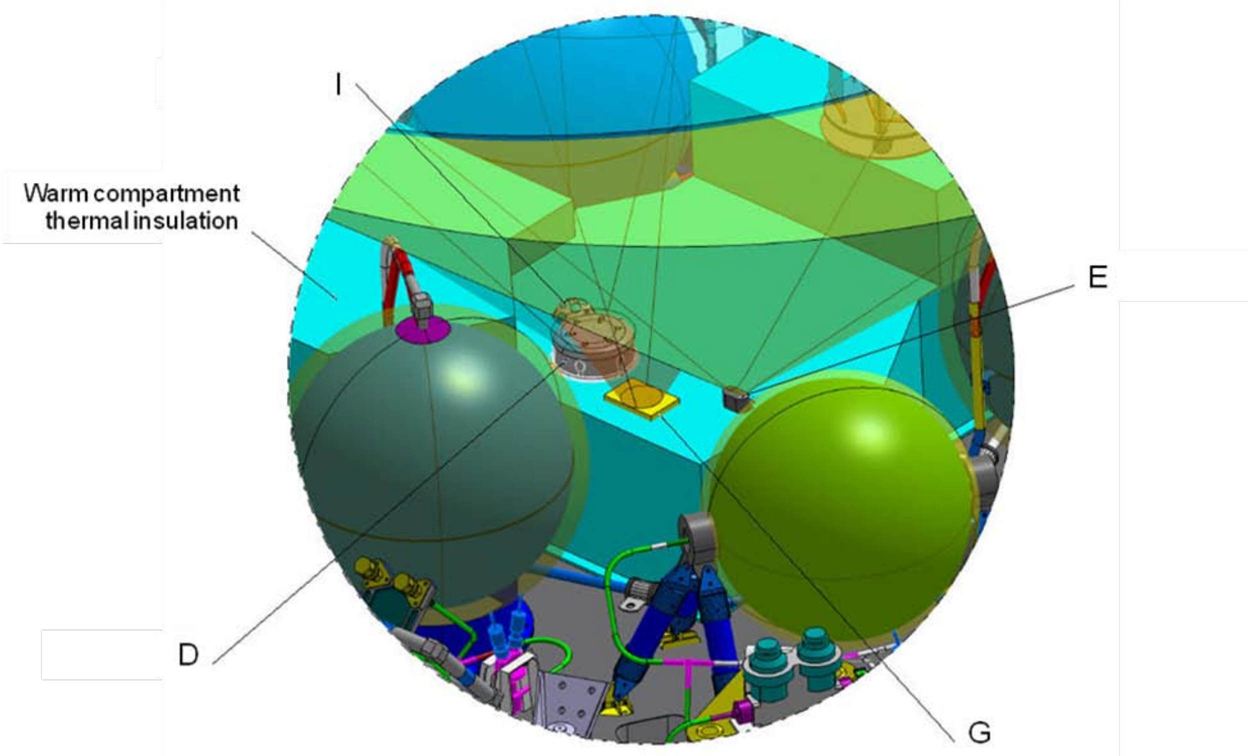

Figure 5-7. Close-up of several SPL accommodation test case sensors, mounted above the warm enclosure to allow contact with external environment and unobstructed upward-pointing fields of view.

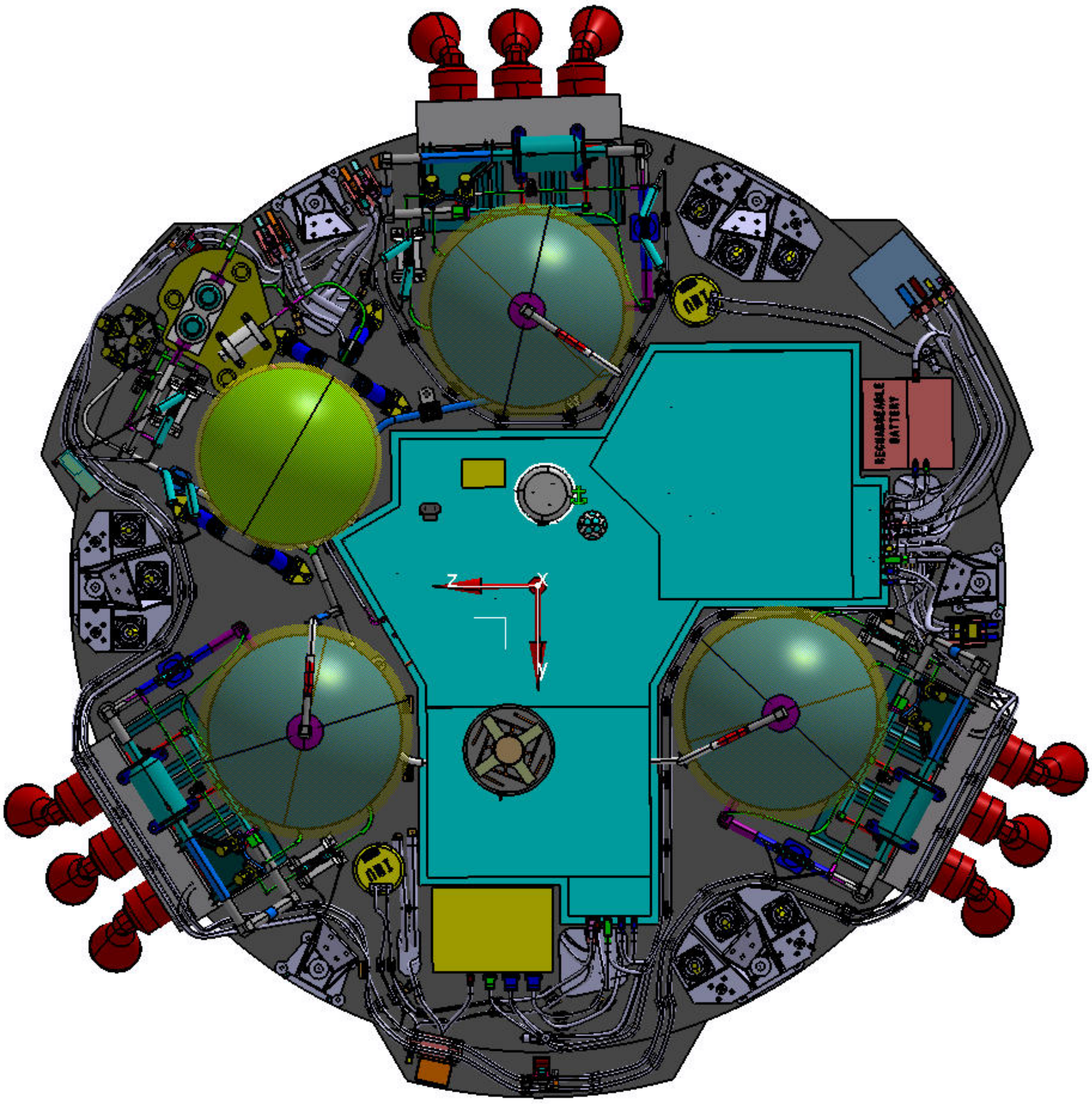

Figure 5-8. View of EDM Surface Platform with provisional routing of harness, RCS piping, etc.

5.4 Mechanical Design and Interface Requirements

The mechanical environment and test requirements for the EDM can be found in [IR 18].

The SPL shall not require deployment by the system.

Following the touchdown on Mars Surface, the ESP will come to rest with the following conditions:

- attitude <40° with respect to local horizontal (combination of worst cases of terrain slope and rock size)
- azimuth random between 0 and 360° (azimuth is not controlled by the ESP during the final approach)

- with the centre of the EDM baseplate lying between 0.25 m and 0.60 m above the nominal martian surface.

It should be noted that interaction of the RCS plumes with the martian surface material and the landing event itself are likely to loft dust, some of which is expected to settle on the EDM surface platform, including sensor units.

5.4.1 Interconnecting Harness Definition

The design, definition and procurement of the SPL instrument harness shall be under SPL PI responsibility as well the verification/assessment of its compliance and compatibility with respect to the applicable support specification. The SPL Harness can be split as follows:

- SPL System Harness, located in the warm compartment area, and connecting the CEU to the CTPU for power and CAN Bus data links.
- SPL Instrument Harness, interconnecting the sensors located either internally to the Central Bay or externally to the Central Bay and passing through the to SPL interface connector bracket (named CB CB04)

The preliminary interconnecting diagram on the SPL shall be implemented as shown in Figure 5-9. As a preliminary indication, the length of the harness segment between the CEU and sensors shall not exceed 2 m.

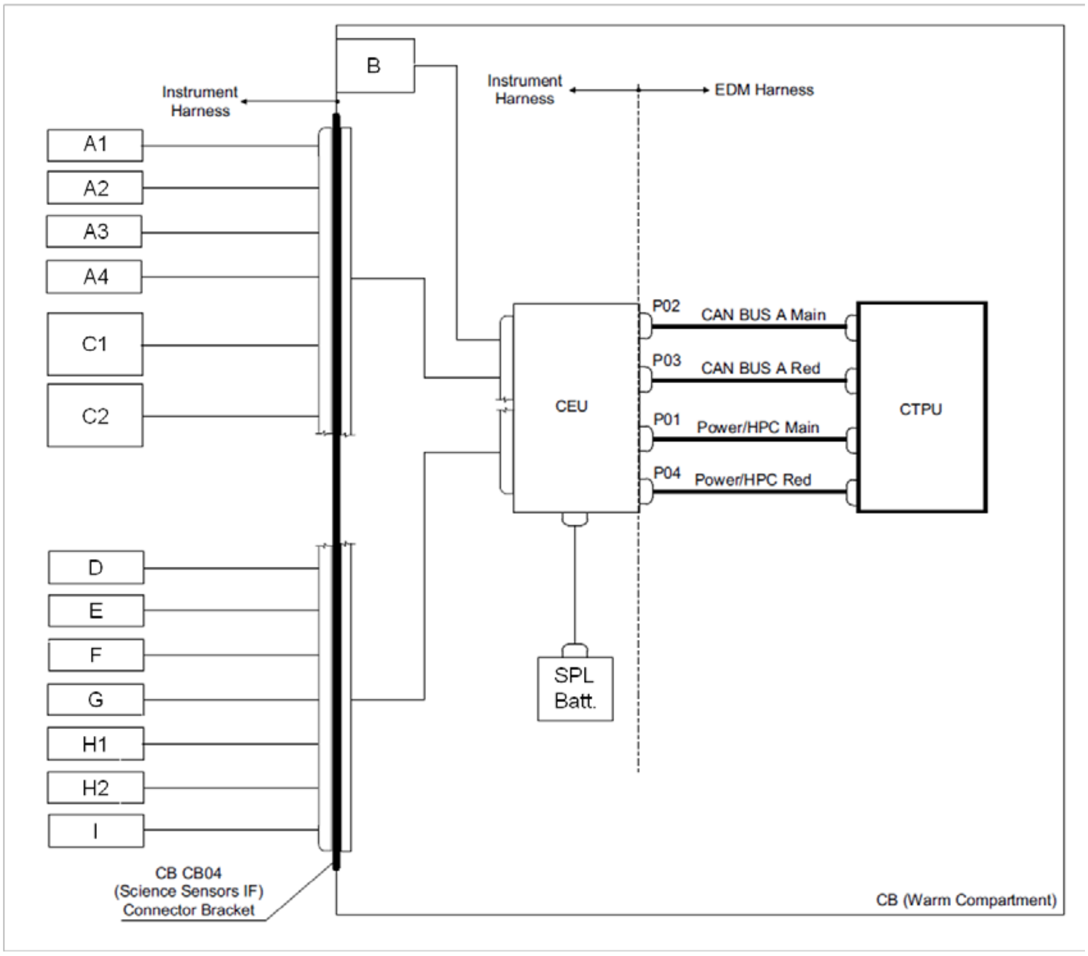

Figure 5-9. Preliminary interconnection scheme for the Surface Payload.

