MSPC Executive summary

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MARS SURFACE PLATFORM CAPABILITIES

Executive summary D6

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1. INTRODUCTION

1.1. SCOPE AND PURPOSE

This document is produced in the frame of the MARS SURFACE PLATFORM CAPABILITIES (MSPC). It is contributed by TAS – I and DEIMOS Enghenaria (E).

It consists in the Deliverable DR-6, and provides a summary of the findings of the Study. It is appropriate for publication within ESA.

The objective of this study is help and define how to maintain and further develop a European access to the surface of Mars, the major destination for European exploration, following the most recent approved and developed / in development missions (EXM 2016, EXM RSP).

The study represented the occasion for introducing all the **heritages** and **lessons learned** from ExoMars EDM Schiaparelli and ExoMars RSP missions: all the experience matured in the recent years has been injected into this exercise. All the most critical aspects related to the EDL, the parachute system, the avionics, the thermal protection and the thermal control system, the configuration and the structure have been reviewed in order to obtain a better system design and improved performances leading to more resources for the payload, for payload support functions and platform systems for power generation, thermal control, deployment etc., all concurring to an improved landing platform (in general, to extra equipment).
So, the study could shed some light on the possibility to have an improvement of the performances of the EDM Schiaparelli flown in 2016 on board of the TGO, and assumes that the lander:

- would be flown as a single entity accommodated in a dedicated carrier (i.e. no more TGO),
- would be provided a spin – stabilised ballistic entry state,
- would have the same sizing of the heatshield diameter of Schiaparelli.

The study results show that it would it be possible, by revisiting and upgrading some parts of the system, to obtain larger amount of resources as compared to Schiaparelli, which can be used for new instruments, new equipment, or new supporting elements

The Study activity provided :

- An assessment of the state of the art of Mars landing modules using ESA/European technologies with flight heritage (Schiaparelli)

- A review of lesson learned from development and from measured flight performances of known (ESA) as well as other missions for which relevant information was available (Schiaparelli, EXM RSP, Insight, MER)

- High-fidelity trajectory simulations were performed so as to quantify how the proposed improvements on the vehicle translate into EDL performance;

- The reconfiguration of the as-flown lander following the identification of a set of applicable changes, (after having stripped out all the payload instruments and their support functions). The reconfiguration exercise was applied almost to all the subsystems, though some were more impacted than other. Reconfiguration has meant a complete review in some cases and a simple optimization for other cases. The study surveys: short, medium and long lived platform.

- A review of the applied margin with proposal for modification of the margin philosophy where applicable

- The full update of the CAD model and provision of a 3D-XML file, both useful for a new CDF exercise

- An assessment and roadmap for possible / desirable / necessary technology development advancements which, though keeping the heritage architecture, allow incremental enhancements of the platform.

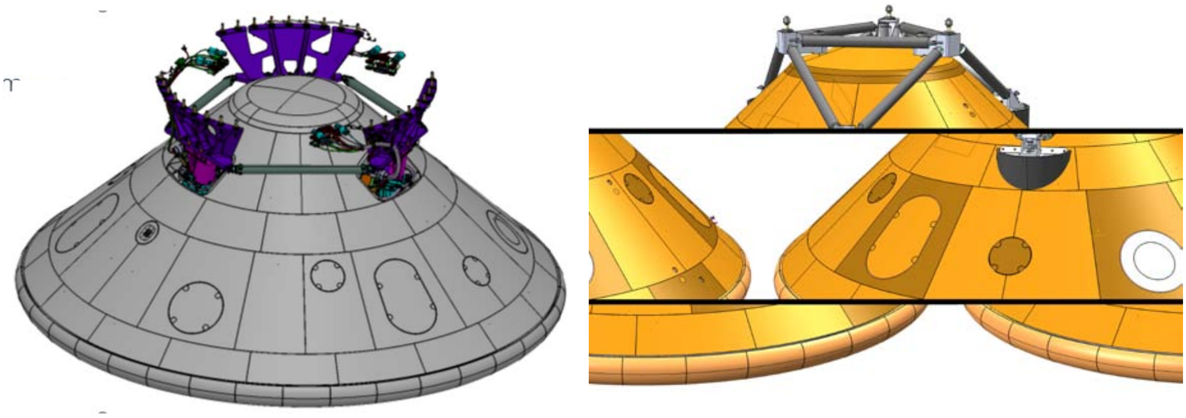

Figure 1-1*Left*: EXM EDM “Schiaparelli”, *Right*: EDM review as result from the MSPC study. The exercise of reconfiguration has been carried out keeping the EXM EDM lander sizing (same diameter of the platform)

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1.4. DEFINITIONS AND ACRONYMS

Acronym	:	Description
ADS	;	Airbus Defence and Space
ARC	:	NASA Ames Reasearch Center
ASW	:	Application Software
BCV	:	Back Cover
BoP	:	Break-Out Patch
BS, BSH	:	Back Shield
CDF	:	Concurrent Design Facility
CFD	:	Computational Fluif-Dynamics
CG, CoG, CoM	:	Centre of Mass/Gravity
CM	:	Carrier Module
DM	:	Descent Module
DPTD	:	Discovery Preparation and Technology Development
DSM	:	Deep Space Manoeuvre
EDL	:	Entry, Descent and Landing
EDM	:	EDL Demonstrator Module
EIP	:	Entry Interface Point
EPM	:	Earth Pointing Mode (GNC, Attitude)
EQSR	:	Engineering Qualification Status Review
FS, FSH	:	Front Shield
GEC	:	Global Entry Corridors
HGA	:	High Gain Antenna
FGE	:	Fluid Gracity Engineering Ltd
FPA, IFPA	:	Flight Path Angle, Inertial Flight Path Angle
HDG,IHDG	:	Heading, Inertial Heading
IMU	:	Inertial Measurement Unit
ISRU	:	In Situ Resource Utilisation
KOM	:	Kick-off Meeting
LEC	:	Local Entry Corridors
LL	:	Lessons Learnt
LGA	:	Low Gain Antenna
LIC	:	Lauch Injection Correction
LP	:	Landing Platform
MCI	:	Mass Centring and Inertia
MEADS	:	Mars Entry Atmospheric Data System
MEDLI	:	Mars Entry Descent and Landing Instrumentation
MER	:	Mars Exploration Rovers
MoI	:	Moment of Inertia
MOI	:	Mars Orbit Insertion
MPL	:	Mars Polar Lander
MPPT SAR	:	Max Power Point Tracker Solar Arrays Regulator
MSL	:	Mars Science Laboratory
NCR	:	Non-Conformance Report
NDA	:	Non-Disclosure Agreement

Acronym	:	Description
OBC	:	On-Board Computer
PAS	:	Éarachute Assemby Subsystem
PCDE	:	Power Converter & Distribution Electronics
PFA	:	Post-Flight Analyses
PHX	:	Phoenix
PLTE	:	Post-Landing To Egress
PSM	:	Pre-Separation Mode (GNC, Attitude)
RCS	:	Reaction Control System
RDA	:	Radar Doppler Altimeter
RfD	:	Request for Deviation
RfW	:	Request for Waiver
RHU	:	Radioisotope Heating Unit
ROCC	:	Rover Operations Control Centre
RPM	:	Revolutions Per Minute
RSP	:	Rover Surface Platform
S/A	:	Solar Arrays
S/W	:	Software
SAIG	:	Schiaparelli Anomaly Investigation Group
SCC	:	SpaceCraft Composite
SIB	:	Schiaparelli Inquiry Board
SoW	:	Statement of Work
SP	:	Surface Platform
SPM	:	Sun Pointing Mode (GNC, Attitude)
SPOCC	:	Surface Platform Operations Control Centre
TBD	:	To Be Determined
TCM	:	Trajectory Correction manoeivre / Trim Correction Manouvre
TGO	:	Trace Gases Orbiter
TRL	:	Technology Readiness Level
UHF	:	Ultra-High Frequency
VOR	:	Vorticity Ltd

2. EXECUTIVE SUMMARY

2.1. EDL SUMMARY

The Mars Surface Platform Capabilities (MSPC) study determines how to capitalize and improve on the Entry, Descent, and Landing (EDL) system of the 2016 ExoMars Schiaparelli mission. Compared to Schiaparelli, MSPC has more redundancy and enhanced EDL capabilities.

