# EXOMARS MISSION DESCRIPTION AND ARCHITECTURE

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## *INTRODUCTION*

EXOMARS is the first mission of the European led Exploration programme in ESA. It will demonstrate qualification of flight and in-situ technologies that are key ones to support European ambitions for future Exploration missions. Its objectives are:

- Safe, entry, descent and landing of a large size payload (Descent Module)
- Surface mobility (Rover) and access to the sub-surface (Drill)

In parallel important scientific objectives will be accomplished through a state-of-the art scientific payload and on surface mobile platform.
The mission includes two groups of scientific instruments that are planned to be accommodated on the Rover (Pasteur Exobiology Payload) and the Lander (Geophysical Environmental Package). The main scientific objectives to be addressed by these science instrument packages are:

- Search for traces of past and present life,
- Characterisation of Martian geochemistry and water distribution at various
- locations,
- Improvement of the knowledge of the Mars environment and geophysics,
- Identification of possible hazards before landing other spacecraft or , in the longer term, humans on Mars

The Exomars Phase B1 was to study three different mission scenarios for the ExoMars mission:

Baseline scenario

The Baseline scenario features launch in 2013 of a Composite Spacecraft made up of Carrier and Descent Module, using a Soyuz 2-1B launch vehicle. In this scenario the Data Relay Satellite used to support the mission is the NASA Mars Reconnaissance Orbiter (MRO).

Option 1 scenario

The option 1 scenario is the same as the baseline, except for the data relay function, which is performed by a European Mars Telecommunications Orbiter (MTO), launched separately with another Soyuz vehicle.

Option 2 scenario

In the option 2 scenario, a composite of Orbiter and Descent Module is launched in 2013 by an Ariane-5 ECA vehicle. The Orbiter performs the carrier functions until delivery of the DM; thereafter it performs the data relay function from Mars orbit.

All scenarios were requested to have a back-up feasible in 2015/2016.

The phase B1 has been completed in March this year; the outcomes of the phase B1 have been reviewed by the Agency in the System Requirements Review, the Board of which was held in April.
A programmatic and financial proposal for the development and exploitation phase of ExoMars was meanwhile produced by Thales Alenia Space -Italia (at the time Thales Alenia Space – Italia) to allow the Agency conducting an Implementation Review (a key programmatic milestone mandated by the 2005 Ministerial Council in Berlin) with the purpose of selecting:

1. Mission configuration (baseline, Orbiter option including the Ariane-5 launcher, or baseline with an autonomous European data relay communication Orbiter)
2. Final payload configuration
3. Launch date.

The ExoMars mission is presently in the Bridging Phase B1 design phase where the mission architecture, requirements and system level design are being reviewed following the outcomes of the SRR. Actually this activity has started for the B/L, waiting for the conclusions of the IRev, and will need a second review step, called Baseline Consolidation Review, to be held before the end of the year.
The purpose of the BCR is also to pave the way to the system Preliminary Design Review to be held in spring 2008.

## *SRR FOLLOW-ON AND IREV INDICATIONS*

During the SRR the Industry has got new inputs regarding three fundamental aspects of the mission:

- Ariane 5 performance
- Global Dust Storm
- Mass of payload

These new inputs have been considered and have led to different solutions for launch and transfer to Mars than what presented in the SRR documentation itself.

Ariane 5 performance

The AR5 mass performance is shown in table below for some declination departure and escape velocity values. For the trajectories of interest to Exomars direct injection, declination close to 0° and $V_{esc}$ around 2.5 Km/s, this performance is in the range 5300-5500 Kg, lower by almost 20% than that predicted by the models previously in use.

| Vinf | Dec=5 | Dec=0 | Dec =-5 |
|---|---|---|---|
| 2.0 | 5295 | 5549 | 5470 |
| 2.5 | 4856 | 5180 | 5127 |
| 3.0 | 4340 | 4744 | 4729 |
| 3.5 | 3763 | 4251 | 4286 |
| 4.0 | 3141 | 3714 | 3808 |

**Table: Range of AR5 mass performance for ExoMars**

The mass budgets of the various launch options have to show a 5% positive mass reserve with respect to the corresponding launch capability, after accounting for item maturity margins, a 20% system margin, and 5% Δv margins and 100% AOCS propellant margins.