The SPL PI shall provide inputs via the SPL E-ICD to allow the EDM Prime to define the routing of the SPL harness. The EDM Prime will support the SPL PI in the definition of the SPL harness accommodation. To facilitate this, the SPL PI shall provide the harness physical data, connectivity list, routing and specific mounting/fixation constraints, bending radius constraints and all the other data deemed necessary.

5.5 Thermal Design and Interface Requirements

The thermal environment to be encountered by the EDM is described in [IR 16].

The internal thermal environment of the SPL component within the ESP warm compartment shall be the same as for the EDM equipment to acquire the SPL data and transmit them to the OM during the foreseen pass. The thermal energy to maintain the SPL components warm shall be provided by the SPL battery and any associated heaters shall be procured by the SPL PI and controlled by the SPL CEU.

The thermal energy required to maintain the thermal control of the SPL units will be defined by the SPL PI on the basis of the SPL thermal design and operating constraints with ESP boundary conditions specified by the Prime Contractor. For information, current analysis shows that the energy needed to maintain the SPL CEU at -40°C and the battery at -30°C for the first 4 sols after landing is 125 Wh, assuming that the CEU is permanently OFF (i.e. worst case with no internal dissipation). It shall be noted that this energy corresponds to a landing site located in Meridiani Planum region.

The EDM will not provide thermal control to the external SPL instrumention/sensors. They shall be directly exposed to the Martian environment (as described in [IR 3]), with the SPL fully autonomous for their thermal control and any associated heaters.

The thermal design of the SPL shall be responsibility of the SPL PI, taking into account the environmental conditions envelope that shall be provided by the EDM Prime (see [IR 16] and [IR 21]), for both internal and external components of the payload.

The SPL team shall design their SPL thermal control using thermal mathematical models made according to [IR 17]. The models shall be delivered to EDM responsible for integration in the EDM overall thermal mathematical models and final verification of the EDM design.

5.6 Electrical Design and Interface Requirements

The total power and energy demands of the SPL shall include needs for thermal control during the surface phase, and maturity margins, which shall be applied as follows:

- 5% of the current best estimate for recurrent units
- 10% of the current best estimate for modified units
- 20% of the current best estimate for new units

During the cruise phase when SPL is ON, the power to the SPL will be provided by the CTPU through a LCL via a redundant unregulated voltage line 22V-36V @1A. After touchdown on Mars and before entering hibernation, the CTPU will power the SPL CEU and command via CAN Bus the SPL to rely on its primary battery. The disconnection of the external power supply lines to the SPL will then be realized by the CTPU once switch-over is confirmed by CEU via CAN Bus and in any case a predefined time-out period (a few seconds) is expired. From that moment on, the SPL survival and operation shall rely on its own battery until the end of the SPL surface mission.

5.7 Electromagnetic Compatibility Requirements

See [IR 19] for EMC requirements.

5.8 Data Handling Design and Interface Requirements

The only command & data link with the CTPU shall be a redundant (bus A and Bus B but only one controller) CAN Bus data link (see [IR 22] and [IR 23] for details). The data exchange shall be only performed via the CAN Bus. Using the CAN Bus both the command for the Health check and the timeline for the Mars surface operations can be transferred form the CTPU to the SPL CEU. The same CAN Bus shall be used for downloading the science data stored in the SPL CEU to the CTPU for its subsequent transmission to TGO via the UHF link.

The maximum SPL data volume that can be acquired by the CTPU and further transmitted to the TGO is 50 Mbit, for the 8-sol mission.

The CTPU will be in charge of downloading all SPL data. SPL data processing and compression will not be performed by CTPU; therefore these functions, if needed, shall be implemented in the SPL CEU because the CTPU will only acquire and packetize the transferred data for subsequent transmission to the TGO at the telecommunication passages.

The CEU shall execute the experiment cycle(s) driven by a timeline that is pre-stored on the non-volatile memory of the SPL CEU but that can be changed in cruise check-out session through command send by Earth directed to the Orbiter Module, forwarded to the EDM CTPU via the 1553 bus and finally dispatched to the SPL CEU through the CAN Bus.

The thermal control of the SPL on the Mars surface shall be in charge of the SPL itself, with the power provided by its own battery.
On Mars surface, the data exchange between the SPL and the CTPU will be as follows:

- The SPL shall be fully autonomous in performing its timeline
- A few (TBD) minutes before the communication windows with the TGO, the CTPU will exit from hibernation based on its own timers and will start a data download session with the SPL to recover all the stored (even compressed) data inside the SPL CEU.
- After the communication window is terminated, the CTPU link with the SPL CEU will be interrupted because the CTPU enters again in hibernation.

5.9 Computational Resources

The SPL CEU shall be capable of receiving an updated timeline prior to EDM separation from the Orbiter Module.

Data processing and compression (if needed) shall be performed by the SPL CEU. The CTPU will acquire the SPL data from the CEU and will packetize it for the return link via the TGO to ground.

5.10 Planetary Protection and Contamination Requirements

5.10.1 Bioburden Control

The 2016 ExoMars EDM mission is assigned COSPAR planetary protection category IVa [IR 4]. See also [IR 26] for more information.

The SPL shall be compatible with alcohol cleaning (IPA or ethanol) and with damp swab assays as per assay procedure described in [IR 4]. The SPL shall be assembled and maintained in ISO level 8 cleanrooms in operation, or better, with appropriate controls and procedures.

The bioburden on the SPL at delivery shall be ≤ 1000 bacterial spores on exposed internal and external surfaces. The average bioburden of the SPL shall be ≤ 300 bacterial spores/m² on exposed internal and external surfaces.

Compatibility of the SPL hardware with Dry Heat Microbial Reduction (DHMR) as described in [IR 4] shall be assessed.

The SPL PI shall provide an organic materials inventory of bulk constituents present in quantities of 1 kg or more on the SPL.

5.10.2 Applicable Mission-Level Cleanliness and Contamination Requirements

An SPL Cleanliness and Contamination Control Plan shall be provided by the SPL PI to give evidence of procedures and methods implemented to fulfil the Cleanliness and Contamination Control Requirements [IR 20] during the life of the programme, from design to end-of-life.

The Cleanliness and Contamination Control Plan shall:

- identify the contamination sensitive items and describe the effects of contaminants on their performance
- contain the molecular and particulate cleanliness requirements for the contamination sensitive items as well as for the non-sensitive surfaces that are allocated to the major project phases, e.g. at item delivery, end of MAIT, at launch, BoM, EoM
- define the requirements that have design impacts such as Parts, Materials and Processes (PMP) selection criteria, venting, purging and thrusters' locations (where applicable)
- define the contamination control flow
- describe selected methods, procedures and instruments to control contamination levels; in particular the contamination monitoring methods and tools, the inspection procedures and tools, the verification of tools or hardware and the dedicated cautions for critical AIV operations
- define the cleaning and decontamination methods, procedures and tools
- describe the provisions for packaging, storage and transportation of critical items
- define environments and facilities
- contain the contamination predictions budgets
- provide mitigation and corrective actions, i.e. define corrective actions in terms of design, shielding, purging, bakeout in case the predictions are outside acceptance limits
- define responsibilities and authorities assigned for the implementation of the cleanliness and contamination control tasks
- define the define the forms that are used to document the cleanliness and contamination control activities

5.10.2.1 Cleanliness Requirements

A cleanliness level of **300A** (TBC) is required for SPL external general surfaces (i.e. defined as non-sensitive) at delivery for integration onto the EDM SP.

For sensitive surfaces, the molecular and particulate requirements shall be defined in a way that during the whole life-cycle the payload performances are met.

5.10.2.2 Cleanliness Certificates

For all items for which cleanliness levels at delivery are defined, a cleanliness certificate shall be part of EIDP.

5.10.2.3 Material Selection

The selected materials shall produce low particulate and molecular contaminants. The baseline for material screening is that materials shall have less than 1% TML and 0.1% CVCM when tested per ECSS-Q-ST-70-02C [IR 8].

Modelling of the outgassing phenomenon shall be based on dynamic test results only and not on screening results obtained from ECSS-Q-ST-70-02C [IR 8] (see 5.10.2.4).

Bake-out shall be performed on materials that have an RML or CVCM out of requirement.

5.10.2.4 Outgassing Requirements

The SPL shall be designed to withstand an outgassing rate until EoM in the order of 10^{-12} $g/cm^2/s$ (TBC) and have to guarantee an outgassing rate of their H/W until EoM in the order of 10^{-14} $g/cm^2/s$ (TBC).

Bake-out shall be performed on materials that are identified as critical (i.e. major contributor), in case outgassing analyses show that the maximum acceptable limits on sensitive surfaces are exceeded.

The SPL shall be designed to withstand a total contamination deposition due to propulsion systems (hydrazine RCS thrusters) in the order of 10^{-3} g/cm^2 (TBC).

5.10.2.5 Cleanability

Any SPL item shall be designed for cleanability and compatible with at least the following cleaning methods:

- hand wiping using wipes low in extractable non-volatile residues and particulate and high purity solvents
- vacuum cleaning

In case of incompatibility, the SPL team shall identify alternative methods and cleaning procedures.

5.11 Surface Payload Lifetime

The SPL shall have a ground lifetime, including storage, for system AIV and testing from its acceptance until launch of at least 60 months.

The SPL shall have a flight life (from launch to landing) of at least 12 months.

