ExoMars Mission Overview
and
Project Status

ASTRA 2006

ESTEC – 28 November 2006

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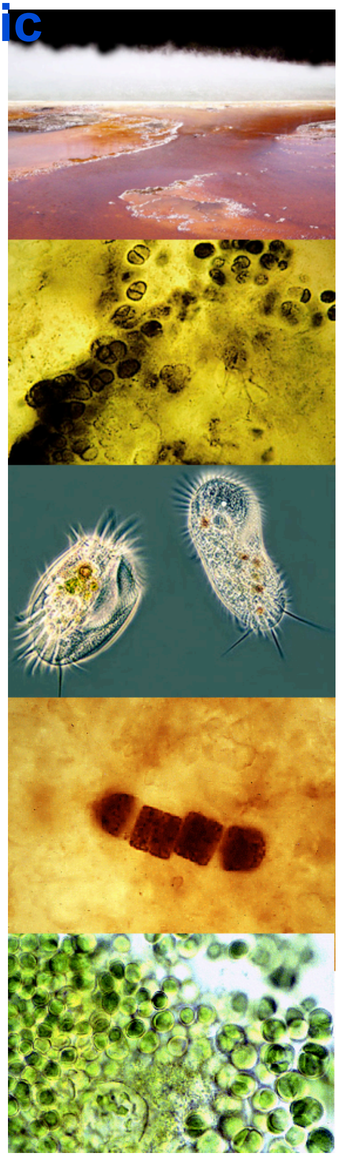
Mission Objectives

First European led Robotic Exploration Mission combining development of key exploration enabling technologies with major scientific investigations

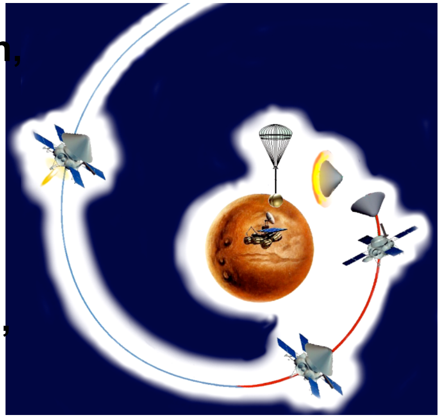


- ☐ Main technology demonstration objectives
  - Safe Entry, Descent and Landing of a large size payload (Descent Module)
  - Surface mobility (Rover) and access to the subsurface (Drill)
- ☐ Main scientific objectives
  - Search for traces of past and present life and characterize Martian chemistry and water distribution
  - Improve the knowledge on Martian's environment and identify surface hazards to future human missions

Baseline Mission

Launch Window: 6st May to 26th May 2011 (Backup: 19th April to 9th May 2013) on Soyuz 2b from Kourou

Arrival: June 2013 (backup March 2015), after GDS season, HEO and Delayed Transfer strategies



S/C Composite: Carrier Module plus Descent Module (including Rover and GEP)

Landing: Following ballistic entry from hyperbolic arrival trajectory - EDLS based of Heat Shield, Parachute, Retro-rockets and Airbags

Landing Range: Latitudes between –15º and +45º, all longitudes
Altitude ≤ 0 m relative to the MOLA zero level

Payload:

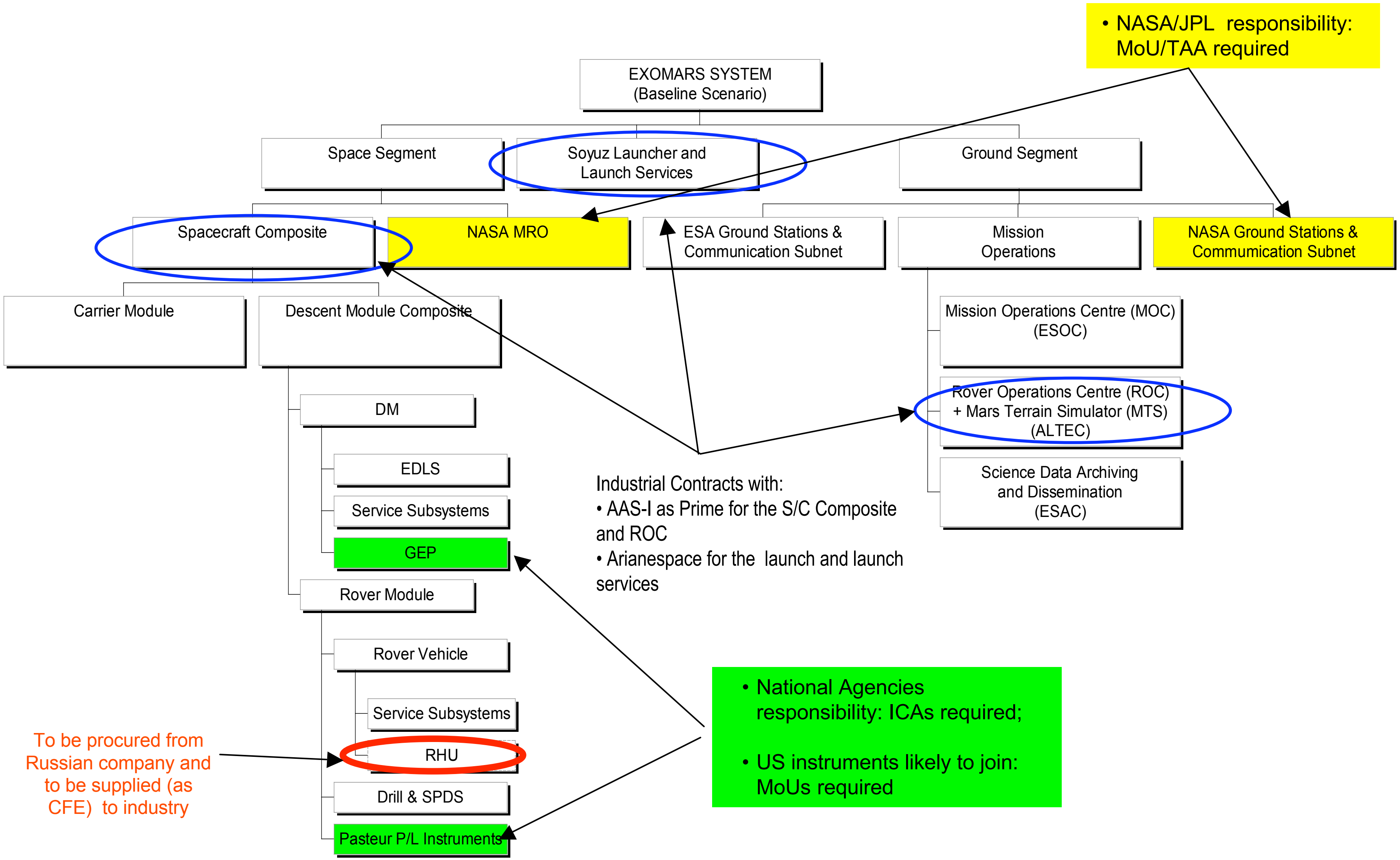
Rover and its Pasteur Payload: Mass 150-180 kg, includes:
- Drill (up to 2 m depth) & SPDS
- Instruments ~8 kg
- Mobility ~10 km

Geophysics/Environment Package (GEP): Mass ≤ 20 kg, includes:
- Instruments (4-5 kg TBC)

Data Relay: To be provided by NASA (MRO or equivalent orbital asset)

MOPs and GS: MOC at ESOC (up to Rover egress TBC); ROC (& MTS) at ALTEC (afterwards)

Baseline Mission Elements Tree



- NASA/JPL responsibility: MoU/TAA required

EXOMARS SYSTEM (Baseline Scenario)

- Space Segment
  - Spacecraft Composite
    - Carrier Module
    - Descent Module Composite
      - DM
        - EDLS
        - Service Subsystems
        - GEP
      - Rover Module
        - Rover Vehicle
          - Service Subsystems
          - RHU
        - Drill & SPDS
        - Pasteur P/L Instruments
  - NASA MRO
- Soyuz Launcher and Launch Services
- Ground Segment
  - ESA Ground Stations & Communication Subnet
  - Mission Operations
    - Mission Operations Centre (MOC) (ESOC)
    - Rover Operations Centre (ROC) + Mars Terrain Simulator (MTS) (ALTEC)
    - Science Data Archiving and Dissemination (ESAC)
  - NASA Ground Stations & Commumication Subnet