MSPC supports additional extra equipment mass, to enable scientific Mars missions (e.g., rover, stationary instruments, and even a drone). Despite the crash landing, most flight systems on Schiaparelli were demonstrated successfully on Mars. As technology demonstrator, the mission returned a trove of flight measurements. These are valuable to reduce uncertainty margins on engineering models, which drive EDL mission design.

MSPC applies the recent lessons from Schiaparelli, together with an internal vehicle reconfiguration which increases the packing density. The reconfiguration achieved an MSPC entry mass of at least 681 kg, compared to about 600 kg on Schiaparelli. The additional mass can be used for scientific instruments and supporting hardware. In addition, the approach to Mars was changed (the lander is brought much closer to the planet before separation), the heat shield margins were updated using the flight analysis of Schiaparelli (documented and reviewed in MSPC), and the parachute deployment mechanism was changed from a mortar firing to a pilot chute (inspired by developments for ExoMars 2022). Therefore, MSPC leverages the knowledge gained from ExoMars Schiaparelli, and converts the vehicle it into a multi-purpose science platform of moderate size and cost.

Deimos Space has quantified how the proposed improvements translate into EDL performance. High-fidelity trajectory simulations were performed, first assuming the Schiaparelli landing site as a reference. The entry mass was ranged from about 580 kg to 730 kg, which includes the 681 kg of the MSPC reconfiguration. The results show that MSPC, despite being heavier, actually has a wider entry corridor than Schiaparelli. It means that landing 681 kg is feasible, and even 700 kg if that can be accommodated within the vehicle. A major difference with Schiaparelli, is that the MSPC EDL performance is constrained by the parachute system in the descent phase, instead of the maximum heat flux encountered during entry. The heat flux constraint left Schiaparelli unable to land over 600 kg. The importance of the parachute for MSPC has another advantage. When landing at lower elevations on Mars, the descent phase becomes longer and the performance of MSPC naturally improves. This was confirmed in an extended EDL analysis, considering more global landing sites in an equatorial latitude band. The results show that MSPC can access similar Mars regions as Schiaparelli, but again with more payload. Contrary to Schiaparelli, the MSPC platform can handle increasing payload as the landing site elevation reduces. This opens up the possibility of customizing the MSPC EDL system to its landing site, using dedicated studies for specific locations on Mars. Finally, the results indicate that further work on updating the heat shield margins, introducing parachute reefing, or deployment range triggers, are promising areas to solidify and extend the MSPC platform design. More technological evolution options for MSPC, and more generally Mars EDL, have been documented in the reports.

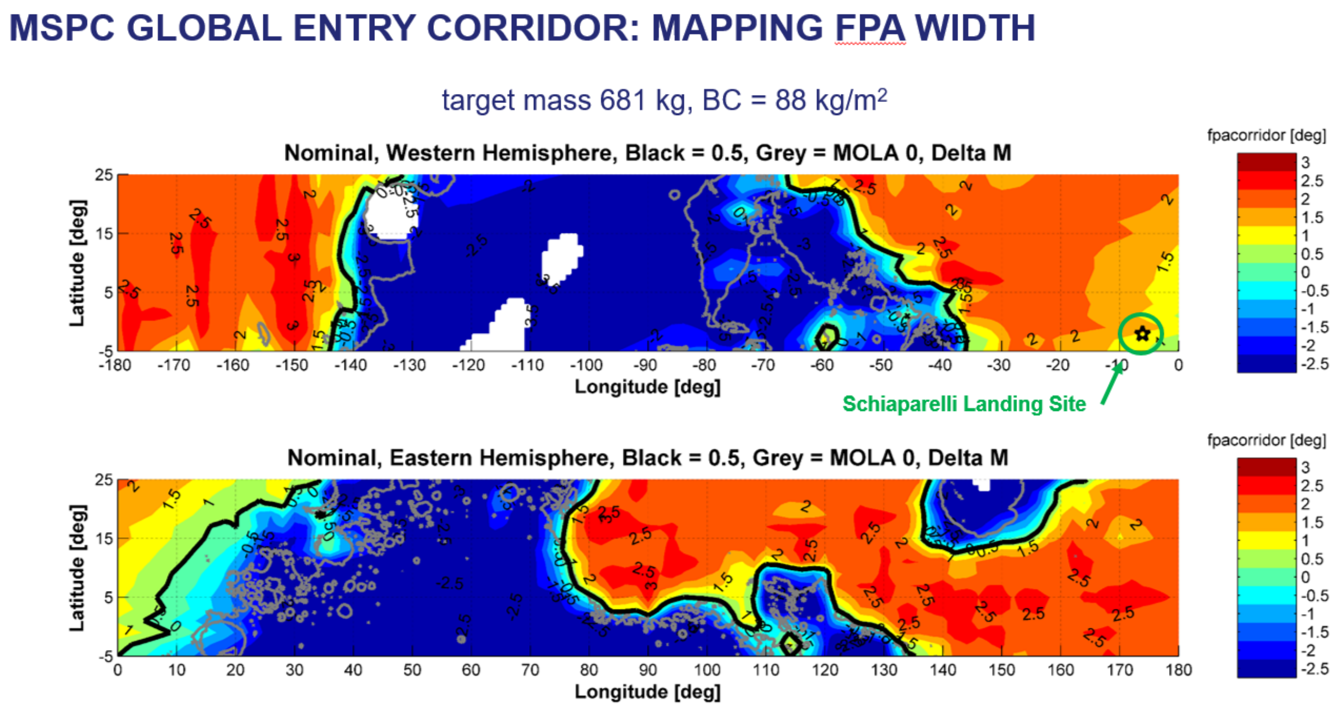


Figure 2-1 Achievable target landing sites at Global Entry Corridors level: FPA Width

2.2. RECONFIGURATION

In Tab 2-1 is the MSPC summary table encompasses all the major changes which we have introduced in our platform reconfiguration and which concur altogether to an increase of the overall entry mass, usable volume, and, more in general, to an increase of resources. This table is qualitative only.