The SPL shall be designed to support a minimum lifetime on the martian surface of 4 sols, based on the nominal landing site scenario. (Even in the case that SPL measurements are concluded in less than 4 sols, the lifetime still needs to be at least 4 sols (for the nominal equatorial landing site) in order to transfer the data to the CTPU.)

6 SURFACE PAYLOAD MANAGEMENT

The ExoMars 2016 mission is a joint mission between ESA and NASA.

The management of the ExoMars 2016 mission is under the responsibility of the ESA ExoMars Project Manager located at ESTEC, Noordwijk, the Netherlands; ESA will design, manufacture, integrate, test, calibrate, and deliver for launch, the ExoMars 2016 spacecraft composite. Some of the ESA responsibilities will be discharged to a European industrial team led by a Prime Contractor, Thales Alenia Space Italy (TAS-I).

It is intended that there will be a single PI, who shall be the SPL Provider. The selected SPL PI shall comply with the requirements and processes detailed in this E-PIP.

6.1 Organisation and Responsibilities

6.1.1 Project Responsibilities

The management of the ExoMars programme is under the responsibility of the ESA Project Manager located at ESTEC, Noordwijk, The Netherlands.

The project implementation office at ESTEC will appoint a Payload Manager. It is the responsibility of Project Payload Management to oversee and coordinate the individual instrument development programmes to ensure compliance to the requirements, policies, and resources of the project.

The ESA Payload Manager will monitor the programmatic and technical progress of the design, development, and verification of the SPL. The Payload Manager shall be the primary programmatic and technical interface between the SPL PI and the Project.

The Payload Manager will be responsible, at a minimum, for overseeing the following aspects of the development of the SPL. The Payload Manager is:

a. responsible for, in cooperation with the PS, the programme interface with the SPL PI, including management, technical and schedule aspects;
b. responsible for ensuring, in cooperation with the ExoMars EDM Manager that the SPL is compatible with the EDM design, that the interfaces are properly defined and controlled, and that sufficient resources are allocated;
c. responsible for ensuring that the SPL performance, model philosophy, development and verification planning are compatible with the Project need and the overall mission schedule
d. the ESA document owner for the SPL E-IRD and E-ICD.

Payload system-level issues not specifically covered in the preceding list of responsibilities will be managed by the appropriate members of the ExoMars EDM project team in a coordinated fashion.

The ESA Project Team is not responsible for supporting the development of tools/services in the SPL team's institutes for conducting scientific analysis of their data.

6.1.2 Project Scientist

ESA nominates the ExoMars Project Scientist (PS). The PS is located at ESTEC, and works in close cooperation with the ExoMars Project Manager (PM) and the ExoMars Management team (Figure 6-1). The PS is responsible for the mission's overall scientific coordination, and is the Agency's interface with the ExoMars science community. The detailed scientific management of the ExoMars programme is described in [IR 2].

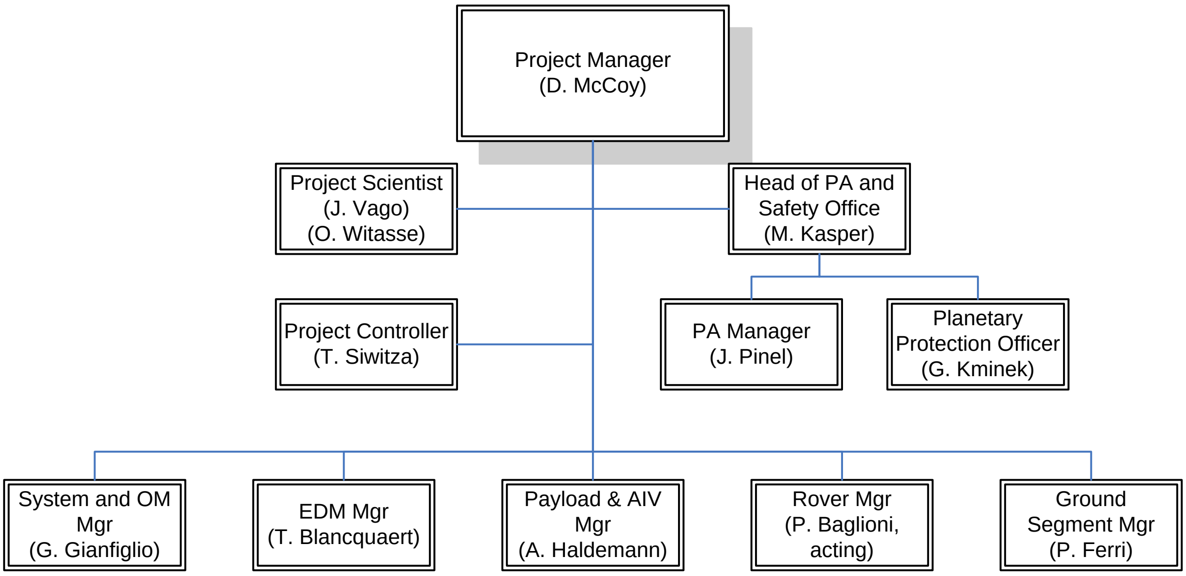

Figure 6-1. ESA Project Organisation for the ExoMars Programme.

The PS will organise all Announcements of Opportunity for instruments and investigations to be performed in the ExoMars mission, independent scientific peer reviews, and science consultation meetings with investigators. The ExoMars Project Scientist will chair the ExoMars Science Working Group (ESWT), and coordinate its activities (the role of the ESWT is described in the next section).

During all phases of the mission—from the beginning of the implementation phase until the end of the exploitation phase—the PS will be responsible for all scientific issues within the Project. The PS will advise the PM on technical matters affecting the mission's scientific performance. In particular, the PS will participate to the critical analysis of hardware design, performance, and operations with the objective to verify that the mission's scientific objectives can be fulfilled. The PS will interface with the Planetary Protection Officer to help implement a protocol that maximises scientific return whilst conforming to planetary protection directives.

The PS will coordinate the scientific community's participation and support to milestone reviews during the project development phase. The PS will organise meetings with the scientific community to assist on project development issues that may impact the mission's science return; for example, in case a reduction of instrument mass is necessary. The PS, in cooperation with the ESWT, may also establish ad hoc working groups to address specific mission aspects requiring consultation with the scientific community; for example, to propose a list of candidate landing sites and to participate in the down selection process.

The PS will coordinate the ExoMars science operations with the operations managers, under the PM responsibility. The PS will organise and be part of the science team supporting the (almost) real-time data evaluation and analysis capability necessary to effectively plan and conduct Rover surface operations.

The PS will ensure an orderly, prompt, and fair implementation of the mission's data exploitation phase, will encourage the creation of multidisciplinary science teams to thoroughly analyse instrument results, with a view to maximising the mission's science return and to promptly publish its results.

The PS will support the definition of agreements that may be important for the mission's scientific outcome; for example data-sharing agreements, inter-agency instrument cooperation agreements, etc.

The PS will regularly inform the international scientific community of ExoMars scientific, programmatic, and mission-development progress via Newsletters, web sites, press releases, brochures, etc. The PS will also contribute to ESA's reporting, to PB-HME and Advisory Bodies, on scientific aspects of ExoMars.

6.1.3 Principal Investigator Responsibilities

A single Principal Investigator (PI) shall be the Agency's point of contact for the SPL and be responsible for providing the entire SPL, including all sensors included in the selected SPL. The SPL PI shall represent all the SPL's supporting institutions.

The PI shall bear the primary responsibility for ensuring that the SPL meets the objectives of the selected science investigations and is implemented within the programmatic and technical resource allocations determined at its confirmation. The PI retains ultimate responsibility for the investigation but may choose personnel to have lead responsibility for specific activities.

The SPL PI will report regularly to the Project, and will demonstrate during formal reviews compliance with the SPL scientific objectives, the applicable spacecraft system constraints, the spacecraft interfaces, and the programme schedule, as defined initially in the Experiment Interface Requirements Document (E-IRD) and then later in the mutually agreed SPL Experiment Interface Control Document (E-ICD). The final acceptance of instrument hardware or software for integration to the spacecraft shall be under ESA responsibility. Compliance to these items in a timely and satisfactory manner is vital for confirmation for flight.

The SPL PI shall:

1. Be the investigation's primary point of contact with other Project elements regarding investigation requirements, schedules, and funds. Represent the team in relevant Project reviews.

2. Participate in science team meetings and associated working groups, providing inputs on topics including but not limited to, archiving, science operations, instrument requirements development, and other topics. These inputs may require participation and deliverables from other members of the SPL team, to be coordinated by the PI.
3. Generate and maintain other documentation as required.
4. Ensure that the design and fabrication of the SPL and its development and testing are appropriate to the objectives of the investigation and meet the mission environmental and interface constraints.
5. Establish and manage margins to ensure successful hardware integration and implementation of the SPL.
6. Conduct SPL reviews as defined in the following sections.
7. Be responsible for SPL quality assurance, reliability, and selection of parts and materials.
8. Ensure that the planetary protection requirements are understood and implemented correctly.
9. Ensure that the SPL development meets the project approved schedules and, if appropriate, cost plans. De-scope the investigation as needed to stay within allocated resources, with approval from the PI, PS and other management personnel.
10. Establish requirements, interface control documents (ICDs) and other documents as required herein and after selection, schedules through negotiations with the project, and establish, as appropriate, transfer of funds through negotiation with the funding authority.
11. Ensure that the SPL is properly qualified and calibrated at instrument level prior to shipment of the Flight Model.
12. Demonstrate that the design and performance of the SPL meets the science requirements.
13. Support SPL integration, system test procedure development and maintenance, instrument and ground support equipment (GSE) integration, and EDM system testing at the EDM contractor and launch site. Some support in situ is required for all of these venues; however remote test support may be acceptable once integration has been established.
14. Support the preparation and execution of mission operations, including participation in end-to-end system tests.
15. The PI is also responsible for data analysis, and overall conduct of the investigation.
16. Prepare, certify, and release data products to the Planetary Science Archive (PSA) and other archives according to the still-to-be-finalized ExoMars EDM data management and archival requirements.
17. Ensure that the reduction, analysis, reporting, and archival of the results of the investigation meet with the highest scientific standards and completeness, consistent with budgetary and other recognized constraints.
18. Ensure development and readiness of tools and services that are required for conducting scientific analysis of their SPL's data.
19. Ensure the timely provision to the ExoMars EDM project of each SPL deliverable.

6.2 Communications with ESA, Industry and Partners

Communications are defined as the exchange of information, which affect technical standards, deliveries, time schedule, costs, or any other payload-relevant aspect of the project.

Communications among the various agencies and scientists will be required to follow the processes described in relevant documentation being prepared by ESA.