Industrial Contracts with:
- AAS-I as Prime for the S/C Composite and ROC
- Arianespace for the launch and launch services

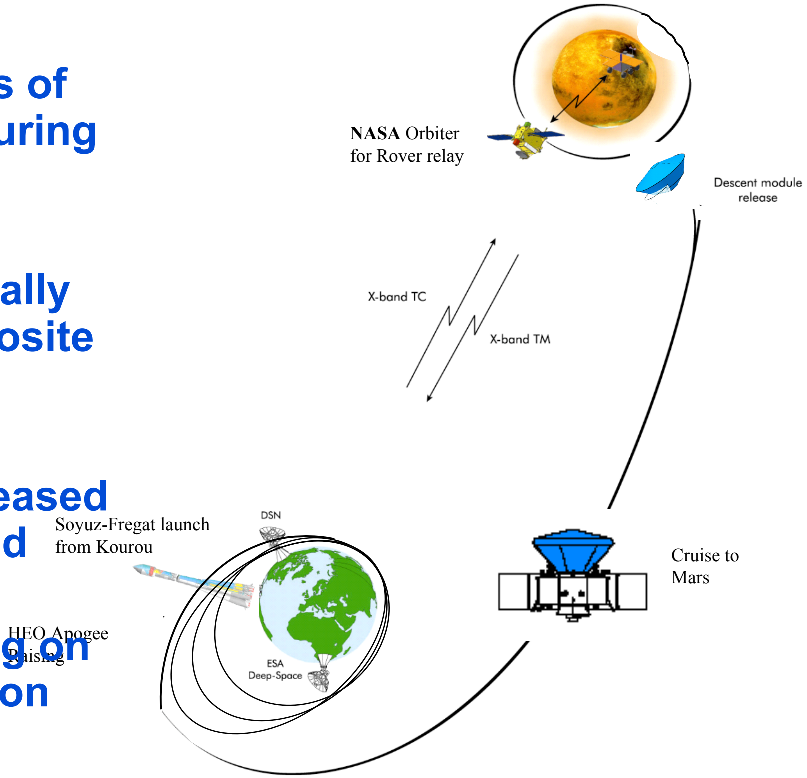
- National Agencies responsibility: ICAs required;
- US instruments likely to join: MoUs required

To be procured from Russian company and to be supplied (as CFE) to industry

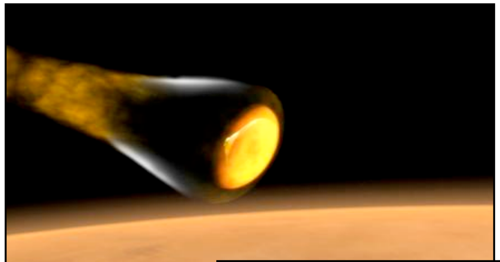
Launch and Mars Transfer Strategy

- Soyuz ST 2-1b/Fregat will insert the Spacecraft Composite into GTO (~36000 km)
- After separation from the launcher, the CM will take the Spacecraft Composite into a Mars delayed transfer trajectory (Vinf = 2.87 km/s) by means of a series of apogee raising manoeuvres
    - The delayed transfer trajectory (about 2 years of cruise) is needed to avoid landing on Mars during the GDS and Superior Conjunction
- A Mid Course Manoeuvre will be performed to finally target the arrival to Mars of the Spacecraft Composite (from the hyperbolic approach trajectory)
- At the end of the cruise phase, the DM will be released thus initiating its Coasting and Entry, Descent and Landing (EDL) phases
    - The DM release will occur 1.5 h before landing on Mars. The CM will then continue on its collision course to Mars

Launch in 2011
(Backup in 2013)



Entry Descent and Landing Strategy

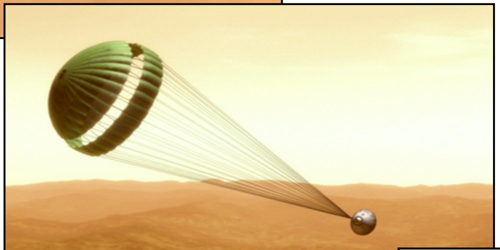


Entry

Entry Interface Point (EIP) at 120 km (spherical altitude)