The current re-configuration exercise assumes as baseline boundaries the same reference scenario as Schiaparelli. Thus, we are assuming the same landing site, the same reference trajectories as Schiaparelli, whilst the separation conditions shall take into account the release from a spinning, dedicated carrier (no coasting phase) imparting an axial delta-v only . The key objectives of the reconfiguration are:

- for the medium and long/lived platform study: maximization of the internal volume and power generation system
- for the short lived platform allocation of a simple rover with dedicated egress system configuration. (As alternative to mini-rover, configuration to host scout helicopters is considered as option, but no furtherly analysed)
- Optimization of the mass by revision of the allocated budgets for Schiaparelli, revisited taking into account the Lessons Learnt for the flight and the understanding of margins emerged from post-flight analyses

Table 2-1Summary of principal aspects which have been considered in the redesign of the EDM

System	Item	Change
EDL	Ballistic Coefficient	*From 80 up to to 100 kg/sqm (MER).*
	PAS: Parachute System	*Accommodation in a toroidal-shaped bag, which clears out quite some volume for the Payload: ia a change to a EXM-RSP like European PDD, bag shape. The back shell is modified*
	RCS	*Propellant and pressurant tanks accommodation: cut outs in main platform structure enabling partial accommodation in the lower part of the platform, towards the crushable structure*
		Piping layout
	IMU: Inertial Measurement Unit	*European unit and redundancy (2X). The same layout as EXM - RSP is envisaged*
	TPS Thermal Protection System (Front Shield)	*Reduced Design margin,driven from the absence of a coasting phase*
UHF	Transceiver	*Implemented Redundancy*
	Platform Antenna	*Monopole (inherited by EXM Rover), driving the accommodation of a grounding panel*
Power & DH	Battery & Solar Arrays	*The primary battery has been eliminated, in favor of a rechargeable battery and 1.75m2 3.3m (total) of solar arrays at platform level to cope with a order of months survival requirement*
	Architecture	*Integrated DH and Power (Rover)*
Structure	Main Separation Assembly	*No rotation drive, and, the interface with main separation assembly is no more separating from a S/C (the TGO), but it is disengaging from a dedicated carrier via a dedicated mechanism*
	Front Shield /Back Cover Separation Mechanism	*Can be redesigned (from EXM RSP)*
	Surface platform struts	
	Primary structure	*Internal structs (bars) are removed, clearing more volume insid ethe Lander. The structure has been re-designed by removal of the twelve CFRP beams (six bipods) providing fixation support to the Surface Platform. Loads run through the Back Cover which will be reinforced to work with structural function. A refision of teh ballast mass may help in gaining some more mass savings, too.*
Thermal Control System	Heat Piping, MLI, thermal Capacitors etc	*TCS architecture can be enhanced by reviewing the heat piping routing and introduction of more efficient thermal Capacitors. A solution for on-surface phase would be the implementation of RHUs + LHP. As for the cruise, the change on the coasting phase produces most of the thermal benefit and reduces the issueof thermal control which can be easily managed by classical tools*

2.3. RECONFIGURATION OF THE MAIN SEPARATION ASSEMBLY

The Schiaparelli Main Separation Assembly (MSA) configuration is conceived to provide the required energy to separate the EDM from TGO, to disconnect the electrical lines and accelerate and spin the EDM up to the required velocity. See picture

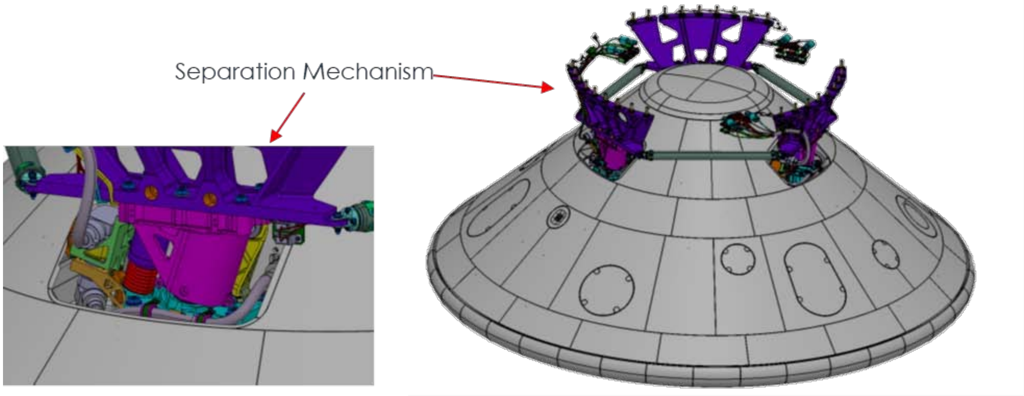


Figure 2-2 EXM EDM MSA

The new separation system configuration is derived from the ExoMars RSP mission and is based on a structure made of struts connecting brackets located on the base and lateral side of the back cover.

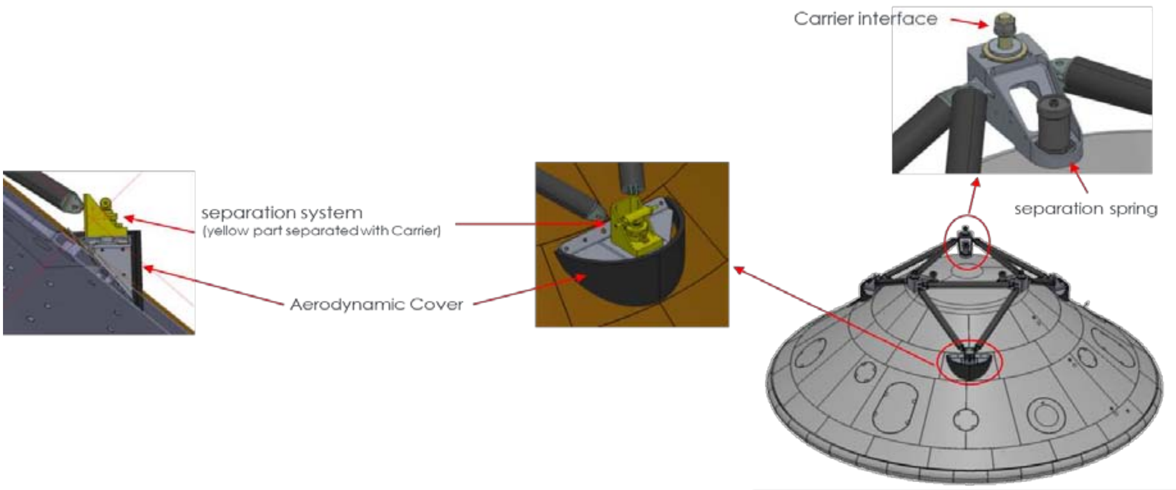


Figure 2-3 MSPC EDM MSA

2.4. SURFACE PLATFORM STRUCTURE

For EXM EDM two sets of 6 struts (with different length) are foreseen to support the Surface Platform:

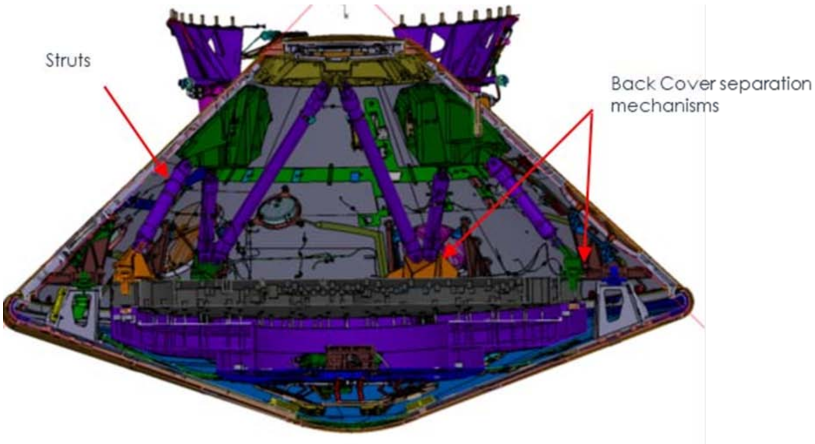


Figure 2-4 EXM EDM Struts

The new configuration is based on a re-design of back cover cone structure, where the EDM struts and BC I/F are removed. This new type of structure has to be analysed in detail for a correct sizing, by dedicated and detailed mechanical analysis. As for now, the BCV mass has been increased by 25% wrt the BCV of Schiaparelli to account for expected modifications for the structural functionality. The 25% is considered a reasonable figure based on heritages and experience

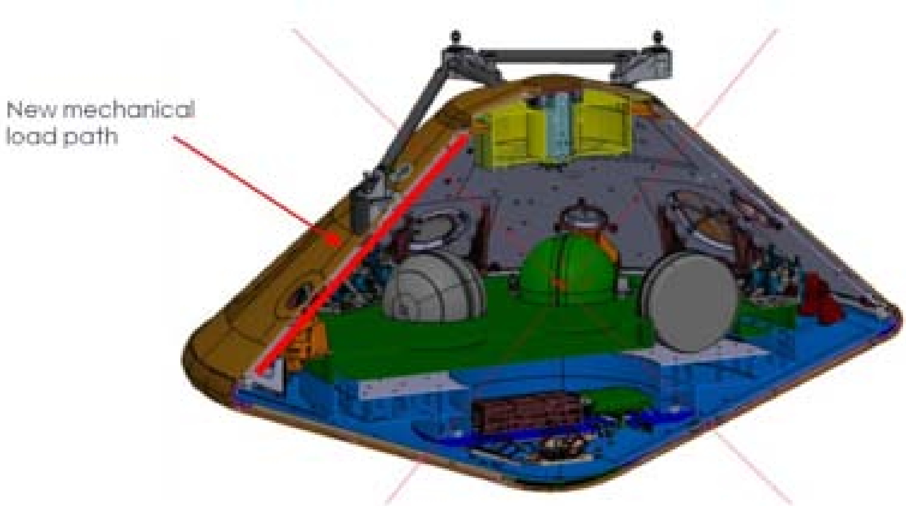


Figure 2-5 MSPC reviewed structure

2.5. PAS RECONFIGURATION

EXM EDM PAS was quite a bulky object filling up most of the internal volume of the EDM capsule.

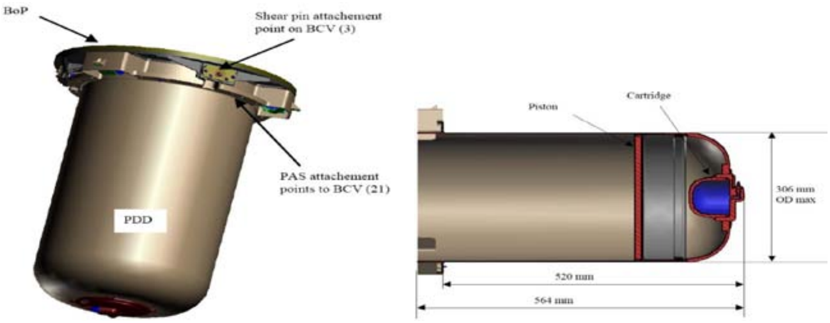


Figure 2-6 EXM EDM PAS dsign

The MSPC PAS is inspired by the EXM RSP , which allows to reduce the canister dimensions by 284mm wrt EDM design. The Back Cover configuration is slightly affected by this new PAS design:

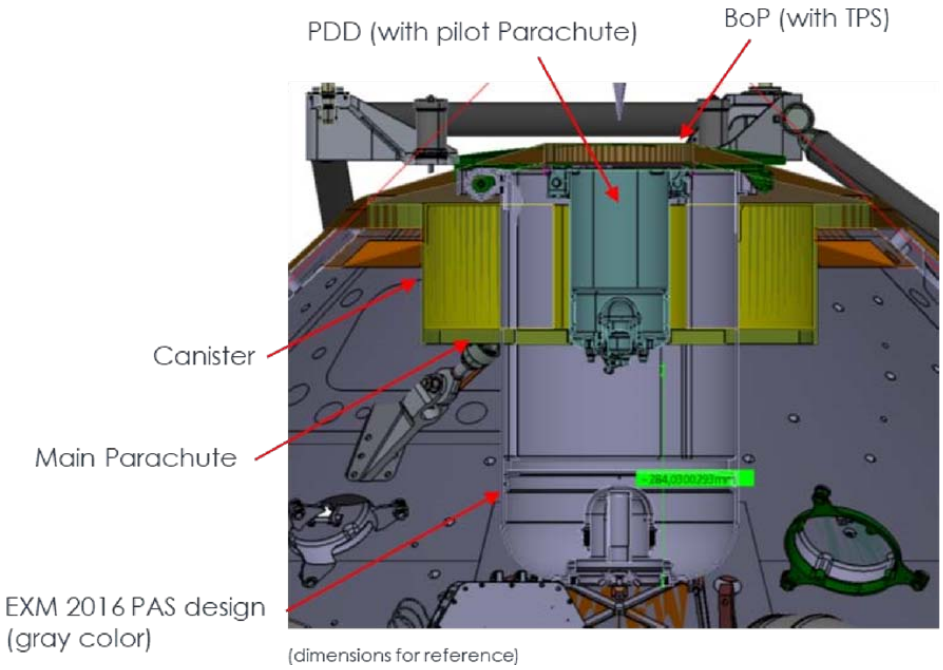


Figure 2-7 Updated PAS design

2.6. BACK-COVER

The different PAS IF ring diameter and Break out Patch shape require modification of the Back-Cover aeroshape in the area of the PAS mechanical interface

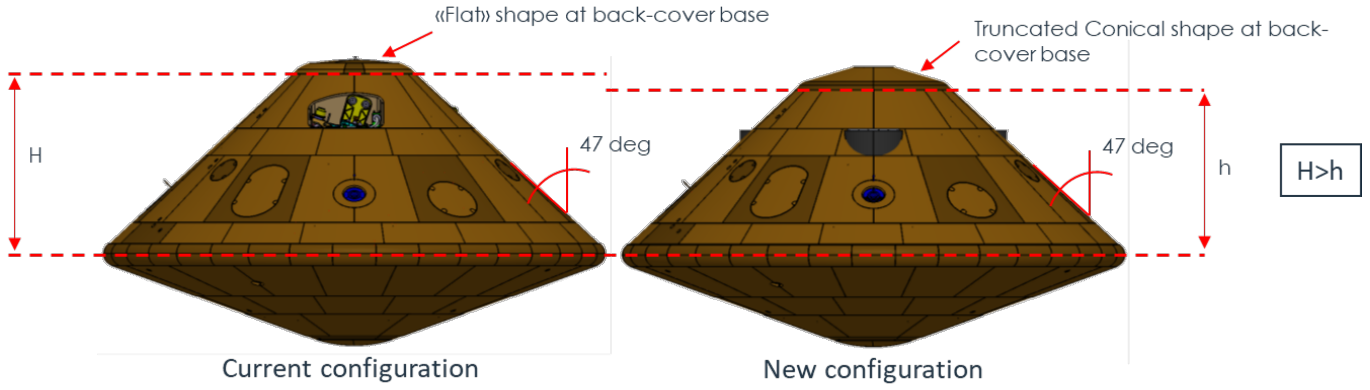


Figure 2-8 Left: EXM configuration; Right: MSPC Aeroshape difference driven by new PAS shape and dimensions

