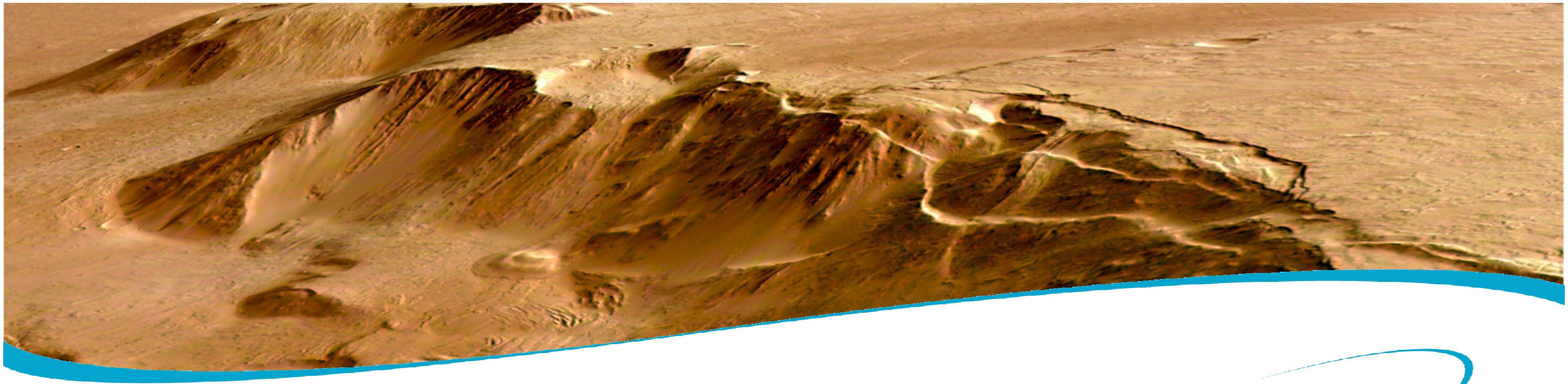


The ExoMars Mission

Turin, 23 September 2010

Pasquale Santoro
ExoMars Project Manager

Template reference : 100181708K-EN

BU-OOS

Turin, 10 September 2010

The ExoMars Programme will be the first of the ESA Aurora Exploration Programme with the objective of demonstrating key flight and in-situ enabling technologies and will pursue scientific investigations.

The Mission objectives will be pursued as a part of a broad cooperation with NASA.

Two missions are foreseen for the 2016 and 2018 launch opportunities to Mars

2016 Mission under ESA lead, consisting of an Entry Descent & Landing Demonstrator (EDL-demo) module and an Orbiter module to provide data relay functions for the subsequent ESA-NASA missions and investigate Martian atmosphere trace gases and their sources;

2018 Mission under NASA lead, to which ESA will provide a Rover system that shall demonstrate mobility on the surface and the capacity for reaching below the surface (drill), and deploy the Pasteur Payload to search for signs of past and present life on Mars and investigate the water/geochemical environment.

Program Phases

- **Preliminary Design Phases**
  - Phase B2:
    - Completed in March 2009 with the Interim System PDR
  - Phase B2 Extension (B2X)
    - To include changes to mission based on International Cooperation modifications.
    - Completed in March 2010
  - Phase B2 Second Extension (B2X2)
    - Leading to a the System PDR for the ExoMars Programme
    - Will be completed in March 2011

- **Technology Development and Critical procurements**
  - Advanced C/D in parallel with the Phase B2
  - Advance CD second Slice in parallel with the phase B2X2
  -

- **Development and Qualification Testing Phase**
  - Phase C/D starting in April 2011

ExoMars Industrial Team

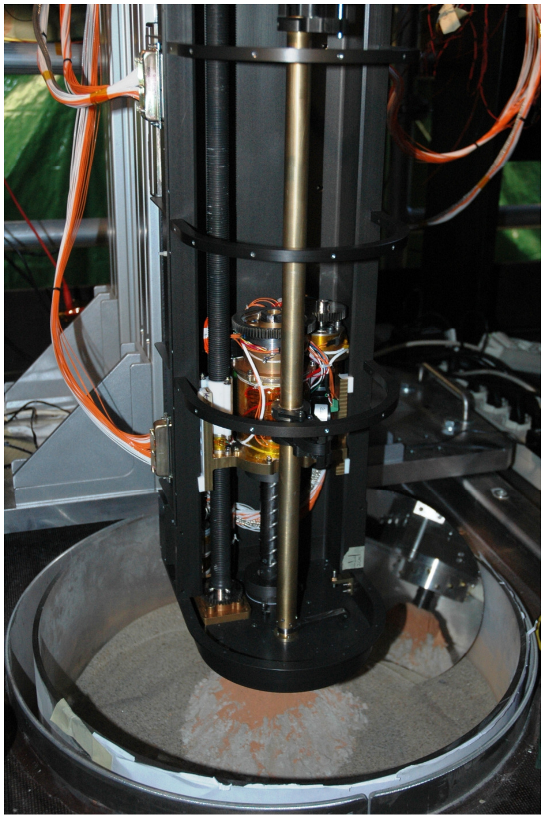
The Industrial team is going to be finalized in accordance with the ESA best practices

The main contractors and all the supplier of equipment requiring technology development are already on-board

This allowed, during the previous phases, the development of technological breadboards:

- Rover Vehicle Locomotion
- Drill
- Sample Preparation and Distribution System (SPDS)

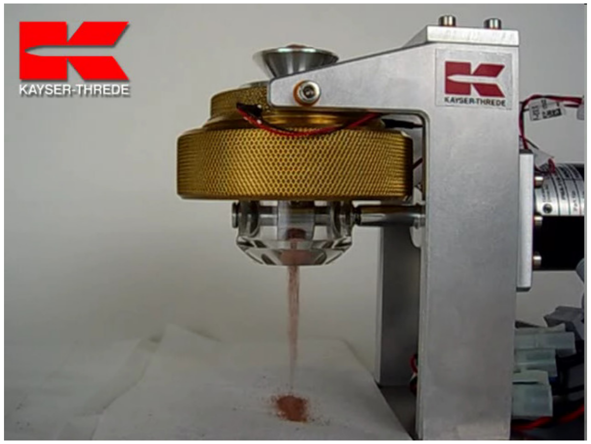
Development BBs



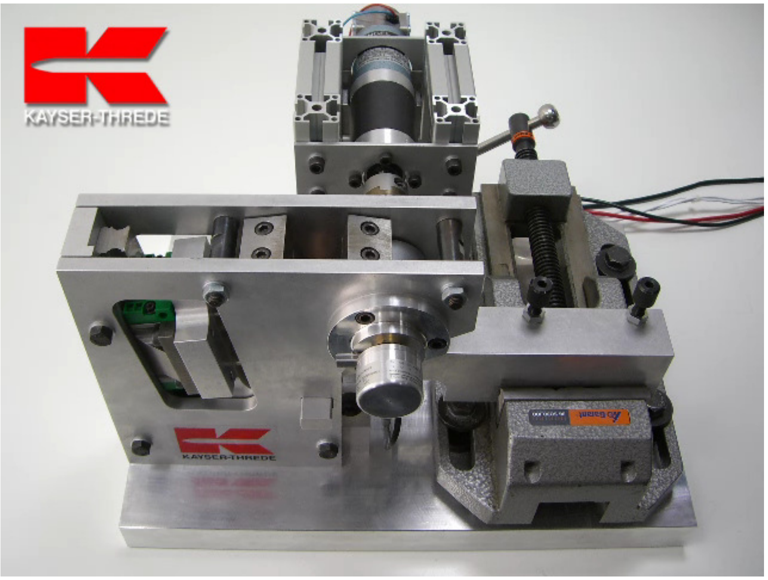
Drill BB

Locomotion BB

Development BBs



Dosing Station BB



Milling Station BB

ExoMars Industrial Team

Industrial Team- Main Contractors

- **Thales Alenia Space Italia** — Prime Contractor & System Integration
  - **Orbiter Module** — TAS-I
    - **Orbiter Module Bus** — TAS-F
      - **Mechanical Thermal Propulsion** — OHB
    - **Main Separation Assembly (MSA)** — RUAG
    - **Science Instruments** — ESA CFIs
  - **EDL Demonstrator (EDM)** — TAS-I
    - Entry & Descent — TASF
    - Surface Platform Structure & Separation Mechanism — SENER
    - Front Shield Separation Mechanism — SENER
    - **Scientific Instruments** — ESA CFIs
  - **Rover Module** — TAS-I
    - **Drill** — Galileo Avionica
    - **Rover Operations Control Centre** — ALTEC
    - **Rover Vehicle** — Astrium Ltd. UK
      - **Chassy & Locomotion** — RUAG
    - **SPDS** — Kaiser Threde
    - **Analytical Laboratory Drawer** — TAS-I
    - **Pasteur Payload** — ESA CFIs

Industrial Team –Equipment Contractor

EDL Demonstrator

- Radar Doppler Altimeter: TAS-I
- Central Terminal Power Unit: TAS-I
- Parachute: Aero Sekur (Italy)
- UHF Transceiver (common with the Rover Vehicle): QINETIQ (UK)
- Inertial Measurement Units: Northrop Grumman (USA)
- Heat shield Astrium SAS-ST (France)
- Front Shield Structure: SENER (Spain)
- Parachute Deployment Device : General Dynamics (USA)
- Back cover Structure: TAS-F (France)
- Reaction Control Subsystem: TAS-F (France)
- Thrusters: Astrium (Germany)

Rover Vehicle

- On Board Computer: RUAG AB

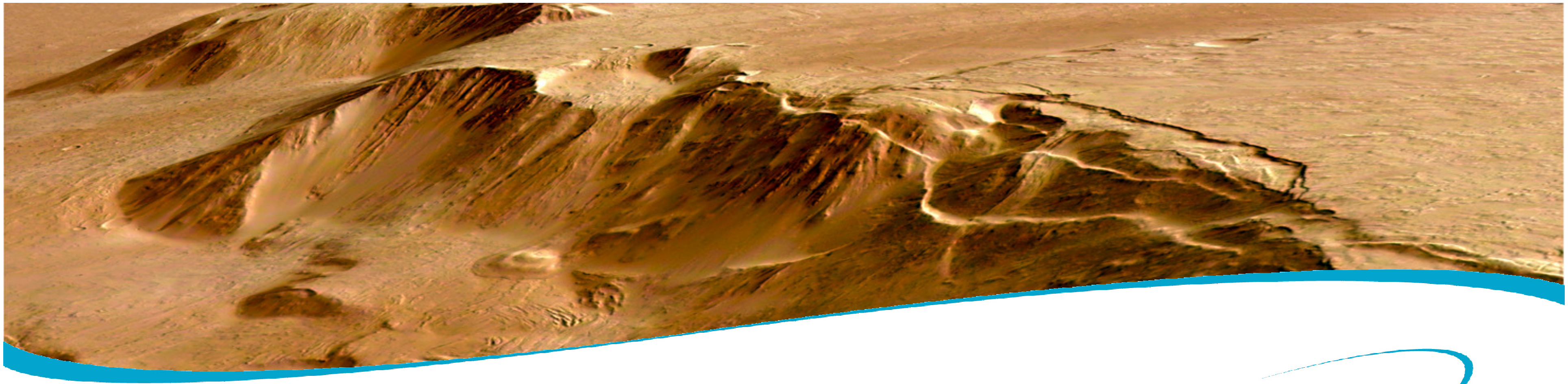
Planetary Protection

The ExoMars activities will be carried out in accordance with the ESA Policy on Planetary Protection, which complies with the COSPAR planetary protection recommendations.

The ExoMars mission is classified as Planetary Protection Category IVa (2016) and IVb (Rover being a mission with life detection instruments and potentially accessing special regions on Mars).