Reference Ballistic Coefficient (at Mach 25) 72 kg/m2 (for a 3.4 m front shield base diameter)

Velocity Range: start ~ 5.8 km/s (~ Mach 25); end ~ 430 m/s (Mach ~ 1.8)

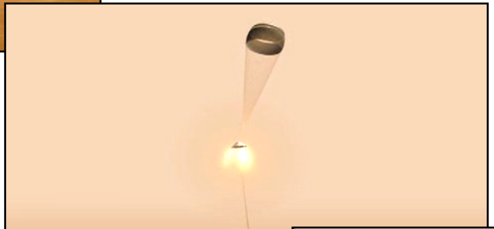


Descent

Disk gap band single parachute (trade-off on-going for dual stage parachute)

Altitude at parachute opening > 5 km above landing site

Velocity Range: start ~430 m/s; end ~85 m/s



Terminal Descent

Solid Retrorockets for braking and horizontal velocity control

Velocity Range: start ~85 m/s; end ~10-15 m/s

Landing

Landing with airbags

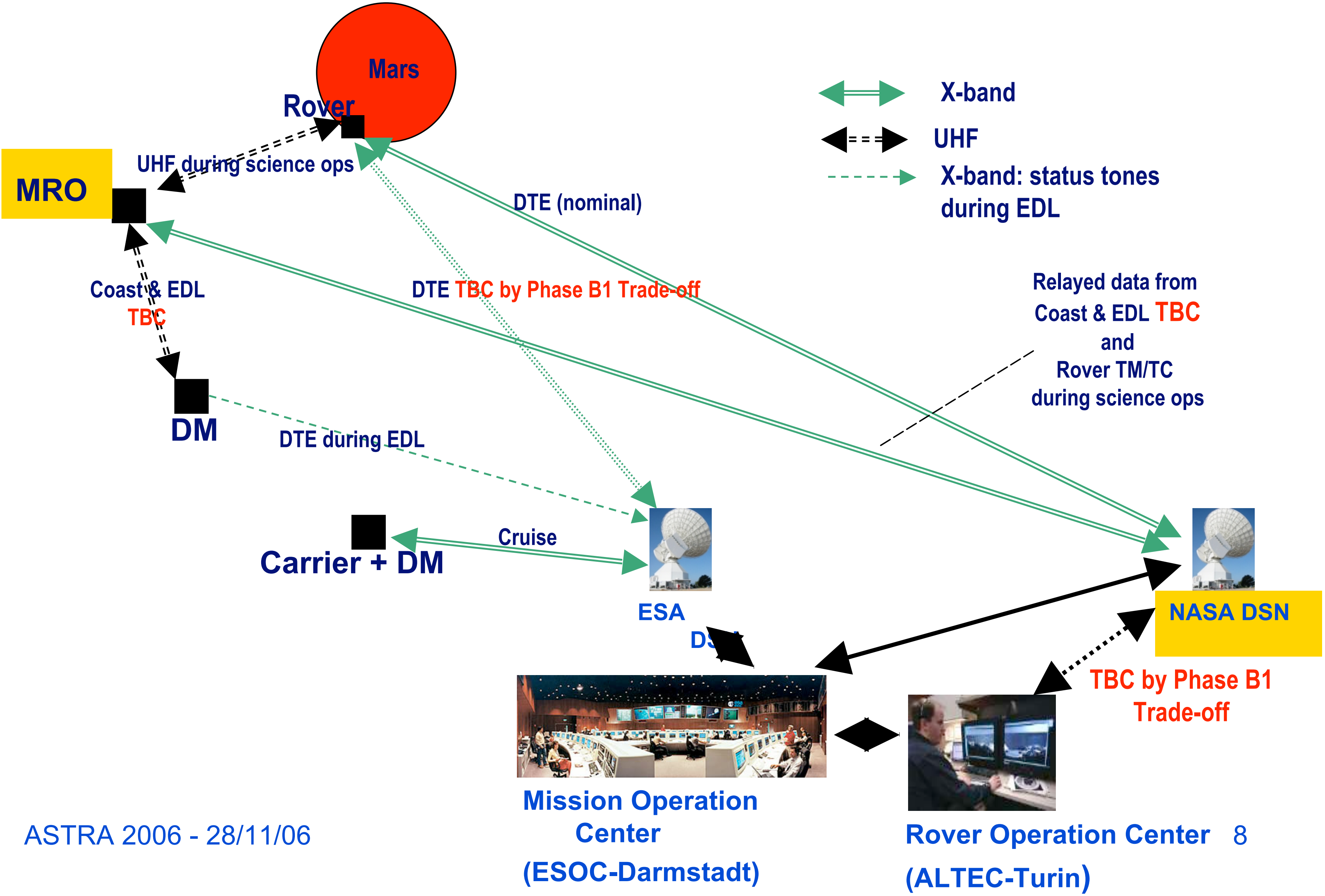
Altitude of final drop ~15 - 20 m

Velocity Range: start ~10–15 m/s; end 0 m/s

Courtesy of Vorticity/AeroSekur