2.7. REACTION CONTROL SYSTEM

For EXM EDM the RCS was based on based on monopropellant (Hydrazine) pulsed engines with a pressurized feeding system.
The architecture is based on 9 engines of 400N thrust separated in clusters of three engines symmetrically accommodated at 120° sectors on the surface platform, the external engines of each cluster have a tilt angle of 13 deg. The engines and layout of the clusters of proposed to be maintained as per current Schiaparelli configuration, while the tanks location and feeding lines are revised in the MSPC re-configuration exercise, aiming at getting more volume.

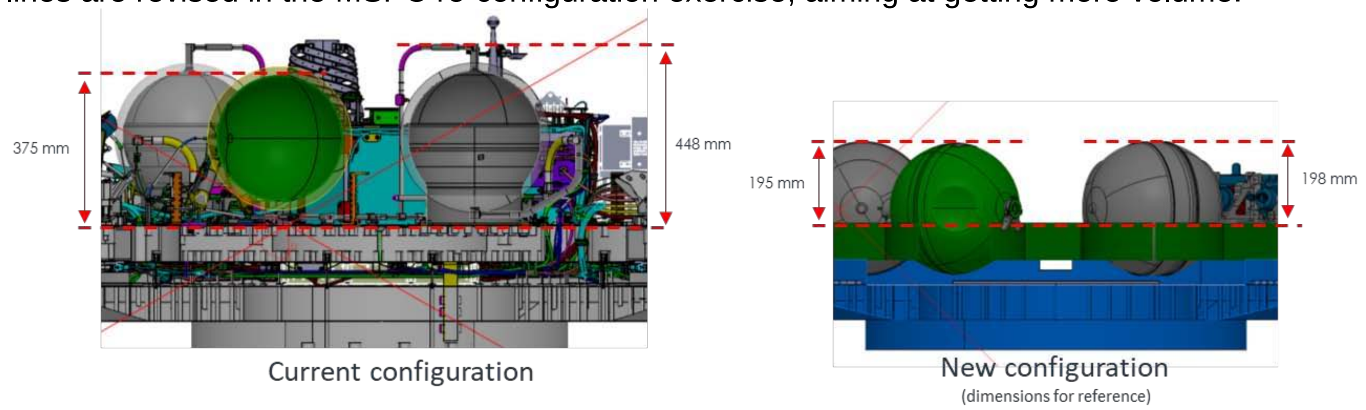


Figure 2-9Left: EXM EDM RCS configuration; Right: new accommodation of tanks, obtained by cut-outs in the Surface Platform

2.8. HEAT SHIELD

Schiaparelli design for TPS sizing has been based on over-conservative assumptions for the definition of fluxes and heat load. Norcoat Liège material is considered fully qualified for operation up to 1860 kW/m^2. In terms of instrumentation, Schiaparelli configuration proved to be crucial, thanks to the Real Time telemetry, to provide relevant information on TPS performance in real flight and to derive the key rules for sizing.

As for MSPC, the material choice is confirmed (Norcoat Liège), though revisited in term of sizing: its thickness is reduced by 25% (from 12mm to 9mm in the Front shield). Instrumentation accommodation could be subject at some optimisation in terms of sensors location. Methodology is identified and well known and established.

2.9. TCS

The thermal control approach of EXM EDM was based on a classical combination of insulation blankets (MLI and Foam), single layer insulation with specific finishes (SLI), heaters, thermostats and thermistors optical finishes, high conductance skins, thermal fillers , thermal washers , thermal capacitors. The issue which showed up on the nozzles and combustion chambers should there be no more because the absence of a coasting phase eliminates the long exposure of the nozzles. So, a wrap-up of the nozzles in MLI will be no more necessary.

From a TCS viewpoint, the MSPC spinning carrier concept should have a beneficial effect on the thermal exposure and thermal gradients of the vehicle. Moreover the application of new coating ceramic – metallic material could even improve the overall thermal Control System. First-Flex material will be coupled to the TPS both on Back shield and on Front shield (respectively with different grade of protection).

As for the Central bay, the approach of cavity-in-the-cavity providing strong insulation is confirmed. The new requirement /assumption is that no global dust storm occurs. This allow to avoid the implementation of new technologies/ Development (RHUs, Fuel cells). Thermal capacitors are strongly recommended, with the task to act as energy-storage device to help surviving the cold night with no/minimum electrical heater power. Of course, the adoption of RHUs has impacts un terms of radiators.

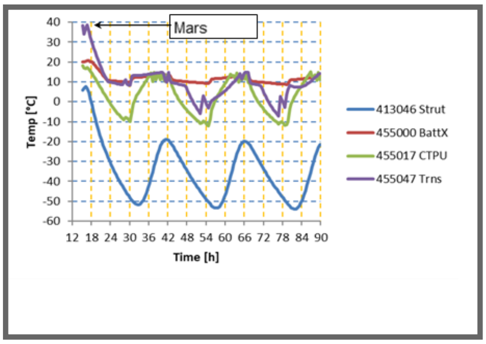


Figure 2-10 Typical temperature trend with capacitor at 12 °C

2.10. GNC

Adaptation for MSPC concern mainly the spin stabilized cruise attitude wrt inertial stabilized attitude and the lack of a Deep Space Manoeuvre (DSM). MSPC GNC approach will be a "mix" of the two approach of EXM EDM and RSP. EXM EDM EDL GNC summary is illustrated in Fig. 2-9