Implementation of Planetary Protection rules and requirement are design and AIT drivers:

- Compatibility with sterilization methods
- Equipment lay out
- AIT facilities and integration methods



The 2016 Mission

Carlo Cassi
ExoMars Systems Engineering Manager

Template reference : 100181708K-EN

BU-OOS

Turin, 10 September 2010

2016 Mission

- **ESA leadership**

- **Technical Objectives**
  - To demonstrate European ability to land a surface package on Mars

- **Scientific Objective**
  - Characterize Martian atmosphere gases (“Trace Gas”)

- **Data Relay**
  - Provide communications link to ground for future (2018-20) ESA/NASA missions

- **Operations**
  - Operations will be will be performed by ESOC.
  - Science Operations for the NASA Instruments of the Orbiter will be managed by NASA, having ESOC the responsibility of commanding and telemetry monitoring of the Instruments through coordination with NASA responsible groups

2016 - Mission Overview

DM Release: Oct 2016

Launch: Jan 2016

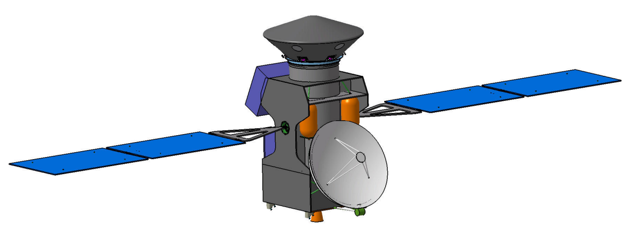
Arrival: Oct 2016

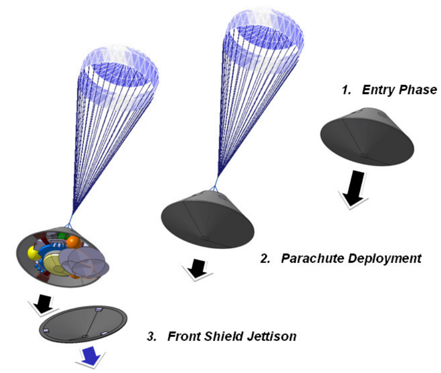
Landing Accuracy : 50 km 3σ (goal 35 km) along track landing ellipse semi-major axis

Separated Elements

Launcher: e.g. Atlas V 421-

Spacecraft Composite

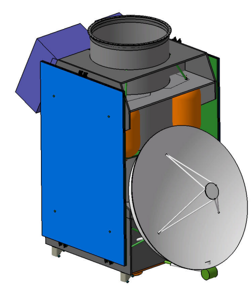




EDL Demonstrator

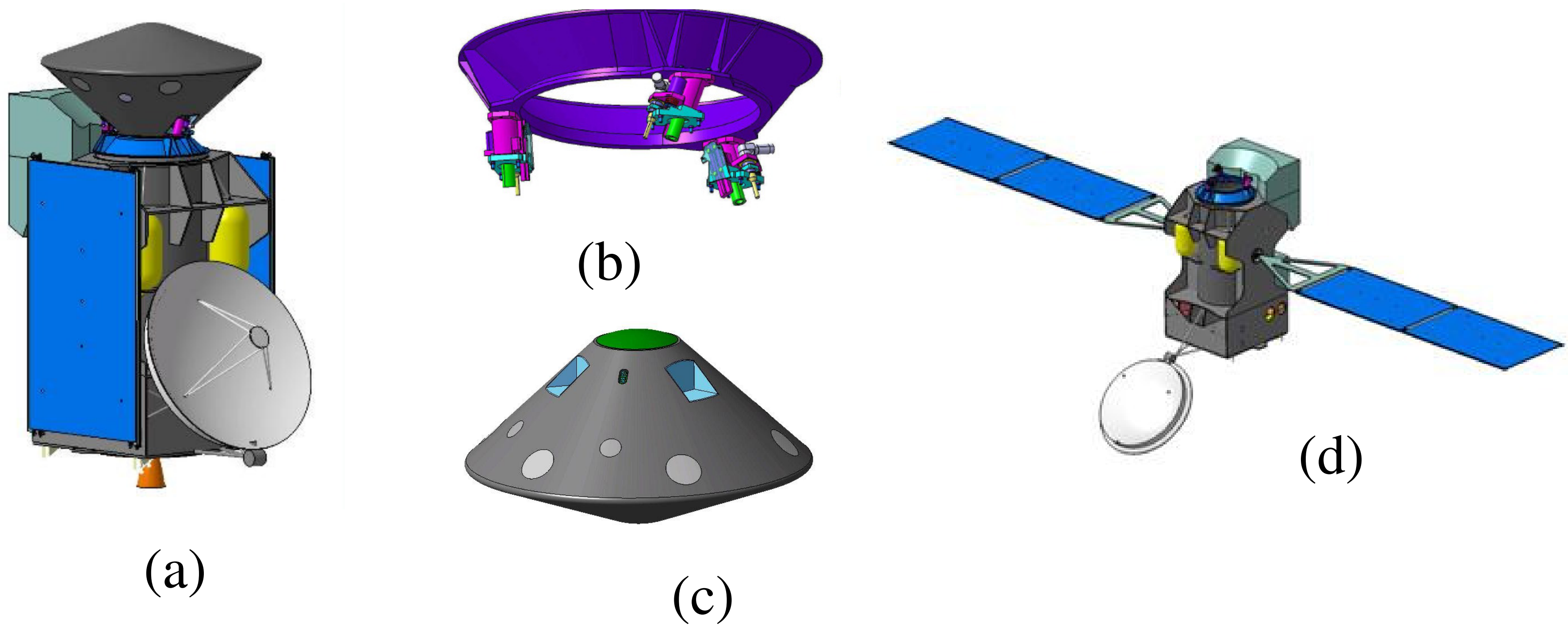
Back-up:
NASA DSN

Primary link:
ESA DSN



ExoMars Orbiter

2016 Mission Composite Spacecraft



ExoMars Composite Spacecraft, from left: (a) stowed composite, (b) Main Separation Assembly, (c) EDL Demonstration Module, (d) Mars orbit configuration after EDM deployment.

2016 Mission - Spacecraft Composite

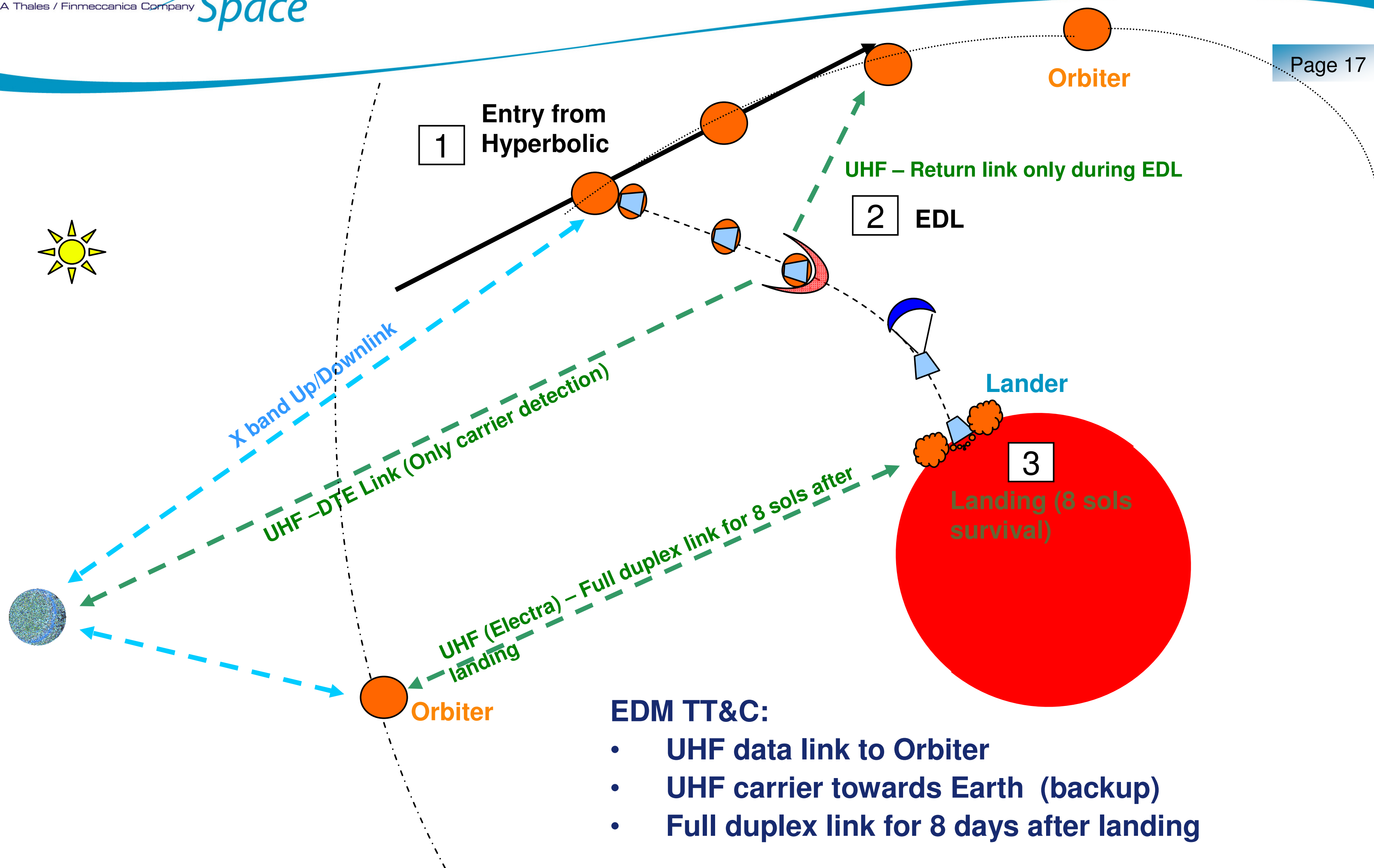
- Maximum launchable mass* =4404 kg (TBC following launcher performance analysis)
  - Orbiter dry mass* = 1365 kg
  - EDL Demo dry mass* = 600 kg
  - Propellant needed for the mission = 2190 kg
  - Max propellant load* = 2439 kg
- **Power generation capability**
  - **Two solar wings 20 m^2 for 1800 W @ 1.6 AU distance from Sun**
  - **Two Lithium-Ion batteries providing about 5100 Wh BOL (nameplate capacity 180Ah).**
- **Communications**
  - **Two Deep Space Transponders boosted by two 65 W TWTA**
  - **One 2.2 m HGA**
  - **Three LGA's**
  - **Two Electra Transponders for proximity links (Orbiter-Mars assets)**
- **Propulsion**
  - **1x424 N Main Engine**
  - **12x10 N Reaction Control Thrusters**

2016 - Mission Timeline

Event	Date
Launch window	7-27 January 2016
Deep Space Manoeuvre	20-29 May 2016
OM-EDM separation	16 October 2016
EDM landing	19 October 2016 (Ls = 244°)
OM Mars Orbit Insertion	19 October 2016
1st pericentre of insertion orbit (EDM pass 1)	23 October 2016
2nd pericentre of insertion orbit (EDM pass 2)	27 October 2016
Nominal start of aerobraking	8 November 2016
Nominal end of aerobraking / start of science phase	25 June 2017
End of science phase (1 Martian year + 30 days)	13 June 2019
Arrival of 2018 ExoMars Rovers	15 January 2019
Nominal end of mission	31 December 2022

Table 1: Nominal sequence of events

2016 - Communications



EDM TT&C:

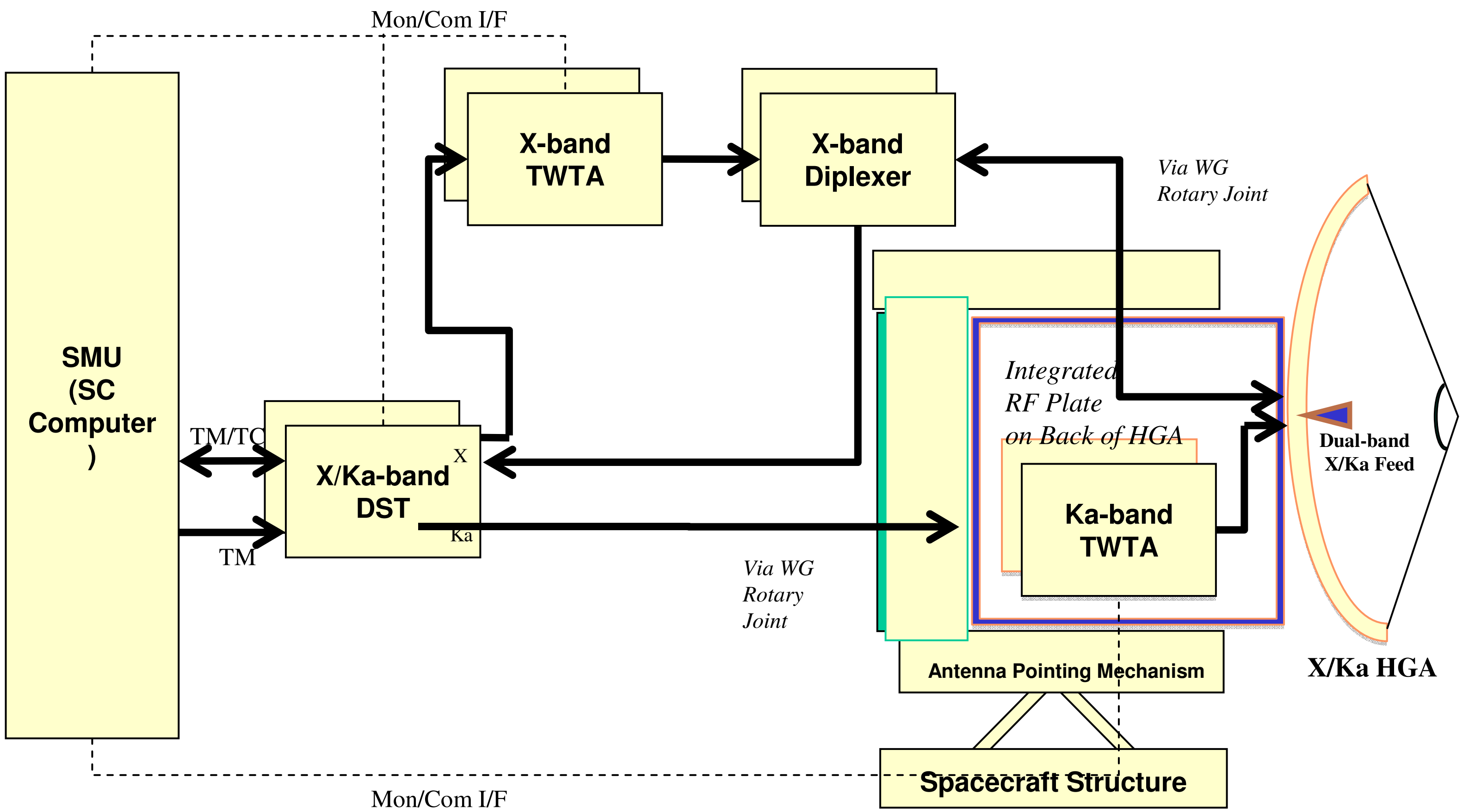
- **UHF data link to Orbiter**
- **UHF carrier towards Earth (backup)**
- **Full duplex link for 8 days after landing**

- **Orbiter Module - Science**

  - 5 Science Instruments on-board to remotely sense the presence, quantity and potential sources of Methane in the Martian atmosphere
    - MATMOS (Mars Atmospheric Trace Molecule Occultation Spectrometer)
    - SOIR-NOMAD (Solar Occultation in the InfraRed (SOIR) – Nadir and Occultation for Mars Discovery (NOMAD)
    - EMCS (ExoMars Climate Sounder)
    - HISCI (High Resolution Stereo Color Imager)
    - MAGIE (Mars Atmospheric Global Imaging Experiment)

- **Orbiter module - Communication**
  - X-Band system for the Orbiter-to-Ground link
  - Ka Band System back-up Orbiter-to-Ground link
  - UHF-Band system for the proximity link between Orbiter and Mars surface assets.