6.3 Project and Surface Payload Schedules

The overall schedule is shown in Figure 6-2.

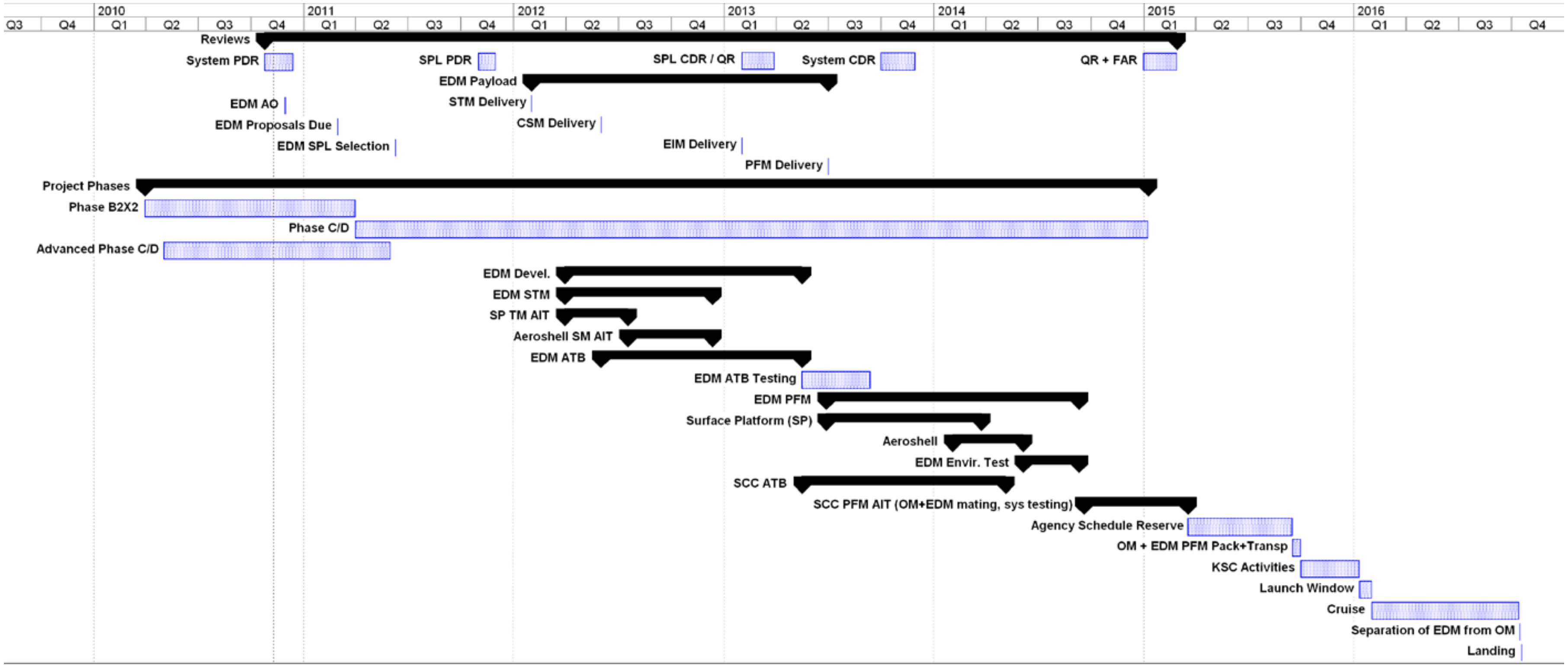

Figure 6-2. Overall schedule for the ExoMars EDM

6.4 Reviews

The SPL PI will be expected to support Project design and management reviews for the Project, EDM, and Operations systems, as well as occasional informal Project reviews as needed.

The ESA Payload Office will establish the review board for the SPL that will conduct formal "milestone" reviews of SPL programmatic and technical progress throughout development. The SPL review board shall advise the Project as to the feasibility and adequacy of the SPL team's plans and progress. Additionally, the Payload Office will meet with the SPL team on a more frequent basis as needed to understand technical, cost, and schedule progress.

The SPL PI should plan to conduct technical peer reviews prior to milestone reviews to validate approach and design aspects in detail. These peer reviews will be summarized at the milestone reviews.

Table 5 summarizes the reviews for the investigation that the SPL team is expected to support. Details on some of the more significant reviews are provided in the following subsections.

Table 5. ExoMars 2016 EDM SPL Reviews

Review Type		**Frequency**
SPL Level Reviews and Meetings:		
	Preliminary Design Review	1
	Critical Design Review / Qualification Review	1
	Instrument Integration Readiness Review (I2R2)	3
	Environmental Test Readiness Review	1
	Instrument Delivery Review	1
	ESA Quarterly Progress Meeting	Quarterly
	SPL Interface Meetings	As needed
	Peer Reviews (prior to formal reviews)	As needed
Project Reviews (for which SPL support is anticipated):		
	Preliminary Design Review	1
	Critical Design Review	1
	Qualification Review	1
	Ground Segment Readiness Review	1
	Flight Acceptance Review	1
	Flight Readiness and Launch Readiness Review	1
	In-Orbit Commissioning Review	1

6.4.1 SPL Interface Meetings (SPLIMs)

To foster close interactions between the SPL team and EDM system technical personnel, a series of meetings will be scheduled to work out interface issues and document the design in the ICD. The ExoMars EDM Project will host the initial “Kick-Off” meeting at ESTEC. Some SPLIMs that follow can become “virtual” meetings, with the SPL PI and their team supporting by a combination of conference calls, video conferences, and e-mails.

These are not formal reviews, but rather technical (only) interface meetings between the SPL engineers, the EDM engineers, and ESA project staff. The initial focus will be on hardware and software interface issues, but will transition into resource sub-allocation discussions and operational strategies as the launch date approaches.

6.4.2 SPL Preliminary Design Review (PDR)

The SPL PI will hold the PDR at the hardware developer’s location to complete the preliminary design review process which shall take place by December 2011. This review shall also function as an interface review, allowing the Project insight into the progress being made in the SPL design and comparison to the planned performance and estimated margins. An SPL E-ICD shall be prepared, in signature-ready form, as input for the review. The review will evaluate description of interfaces and allocations of EDM resources. The E-ICDs go under formal change control less than 30 days after the review, supporting a formal freeze of interfaces with the EDM.

Also for the PDR, a Design Report (DR), a Design and Development Plan (DDP), a Planetary Protection Plan and a Product Assurance (PA) Plan will need, among other documents, to be delivered and reviewed.

The SPL PI has the option of completing the PDR at the time of the interface review.

6.4.3 SPL Critical Design Review / Qualification Review (CDR/QR)

The last design review prior to initiating flight hardware fabrication is the SPL Critical Design Review (CDR). The SPL CDR precedes the Project CDR at the completion of the instrument detailed design. Topics include status of hardware design, fabrication, test, and calibration, software design and test plans, assembly subcontracts and parts status, plans for integration, description of support equipment, finalization of interfaces, command and telemetry requirements, implementation of planetary protection requirements and discussion of environmental and system tests. The SPL CDR includes reports from technical Peer Reviews held in preparation for this review. The findings of the SPL CDR will be reported at the Project CDR, with the PI in a supporting role. The SPL flight design must be fully qualified prior to initiating of the build of the Flight Model, and, as such, the agenda of the SPL CDR will be expanded to cover the objectives of a Qualification Review. The purpose of the SPL QR is to confirm the completeness of all qualification testing of the SPL design. Irrespective of the model philosophy chosen, (Qualification+Flight Acceptance or Engineering Model+Protoflight approach) the SPL CDR/QR serves as the gateway to the initiation of the flight model build.

6.4.4 SPL Instrument Delivery Review (IDR)

The SPL PI will conduct an Instrument Delivery Review (IDR) for both hardware and software. This review is held just prior to delivery of the SPL to the EDM. Topics include results of verification of the SPL's compliance with its own functional requirements and the E-ICD, the results of environmental testing, verification of bioburden levels, and the completeness of the end item data package (EIDP). Closure and risk-rating of pre-delivery problem/failure reports will also be reviewed. This review will confirm that the SPL flight model meets all requirements and performance capabilities. Successful completion of this review is a prerequisite for authorisation to ship the SPL to the EDM integration site.

6.4.5 Use of Teleconferencing and Video Conferencing

All PIs will be required to support a Project standard for video and teleconferencing. Wherever possible, the entire Project will utilize collaborative online meeting, screen sharing, teleconferencing and conference facilities to minimize travel expenses for routine meetings.

6.5 Configuration Management

As defined in the ECSS P-001B Glossary of Terms,

- **"Configuration Management** is the "*activity for establishing and maintaining consistent records of the performance parameters of a product and its functional and physical attributes compared to product design and operational requirements*"
- the **Configuration Baseline** is the "*approved status of requirements and design of a product at project key milestone that serves as reference for activities throughout the life cycle of the product*"
- a **Configuration Item** is the "*aggregation of hardware, software, processed materials, services or any of its discrete portions, that is designated for configuration management and treated as a single entity in the configuration management process*" and
- **Configuration Identification** is the "*coordinated activities to establish rules for configuration item selection, configuration baseline content definition, and product and document identifiers definition*."

By way of an example from the ExoMars Rover, [IR 6] defines the Configuration Control Requirements for the Rover's Pasteur Payload, based on the ExoMars Configuration Management Requirements [IR 7]. An equivalent document for the SPL will be issued.

The objectives of Configuration Management are to establish:

- a configuration identification baseline system which defines through approved specifications, interface documents and associated data the requirements for the instrument,
- a configuration control system which controls all the changes to the identified configuration of the instrument,
- a configuration accounting system which documents all changes to the baseline configurations, maintains an accurate record of configuration change incorporation, and ensures conformity between the end item As Built Configuration

(ABCL) and its appropriate design and qualification identification (CIDL including waivers).

6.6 Deliverable Items

This section gives the delivery dates for various deliverables (both hardware and software) expected from the SPL PI. Associated documentation shall accompany each delivery, as described in sub-section 6.6.3.

6.6.1 Hardware

6.6.1.1 Surface Payload Structural and Thermal Model

SPL STM: February 2012. See section A1.3.1 for a description of this model and associated requirements.

6.6.1.2 Surface Payload Electrical Interface Model

SPL EIM (for EDM ATB): February 2013. See section A1.3.3 for a description of this model and associated requirements.

6.6.1.3 Surface Payload Flight Model and Flight Spare

SPL FM (for EDM PFM): July 2013. See sections A1.3.4 and A1.3.5 for descriptions of these models and associated requirements.