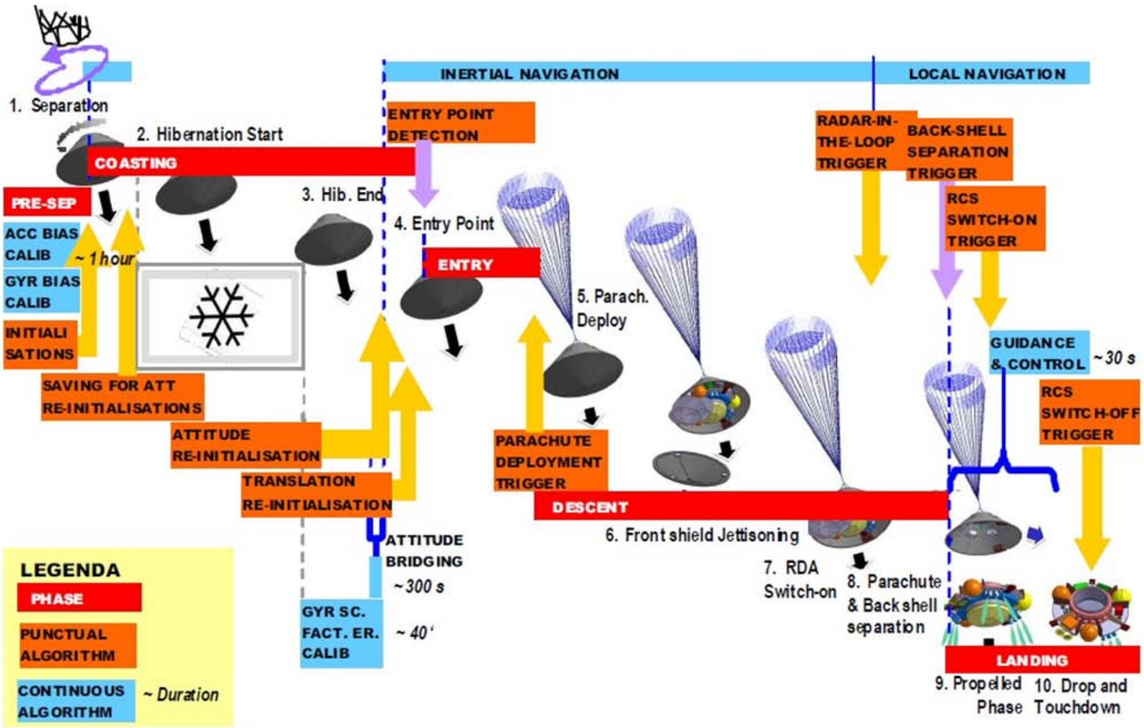


Figure 2-11 **Schiaparelli EDL GNC Design – Phases, Events and GNC Modes**

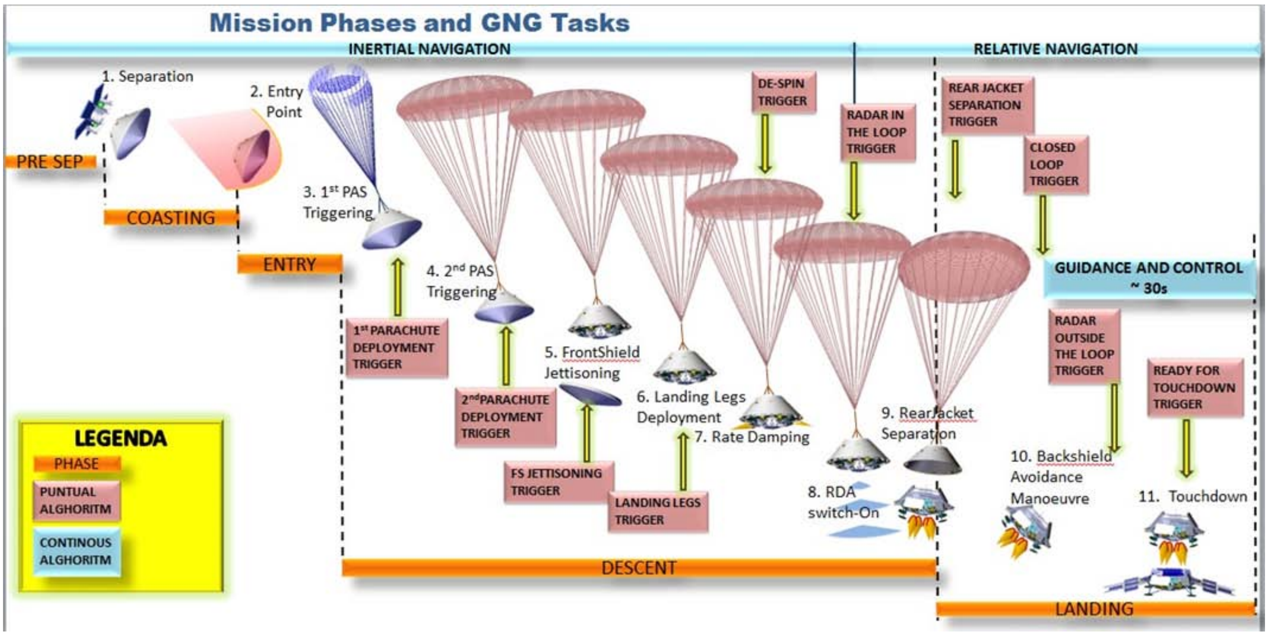


Figure 2-12 **Schiaparelli EDL GNC Design – Phases, Events and GNC Modes**

2.11. AVIONICS

EXM EDM was based on battery, and for a short duration mission. In MSPC we assume a surface mission out of the GDSS. The large volume clearance in the vehicle internal part allows the implementation of solar arrays. This opens to the possibility of much extended time for a surface mission. MSPC can accommodate three double solar panels for a total of 3.3 m^2, even offering the possibility to survive in GDSS scenario, for a limited n of days. The basic assumption are that the Power Subsystem would rely on:

- MPPT solar array regulation, to cope with varying irradiance/temperature conditions
- Unregulated bus voltage, single bus in the 28-32V range (all users) direct coupling to the battery

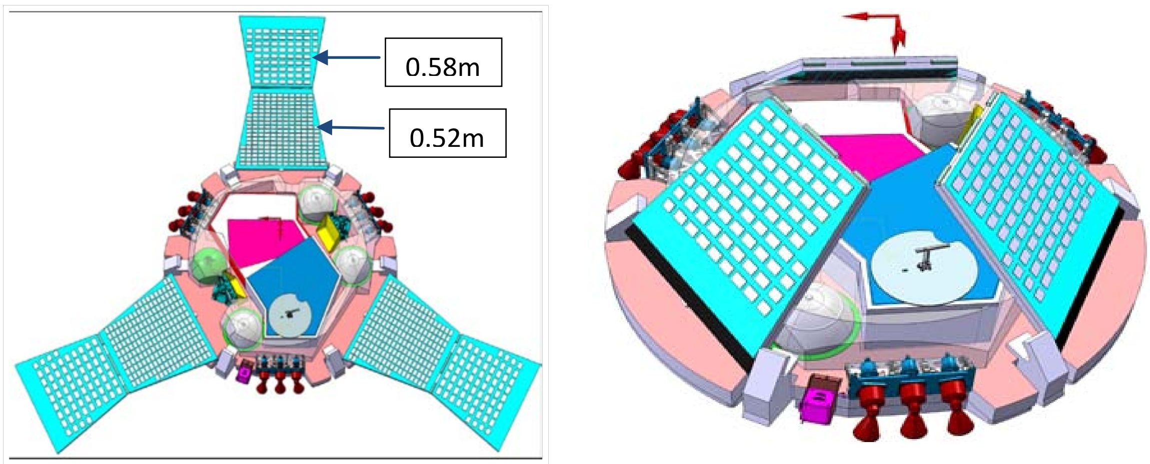
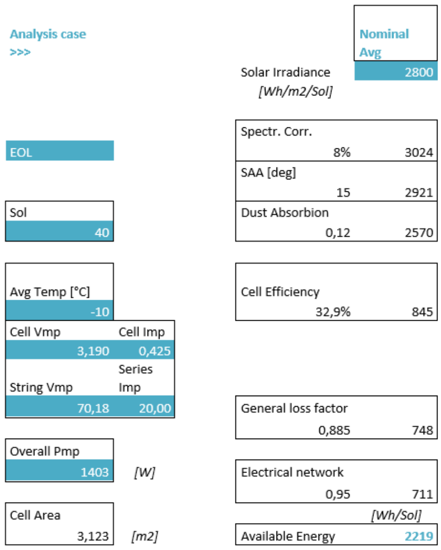


Figure 2-13 **MSPC Configuration with deployed SA (left) and stowed SA (right)**

For such configuration, assuming a 95% filling factor, we can glue up to 1034 solar cells, and deliver in the nominal average case 2219Wh/sol



2.12. COMMAND AND DATA HANDLING

For MSPC the baseline is represented by a centralised OBC based on SoC design with integrated support for data buses to cope for all platform needs from EDL to P/L operations.