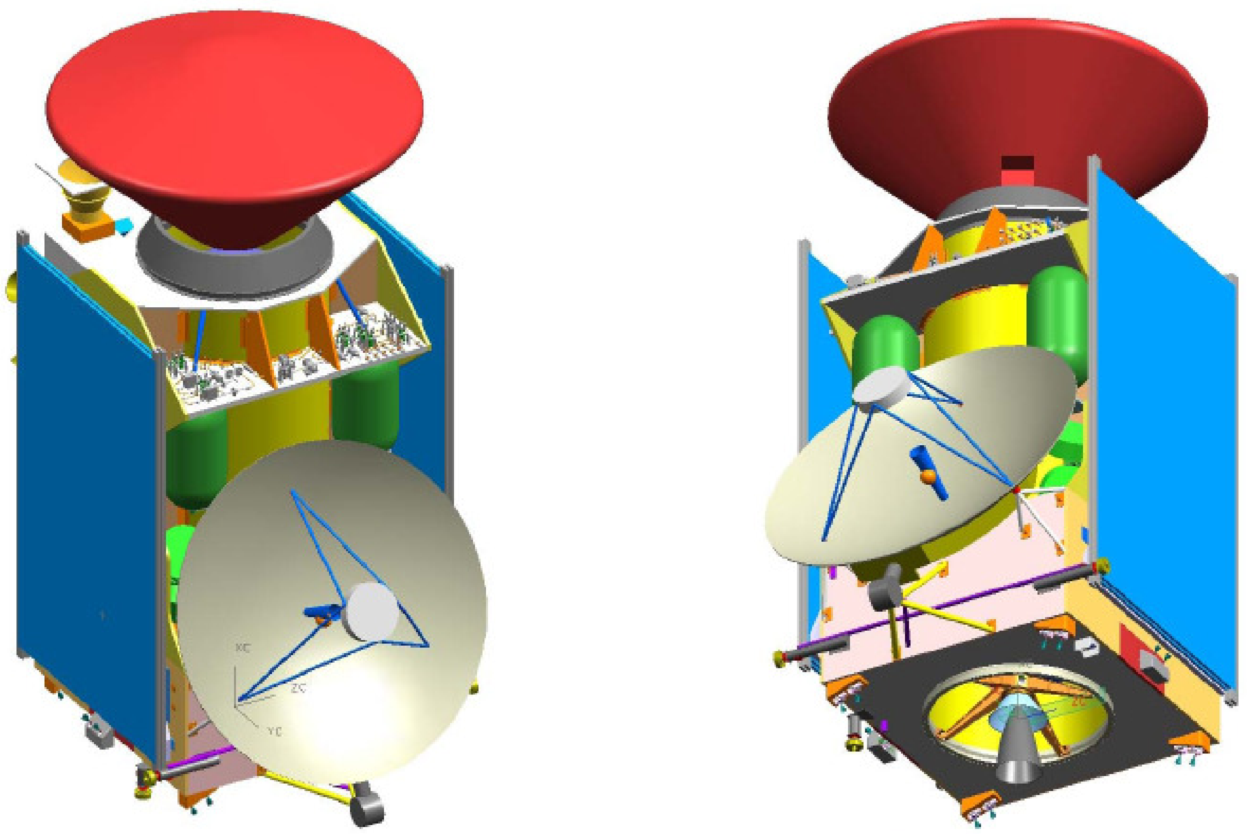
2016 Mission Orbiter Module



2016 Mission Orbiter Module

Design Parameter	*Ka –band Jan '10*	*Ka-band July '10(Delta)*
Antenna Efficiency	***31%***	***Est. 50% (+2 dB)***
Circuit Losses	***-5.2 dB***	***Est. -2.2 dB (+3.0 dB)***
Antenna Pointing Loss	***-3.9 dB***	***Est. -0.6 dB (+3.3 dB)***
	8h pass	**8h pass**
Min Daily Data Vol, Gb	***1.7***	***11.0***
Max Daily Data Vol, Gb	***47.1***	***91.9***
Avg Daily Data Vol, Gb	***11.2***	***39.5***
Min Elevation Angle	***20°***	***20°***
Avg Data Rate	***697 kbps***	***2,146 kbps***

Orbiter Module Configuration (at Launch)

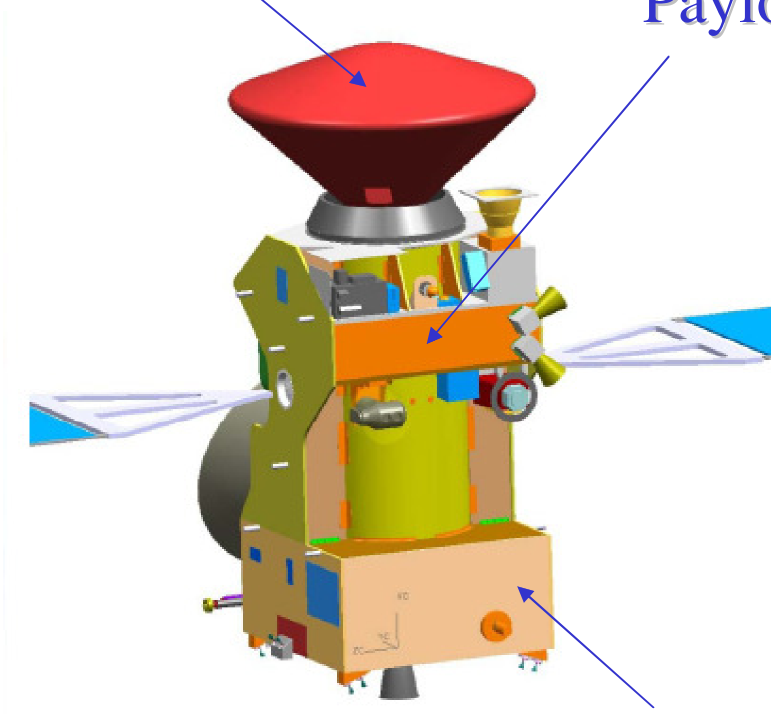


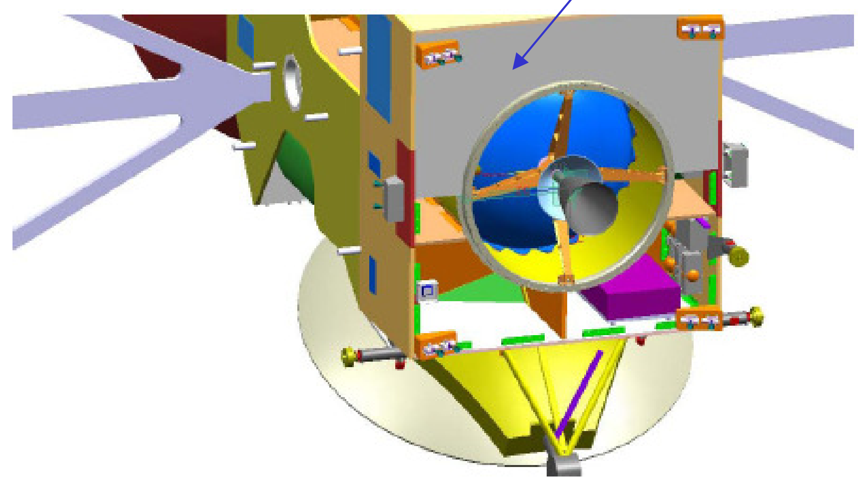
Orbiter Module Configuration

EDM

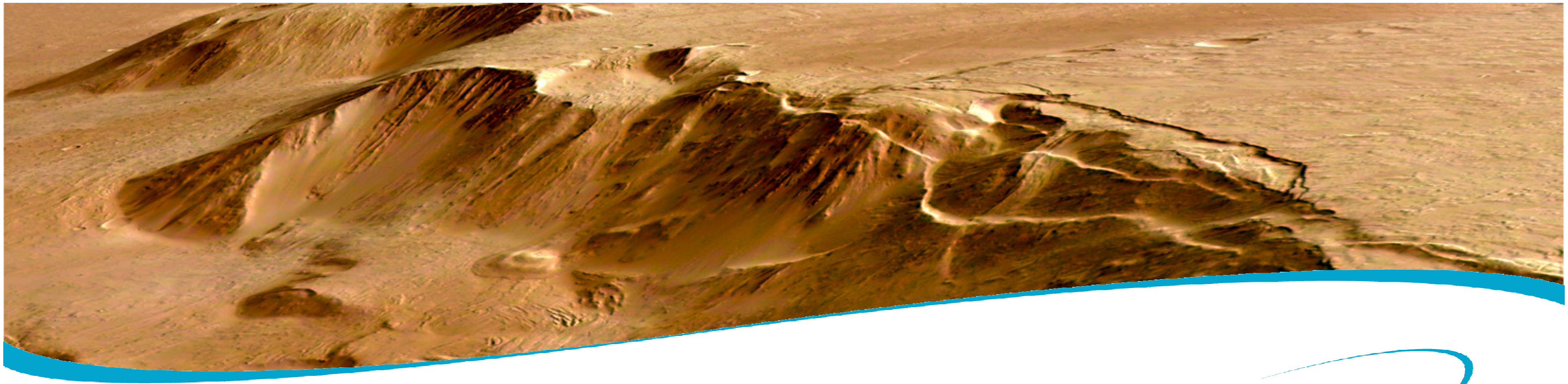
Payload Deck

Propulsion Deck





Service Module (Avionics)



The 2016 Mission

EDL DEMONSTRATOR MODULE

Maurizio Capuano
ExoMars EDM Manager

BU-OOS

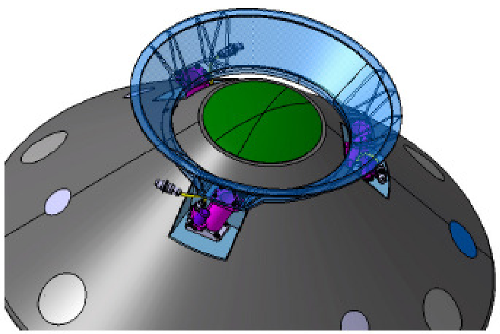
Turin, 10 September 2010

2016 Mission EDL Demonstrator

- Heat shield diameter of about 2.4 m - MER-like aerodynamic profile
- 600 kg entry mass along a hyperbolic entry trajectory.
- System designed to survive the possibility of a severe dust storm.
- Heat Shields based on Norcoat-Liege (ablative material Beagle2 heritage)
- Deployment after entry of a single stage Disk gap band parachute
- Approach to Mars surface by using a closed-loop Guidance, Navigation and Control (GNC) system that will guide a liquid propulsion system by the actuation of a cluster of thrusters operating in pulse on-off mode.
  - Radar Doppler Altimeter assembly
  - Inertial Measurement Units
  - Pulsed modulated engines for final braking 400 N hydrazine engines (CHT 400)
- 300 kg landing mass
- Surface Platform release and landing on a crushable structure