For the airbags, two concepts are currently being studied: one similar to the MER bouncing airbags; the other utilising vented airbags

Baseline Communications Architecture



X-band

UHF

X-band: status tones during EDL

Mars

Rover

MRO

UHF during science ops

DTE (nominal)

Coast & EDL TBC

DTE TBC by Phase B1 Trade-off

DM

DTE during EDL

Relayed data from Coast & EDL TBC and Rover TM/TC during science ops

Carrier + DM

Cruise

ESA DS

NASA DSN

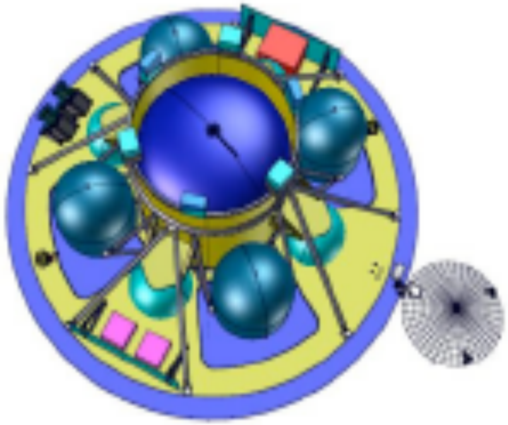
TBC by Phase B1 Trade-off

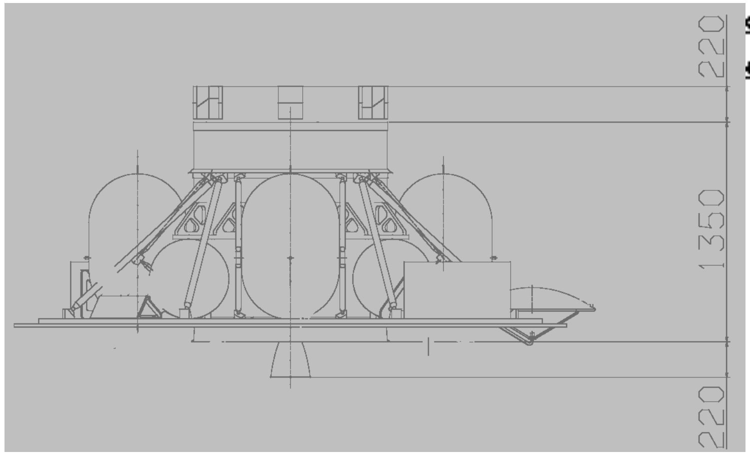
Mission Operation Center (ESOC-Darmstadt)

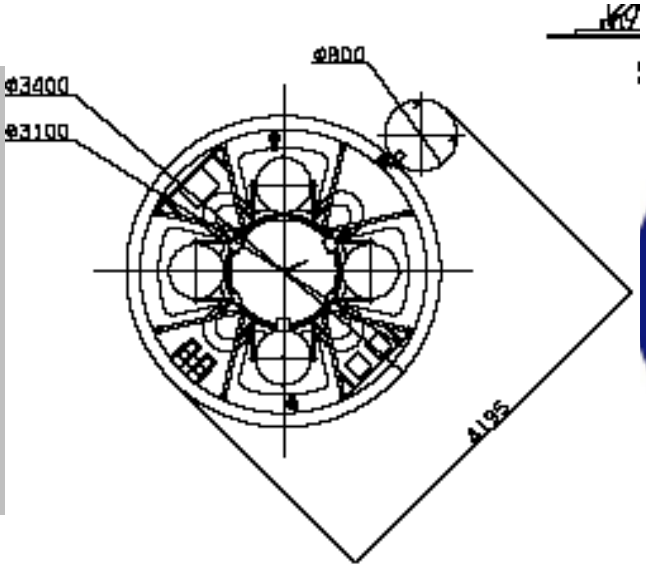
Rover Operation Center (ALTEC-Turin)