6.6.1.4 Surface Payload Ground Support Equipment

See section A1.7 for a description and associated requirements.
SPL MGSE: for SPL models delivery and handling, as needed
SPL EGSE/SGSE. February 2013

6.6.2 Software

6.6.2.1 CEU Software Model (CSM)

See section A1.3.2 for a description and associated requirements.
CEU Software Model: June 2012.

6.6.3 Documentation and Models

ESA uses as a minimum the following documents (Table 6) to control the development of the SPL, its interface with the spacecraft, and the certification of the flight worthiness of the SPL and its software. The SPL team shall deliver copies of the following controlling documentation at various stages in the SPL life cycle, consistent with the standard practices of their institution and ESA.

The exact composition of this list may change after selection, but prior to confirmation.

Table 6. List of required documents

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
Management									
Inputs, if any, to E-IRD	The E-IRD is under ESA Configuration Control.	x			x				x
SPL-QR Quarterly Reports	A quarterly progress report containing the achievements of the previous quarter and the plans for the upcoming quarter(s) with a list of concerns, top risks, mass resources, and PP developments. Due 15 Jan, 15 April, 15 July, 15 Oct every year until EoM.								x
TRL Questionnaire	A development status checklist made up of questions about instrument development provided by ESA in spreadsheet format.	x			x				x
SPL-SCD Project Schedule	All along the project development cycle the SPL team must maintain and update a development schedule compatible with the Microsoft Project application to enable further schedule integration and analysis at project system level.	x			x		x		x

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
SPL-ICD Inputs to Experiment ICD (E-ICD)	The Experiment Interface Control Document is a binding document between the ExoMars project and its Prime, and the SPL team and LFA. It is under ESA Configuration Control. It defines all requirements and processes applicable to the SPL team for the development of their instrumentation. It also defines all agreed interfaces to the spacecraft to which the SPL shall be compliant.	x	x	x	x	x	x	x	x
SPL-CM Compliance Matrix	The design compliance matrix forms part of the E-ICD (as an Annex) and should confirm that the SPL design satisfies the project requirements and highlights the potential cases of non-compliance.	x			x		x	x	
Assembly Integration and Verification									
Inputs (Requirements) to System AIT Plan, if any, to be in the E-IRD	In E-IRD				x		x		x

Document Title (or description of data)	**Description**	**SPL PDR**	**SPL STM delivery**	**CSM Delivery**	**SPL QR/CDR**	**SPL EIM Delivery**	**SPL QR / FM Delivery**	**FAR**	**as required**
SPL-EVP Experiment Verification Plan	Consistent with Composite level. This document is the master plan for the SPL verification process; it shows how all requirements will be verified in a coherent manner. The Test plan shall be issued as a separate document.	x			x		x		
Input, if any, to EDM Verification Plan					x		x		x
SPL-VCD Verification Control Document	Using standard ExM (DOORS-compatible) format	x			x		x	x	
Inputs (Requirements) to Facilities and Transportation Plan, if any	In E-IRD, or E-ICD				x		x		x
Inputs (Requirements) to S/C Launch, LEOP and Check-out Phase Support Plan, if any	In E-IRD, or E-ICD				x		x	x	x
SPL-AIT Experiment AIT Plan	This document details the test requirements for specific test activities described in the EVP.	x			x				

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
Experiment Test Procedures	For Instrument Progress Meetings or Test Readiness Reviews. Description of test objectives with detailed protocol.								x
Experiment Test Reports	Results achieved relative to Test Procedure		x	x	x	x	x	x	x
Experiment Verification Reports (as needed)	Design reports, analyses etc. as needed.		x	x	x	x	x	x	x
Inputs (Requirements) to Ground Operations Plan, if any, to be in the E-ICD	Requirements in E-IRD Process for other inputs to be defined…	x			x		x	x	x
Inputs to Mission Database Verification Plan	Requirements in E-IRD Process for other inputs to be defined…	x			x		x	x	x
Instrument Model and GSE Hardware / Software Matrix	Lists the deliverable hardware and GSE and the corresponding on-board, GSE or test software and associated development, validation and simulation tools and mathematical models.	x			x		x	x	
Engineering									

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
SPL-DDP Experiment Design and Development Plan	The DDP describes the major design and development activities leading to the production of the SPL flight model; it's the plan of all work on the instrument.	x			x				
SPL-FCP Experiment Fracture Control Plan	This plan describes how to implement the applicable fracture control requirements. See [IR 10] (ECSS-E-ST-32C), Annex F.	x			x		x		
SPL-DR Experiment Design Report	The document provides the current design definition of the SPL; it evolves with the development of the SPL models and an updated version is released for each major review. For the PDR it shall be a report of breadboard design activities accomplished up to the PDR.	x			x		x		
Electrical schematics in Design Report	Sufficient electrical schematics to describe design.	x	x		x	x	x		x
Software architecture and detailed design	Described in separate document or relevant Design Report								x
Thermal Mathematical Model (TMM) Report	Textual description of TMM (assumptions, unit descriptions, material properties, etc.)								x

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
(Thermal) Geometrical Mathematical Model (GMM) Report	Textual description of GMM (assumptions, unit descriptions, dimensions, etc.)								x
SPL-THR Thermal Analysis Report	The scope of this document is to describe the thermal design of the SPL, the analysis and the results.	x			x		x		
(Structural) Finite Element Model (FEM) Report	Textual description of FEM (assumptions, unit descriptions, dimensions, etc.)								x
CATIA CAD Model Report	Textual description of CAD model (assumptions, unit descriptions, dimensions, etc.)								x
SPL-STR Structural Analysis Report	The purpose of this document is to analyse the structural integrity of the SPL with respect to its flight environments (launch, cruise, in-orbit, EDL, and surface).	x			x		x		
Declared Materials List (DML)	All parts, materials and processes intended for building the flight model are declared at PDR in order to identify critical items.	x	x		x	x	x		
Declared Components List (DCL)	ESA-provided template	x	x		x	x	x		

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
Declared Processes List (DPL)	ESA-provided template	x	x		x	x	x		
Critical Items List (CIL)	List of elements (hardware or software) or of elementary processes, which may particularly endanger the development or mission success of the SPL. The CIL is developed based on the Risk Analysis.	x	x		x	x	x		
Configuration Items Definition List (CIDL)	The CIDL lists, for each model or version of each CI/hardware item, all the documents, their applicable issues and revisions and associated changes (RFW, RFD, NCR), that define the configuration baseline.	x	x	x	x	x	x		
Failure Detection, Isolation and Safing Plan (FDIS)	The objectives of the draft FDIS Analysis is to verify that all failures anticipated by the FMECA Entries are properly covered by a FDIS action.	x			x		x		
As-Built Configuration List (ABCL)	Lists all the documents and their issues and revisions defining the as built configuration.		x	x		x	x		

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
Organic Materials Inventory	The organic materials inventory of bulk constituents has to include the following information: Identifier (e.g., FM 300 Epoxy Film adhesive), chemical composition, use (e.g., bonding of heaters for cruise stage shunt radiators), mass estimate, rating and reference for outgassing, process parameters (if processed), and supplier.	x			x		x		
Drawings									
SPL-DRW Overall Assembly and Geometrical Drawings Mechanical Interface Drawings Electrical I/F and Grounding Diagrams Thermal drawings	These drawings shall be deliverables and under configuration control. Unit circuit diagrams may need to be available on site for review.	x			x		x		
Flight Operations / Ground Segment									
SPL User Manual	Including Inputs to FOP (if any)				x		x		

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
Experiment Commissioning Plan					x		x		
Experiment Flight Operations Plan					x		x		
Experiment Inputs to Flight Procedures (nominal and contingency / recovery)					x		x		x
Instrument Database / TM / TC (IDB)					x		x		
Experiment Simulation Procedures					x		x		
Data Archive Plan	Plan for data product generation and archiving	x			x				
Ground Support Equipment									
Experiment GSE ICD	Part of E-ICD	x			x		x		x
Experiment GSE Equipment Test Plan	6 months before GSE Acceptance tests	x			x		x		x
Experiment GSE Equipment Test Procedure	4 weeks before GSE Acceptance Tests		x		x		x		x

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
Experiment GSE Equipment Test Report	4 weeks after GSE Acceptance Tests		x		x		x		x
Experiment GSE test and calibration reports	See GSE-10, calibration reports to be provided after GSE acceptance until launch depending upon use.		x	x	x	x	x	x	x
Experiment GSE User's Manual	Including GSE -12 Maintenance Instructions, -13 GSE Packing Transport and Handling Instructions,				x		x		
Experiment Software Simulator User Manual	Describes content and use of the CEU Software Model (CSM).			x	x		x		x
Experiment GSE Design and Development Plan	This provides the plan for how the design of the SPL ground support equipment will be implemented.	x			x				
Experiment GSE Design Description Report	This will provide detailed design information about the SPL ground support equipment required for all phases of the SPL integration and verification; first in stand alone configuration and later on at integrated spacecraft system level.	x			x				
Logistics Support									

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
Shipping List	List of items with sufficient description for identification and notes any appropriate certifications (e.g. safety).	D	x		x	x	x		
Payload									
Experiment Alignment Plan	Describes procedures for implementing any alignment requirements. This is part of AIT planning for the SPL.	x			x		x		
Planetary Protection and Contamination Control Implementation Plan	Where the PP plan within the E-ICD describes the overall approach to meet the PP requirements, the PP&CC IP provides details of the specific implementation of contamination control and planetary protection, both of which will evolve with the project, such that the PP&CC IP is expected to be a living document.	x			x		x		
Product Assurance									
Log Book	Traceable history of all events linked to the SPL, starting from qualification. See [IR 9] (ECSS-Q-ST-20C), sub-section 5.5.9.2.		x	x			x		

Document Title (or description of data)	Description	SPL PDR	SPL STM delivery	CSM Delivery	SPL QR/CDR	SPL EIM Delivery	SPL QR / FM Delivery	FAR	as required
PA Plan (PAP)	The Product Assurance (PA) Plan describes the quality assurance, safety and reliability, maintainability, EEE parts, Software and Materials and processes assurance activities undertaken by the SPL team from the design phase to the acceptance of the Equipment. It ensures that the unit is designed, manufactured, qualified and tested for acceptance in compliance with the relevant project requirements and the relevant ESA procedures as per the E-IRD.	x			x		x		
Failure Modes, Effects and Criticality Analysis (FMECA)	The Failure Modes Effects and Criticality Analysis will start at PDR at a high level instrument functional block; it will be extended to lower levels as the design / development progresses.	x			x		x		
Risk Analysis (RSK)	Itemisation and description of all technical risk items in a table that includes the probability and consequence evaluation, and the proposed mitigation strategy for each risk. Consequence is to be evaluated at the level of the SPL only.	x			x		x		

6.7 Receivables

The EDM Experiment Interface Requirements Document (E-IRD) will be delivered to the SPL PI after selection, and as the document is updated thereafter. Further document deliveries (e.g. technical descriptions of the EDM) to the SPL PI will be specified after selection.