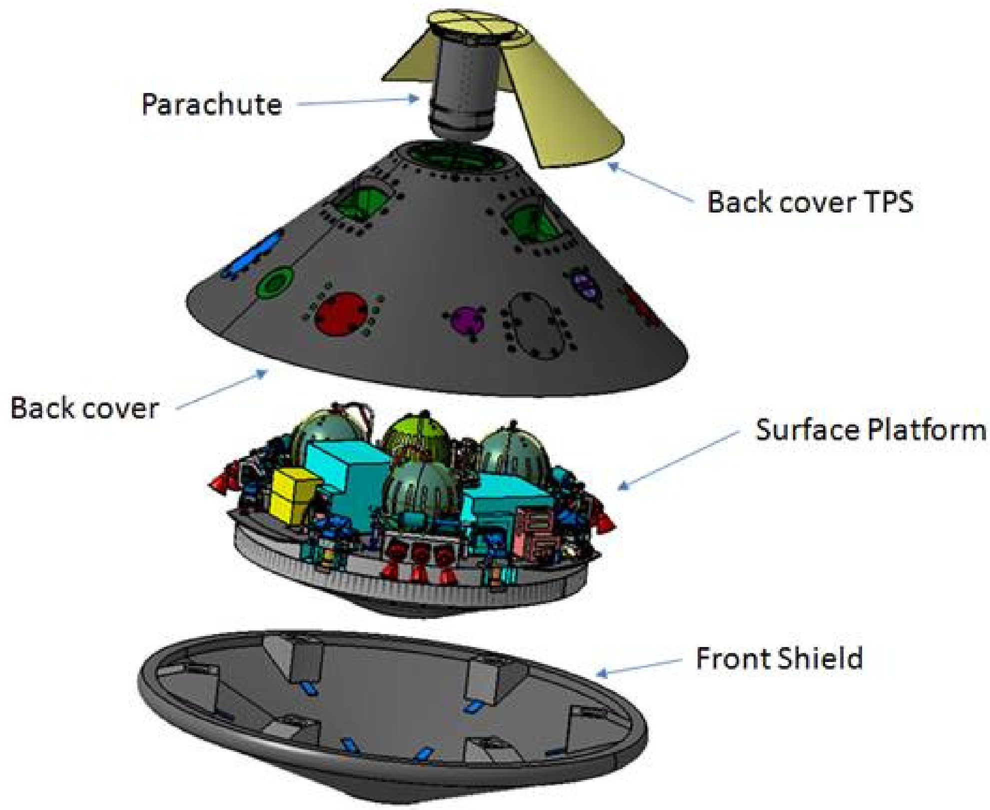
The EDL Demonstrator will survive on the surface of Mars for 8 sols by using the excess energy capability of its primary battery. Surface Payload on board of the Surface Platform will provide experimental information on key atmospheric and surface physical-chemical processes.

Mechanical Configuration

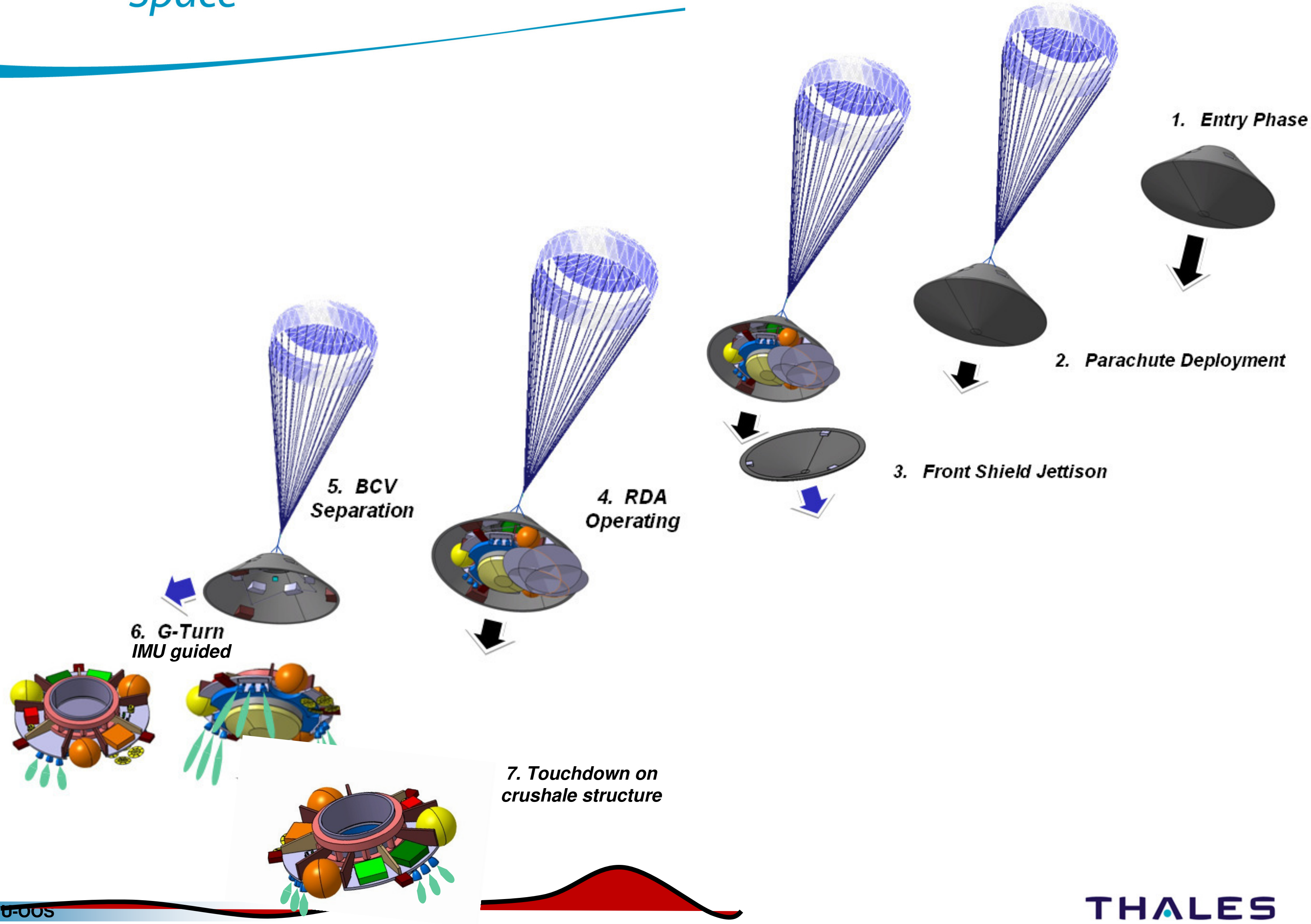


The EDM is constituted by the following main subsystems/eq

- AEROSHELL
  - Front Shield Separation Mechanism (FSSM)
  - Parachute (PAS)
  - Back Cover (BCV)
  - Front Shield
  - Back Shield
  - Thermal Control System (TCS)
- SURFACE PLATFORM
  - Structures
  - Reaction Control System (RCS)
  - Electrical & Power System
  - Data Handling System
  - GNC sensors
  - UHF telecommunication equipment
  - Thermal Control System (TCS)
  - Surface Sensor Suite (ESA CFI)



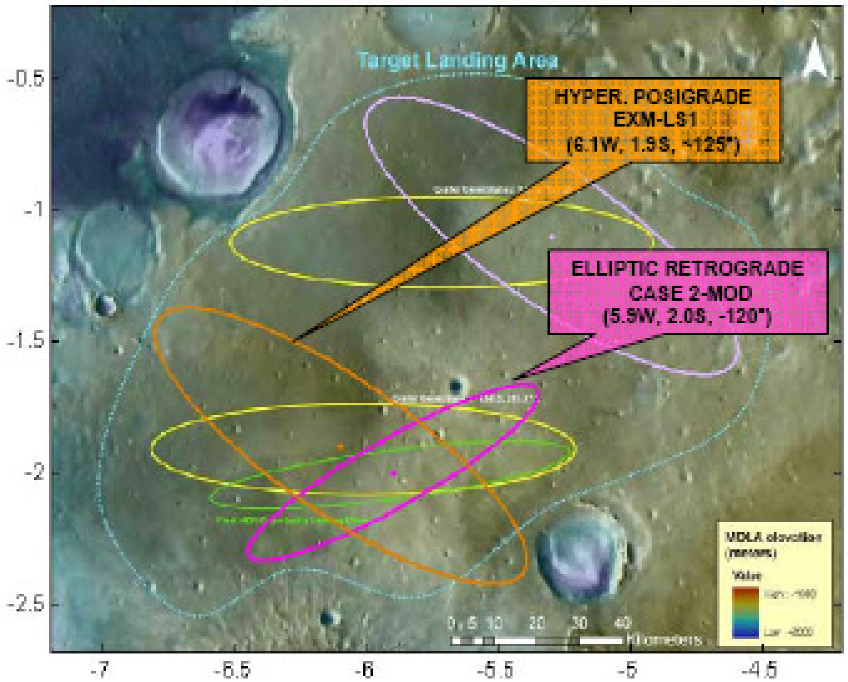
EDL Events

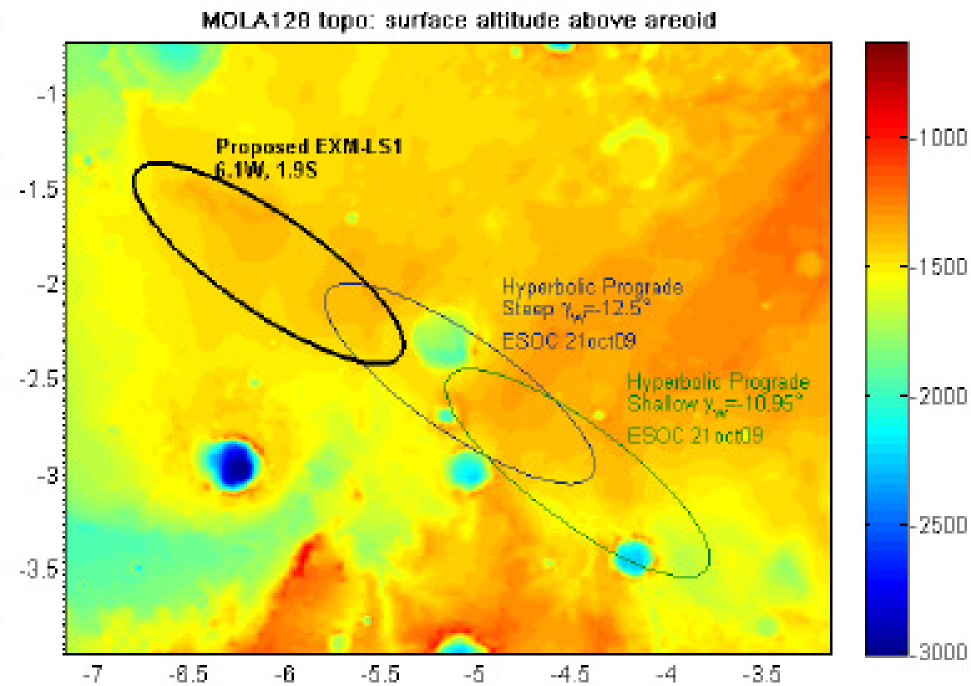

1. Entry Phase
2. Parachute Deployment
3. Front Shield Jettison
4. RDA Operating
5. BCV Separation
6. G-Turn IMU guided
7. Touchdown on crushale structure

2016 Mission Landing Site: Meridiani

- **Reference 6.1°W, 1.9°S. h_{MOLA}=-1424m**

Elliptic Ref. Site2-mod, Lon = 5.9W, Lat = 2.0S, ZMOLA= -1437 m
Hyperbolic Ref. Site3 ➔ EDL LS1, Lon = 6.1W, Lat = 1.9S, ZMOLA= -1424 m