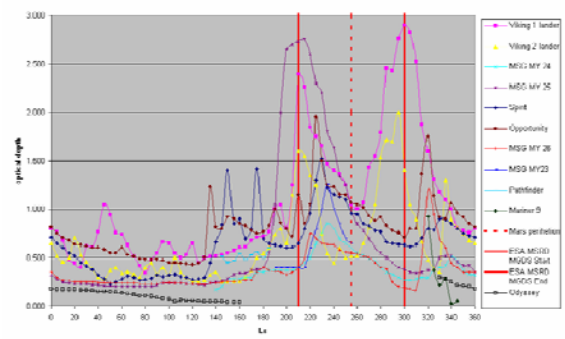
These limitations have practically led to abandon the Orbiter option with elliptic release, characterised in the w.c. scenario by a dry mass of about 1150 Kg for a propellant mass of about 3600 Kg, to carry an 1150 Kg Descent Module to enter the Mars atmosphere at an altitude of 120 Km, conventionally known as Entry Interface Point (EIP).

Even with the 1000 Kg DM the mission as originally conceived is not feasible.
However the AR 5 launch is perfectly capable to carry the baseline SC (expendable Carrier and Descent Module) into a Mars orbit from which the DM can be released.

GDS

As known the Mars atmosphere is periodically subjected to dust storms that cause a relevant decrease of the sun illumination, called optical depth.

These storms are defined as "local" when are limited to a certain area and last for a relatively short period of time.
There is however a period of the Martian year during which these storms assume a global character and influence the all atmosphere between TBD southern latitude and TBD northern latitude. This period is cantered around the Mars perihelion.
The graph in figure below shows the value of optical depth during the Martian year as observed through different missions.
The graph shows that From Ls = 340 deg to about 180 deg a clean environment (low probability that τ >1) is met. From 180 to 340 deg the "dusty" environment is found.
This is called Global Dust Storm (GDS) season.



**Measured atmospheric optical depth τ as function of Mars solar longitude for some missions (courtesy of ESTEC)**

The primary task of landing a Rover on the Mars soil must take into account the presence of both local dusts storms and GDS seasons; this is practically translated in being able to pass through periods of 1 week during which τ is up to 2 and operate normally outside the period when T>1.
The nominal Rover mission must last 180 sols (Martian day = 23 h 48 min).
A goal of the mission is to hibernate the Rover through the period of GDS and to resume operations for another 6 months after the end of that season.

Mass of payload

At the time of SRR the outcomes of the Payload Confirmation Review were made available.
In that review it was identified that a consistent and valuable set of Pasteur instruments would have to weigh approximately 16.5 Kg.
This requirement, together with important findings of the SRR, has brought in the necessity to re-consider the mass of the Rover that is actually evaluated to be 205 Kg, from previous 165 Kg, and the accommodation

constraints that indicate in the vented airbags solution the most feasible one.

An independent GEP accommodation study was also conducted and came to the conclusion that 30 Kg would be needed for the GEP instruments and the relevant services (power, command &control and communications).
The study has also identified an important criticality in the deployment of the Seismometer and the soil physical properties Instrument: these two instruments would require a robotic arm and this device is difficult to accommodate inside the baseline DM.
This requirement has mainly impact on the design of the DM Support and Egress System (SES), the platform supporting the Rover and many avionic equipment during landing, in which the GEP has to be mounted as well.

For sake of completeness the table below reports the status of the DM and Rover masses at the time of the SRR.

| | | NON-VENTED | VENTED |
|---|---|---|---|
| SOYUZ | DMC total mass (20% included) | 909 Kg | 1028 Kg |
| | GEP overall mass | 0 Kg | 20 Kg |
| | Rover Module total mass | 150 Kg | 165 Kg |
| | PPL mass | 8 Kg | 12.5 Kg |
| | | | |
| ARIANE 5 | DMC total mass (20% included) | 1211 Kg | 1113 Kg |
| | GEP overall mass | 20 Kg | 20 Kg |
| | Rover Module total mass | 150 Kg | 185 Kg |
| | PPL mass | 8 Kg | 16 Kg |

**Summary of the DMC mass in the SRR mission scenarios**

The launchability analysis for Soyuz (vented airbags) is based on a Carrier dry mass of 480 Kg for a propellant mass of about 1500 Kg, to deliver a 1000 Kg Descent Module into the Mars atmosphere from a hyperbolic trajectory.
The launch is feasible but the reserve is 3%, thus not meeting the ESA requirement.
As said above, the option 2 launch with AR 5 is now no more feasible due to the launcher performance in the Exomars launch declination and escape velocity range.

In conclusion, the mass budget, already identified as a critical item at the time of the SRR, is now made worse by the consolidation of the payload requirements discussed above.

***New mission scenario***

The combinations of the above constraints and other considerations have recently led to a re-definition of the baseline mission that can be summarised as follows:

- Launch date: Dec 2013
- Spacecraft Composite: Carrier + Descent Module
- Launcher: Ariane 5 from Kourou(back-up Proton from Baikonur - TBC )
- DM released from Mars orbit
- CM expendable (crash on Mars)
- Landing between 10° South and 30 ° North
- DM landing configuration with vented airbags
- Data relay function provided by a NASA spacecraft.