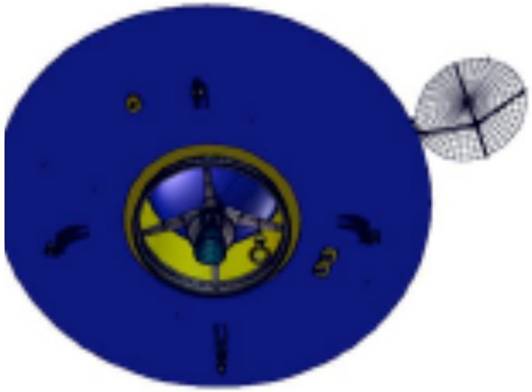
Carrier Module

- ❑ The Carrier Module (CM) provides structural support to the Descent Module (DM) and will accurately target the DM entry into the Martian atmosphere
- ❑ Moreover the CM provides the propulsion capabilities required to complement the Soyuz launch and to perform the LEOP and Cruise manoeuvres
- ❑ Current baseline is a 3-axis stabilised module
  - ➢ Wet Mass ~ 1950 kg (490 kg dry mass)
  - ➢ Average Power ~ 500 W (from Solar Arrays)
  - ➢ X-band communication link to Earth
- ❑ After DM separation, the CM will crash on the Martian surface







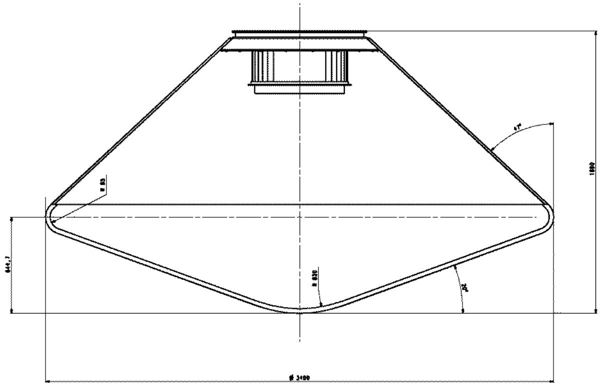


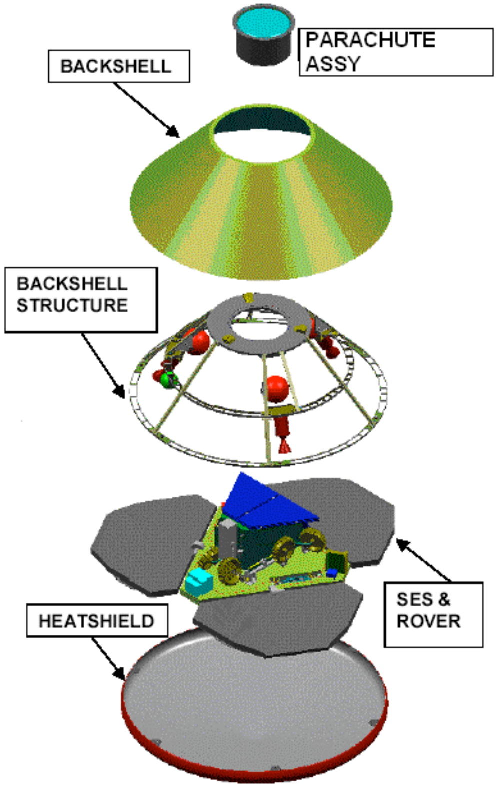
Descent Module

- ☐ **Following separation (from the CM), Coasting and EDL phases, the Descent Module (DM) will deliver onto the Mars surface the Rover and the GEP**