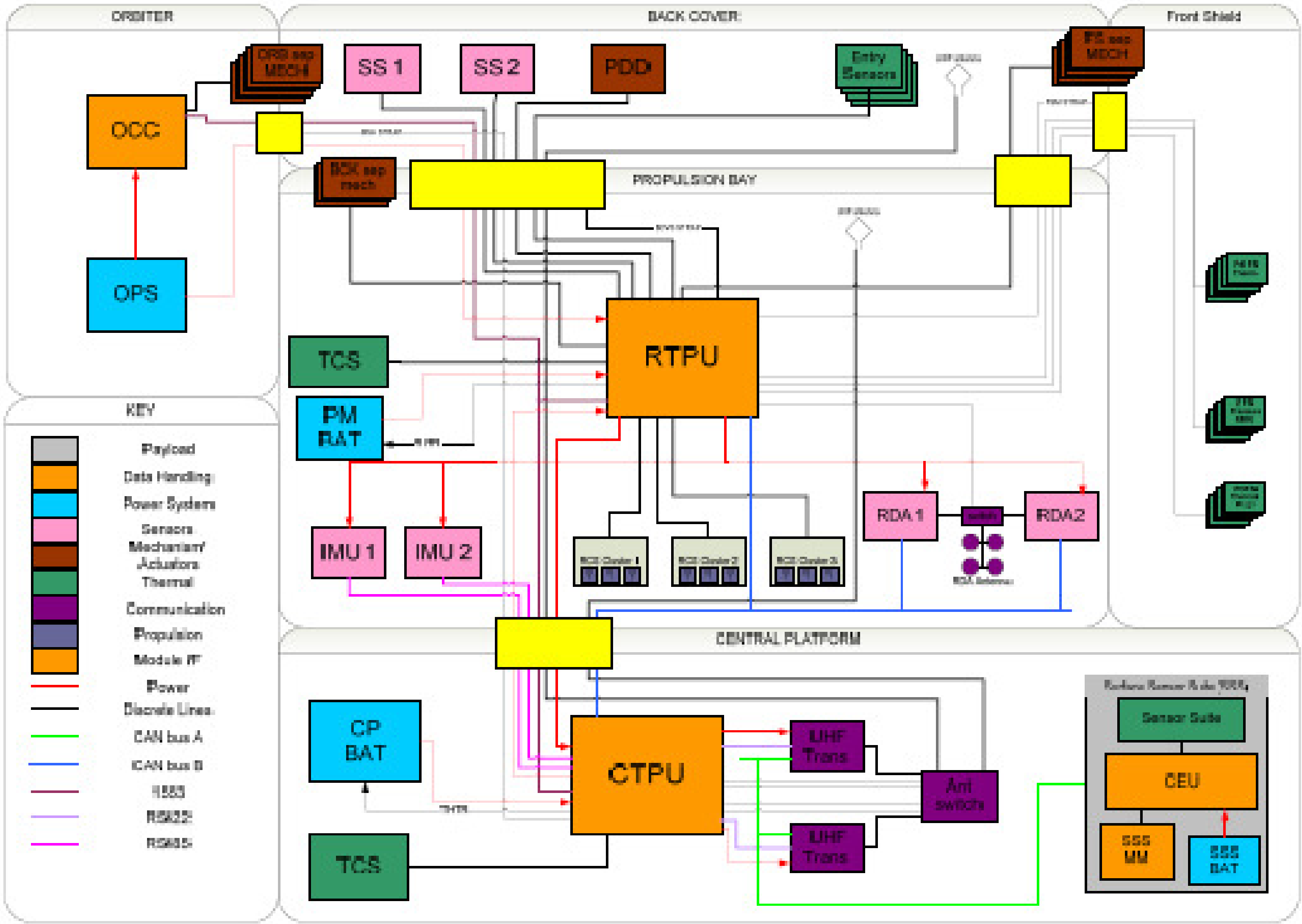


EDL Sensors

- Monitoring TPS and structural performance
  - Thermal Plugs, Thermistors, Recession sensors
- Monitoring heat fluxes
  - Calorimeters, Radiometer (optional)
- Monitoring flow field, aerodynamic performance, atmospheric density
  - Pressure sensors
  - Rebuilding of aerodynamic attitude
  - Better reconstruction of drag, possible application to density reconstruction coupled with accelerometers (aerodynamic models)
- S/S performance
  - Accelerometers on Surface Platform structures for impact load measurement
  - Strain Gages on PAS bridles
  - Pressure and temperature sensors on RCS lines
- Visual (optional)
  - Camera for event (separation, PAS deployment)

  OR
  - Camera for terrain imaging and application to future visual navigation systems, hazard mapping techniques

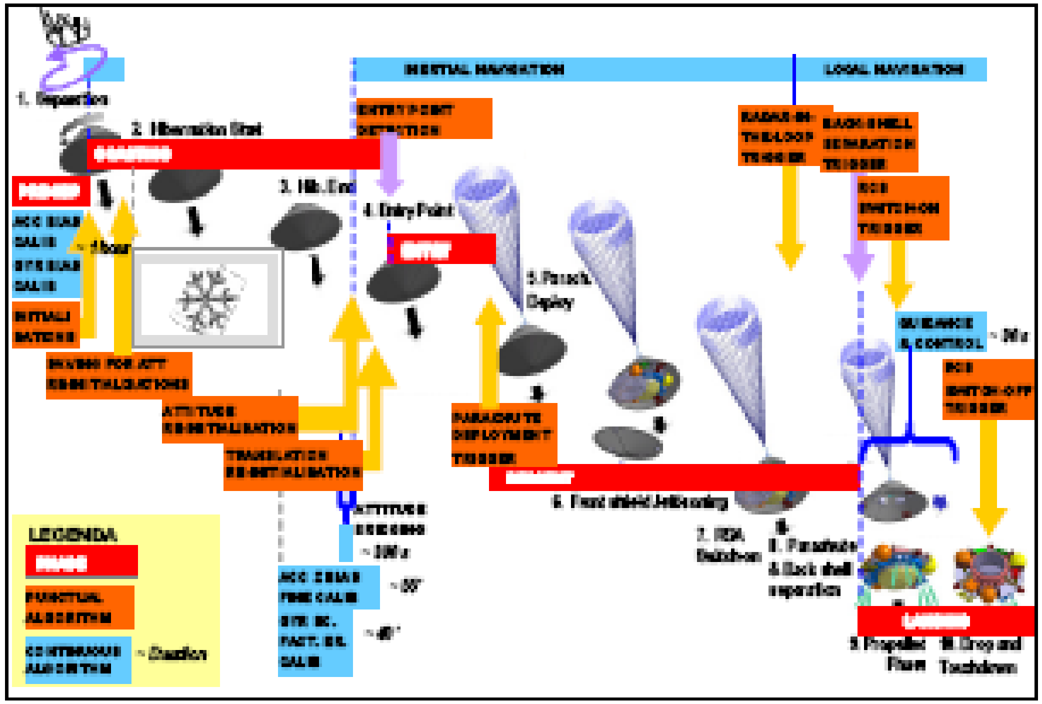
Functional Architecture



GNC Design

GNC drivers

- Fully autonomous
- Inertial Measurement Unit (x2) for attitude measurements
- Radar Doppler Assembly for velocity and slant range measurement
- Sun Sensors (x2) for EDM attitude reconstruction after hibernation exit.
- Accommodation constraints



Radar Doppler break-down

- Electronic units (x2)
- Beam router (x 1)
- Antennae (x 4)
- All items mounted on a structural support plate capable to absorb the impact load
- Major I/Fs
  - Crushable structures

Parameter	System Requirement
Precision in the altitude control [m]	1.5(*) ± 0.75
Vertical velocity at RCS switch off [m/s]	-1.0 ÷ 1.0
Horizontal velocity at RCS switch off [m/s]	<2.0
Angular displacement vs LV at RCS switch off rel. [°]	<7.0
Angular rate vs LV at RCS switch off [°/s]	<10.0

(*) Distance from the lowest point of the platform to terrain. For altitude at CoG the distance between the lowest point of the platform and the CoG (~0.4 m) has to be summed.

BackCover Design

Backcover drivers

- Capacity to sustain loads (launch, entry loads, parachute loads..)
- Provide stiffness reqt
- Accommodate orbiter MSA I/F, PAS ring, Lander struts, FS/BCV mechanisms, EDM services (UHF..)
- Predictable aerodynamic shape evolution (47°)
- Mass

Backcover structure

- 2.4m diameter cone
- Honeycomb T300/M18 25mm with 0.3mm carbon skin. Reinforcement defined by zones (up to 1.2mm skin)
- Major I/Fs
  - MSA I/F brackets
  - Lander CFPR struts
  - EDM services (UHF, Sun sensors..)
  - FSSM bracket
  - PAS ring

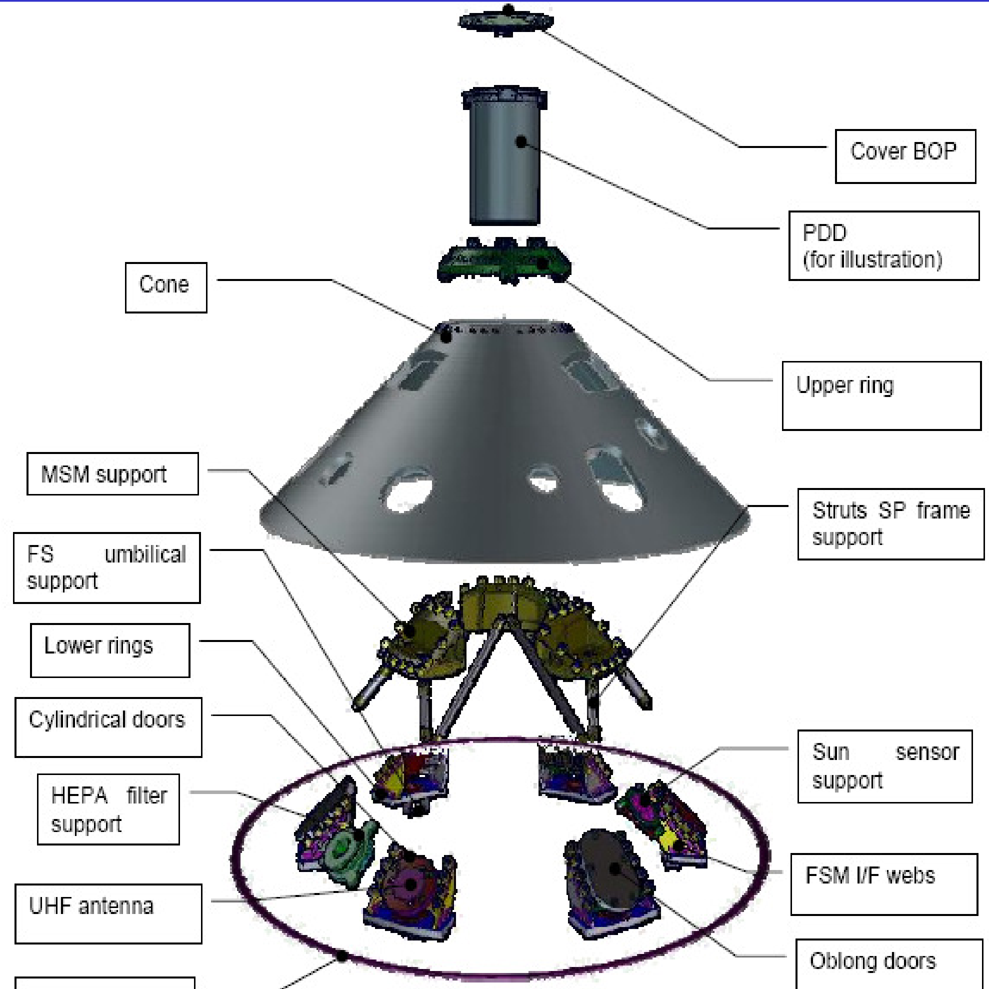


Figure 4.6.1-1BCV structure

Heatshield drivers

- Entry mass
- Aero-thermal loads (flux and energy)
- Mechanical loads (entry loads)
- Protect singularities (antenna, doors, BOP…)
- Predictable aerodynamic shape evolution (70°)
- Mass & Heritage & PP

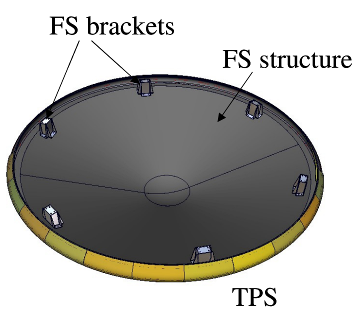
Instrumentation

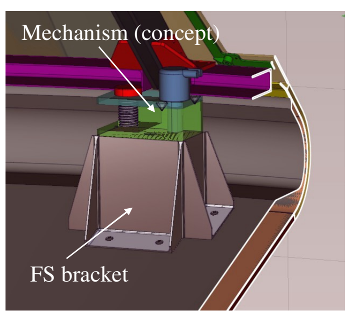
- 7 FS 3BCV Thermal plugs
- 5 FS Pressure sensors
- 5 FS Surface recession
- 3 BCV Integrated pressure sensor & calorimeters (CFE)
- 1 BCV Radiometer (CFE)

Frontshield structure:

Honeycomb 20mm Alu core with M40J/M18 carbon skin

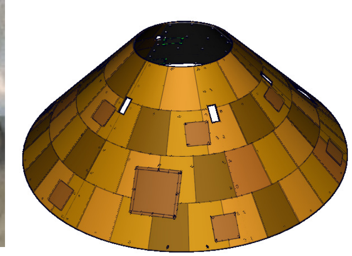
- Accommodate FS bracket separation mechanisms
- Accommodate balancing mass
- Bioseal silicone gasket





Thermal Protection

- •Ablative Norcoat Liege tiles
- • FS 16.8mm evolutive thickness
- • BCV TPS 7.4mm on cone, 9.0mm on BoP
- •. Heritage (NetL, B2, ARD)
- • Qualified wrt max flux and CO_2 up to 1.8kw/m2 to be tested at 2.1kW/m2 +/-10% with a new joint design



Parachutes System Design

Parachute drivers

- Decelerated mass
- Inflation performance Aerodynamic stability (stable at 0° AoA)
- BFR >1.4 for separated items
- Drag & Mass performance
- Mass, Heritage & PP