This scenario has been named enhanced baseline, as it basically responds to the need of increasing the payload mass (larger DM mass) and improves the landing accuracy that for the hyperbolic arrival is around 100 Km, driven by the navigation accuracy at DM release and the shallow flight-path angle at atmospheric entry.
Thus the ExoMars Enhanced Baseline mission scenario is feasible with launch in early December 2013 and a fast (Type-2) transfer. The Carrier + DM composite perform Mars orbit insertion in October 2014. The composite waits in orbit until the end of the then-current season of dust storms expected in May 2015, then DM landing follows. The Carrier is left to crash on the surface, far from the landing site. A backup mission option exists in 2015, with similar characteristics.
An important asset of DM release from orbit, made possible by the Ariane-5 scenario, is the large improvement in landing accuracy. The figure below shows the calculated landing accuracy (semi-major axis of 3-sigma error ellipse) vs. flight-path angle for hyperbolic DM release (the former Soyuz cases) and elliptic release (the Ariane cases). It may be noticed that there are two major contributions to this accuracy: the initial state (navigation) error, which is already ≈30km, independent of flight-path angle, in the hyperbolic case; and the flight-path angle itself. In the elliptic case, the 25-km accuracy requirement is met for any fpa < -12 degrees. In the hyperbolic case, a steep fpa < -14 degrees is required to keep the landing error < 100 km.

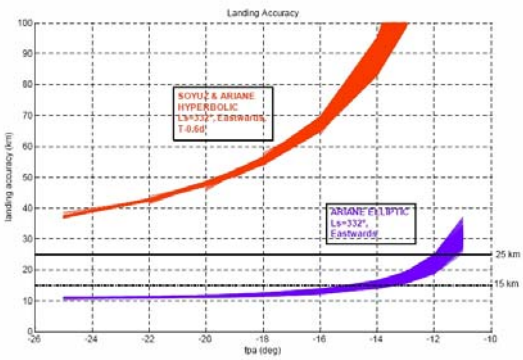



**Figure - Landing accuracy vs. flight-path angle for hyperbolic and elliptic release**

The detailed design of this option has started and will be concluded for the BCR.
The expectation is that it will allow a Descent Module carrying a full 16.5 kg Pasteur payload complement and a 30 Kg GEP.
The Rover design will be based on using two Radioisotope Heater Units to afford the Martian nights and periods with optical depth > 2.
The Ariane-Carrier is a spacecraft capable of ≈2.7-ton propellant load.
This Ariane-5 mission retains some of the benefits that motivated the original Option 2 scenario: quick (< 1 year) journey to Mars; free selection of landing epoch, and enhanced landing site accuracy, consequent on DM deployment from Mars orbit; larger DM and payload than in the Soyuz scenarios.
The above described mission can be implemented by a Proton launch too.

The table below shows a preliminary launchability budget, compiled using the most recent AR 5 performance. A budget is also shown for Proton; the Proton performance can probably be improved when a true launcher trajectory analysis is performed for the Exomars mission.
The mass of the DMC and Carrier are tailored for achieving the 5% launch reserve: in particular, while the DMC mass is supported by a bottom up approach, shown later in this paper, the Carrier mass is just the results of an interpolation w.r.t. the mass of the former baseline mission with Soyuz, and needs confirmation from the re-design of the bridging phase.