This approach implies that it is preferred to rely on SoC features rather than developing customised, FPGA solutions. The known available SoCs (GR712- GR740) provide plentiful of resources and users.

Few data networks (CAN-Spacewire) shared with the platform equipment's are envisaged.

Temperature acquisitions is assumed to be based on digital sensor network. Depending on the actual needs of the platform and possible evolutions of OBC HW different options can be considered with increasing computational power/decreasing TRL level:

1. GR712 – LEON3 FT dual processor
2. GR740 – LEON4 FT quad processor
3. NG-ULTRA based ARM Cortex-R52 quad processor - TRL4

A current rough evaluation estimate a telemetry in the range of 150- 300Mb/day depending on visibility.

2.13. TT&C

The TT&C system on MSPC is based on:

- Shared UHF S/S for entry, descent and surface phase.
- Adaptive Data-Rate (ADR) to cope with orbiter visibility up to 1Mbps with flown transceiver
- Actual Data Volume is dependent on Orbiter selection visibility and antennas selection, expected 150-300 Mbit Sol
- Miniaturized monopole antenna coverage maximized for passes between 30° and 60° elevation
- Helix antenna offers improved coverage of for passes between 10° and 90° elevation (design evolution likely to improve mass, not volume)

2.14. SURFACE PLATFORM CONFIGURATION -OVERVIEW

As can be seen in the Fig. 2-14 to 2-17, the Central bay of MSPC has been enhanced as compared to EXM EDM Schiaparelli: more volume and mass are available for extra equipment, which might include a robotic arm or similar facilities which might concur to an improvement of the surface platform capabilities.

The platform size is increased from Schiaparelli 825 mm diameter to 1060 mm for MSPC. This is possible thanks to a reconfiguration of the harness routing, this freeing up more space.

Dedicated shaping around RCS clusters, lowering of tanks through base-plate cut-outs and removal of internal struts with revised separation mechanisms interface all concur in an optimisation of the configuration. Besides, it has been possible to implement Solar Arrays for Power Generation, two dedicated compartments for MSPC avionics and for instrument /extra equipment. Transceivers, battery on board computer and switches board, all find an allocation on the platform as well.