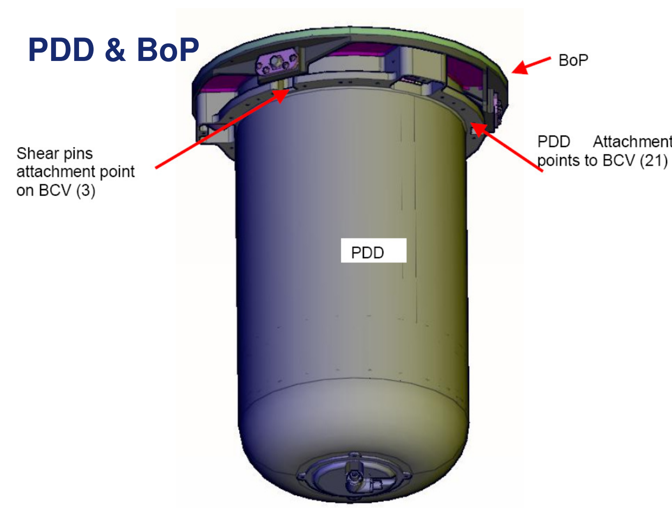
Parachute deployment device

- Mortar selected
- >30m/s deployment velocity
- Shear pin retention system
- Cartridge propellant

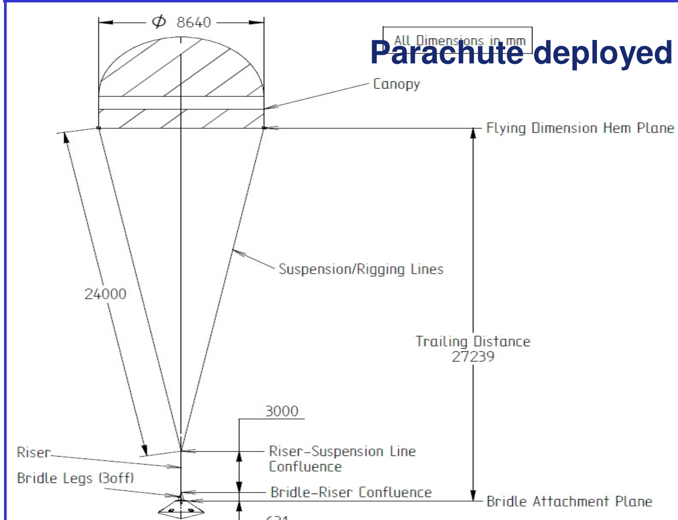
First stage parachute

- 12m nominal diameter Disk Gap Band
  - Require EDM ballast mass for Fs separation
- 22.4% geometric porosity
- Bag&sleeve deployment
- Packing FP 600kg/m3
- Piston retention by parachute
- Supersonic inflation at Mach 2.1
- 75kN max inflation load
- Huygens heritage

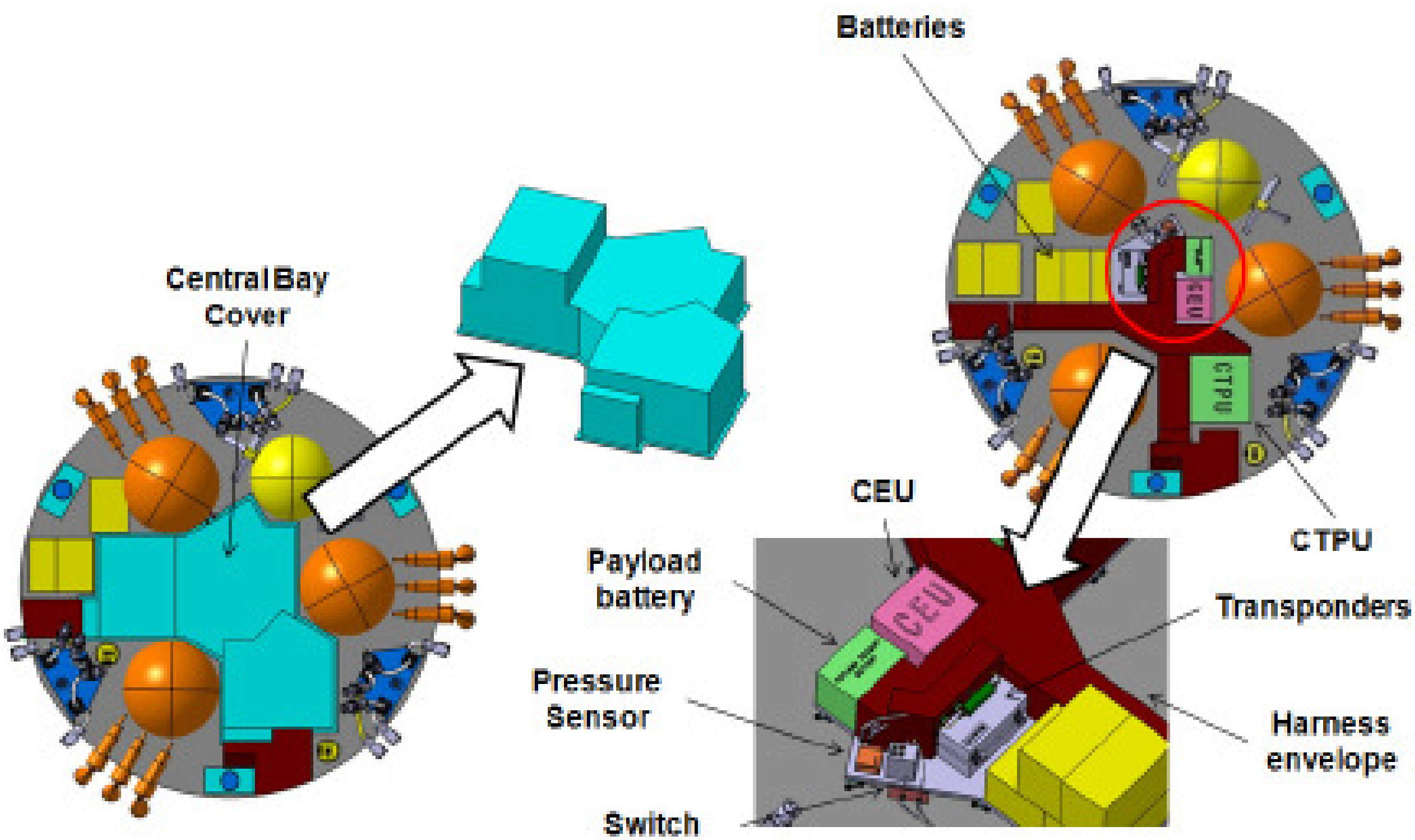
PDD & BoP



Parachute deployed



EDM Surface Platform Overview

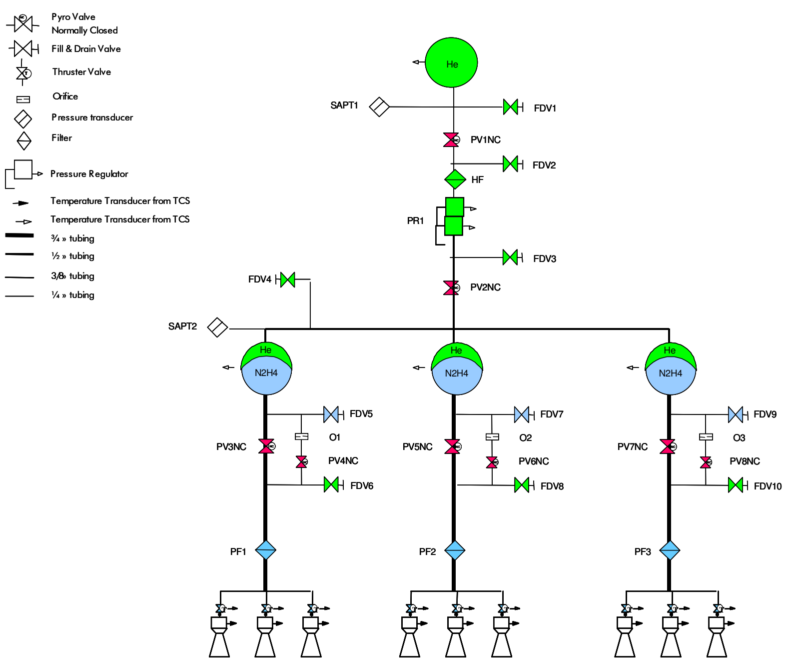


Reaction Control System Design

RCS drivers

- Thrust capability
- Propellant mass
- GNC performance (response time)
- Mass, Heritage & PP

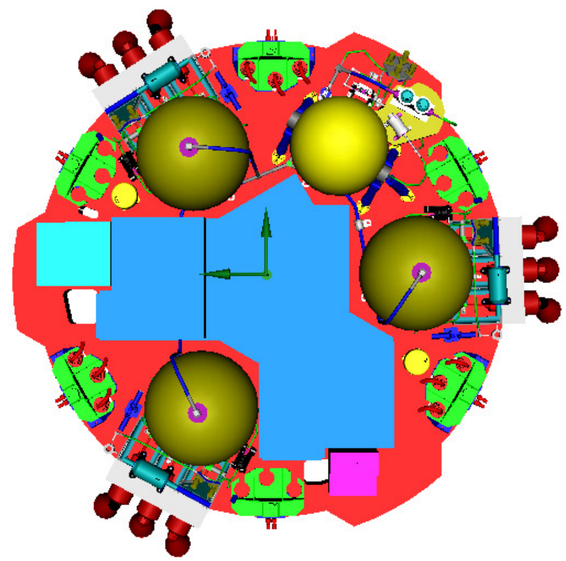
Architecture overview



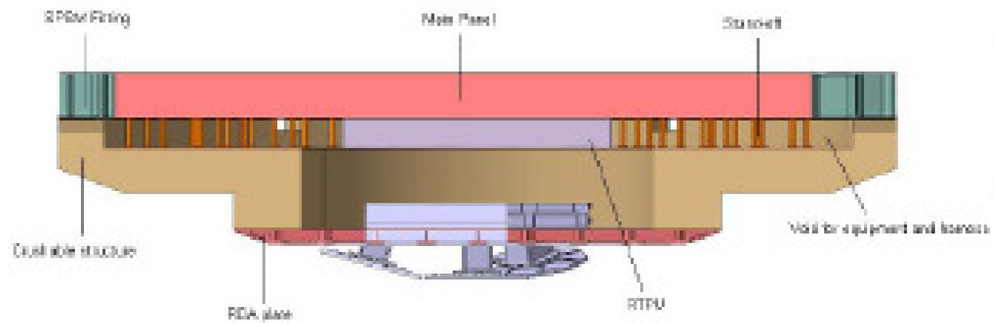
RCS Key features

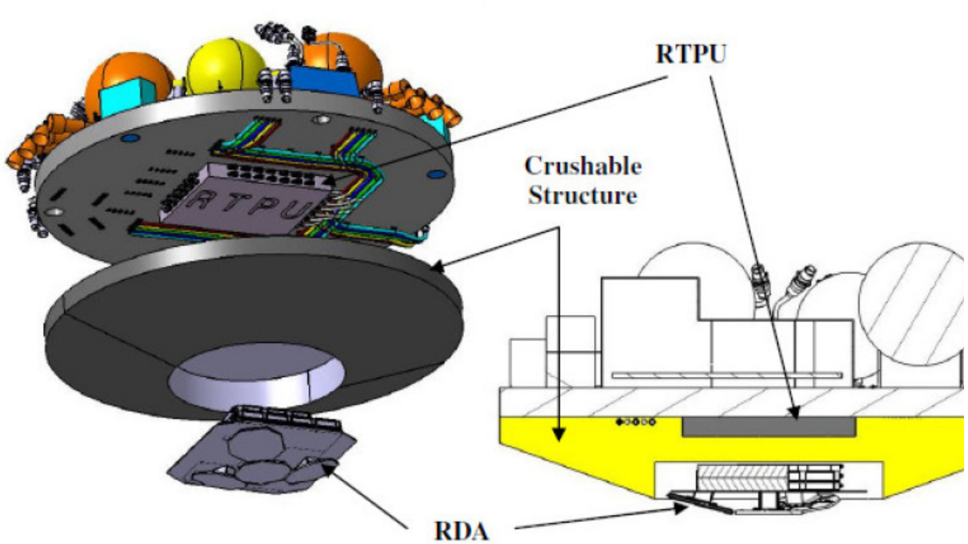
- Independent branches :
  - No fluidic cross talk between cluster branches
- 3x3 hydrazine pulses CHT-400 engines
- PCA: He Pressurisation system &310mm tank & Pressure regulators redundant in series
- PIA: Propellant tanks : 3 tanks (45kg capacity max – ~330mm)
- Engine operating pressure ~ 24 bar
- Bracket & tubing (up to 3/4'' required)