| | | Enhanced baseline | | Enhanced baseline | |
|---|---|---|---|---|---|
| | | 2A | 2B | 3A | 3B |
| | | Ariane 5 Carrier Nominal | Ariane 5 Carrier backup | Proton Carrier Nominal | Proton Carrier backup |
| | | 2013 | 2015 | 2013 | 2015 |
| Escape strategy | | Direct | Direct | Direct | Direct |
| Mars Transfer mode | | Type 2 | Type 2 | Type 2 | Type 2 |
| DM release mode | | Elliptic | Elliptic | Elliptic | Elliptic |
| OM circularisation mode | | | | | |
| Max cruise duration | day | 305,00 | 281,00 | 297,00 | 280,00 |
| *Time to/from storms* | *mo* | *-7,1* | *-4,6* | *-7,0* | *-4,7* |
| Launch mass | kg | 5.330,0 | 5.500,0 | 4.521,0 | 4.896,0 |
| Delta-v budget | m/s | | | | |
| Escape | | | | | |
| DSM | | 840,0 | 901,0 | 2,0 | 599,0 |
| Navigation | | 53,4 | 54,0 | 45,0 | 51,0 |
| *Total cruise DV* | | *893,4* | *955,0* | *47,0* | *650,0* |
| MOI | | 1057,0 | 1175,0 | 1285,0 | 1428,0 |
| DM deorbit | | 15,0 | 15,0 | 15,0 | 15,0 |
| *Total insertion DV* | | *1072,0* | *1190,0* | *1300,0* | *1443,0* |
| Pericentre raise | | | | | |
| Orbit plane change | | | | | |
| Circularisation | | | | | |
| *Total orbit DV* | | *0,0* | *0,0* | *0,0* | *0,0* |
| Total Delta-v budget | | *1965,4* | *2145,0* | *1347,0* | *2093,0* |
| Specific impulse | m/s | 318,0 | 318,0 | 318,0 | 318,0 |
| Delta-v margin | % | 5,0% | 5,0% | 5,0% | 5,0% |
| Propellant residuals | % | 2,0% | 2,0% | 2,0% | 2,0% |
| DM mass | kg | 1350,0 | 1350,0 | 1350,0 | 1350,0 |
| Carrier/Orbiter mass | kg | 750,0 | 750,0 | 750,0 | 750,0 |
| AOCS propellant mass | kg | 25,0 | 25,0 | 25,0 | 25,0 |
| Adapter mass | kg | 190,0 | 190,0 | 190,0 | 190,0 |
| Propellant mass | kg | 2096,4 | 2368,9 | 1282,8 | 2288,1 |
| Sylda | | | | | |
| Launch mass | kg | 4386,4 | 4658,9 | 3572,8 | 4573,1 |
| Launcher performance | kg | 5330,0 | 5500,0 | 4521,0 | 4896,0 |
| Reserve | kg | 943,6 | 841,1 | 948,2 | 317,9 |
| Reserve | % | 17,7% | 15,3% | 21,0% | 6,5% |

**Enhanced baseline launchability (Ariane and Proton 2013 and 2015)**

## *COMPOSITE SPACECRAFT ARCHITECTURE*

### *Enhanced Composite*

The re-design of the enhanced mission is presently on going and will be finalised at the BCR.
The figures reported herewith are therefore to be taken as preliminary values. In particular the configuration presented for the Carrier refers to the Soyuz version of that SC and will certainly turn into a larger SC.
On the contrary the Descent Module design is inherited from the option 2 of the B1 phase for which a “large” DM had already been studied.
A few optimisations of that design will improve the Rover accommodation and allow embarking the larger GEP inside the Lander.

### *Structural configuration*

Thus the enhanced Composite includes the Carrier Module (CM) and the Descent Module (DM) with the Rover. The figure below shows the structural configuration selected after a dedicated trade-off. It is based on an 1194-mm central tube hosting a single MON tank surrounded by four MMH tanks, the 400N

main engine and 6+6 10N thrusters. This configuration is not compatible with passive spin stabilization during the cruise. Therefore the composite is 3-axis stabilized, with body-mounted solar array and sun-pointing attitude. At the end of the cruise, the DM is released by a separation which also spins up the DM at a rate of at least 2 rpm.

In view of the increased Composite mass this configuration will undergo significant modifications as the 1 MON and 4 MMH tanks need to be increased to accommodate more propellant than in the Soyuz configuration.

The larger overall mass this will likely cause the 10N thrusters to be replaced with the 22 N ones, current baseline for the option 2.

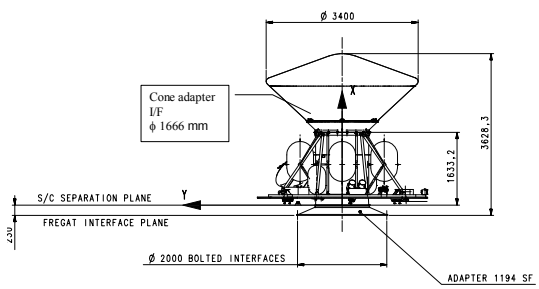
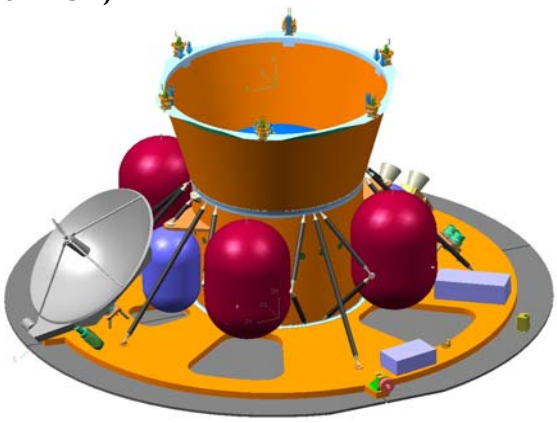



**Figure – Composite structural configuration**

A more detailed view of the Carrier is provided in the figure below, showing the interface cone for supporting the DM, external MMH tanks and HGA in stowed configuration.