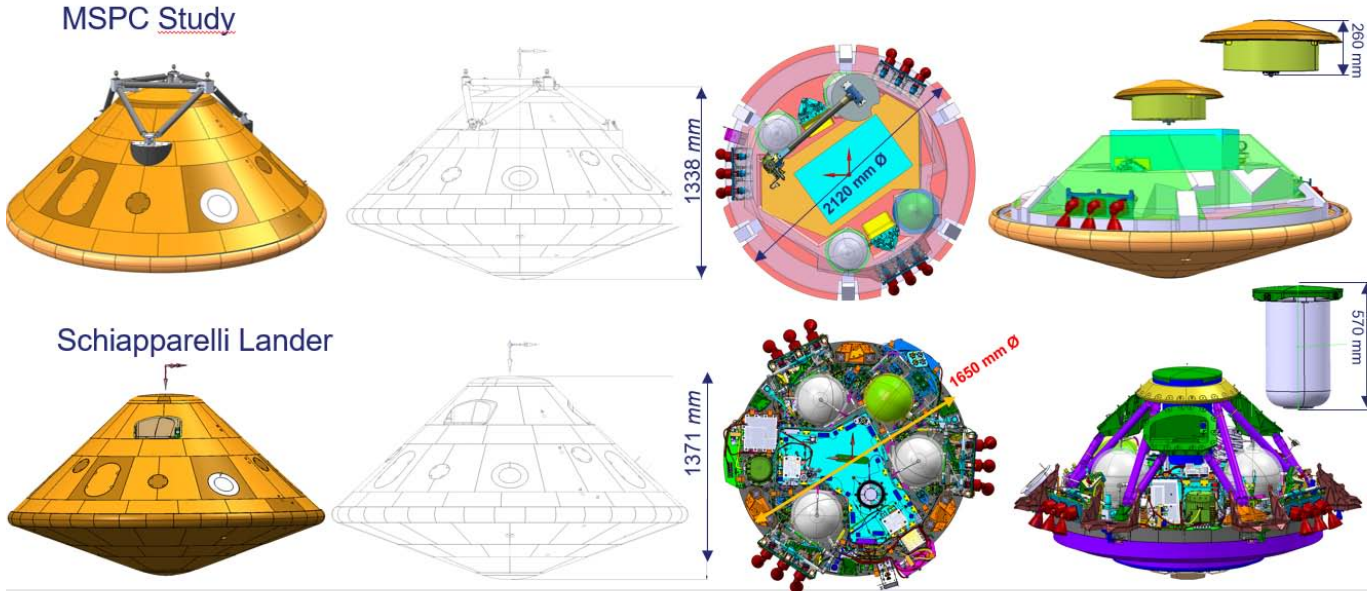


Figure 2-14 Upper: MSPC studyEXM EDM-Schiaparelli Configuration layout

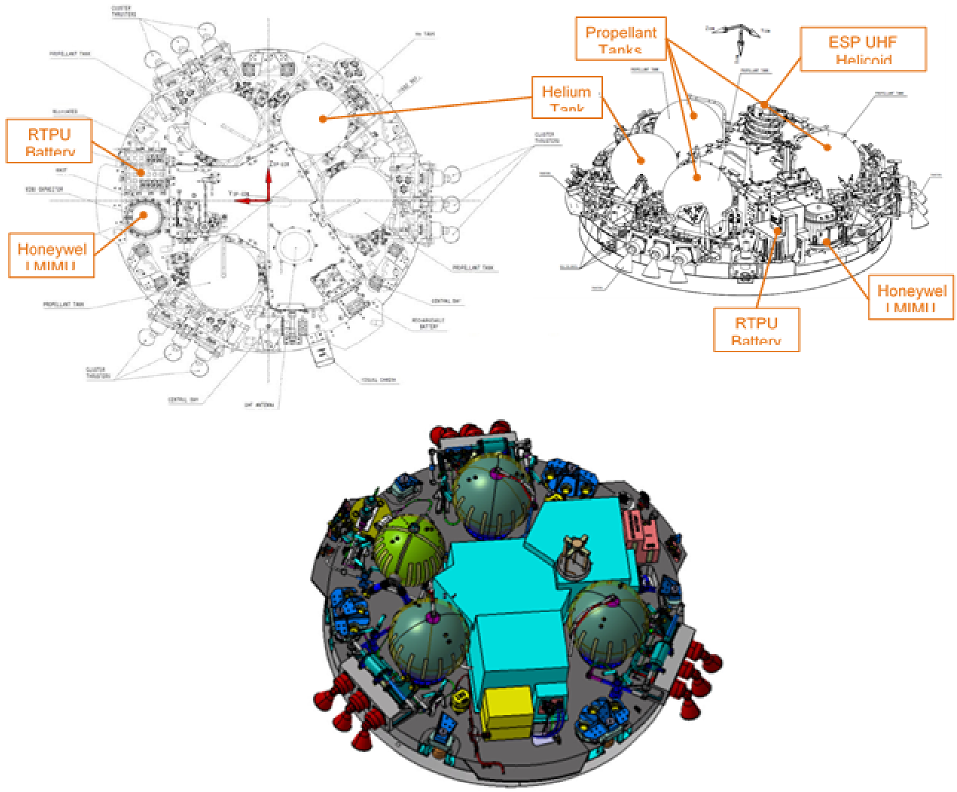


Figure 2-15EXM EDM-Schiaparelli Configuration layout

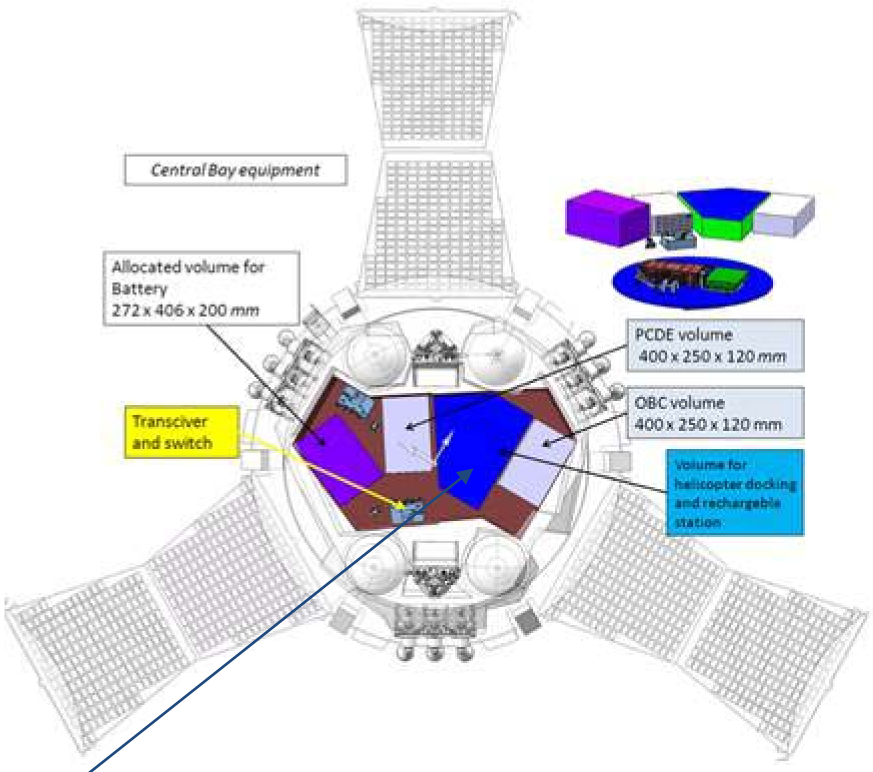


Figure 2-16 MSPC Surface platform Configuration layout

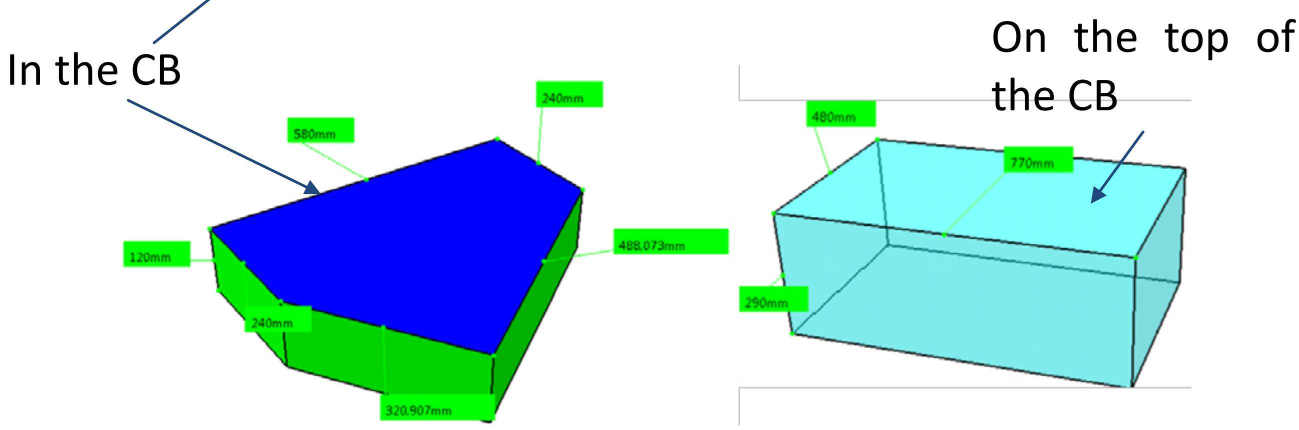


Figure 2-17MSPC-Extra equipment available volumes with overall sizing.

2.15. BUDGETS

MSPC Mass Evaluation				
	BEE (kg)	MMM		Predicted Mass (kg)
		%	kg	
Back Shell	**211.52**	***6%***	**8.13**	**171.03**
Front Shield	**76.30**	***8%***	**2.64**	**78.95**
Surface platform (included Central Bay)	**262.24**	***13%***	**32.95**	**284.62**
EDL Sensors				
COMARS+ (to Back Shell)	1.77	7%	0.13	1.90
Ballast (TBC)	**24.00**			**24.00**
FS Ballast	*20.00*			*20.00*
SP Ballast	*4.00*			*4.00*
Propellant	**39.00**			**39.00**
MSPC TOTAL WET	**551.83**		**43.85**	**599.49**
MSPC Total Dry	**512.83**			**560.49**

The Central Bay, accommodated within the Surface Platform , account for a mass of :

	BEE (kg)	MMM		Predicted Mass (kg)
		%	kg	
SP | Central Bay	**69.89**	***15%***	**10.57**	**80.46**

The available mass for extra equipment depends on the assumed BF and entry corridor case:

ITEM	Initial Schiaparelli evaluation	Current MSPC	Ref. MSPC 1.4 deg corridor	MSPC 1.0deg corridor	Max.MSPC 0.6deg corridor
BF [kg/m^2]	75	77	88	89.5	91.5
Entry Mass [kg]	577	599	681	693	708
Mass for Extra Equipment [kg]	34	0	82	93	109

2.16. CONCLUSIONS

This short-duration study served to consolidate the heritage and lessons learned from the EDM-Schiaparelli- platform, and will help to define and maintain the European access to the surface of Mars (with some applicability also to the Moon surface).

The EDM platform can be improved thanks to few crucial changes

- in the lander design
- in the LEC and BF re-discussion

altogether leading to the possibility to increase the mass available for the extra equipment (including payload) to 82, 93, 109 kg, which can be accommodated in a dedicated volume within the surface platform.

At design level the changes concern:

- Main Separation Assemblies
- Parachute Assembly System (PAS)
- Surface Platform Struts
- RCS system : propellant and pressurant tanks accommodation
- Avionic architecture reviewed vs new requirements
- Addition of Solar Arrays added for power generation during surface operations
- Thermal design (no coasting phase, no GDSS, longer surface lifetime)

The achieved results help outlining the possibility to maintain and further develop European access to the surface of Mars, with a new lander

- **End of document -**