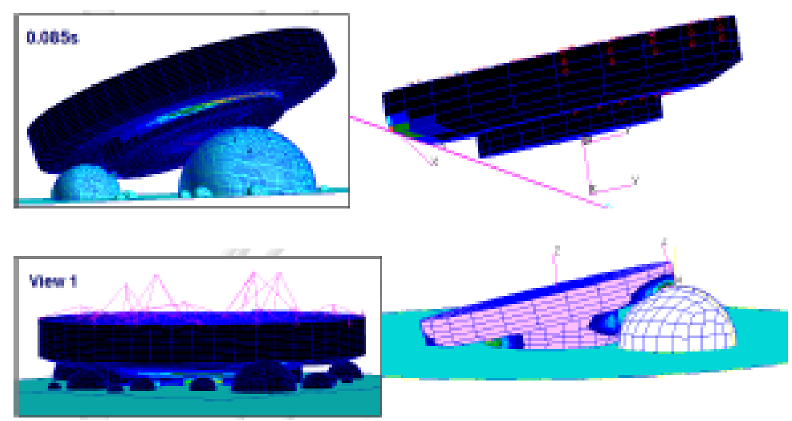
RCS accommodation

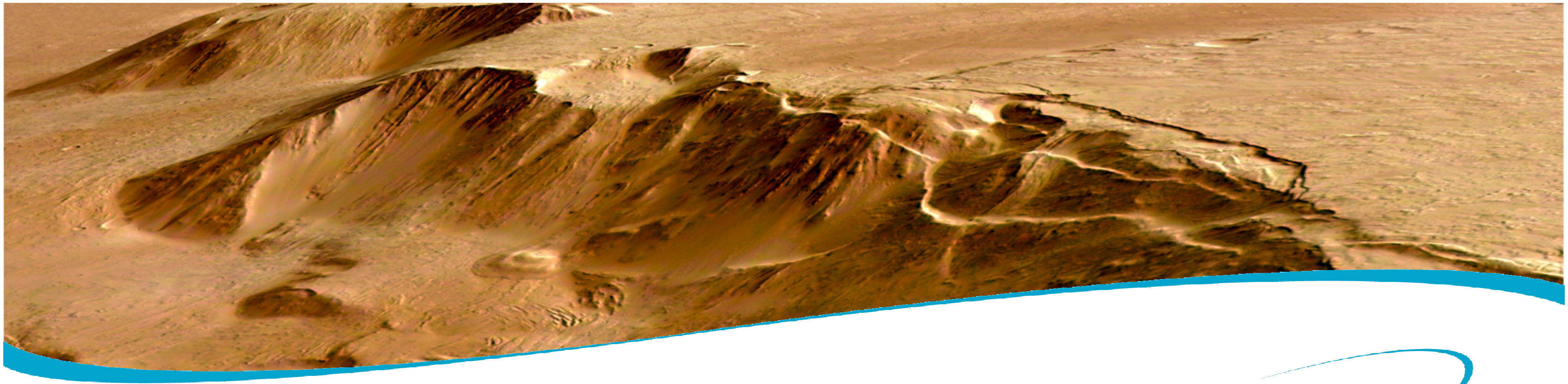


EDM Surface Platform
Crushable Structures Design









2018 MISSION

Andrea Allasio

Deputy Program Manager & Rover Module Manager

Template reference : 100181708K-EN

BU-OOS

Turin, 10 September 2010

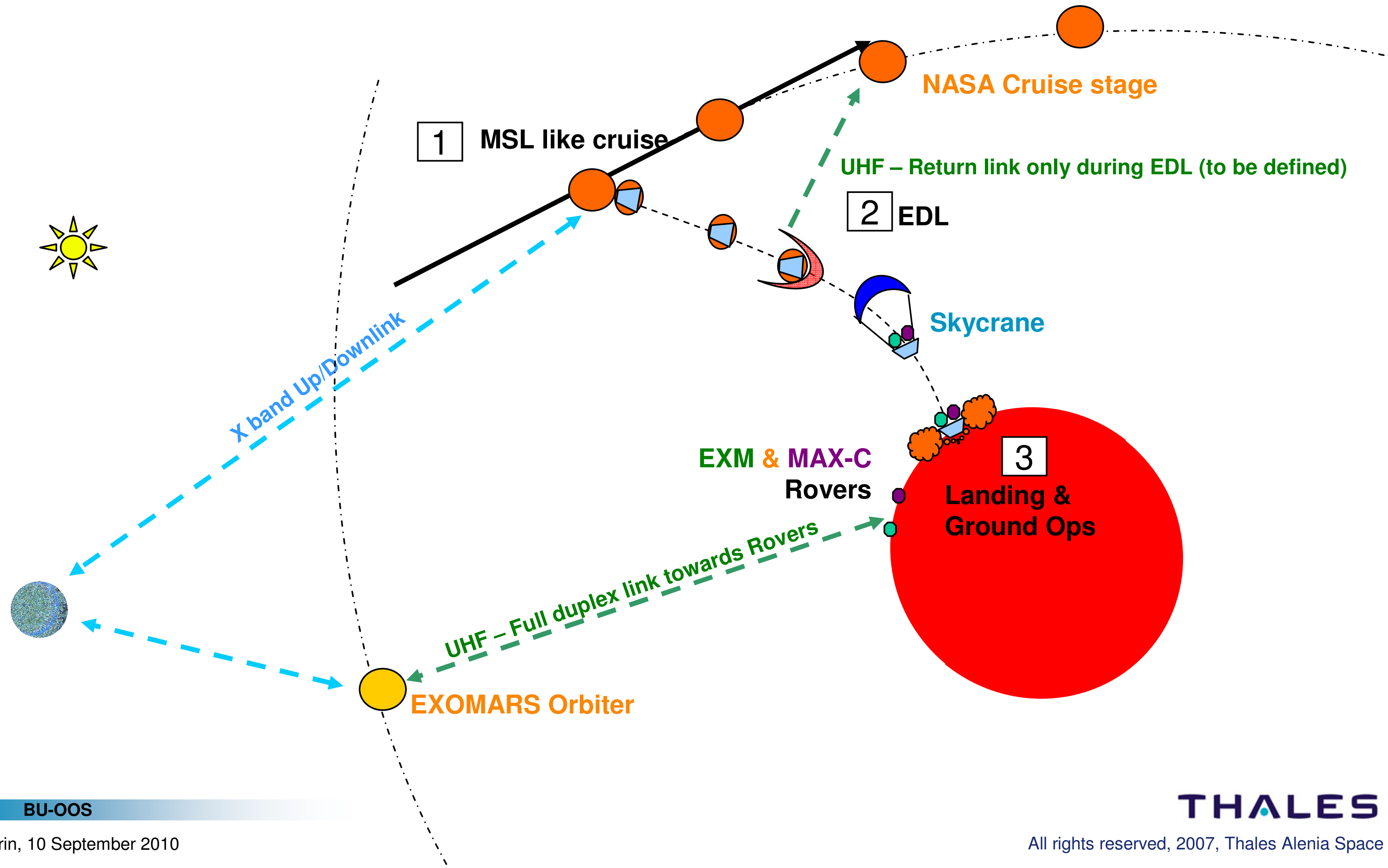
2018 Mission

- **2018 Mission is lead by NASA, providing for that the Launch Vehicle, the Sky Crane travelling to and landing on Mars, and US MAX-C Rover**

- **Mission has two objective categories**
  - Technology Demonstration:
    - **Surface mobility with a Rover,**
    - **Access to the sub-surface to acquire samples;**
    - **Sample preparation and distribution for analyses by scientific instruments.**

  - Scientific Objectives:
    - **To search for signs of past and present life on Mars;**
    - **To investigate the water/geochemical environment as a function of depth in the shallow subsurface;**
    - **To investigate Martian atmospheric trace gases and their sources**

2018 Mission scenario and links

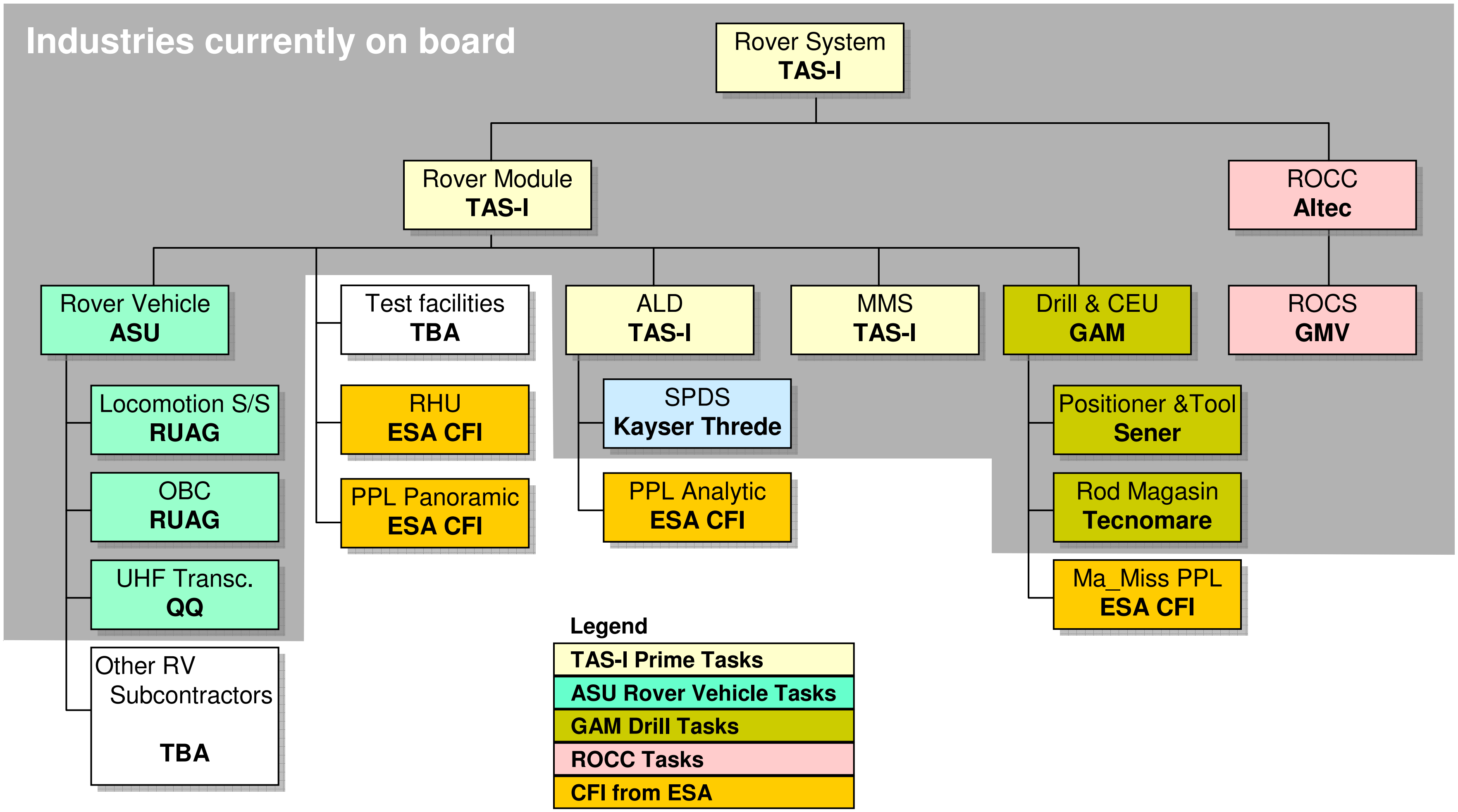


The Rover System for 2018 mission

1. **The ExoMars Rover Module:**
   - Rover Vehicle
   - Drill
   - Analytical laboratory Drawer
   - Pasteur Payload Set (CFI from ESA)
   - Mission Management SW