**Figure- Carrier structural configuration (courtesy of TAS-F)**



### *Avionics configuration*

A tightly integrated command and control architecture is implemented minimizing mass while guaranteeing independency in the CM, DM and Rover developments. The solution bases on a shared computational capability (one computer, with proper redundancy, for CM and DM) and another dedicated computer, with its own redundancy, in the Rover. The RF subsystem has all transponders (1 main and 1 redundant for both UHF proximity link and X-band link to Earth) located in the Rover module, as this element is the final user of the subsystem. This solution was adopted for the phase B1 baseline with Soyuz launch that was, mass-wise, very critical.
However the usage of the Solid State Power Amplifier (SSPA) for several hours during the cruise causes problems of thermal dissipation inside the Rover and it is envisaged to turn to a more classical solution whereby the DM or CM will have their dedicated fully redundant RF X band link for the cruise and for the transmission of tones during the EDLP and the Rover will be fitted with a single RF link for its need on the Mars surface; indeed the Rover does not need a fully redundant X band link because this is already the backup of the UHF one. The decision whether to put the Composite RF units in the CM or DM will be taken in the on going B1 bridging phase.

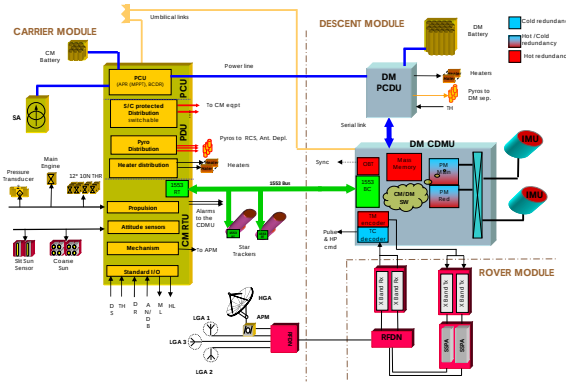



**Figure - Composite avionics configuration**

The cruise computer, CDMU, located in the DM, hosts two redundant microprocessors. For cruise AOCS, both sensors located in the Carrier (star trackers, sun sensors) and the gyros located in the DM will be used. The DM-CDMU also manages the RF units, including transponder and HPA, located in the Rover, LGA and 1m HGA, located in the CM, and Radio Frequency Distribution Networks located in both Rover and CM.

The DM to CM interface is based on a CM-RTU, used to collect the data from the sensors and to dispatch the commands generated by the DM to the CM actuators (main engine, thrusters) and units (PCDU etc.), running on a MIL-1553 bus.

The DM is thermally decoupled from the Carrier. Thermal control is managed by the DM-CDMU. Prior to separation, the Carrier thermal control will heat the DM equipment to their maximum acceptable temperature (thermal boost) to reduce the energy needed by the DM during the coasting and EDL phases, and hence to limit the size of the DM battery. After the separation and until landing, the thermal control of the DM and the Rover will be disabled (i.e. no power for heaters) and only monitors will be enabled. Then the Rover thermal control will start to operate until the end of mission operations.
Clearly the duration of the coasting phase is a driver for the battery design: the shorter the better. However from an operations p.o.v. it would be safer to command the DM separation well before its entry into the Mars atmosphere (EIP), to allow a retry in case of failure in the release mechanisms.
Presently the Composite design is targeted to a release 2 hrs before the EIP.

In the Electrical Power System (EPS) architecture, each module has its own power subsystem, as independent as possible, but each power subsystem is linked with the others in the composite configuration, to share the power sources and optimize mass and performance.

The power sources include the solar array installed on the CM, a rechargeable battery located in the CM, but under responsibility of the Composite's EPS, and an additional rechargeable battery in the DM. In normal sunlit condition, the power provided by the SA is conditioned inside the CM-PCDU and distributed to the CM units, by regulated +28V power bus, and to the DM PCDU, which distributes the power to its own units by another +28V regulated power bus. The DM additional battery is mainly for providing power to the DM units after its separation.
A trade off is on going to evaluate the mass advantages in case the rechargeable battery is replaced with a primary (non rechargeable) battery. However it is known that these batteries have good energy storage capacity w.r.t. rechargeable ones but suffer from a strong limitation in the maximum continuous current they can supply and need to be oversized to overcome this problem. Generally, for short time usage the rechargeable battery should still be advantageous.