6.8 Product Assurance and Safety

The SPL PI shall evaluate the ExoMars Product Assurance Requirements [IR 1] and ExoMars PA Requirements for subcontractors ([IR 24] and [IR 25]) and provide relevant compliance status to ESA.

The SPL PI shall establish, implement and maintain a Product Assurance programme.

The Product Assurance tasks shall be reflected in a Product Assurance Plan, to be issued by the SPL PI and subject to ESA review.

A1 SURFACE PAYLOAD ASSEMBLY, INTEGRATION AND VERIFICATION REQUIREMENTS

This appendix provides preliminary AIV requirements. For more detail, see [IR 5].

The EDM assembly, integration and test at system level involves the Surface Payload (SPL) as an assembly formed by sensors / instrumentation, the SPL CEU, SPL battery, intra-harness and associated mechanical and thermal fittings.

Consequently the SPL elements will be functionally integrated and verified together in stand alone configuration, checking all the internal Surface Payload interfaces before delivery to EDM Prime.

At EDM system level the AIV activities on the SPL will be to verify that:

- the SPL can be properly accommodated in the EDM Surface Platform,
- the SPL CEU is electrically compatible with the EDM CTPU interfaces (CAN Bus and power lines) and conform to the I/F specifications,
- the SPL verified in conjunction with the EDM CAN Bus works properly and is able to exchange data,
- the design of SPL is qualified at the environmental condition (mechanical, thermal, EMC),
- the SPL itself is free from auto-compatibility problems with respect to the other EDM elements,
- the SPL overall (including tools, procedures and resources) is able to fulfil its mission requirements;
- the SPL Flight Model is able to provide all performances required during the mission, and is free from material and workmanship defects.

A1.1 Introduction

The objective of the instrument Verification Programme is to demonstrate that the SPL is fully compliant

- with the instrument functional requirements
- with the mission environment;
- with the spacecraft performance;
- with the spacecraft interface requirements;
- with the operational requirements;
- and that the operational documentation is adequate,

hence that the SPL is capable to contribute to the overall scientific goals.

This section establishes the verification requirements for qualification and flight certification of the SPL units giving specific test levels, durations and describing acceptance and qualification tests and analytical methods for implementing the requirements.

A1.1.1 Definitions

The definitions applicable to the AIV/AIT activities are contained in the relevant ECSS standards for Verification and Testing ([IR 11] and [IR 12]).

A1.1.2 Documentation

Instrument Verification Plan

The PI shall prepare a Verification Plan defining the tests and analyses that collectively demonstrate that instrument hardware and software complies with the mission functional, performance, design and interface requirements laid out in the E-PIP.
Note: The Instrument Verification Plan shall highlight the overall approach which will be undertaken by the instrument consortium to accomplish the SPL qualification and acceptance. When appropriate the interaction of the tests and analysis shall be described.

Verification Control Document (VCD)

1. The SPL PI shall provide a verification control document (VCD) that shows for all requirements the selected verification methods for the different verification levels in the applicable verification stage.
2. The VCD shall provide traceability of the qualification status of the SPL units' hard- and software.
3. The VCD shall provide traceability of the verification of the design and test requirements contained in the E-IRD.
4. The VCD shall be provided to ESA and its selected Prime contractor at the major instrument review milestones and shall be updated with references to documentation which describes actual performed verification (and updated as changes occur).

Analysis Reports

For each analysis verification activity the PI shall submit a formal report, describing the mathematical model and the relevant outputs and interpretations. Several related analyses may be combined into a single report.

Test Related Documentation

For each test defined in the Instrument Verification plan, the PI shall provide:

1. a test specification (configuration, test setup, facility, test goals, requirements to be verified, success criteria, etc.)
2. a detailed step-by-step procedure, and
3. a test report containing the objectives, a description of test setup, a result summary and the as-run procedure.

A1.2 Overview of EDM AIT Sequence

A1.2.1 EDM Model Philosophy

The following models will be used to qualify and accept the EDM:

- Aeroshell Structural Model (SM)
- EDM Surface Platform Thermal Model (ESP TM)
- ESP Qualification Model (QM) (mechanical tests by subcontractor)
- Avionics Test Bench (ATB)

- Proto Flight Model (PFM)

A1.2.2 EDM Surface Platform (ESP) TM

For testing the Martian surface phase an ESP TM is built, consisting of:

- Thermal Model of the ESP baseplate on which the Thermal Bay STM is accommodated.
- Thermal Structural Model of the ESP Thermal Bay TCS, consisting of cover and insulation (avionic units' support panel, stand-offs, foam, etc). This will be reused in ESP QM after refurbishment.
- Thermal Model of ESP Thermal Bay avionic units and harness

The ESP TM is subjected to a TB test in a CO_2 environment simulating the Mars atmospheric/terrain thermal conditions. This test also envelope the coasting thermal case and provides pre-qualification of the thermal control during flight and validation of the thermal mathematical models, used to predict the launch and cruise temperatures for the EDM equipment.

A1.2.3 EDM Surface Platform (ESP) QM

An impact load mechanical qualification is performed on a dedicated ESP QM. The ESP QM is built around the SP Structure and Separation Mechanism QM complemented with mass dummy units and harness, RDA SM, Thermal Bay STM TCS components and some RCS SM items. The Thermal Bay TCS STM is the refurbishment of the items used in the ESP TM.

The mechanical qualification includes the functional verification of the SPSM, the measurements of the separation shock and the vibration test with sine and random to cover the launch loads. Finally a series of 6 impact tests on different typologies of simulated Mars terrain will be performed.

A1.2.4 EDM Avionics Test Bench (ATB)

The ATB is initially composed of the EGSE, the Simulator and the Functional Model of the On Board Computer (or an Engineering Model). In this configuration it is used for OBSW development and validation.

The simulator is the core of the Avionics SCOE, its main functions are:
<u>Provide a simulation of the missing units:</u> on the ATB not all the real units will be installed. Its standard configuration is to have for each set of the same units one real element and the other one is simulated, i.e. represented by a SW model integrated in the simulator environment. This simulated unit is representative of the real unit from a functional and an interface point of view. It receives inputs from the real HW and/or from other SW models and produce relevant output as a real unit.
<u>Provide stimulation for the real HW:</u> introducing in the simulator some values of attitude and velocity the simulator is able to calculate the stimuli value measured in the same condition by the sensors. These values are converted in electrical signals inside dedicated modules (stimulators) and transmitted to the electronic section of each real sensor.

Provide dynamic simulation: the dynamic simulation is able to reproduce a well defined point of the EDL Demonstrator Module trajectory, starting from pre-defined initial conditions, in order to:

- calculate the stimuli for all the involved sensors
- calculate the attitude evolution using the EDM SW model, the output of the simulated actuators and the output of the real actuators
- recalculate the stimuli for the new attitude condition.

In a second phase the ATB will be completed with the EDM EM units to increase its representativeness from the real HW point of view. On this bench the complete verification of the EDM operations will be performed.

A1.2.5 Proto-Flight Model (PFM)

The EDM PFM is composed of the PF Models of its two main components:

- Aero-shell PFM
- EDM Surface Platform PFM

Note that EMC conducted tests are performed on the Surface Platform stand alone to avoid accessibility problems at module level. A TV test without sun simulation is envisaged to finally accept the EDM from thermal p.o.v.
Mass properties are determined for the two configurations relevant from aerodynamic p.o.v.: entry-EDM, and landing-ESP.

The EDM is subject to bio-burden control and must be integrated in ISO 7 Highly Controlled environment, which practically means:

- Work in a class 10000 Clean Room (10 times better of a 'standard' clean room)
- Use of special garments
- Use of bioburden-controlled tools
- Use of bioburden-controlled Ground Support Equipment
- Frequent microbiological assays
- Control of molecular contamination.

A1.2.6 Instrument and Spacecraft Integration

The Integration between the SPL and the EDM will be purely mechanical on the STM, and mechanical and electrical on ATB and EDM PFM. A typical integration flow will include:

1) Instrument health check before starting integration activity, using equipment provided by the SPL team.
2) Mechanical Unit Integration including integration of additional HW like thermal filler (if any), thermocouples, heaters etc.
3) Connection of unit bonding strap and measurement of grounding
4) Power input to unit measurements: first in unloaded condition (only input, unit electrically disconnected), after that in loaded condition
5) Unit switch on and measurements of inrush current and power consumption
6) Electrical integration of the Telemetry and Telecommand lines, with the following objectives:

a) Interface verification in accordance with the electrical design and interface requirements.
b) Correct allocation of all relevant Telemetry and Command tags within the EGSE monitoring & control "housekeeping" data base
c) Verification that the system database is correctly populated with the relevant commands and telemetry data: checking that the commands are addressed in the correct way and the telemetry is correctly decoded.

7) Verification of the electrical characteristics of special I/F not included in the previous cases.

A1.3 Surface Payload Model Philosophy

To accomplish the above verification program and satisfy the mission requirements, taking into account also schedule and cost constrains, a SPL Proto Flight approach is defined, based on payload models hereafter described.

A1.3.1 Payload Structural Thermal Model - STM

The Payload STM will be integrated in the ESP Thermal Bay TM in order to perform the environmental qualification test campaign described above. The Payload STM shall reproduce the real SPL flight model behaviour from a structural and thermal point of view and be flight representative for the following characteristics of each payload element (battery, CEU, sensors, harness):

- MCI (mass, centre of gravity, inertia)
- Footprint
- Overall dimensions
- Area and properties of conductive surface
- Properties of external surfaces (and preferably area)
- main vibration mode frequency and participation factor (if element mass exceeds 1 kg).
- power dissipation through internal heaters (and preferably power profile if significant)
- Thermal inertia (tbc)

The main purpose of the STM is to:

- Verify SPL units' accommodation on the ESP
- Preliminary verify the SPL structural design
- Verify the mathematical mechanical models by dedicated vibration test
- Derive, respectively confirm the mechanical loads for SPL units' qualification
- Support qualification of spacecraft structures in a representative environment
- Preliminary verify the payload thermal design
- Support qualification of spacecraft thermal design in a representative environment
- Verify the mathematical thermal models by dedicated thermal test
- Debug the mechanical integration procedures that will be applied on PFM

In case the SPL includes some mechanisms (shutters, covers, actuators, etc) it is a good practice to have a flight representative mechanism on the STM: in this way that mechanism can be preliminary verified in the frame of TM test campaign.