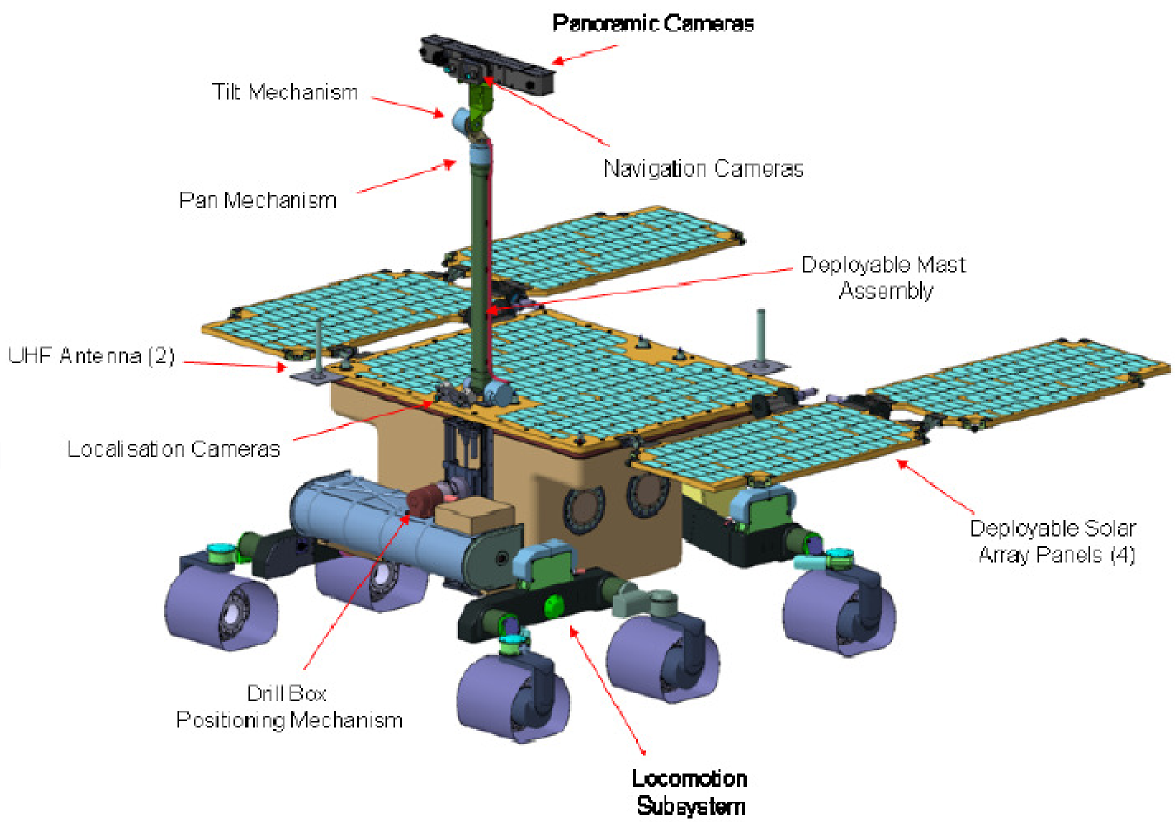
2. **The Rover Operation Control Center located C/O ALTEC (Turin)**

Industries currently on board



Rover Module Overview

- Landing latitude: 5°S to 35°N
- Nominal mission: 180 sols (185 Earth days)
- Nominal science: 6 Experiment Cycles + 2 Vertical Surveys
- Experiment Cycles duration: 17÷22 sols
- Travelling to a 70m target within 1 Sol
- Rover mass:300 kg
- Payload: Pasteur Payload Set



ExoMars Rover carries a comprehensive suite Panoramic and Analytical instruments dedicated to exobiology and geology research called Pasteur Payload.

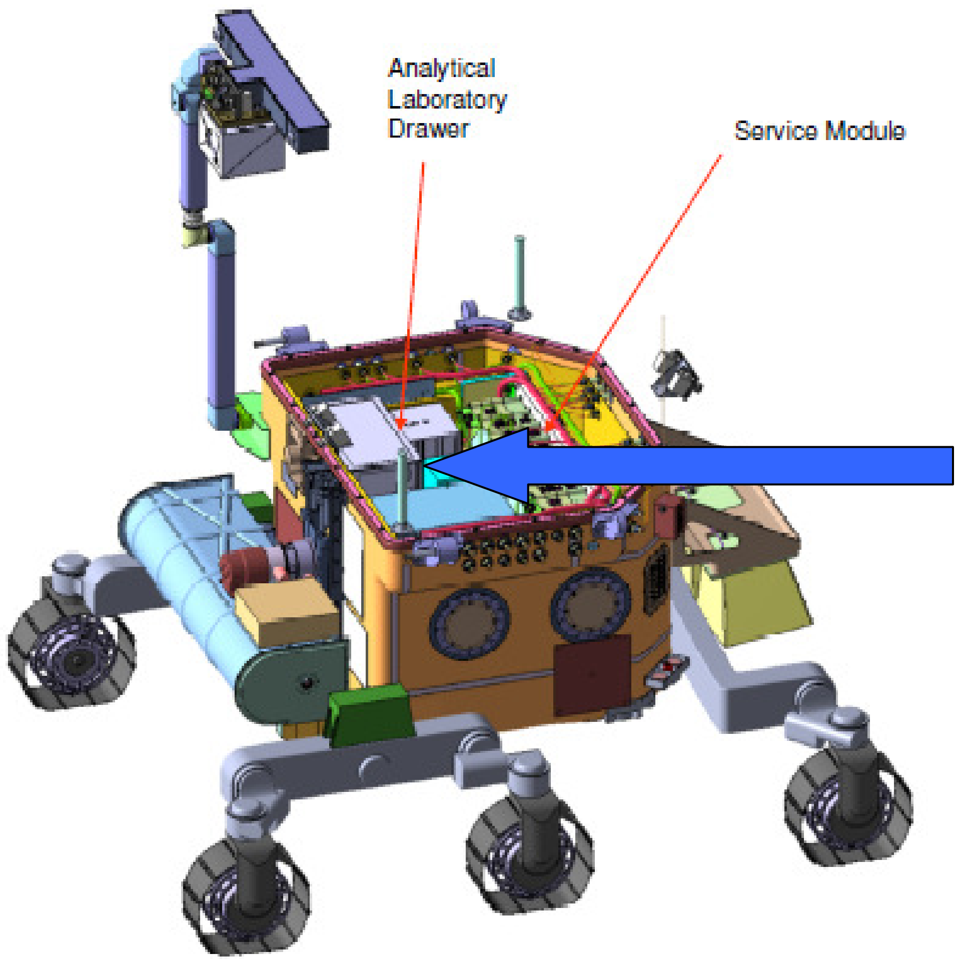
ExoMars baseline PPL set is composed by 7 instruments + 2 under assessment:

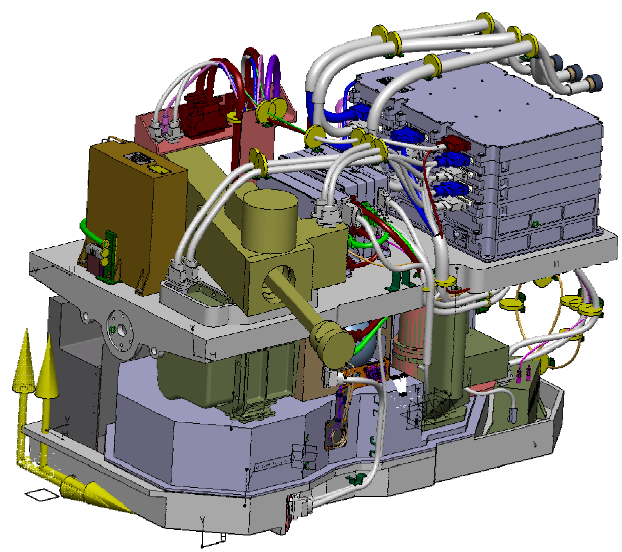
- **Mounted inside the ALD**
  - MIRU (Micromega InfraRed Unit): Infrared Microscope for hyperspectral imaging
  - RAMAN IOH (Raman Spectrometer)
  - MARS XRD (X-Ray Diffractometer)
  - MOMA (Mars Organic Molecule Analyser): Gas Chromatographer / Mass Spectrometer
  - LMC, Life Marcher Chip
- **Mounted on the Rover Vehicle**
  - PanCam (Panoramic Cameras): Wide Angle multi-spectral stereoscopic Hi Res pan images
  - WISDOM (Water Ice & Subsurface Deposit Observations on Mars): a polarimetric ground-penetrating radar
- **Mounted on the Drill**
  - Ma_Miss (Mars Multispectral Imager for Sub-surface Science): wide-range infrared spectrometer to conduct mineralogical investigations.
  - CLUPI: Close Up Imager

TAS-I will integrated all Instruments but for Ma_Miss

- The Rover Vehicle is the constituent of the ExoMars mission providing Mobility capability and all other primary services required to support the egress and the scientific mission execution.
- Autonomous mobility capability is required for achieving interesting scientific sites, located in a hundred meters range on Mars surface.
- Rover Vehicle implements the following functionalities:
  - Power Generation and Storage, for all Rover Module
  - Thermal Control
  - Communication with the Orbiter
  - Data Handling and Vehicle Management
  - Navigation
  - Locomotion
  - Failure Detection and Safing

ALD and RV SVM accommodation in the Rover

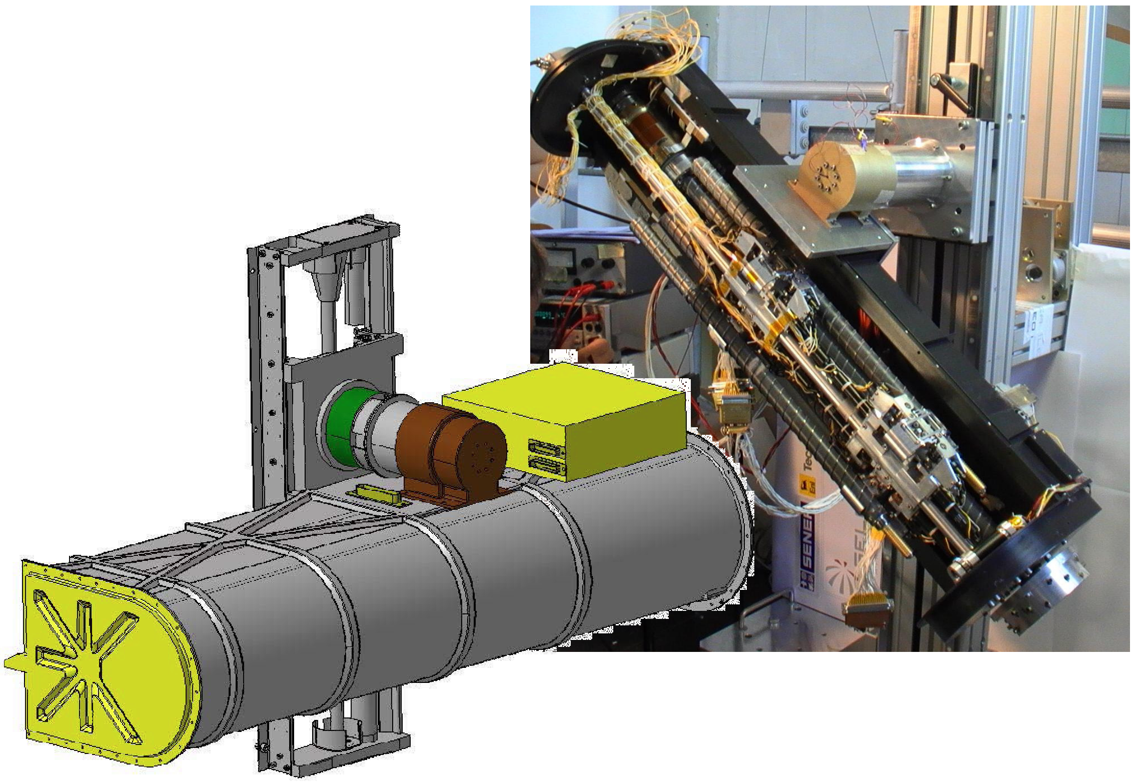


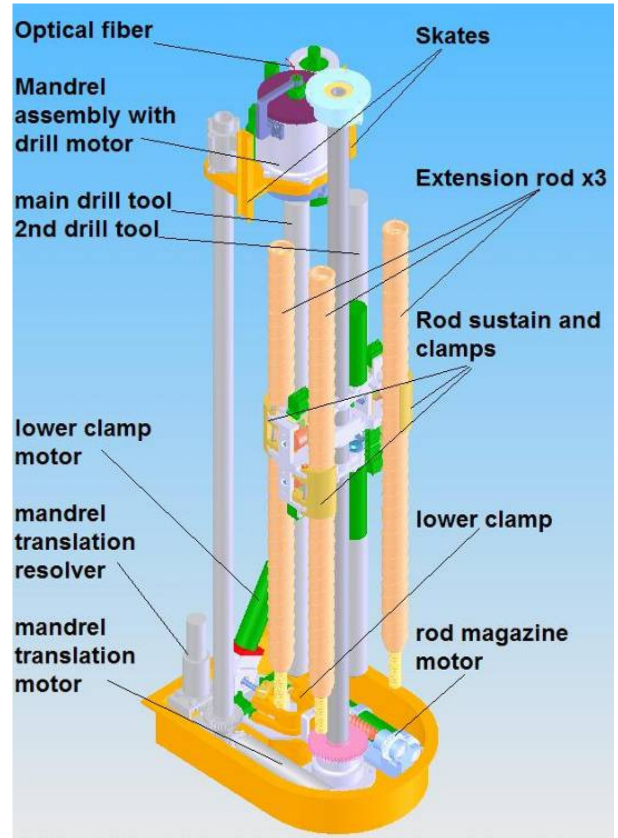


Analytical Laboratory Drawer

Drill

- Drilling down to 2 meter of depth
- Direct sub-surface spectrum analysis while drilling via Ma_Miss





Analitical Laboratory Drawer

The laboratory is implemented by a set of PPL and a set of complex mechanisms, called SPDS. The ALD:

- Takes samples from the Drill
- Crushes samples in powder, dose and store them
- Provides sample to the Instruments
- Preserve samples from contaminants, in a specific **Ultra Clean Zone**
- Disposes samples after analysis

The ALD includes as well the Control Electronic Unit of the Drill, Thermal Control (LHP and RHU), harness and piping.