### *DESCENT MODULE*

The DM is a blunt-shaped re-entry capsule, mounted on the upper side of the Carrier Module. The DM remains attached to the CM through the Cruise and the Mars Orbit Insertion.
From the achieved Mars orbit (presently a 4-sol) until approaching Mars it is released into a trajectory allowing its landing on the Mars surface, in daylight, at

the selected landing site. After surface operations to allow egress of the Rover and deployment of the GEP experiments, the DM functions are nominally completed and its operating life is ended.

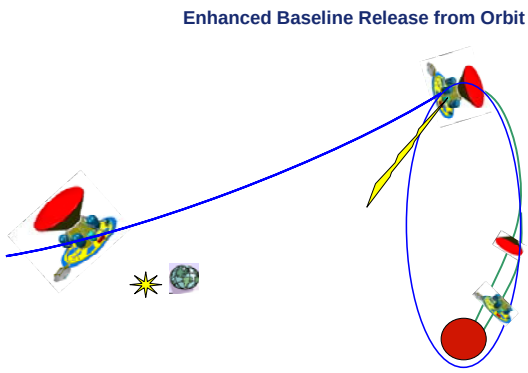



**Figure – DM release from Mars orbit**

The phase B1 has been conducted analysing two landing technologies in parallel:

- The non-vented airbag design, implying heavier parachute and heavier structure and Rover egress system, partially compensated by the lighter (solid-rocket-based) RCS
- The vented airbag design employing a liquid-propellant RCS and allowing more payloads (Pasteur and GEP).

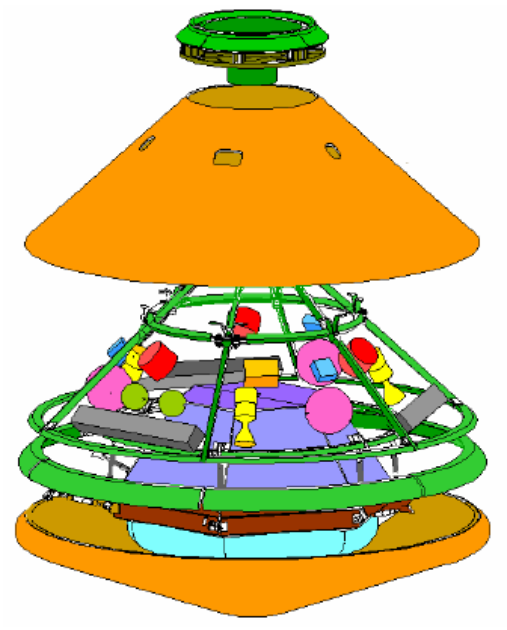
For the reasons said above the vented solution has been chosen for the bridging phase study.
An important advantage of vented configuration is that the airbags and their associated structure are lighter because the airbags are on the underside of the landing platform only.
The vented airbags are presently under test by Aerosekur (I) in the CIRA – Capua (I) testing facility. The figure below shows the drop test recently executed.
To safeguard the program in case the vented airbags are shown to be inadequate the DM still retains the capability to use the more conventional non-vented airbags, however in that case a significant reduction of the embarked payload would have to be afforded.

**Figure – Vented airbags drop test in CIRA – Capua (I)**

The DM for the vented airbags option is shown in figure below.
From a structural p.o.v. the DM is made up of three separable elements: the Front Shield, the Back Shell, and the Lander.

The **Front Shield** is an Al honeycomb composite with CFRP skins, covered with light ablative material. Its diameter is 3.4 m. It is separated from the back shell after the deployment of the parachute. The conical **Back Shell** is made up of a structure covered by a back shield made from the same materials as the front. This structure provides support for the accommodation of the CM/OM separation mechanisms, some DM equipment such as parachute and thrusters, and the interfaces with the Front Shield and Landing Platform.

The **Lander** accommodates the Rover, the GEP and all the other DM service subsystems. The integrated Support Structure and Rover Egress System SES and Air Bag System (ABS) form the landing system.