A1.3.2 CEU Software Model - CSM

The CEU Software Model shall be composed of a SW package, running on a commercial HW platform, which shall be representative of the flight CEU in terms of:

- Capability to I/F to the CTPU on the CAN Bus physical layer
- Capability to exchange data on the CAN Bus with the CTPU, according to the specified CANOpen bus protocol
- Capability to manage, from a functional point of view, commands and telemetry data in a representative way
- Capability to generate a flight representative data volume
- Capability to simulate SPL operative modes and time synchronization

The CSM will be installed on the EDM Avionic Test Bench (ATB) to simulate the CEU to CTPU OBSW I/F and data exchange. The content of the scientific data need not be representative; only the communications flow will be validated.

A1.3.3 Payload Electrical Interface Model - EIM

The payload Electrical Interface Model shall be representative of the flight SPL in terms of:

- Interface connectors
- Electrical I/F with the CTPU, satisfying the flight electrical requirements
- Capability to exchange data with the CTPU, according to the specified CANOpen bus protocol.
- Capability to manage commands and telemetry data in a representative way
- Capability to generate a flight representative data volume
- Functional Interfaces (e.g.: operative modes, time synchronization, etc.)
- Capability to upload/download CEU SW and accessibility to all memories
- Representative electrical conductance EMC characteristics

Flight-representative scientific capabilities are not required of the SPL EIM.

The main purpose of this model is to verify the functional/electrical interfaces between CEU and CTPU. The realistic content of the scientific generated data is not necessary: only the packet structure (length, header field content, etc) and volume will be verified. HK, events and diagnostics shall be fully compliant with flight model.

The SPL EIM shall be delivered to the Prime already functionally and electrically integrated. This means that the SPL team has verified the overall autonomous operation of the surface payload package in terms of resources, timeline and operational constraints as well as their auto-compatibility. The Payload EIM will be electrically integrated on the EDM ATB together with the Engineering Models of the EDM avionic units plus a flight representative harness.

After that, the resulting EDM ATB will be used mainly to:

- Verify the CEU/CTPU electrical I/Fs
- Verify the EDM OBSW in a real HW environment
- Perform the Integrated Sub-System Test (ISST) and the Integrated System Test (IST)
- Perform reference runs for the test that will be repeated on PFM
- Debug and verify the Flight Operation Procedures (FOP)
- Debug the test sequences that will be reused on PFM
- Perform the conducted EMC (confidence level)
- Validate the Electrical Ground Support Equipment (EGSE) and the related procedures

Furthermore, during the mission the EIM integrated on the AVM will remain available to support SW maintenance, investigations, SW upgrading.

Note: in case SPL element Engineering Model (EM) or Qualification Model (QM) is available it can be delivered in place of the EIM, provided that EM/QM functionalities satisfy the minimum set of requirements listed above.

A1.3.4 Surface Payload (Proto) Flight Model - (P)FM

The SPL (Proto) Flight Model is the SPL to be used for the mission. It will be integrated on the PFM ESP under bioburden control and involved before launch in the main following activities:

- Mechanical & Electrical I&T
- Payload ISST (Integrated Sub-System Test)
- System Functional Test
- EMC testing (including conducted & radiated EMC, auto-compatibility)
- Environmental Acceptance Test Campaign including:
  - Sine Vibration
  - Acoustic
  - SCC / LV Separation Test
  - Thermal Vacuum Cycling
- Launch Campaign

The SPL PFM shall be delivered to the Prime already functionally and electrically integrated. This means that the SPL team has verified the overall autonomous operation of the surface payload package in terms of resources, timeline and operational constraints as well as their auto-compatibility.

A1.3.5 Surface Payload Flight Spare Model – FS

A flight spare philosophy shall be defined and implemented by the SPL PI in order not to exceed, in case of failure, a maximum down time of 3 weeks for Flight Hardware and 48 hours for GSE, during every nominal AIT sequence at SPL, spacecraft or System level.

The spare philosophy shall take long lead-time procurement into account.

GSE spare parts shall be all and only those items, electronic boards and mechanical parts that cannot be directly provided through commercial vendors within a short time frame in line with the 48 hrs requirement or that require very long procurement time.

The SPL PI shall be in charge of the Spare Parts List definition and procurement upon Agency approval.

Flight spares shall be at the same level of bioburden control and documentation as the flight models.

Further models needed to develop and qualify the SPL design are not requested by EDM Prime.

A1.4 Surface Payload and EDM Integration

The Integration between the SPL and the EDM will be purely mechanical and thermal on the STM, mechanical, and electrical on AVM and mechanical, thermal and electrical under bioburden control on PFM.

The main activities under SPL PI responsibility are:

- Instrument health check before integration, using equipment provided by the SPL team.
- SPL mechanical and electrical integration
- SPL functional check using dedicated Interface Test Equipment provided by the SPL team
- Demonstrate that the SPL is within the bioburden allocation.

After completion of the above activities it is verified that the payload is suitable for integration on the ESP. The successive activities are under EDM Prime responsibility with the support of the SPL team.

A1.5 Surface Payload and EDM Testing and Verification

After the SPL integration, the EDM payload will be involved in the system testing activities.
On the TM(/QM) the payload is substantially passive, representative only from a thermal and structural point of view.
On the ATB and PFM, the payload will be subjected to an ISST and an IST.
The SPL ISST will be used repetitively to verify nominal functioning of the SPL after environmental tests or other major AIT milestones.
During the IST the SPL will be exercised in operative configurations together with the rest of the spacecraft in order to simulate the real mission phases. The main purposes of the payload IST will be:

- Correct management of exchange of TM/TC between CEU and CTPU
- Verification of correct SPL management by the EDM OBSW in cruise and on Mars mission phases
- (Simulated) science data acquisition, as adequate or feasible during the ATB- or PFM- test configuration.
- Verification of storage capabilities of scientific data in CTPU

- Verification of the correct transmission of scientific data to the TGO (simulated) when foreseen in the mission profile
- Specific instrument performance tests that have to be done at spacecraft-PFM level (if any).

The SPL will be switched off during the mechanical tests (sine, acoustic, separation) as they are during launch.
The SPL will be active during the EMC testing and during the Thermal Cycling in vacuum chamber and Mars Environment.
During the launch campaign the Integrated System Test will be repeated after transportation to the launch site, plus health checks before final SCC mating on the launcher.

A1.6 Verification and Test Methods

A1.6.1 Structural Mathematical Analysis

1. The mechanical properties of the SPL shall be calculated by means of Structural Mathematical Models (SMMs).
2. The PI shall use models for his own design and shall also provide model(s) to the Agency for use during spacecraft design and test results predictions. The PI shall update the models according to SPL and system test results.
3. The SPL SMMs shall be delivered according to the dates defined in the project schedule.

A1.6.2 Thermal Analysis

A thermal analysis of a payload unit shall be performed by the unit responsible with the following objectives:

1. Verify that internal parts and materials are below their maximum allowed temperatures under acceptance/qualification testing;
2. Verify the ability of the thermal design to maintain the internal required temperatures and intended heat flow pattern that ensure performance requirements under the worst flight cases;
3. Verify the compliance with the spacecraft interface requirements under the worst flight cases.

Thermal Mathematical Models

1. Unit thermal analyses shall be performed by the unit responsible using a Detailed Thermal Mathematical Model (DTMM) and a Detailed Geometrical Mathematical Model (DGMM).
2. A unit Interface Thermal Mathematical Model (ITMM) and Interface Geometrical Model (IGMM) for coupled thermal analysis with the spacecraft shall be derived from the DTMM and the DGMM, respectively.
3. Requirements to insure compatibility of the interface models with the spacecraft will be defined during the Definition Phase (TBC).

Analysis Tools

For unit detailed thermal analysis, the following software packages are recommended:

- Thermal network solver: ESATAN v 9.4 or higher;
- Radiation coupling computation: ESARAD 5.6.1 or higher.

For ITMM exchange, models shall be compatible with the format of the following tools:
- Thermal network solver: ESATAN;
- Radiation coupling computation: ESARAD.

Note: both tools are available within the ESATAN Thermal Modelling Suite (TMS, currently version r2).

A1.6.3 Testing, General Rules

As a guideline for the PI the following sequence of tests is usually required:
a. Visual Inspection
b. Dimensions Verification
c. Physical Properties
d. Functional Test
e. Low Level Sine
f. Random Vibration - 1 axis
g. Low Level Sine
h. Functional Test
i. Thermal Vacuum (2 cycles)
j. Functional Test
k. Grounding / Bonding / Isolation
l. EMC Conducted Emission / Susceptibility
m. DC Magnetic Properties
n. Visual Inspection

STRUCTURAL TEST REQUIREMENTS

Structural Test Setup

1. The unit shall be tested in Launch configuration.
2. Test adaptors and / or non flight items shall be removed before test.
3. The unit shall be vibrated in hard mounted configuration through the designated S/C interface points.
4. The PI shall provide any special test adapter required for the test.
5. The adaptor shall have a high first resonance frequency (above 2 kHz) in order not to influence the test. Any amplification from the fixture shall not contribute more than 1% to the G rms value during the random test.
6. Standard Instrumentation and procedural guidelines shall apply and be reflected in the procedure.

MECHANISM TEST REQUIREMENTS

Mechanisms Verification

1. The mechanisms verification test programme shall ensure that the hardware conforms to the design, construction and performance requirements as specified in the relevant applicable documents.
2. Tests shall be performed to check mechanisms launch survival and operational performance.

3. Mechanisms can be considered as structures as far as strength and stiffness tests are concerned, and their design shall be verified against the same requirements as other structural components.

As a reference, the following tests' sequences are applicable:

- Functional tests (before and after thermal vacuum exposure)
- Mechanical environment tests
- Thermal vacuum functional test

Mechanism Lifetime Tests

The lifetime of a mechanism shall be demonstrated by a special test model in the appropriate environment, using the sum of the predicted nominal ground test cycles and the in-orbit operation cycles.

THERMAL TESTS REQUIREMENTS

Thermal Design Verification

1. The thermal design of a payload unit shall be verified by a dedicated thermal balance test according to the guidelines and requirements laid down in sub-section 5.3.5.2 of [IR 12].
2. The thermal balance test will consist of at least a hot and a cold steady-state and several transient phases that simulate conditions experienced during the mission, including actual Sun exposure.
3. The ability of the unit to meet its functional goals and to operate satisfactorily in vacuum in the temperature range expected during the mission shall be verified by a combined thermal vacuum and thermal cycling test.
4. The tests shall be agreed with ESA.
5. The Acceptance Temperature Range shall exceed the Design Temperature Range by an acceptance margin of 5°C.
6. The Qualification Temperature Range shall exceed the Acceptance Temperature Range by a qualification margin of 5°C.