The current mass budget of this configuration is shown in **Error! Reference source not found.**.

| Descent Module | | | | |
|---|---|---|---|---|
| *Vented Airbags Config.* | | Mass (kg) | | |
| **S/S** | **BEE** ( Best Engineering Estimate) **Kg** | **MF** (*Maturity Factor*)**%** | **MMM** (Maturity Mass Margin) **Kg** | **Current Mass kg** |
| Front Shield | 101,6 | | 10,2 | 111,8 |
| *Back Shield* | 42,18 | | 4,22 | 46,40 |
| *Back shell* | 119,0 | | 11,9 | 130,9 |
| Parachute | 57,68 | | 11,54 | 69,22 |
| Airbags System | 32,8 | 20% | 6,6 | 43,46 |
| Reaction Control System | 93,9 | | 18,8 | 112,65 |
| Avionics (DH + GNC) | 26,40 | | 5,08 | 31,48 |
| Support System and Rover Egress System | 77,2 | 8% | 6,2 | 83,35 |
| Electrical Power System | 56,0 | | 7,6 | 63,624 |
| TT&C Equipment | 1,5 | | 0,2 | 1,66 |
| Thermal Control System | 10,0 | | 2,0 | 12,0 |
| GEP | 30,0 | 0% | 0,0 | 30,0 |
| ROVER MODULE | 185,0 | 10% | 18,5 | 203,5 |
| Balance mass | 10,0 | 0% | 0,0 | 10,0 |
| *TOTAL MASS* | *843,3* | | *102,7* | *950,0* |
| | System Margin (%) | | | 20% |
| | System Margin (kg) | | | 190,01 |
| | GRAND TOTAL MASS | | | 1140,05 |

**Table - Descent Module mass budgets**

In this configuration the mass of the Lander is about 550 Kg.
Thanks to the larger allowed DM mass the 1140 Kg above can be exceeded by further optimizing the SES shape (see figure below); this will translate into a larger Lander mass that cannot however go beyond 600 Kg, the maximum figure for which the vented airbags are designed for.

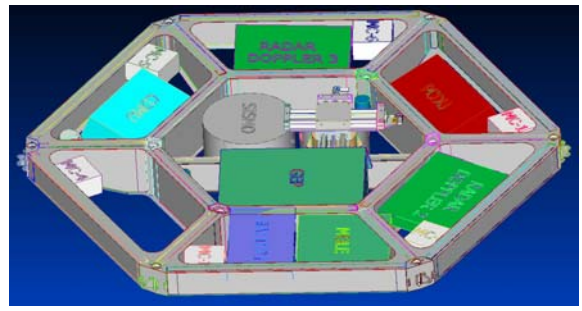


**Figure – SES layout**

***Entry, Descent and Landing System***

The EDLS includes the heat shields (front and back), the parachutes and the RCS. The heat shield TPS

baseline is the lightly ablative Norcoat Liege material (NetLander heritage).
Its mission begins with the separation of the DM from the CM and ends when the DM landing platform is fully deployed.
Once separated from the CM, the DM begins a coasting phase leading to the Mars Atmospheric Entry Point about 120 km above the surface. The duration of the coasting is < 2 hours in the enhanced baseline option.

On atmospheric entry, the heat shield sustains the aerothermodynamics loads, guarantees the DM stability and decelerates it to a velocity compatible with parachute deployment (≈Mach 2, around 7km altitude).
The parachute is a two-stage system for mass optimization. When ≈Mach 2 is reached, the 11m-diameter Pilot (drogue) Chute is deployed to ensure transonic stabilization and deceleration down to Mach 0.8. The 19 m diameter Main Parachute is a ring-slot canopy chute with high drag coefficient and stable aerodynamic properties. Both parachutes have Nylon canopy and Kevlar lines.
Meanwhile, once the parachute has further decelerated the DM to ≈Mach 1, the Front Shield is jettisoned.

In the vented configuration, the landing control strategy is activated with the back-shell (housing the liquid propulsion system) still attached to the Lander. The parachute system is jettisoned at an altitude of a few hundred meters, and the (liquid, throttled) propulsion controls the vertical and lateral velocity to nominally zero. Then the airbags are inflated, the back-shell is jettisoned and the Lander is in free fall for the last ≈10m (the minimum altitude above the ground being determined by the airbag inflation time of 2s).

The duration of the descent sequence of events is a few minutes.

At touchdown, the airbags are designed to absorb the Lander final energy and then immediately deflated and refolded. After the airbags retraction is complete, the Lander is deployed. The duration of the Landing event will not exceed 2 hours.

The RCS approach associated with vented airbags is presently based on modulated thrust, likely to be delivered by a set of liquid rockets: the set includes 3 large rockets (the engine readily available is the Aerojet MR80-B (3191N)) and 2+2 small thrusters for roll control. The propellant load, calculated from 50m/s $\Delta v$ + 5% margin, is 49.6 kg.

## *PLANETARY PROTECTION*

### *Definition and requirements*

Planetary protection concerns the minimization of biological cross-contamination between Earth and other planets. **Bioburden** is the term given to the biological contamination on an item. Of particular interest to Martian missions are the bacterial spores. These spores are extremely resistant to adverse conditions, and it is the level of these spores that the COSPAR requirements concern themselves with.

Meeting the planetary protection requirements through any scheme is difficult, and impacts the entire time span of the mission, from design to operations.

The ExoMars Descent Module Composite (DM + Rover) is classified as Planetary Protection **Category IV b)** for which typical requirements are:

- Bioburden reduction / active sterilization less than 30 bacterial spores (Viking post-sterilisation level) on free external & internal surfaces for the parts coming into contact with the samples
- Microbiological controls
- Clean room assembly (with bioburden controls)
- Lander recontamination prevention (bio-shield)
- Organic material inventories.

In the baseline enhanced mission, the Carrier will crash on Mars. In this case, entry thermal analysis must be provided to demonstrate that the Carrier will be sterilized during the atmospheric entry. This approach was taken for MER (hyperbolic entry), for which it was demonstrated that the cruise systems would reach sufficient temperatures for sterility of all parts. However the approach has to be confirmed for an elliptic orbit entry.

Because some analytical instruments of the Pasteur payload require high chemical cleanliness, beside COSPAR principles for category IV-b mission, ultra-high cleanliness limits will be imposed (e.g., 1ng/cm$^2$ total Carbon) with respect to the more sensitive Pasteur instrument(s).

### *Implementation*

The presently adopted spacecraft level approach is to clean the Pasteur Analytical Laboratory (and drill) to Viking post-sterilization levels and perform **aseptic assembly** of the remainder of the spacecraft, to achieve Viking pre-sterilization levels (cf. Beagle 2, MER, etc.)
The **aseptic assembly** is based on piecewise sterilization of the spacecraft components followed by assembly in an environment which preserves the levels of sterilization.

The Final Dry Heat Microbial Sterilization (DHMS) of the entire SC Composite is not the baseline.
The figure below shows the Planetary Protection flow at system level.

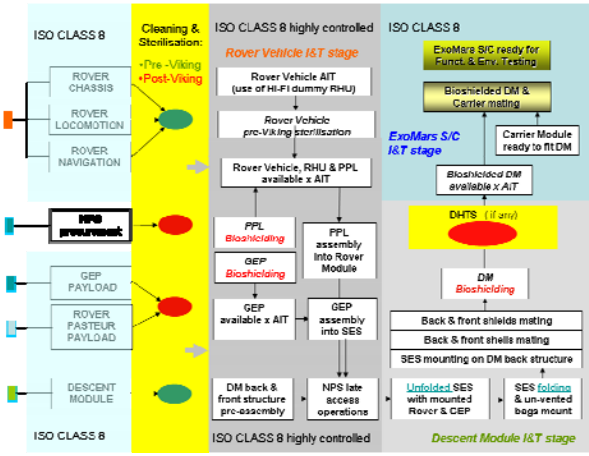



**Figure -Planetary Protection approach- final DHTS excluded**

## *CONCLUSIONS AND PLANNING FOR THE IMPLEMENTATION PHASE*

The Exomars mission is presently undergoing a redesign to adapt it to the enhanced baseline configuration indicated by the Implementation Review. This adaptation will be strongly based on the achievements of the phase B1 which has studied three different alternatives: Baseline (with expendable Carrier), option 1 (with the European data relay Orbiter) and option 2 (with an Orbiter also doing the function of carrier).

The Composite SC will be derived from the baseline expendable Carrier configuration.
The DM will remain the one studied for the option 2, with few improvements and the possibility to increase its mass.
The Rover will also be derived from the then option 2 Rover, accommodating 16.5 kg of Pasteur Payload; but its mass is now expected to be ~ 200 Kg, compared with the previous 185 Kg.

The phase B1 bridging is now on going with the purpose of allowing this re-design to a level such that a very short phase B2 can be conducted, leading to a Composite PDR in April 2008 and a Rover PDR in June. In such a way the detail design C/D phase can start in the second semester 2008.
The equipment level PDR's will be conducted in the course of the same year and the first semester of 2009.

The Carrier CDR, in December 2010, is the first at module level and will authorise the CM PFM Integration.
Rover and DM CDR will follow in March and July 2011, respectively.
The Composite CDR, in November 2011, will give the go-ahead for the Composite PFM Integration and testing which will be completed in May 2012 with the FAR and shipping to the launch base.

Due to the presence of the RHU's inside the Rover and the Lander, it's necessary to allow their integration at the launch site. As a consequence also the integration of the Rover onto the SES and inside the DM must be done there.
This, combined with the aseptic assembly constraints, brings to a long launch campaign (6 months approximately).
Nevertheless a good schedule margin is allowed for the new launch date on December 2013 and the Industrial team is working hard to meet this mandatory target for Europe.