For an electronic unit, the thermal verification can be derived from the unit qualification test, if the unit is adequately internally equipped with thermal sensors and proper steady-state phases are included in the test.

7. Instrument specific thermal testing requirements at unit and system levels shall be defined by the PI.

Test Methods

1. The equipment shall be mounted in a vacuum chamber in a thermally controlled environment.
2. Temperatures shall be controlled, measured and selected such that it can be guaranteed that the test item experiences actual temperatures equal to or beyond the minimum and maximum qualification/acceptance temperatures in the test environment.
3. The SPL shall be qualified using the type of fixations and mountings as designed in the SPL specification.

A1.6.4 Inspections

VISUAL INSPECTION

Visual Inspections shall be performed at the beginning and end of acceptance and qualification testing.

PHYSICAL PROPERTIES

The purpose of physical properties measurements is to determine the equipment physical characteristics, i.e. dimensions, mass, centre of gravity and momentum of inertia.

1. The measurement of physical properties shall include:
- Mass
- CoG
- Momentum of Inertia

2. The following dimensions as a minimum shall be verified:
- interface dimensions
- envelope dimensions (including envelope of separate electronics box, filter, etc. if applicable)

A1.6.5 Calibration

1. The PI shall provide a calibration plan adapted to the scientific requirements and overall development plan of the SPL and EDM.
2. The SPL shall be delivered fully calibrated.
3. Calibration activities at system level shall be only considered when scientifically justified, i.e. when for example the flight configuration is reached only after integration on the EDM. This type of activity is subject of agreement with ESA and the Prime.
4. The calibration plan shall be part of the Instrument Development Plan.

A1.6.6 Final Acceptance

GENERAL REQUIREMENTS

The acceptance process shall demonstrate that the SPL has been fully verified in terms of:
- scientific performances (including calibration and characterization)
- behaviour versus environmental conditions (including EMC)
- all functional and physical interfaces

ACCEPTANCE REVIEW

The acceptance review will check and ascertain the following topics:
- visual inspection and completeness of the hardware to he delivered
- compliance of the interfaces measurements (Spacecraft interfaces)
- availability of a complete set of functional performances data (using both the Limited Performances Test and Full Performances Test procedures)
- availability of calibration and characterization data
- ground support equipment relevant characteristics and documentation
- verification of the S/W configuration

- verification of the built standard
- verification of the bioburden level
- completeness of the Acceptance Data Package

A1.7 Surface Payload Ground Support Equipment Design and Interface Requirements

A1.7.1 Mechanical Ground Support Equipment (MGSE)

The SPL PI shall deliver the MGSE necessary to store, transport, handle and integrate on ESP any SPL flight element hardware, accompanied with appropriate documentation and calibration certificates.

A1.7.2 Electrical Ground Support Equipment (EGSE)

The SPL PI shall deliver the EGSE needed to power and operate the SPL during stand-alone operations and to stimulate the instrumentation and to perform analysis of SPL TM during system tests. The EGSE delivered items shall be accompanied with appropriate documentation and calibration certificates.

The SPL EGSE shall be made up at least of the following items:

- One or more Instrument EGSE workstations for generation of telecommands and for processing of P/L telemetry (health & status and science data.
- Equipment to generate electrical stimuli to the SPL (if needed).
- Dedicated Interface Test Equipment to verify the health status of the SPL stand-alone, prior integration to the spacecraft.
- All cabling and ancillary items necessary to properly use and operate the above mentioned equipments.

The SPL EGSE shall be designed in such a way to be compatible with the system EGSE in term of check-out system, LAN protocol, test languages, etc… because it will be connected to the spacecraft EGSE itself in order to constitute the EDM EGSE used for the tests at EDM level.

The SPL EGSE workstation in charge of performing analysis of SPL health & status TM shall communicate with the Central Checkout System (CCS) via a LAN with TCP/IP protocol.

The SPL EGSE will receive SPL telemetry directly extracted from the Spacecraft Telemetry and routed to the SPL workstation through the CCS (Central Checkout System).

The commanding of the SPL elements is conducted through the main operator console of the CCS.

TM data exchange over the LAN shall follow the EGSE protocol defined by the Prime Contractor in [IR 27].

The nominal monitoring of the SPL shall be done on the SPL station. For a limited set of parameters, the CCS can be in charge of the SPL's housekeeping monitoring.

The SPL EGSE shall remain at the spacecraft integration site until launch.
The maintenance of SPL EGSE shall remain the responsibility of the SPL PI.

The SPL PI shall also provide the necessary manpower and expertise support to integrate the SPL EGSE into the system EGSE. Moreover the SPL PI shall provide on-site support for usage and operation of SPL EGSE, whenever needed in the frame of system level test campaigns.

A1.7.3 Special Ground Support Equipment (SGSE)

The SPL team shall deliver any Special SGSE necessary in support of instrument calibration, interface verification, polarity/health check of optical elements or sensors physical stimulation. The SGSE shall be agreed on a case by case basis depending upon single Instrument needs.

Note. Examples of SGSE are: Optical GSE to perform optical stimulation of camera heads, targets for Instrument calibration, etc… In case purging or other specific maintenances is periodically needed, the SPL team shall provide the equipment necessary to accomplish these operations.

The SGSE delivered items shall be accompanied with appropriate documentation and calibration certificates. The SGSE maintenance and for their on-site usage in the frame of system test campaigns shall be the responsibility of the SPL PI.

7 LIST OF ACRONYMS AND ABBREVIATIONS

AIT	Assembly, Integration and Test
AIV	Assembly, Integration and Verification
AO	Announcement of Opportunity
ATB	Avionics Test Bench
BoM	Beginning of Mission
BSH	Back SHell
CAD	Computer-Aided Design
CAN	Controller Area Network
CB	Central Bay
CC	Cleanliness and Contamination
CCS	Central Checkout System
CDR	Critical Design Review
CEU	Common Electronics Unit
CIL	Critical Items List
COSPAR	COmmittee On SPAce Research
CSM	CEU Software Model
CTPU	Central Terminal and Power Unit
CVCM	Collected Volatile Condensable Mass
DC	Direct Current
DDOR	Delta-Differential One-way Range
DDP	Design and Development Plan
DDS	Data Distribution/Disposition System
DHMR	Dry Heat Microbial Reduction
DOORS	Dynamic Object Oriented Requirements System
DR	Design Report
DSM	Deep Space Manoeuvre
DSN	Deep Space Network
ECSS	European Cooperation for Space Standardization
EDL	Entry, Descent and Landing
EDM	EDL Demonstrator Module
EEE	Electrical, Electronic and Electromechanical
EGSE	Electronic Ground Support Equipment
E-ICD	Experiment Interface Control Document
EIDP	End Item Data Package
EIM	Electrical Interface Model
EIP	Entry Interface Point
E-IRD	Experiment Interface Requirements Document
EM	Engineering Model
EMC	ElectroMagnetic Compatibility
EoM	End of Mission
EOP	Experiment Operations Plan
E-PIP	Experiment Proposal Information Package
ESA	European Space Agency
ESOC	European Space Operations Centre
ESP	EDM Surface Platform
ESTEC	European Space Research and Technology Centre

ESTRACK	ESA Space Tracking Network
ESWT	ExoMars Science Working Team
EVP	Experiment Verification Plan
FDIS	Failure Detection, Isolation and Safing
FEM	Finite Element Model
FM	Flight Model
FMECA	Failure Modes, Effects and Criticality Analysis
FOP	Flight Operations Plan / Procedures
FoV	Field of View
FS	Flight Spare
GMM	Geometrical Mathematical Model
GNC	Guidance, Navigation and Control
GSE	Ground Support Equipment
HPC	High Priority Command
HW or H/W	Hardware
ICD	Interface Control Document
IDR	Instrument Delivery Review
IDS	InterDisciplinary Scientist
IF or I/F	Interface
IMU	Inertial Measurement Unit
IP	Implementation Plan
IP	Transmission Control Protocol/Internet Protocol
IPA	Iso-Propyl Alcohol
IR	Informative Reference
ISO	International Standards Organisation
ISST	Integrated Sub-System Test
IST	Integrated System Test
I2R2	Instrument Integration Readiness Review
JPL	Jet Propulsion Laboratory
LCL	Latch Current Limiter
LEOP	Launch and Early Operations Phase
LFA	Lead Funding Agency
LTA	Long Term Archive
LV	Launch Vehicle
LW	Launch Window
MAIT	Manufacture, Assembly, Integration and Test
MGSE	Mechanical Ground Support Equipment
MOC	Mission Operations Centre
MOI	Mars Orbit Insertion
M&R	Main & Redundant
NASA	National Aeronautics and Space Administration
NCR	Non-Conformance Report
NTE	Not To Exceed
OBSW	On-Board Software
OBT	On-Board Timer
OD	Orbit Determination
OM	Orbiter Module
PA	Product Assurance
PB-HME	Programme Board – Human, Microgravity and Exploration

PCB	Printed Circuit Board
PDR	Preliminary Design Review
PFM	Proto-Flight Model
PI	Principal Investigator
PISA	PI Support Area
P/L	Payload
PM	Project Manager
PMP	Parts, Materials and Processes
POR	Payload Operations Request
PP	Planetary Protection
PS	Project Scientist
QM	Qualification Model
QR	Qualification Review
RCS	Reaction Control System
RDA	Radar-Doppler Altimeter
RFD	Request for Deviation
RFW	Request for Waiver
RML	Recovered Mass Loss
RTPU	Remote Terminal and Power Unit
RX	Receiver
SCC	Spacecraft Composite
SCOE	Special Check-Out Equipment
SGSE	Special Ground Support Equipment
SM	Structural Model
SMM	Structural Mathematical Model
SPL	Surface Payload
SPLIM	SPL Interface Meeting
SPSM	Surface Platform Separation Mechanism
STM	Structural Thermal Model
SVT	System Validation Test
SW	Software
SWT	Science Working Team
TAS-I	Thales Alenia Space - Italy
TBC	To Be Confirmed
TBD	To Be Determined
TC	Telecommand
TCM	Trajectory Correction Manoeuvre
TCS	Thermal Control System
TGO	Trace Gas Orbiter
TM	Telemetry
TM	Thermal Model
TML	Total Mass Loss
TMM	Thermal Mathematical Model
TMS	Thermal Modelling Suite
TX	Transmission / Transmitter
UHF	Ultra-High Frequency
US	United States
UTC	Universal Time Corrected
VCD	Verification Control Document