- ☐ **The DM can be split into two major parts**
  - ➢ **The Entry Descent and Landing System (EDLS)**
  - ➢ **The Service Subsystems, which include the Separation Mechanism and the Structure and Rover Egress Syst (SES)**

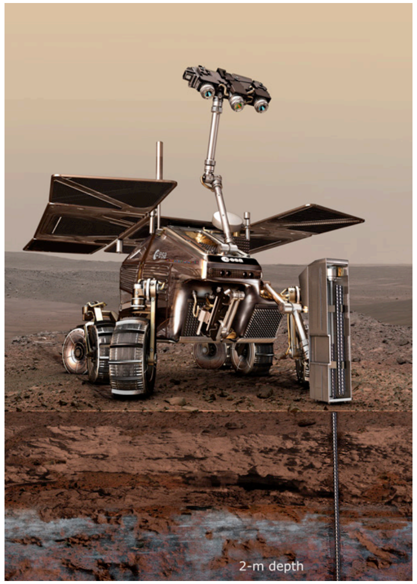
- ☐ **Current baseline is, aerodynamically, similar to MER**
  - ➢ **Mass ~ 1000 kg**
  - ➢ **Energy ~700 Wh (from battery) for Coasting and EDL phases**
  - ➢ **X-band communication tones to Earth and UHF link MRO during coasting and EDL (when MRO in visibili**



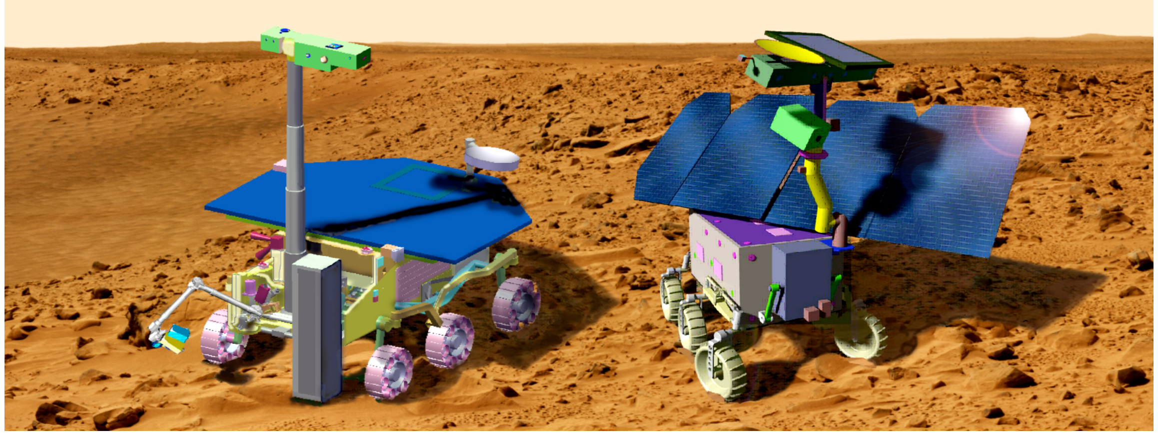


	DM ExoMars	MER
Front Cone Diameter (D)	3.4 m	2.65 m
Fore body Cone angle (?)	70 degrees	70 degrees
Base Radius (R_b)	D/8 m	< D/8 m
Nose Radius (R_N)	D/4 m	D/4 m
Corner Radius (R_c)	D/40 m	D/40 m
Rear Cone Angle (Φ)	47 degrees	˜ 47 degrees

Rover



- ❑ The Rover will ensure regional mobility (several km) to the Pasteur Payload, accommodates its suite of Instruments and provides the required resources (power, thermal control, telecommunications, etc)
- ❑ The Rover also includes a Drill-based Sample acquisition Preparation and Distribution System (SPDS) which will allow for accessing Mars surface and sub-surface (down to a depth of 2 m)
- ❑ Current baseline
  - ➢ Mass ~ 180 kg
  - ➢ Average Power ~ 120 W (by Solar Array assuming RHUs availability)
  - ➢ X-band communication link for DTE and UHF band for Proxi-link with MRO
  - ➢ Two Thermal Control solutions still under trade-off: with and without RHU’s



Concept with RHUs   **Concept without RHUs**

Mission Operations Concept (1/2)

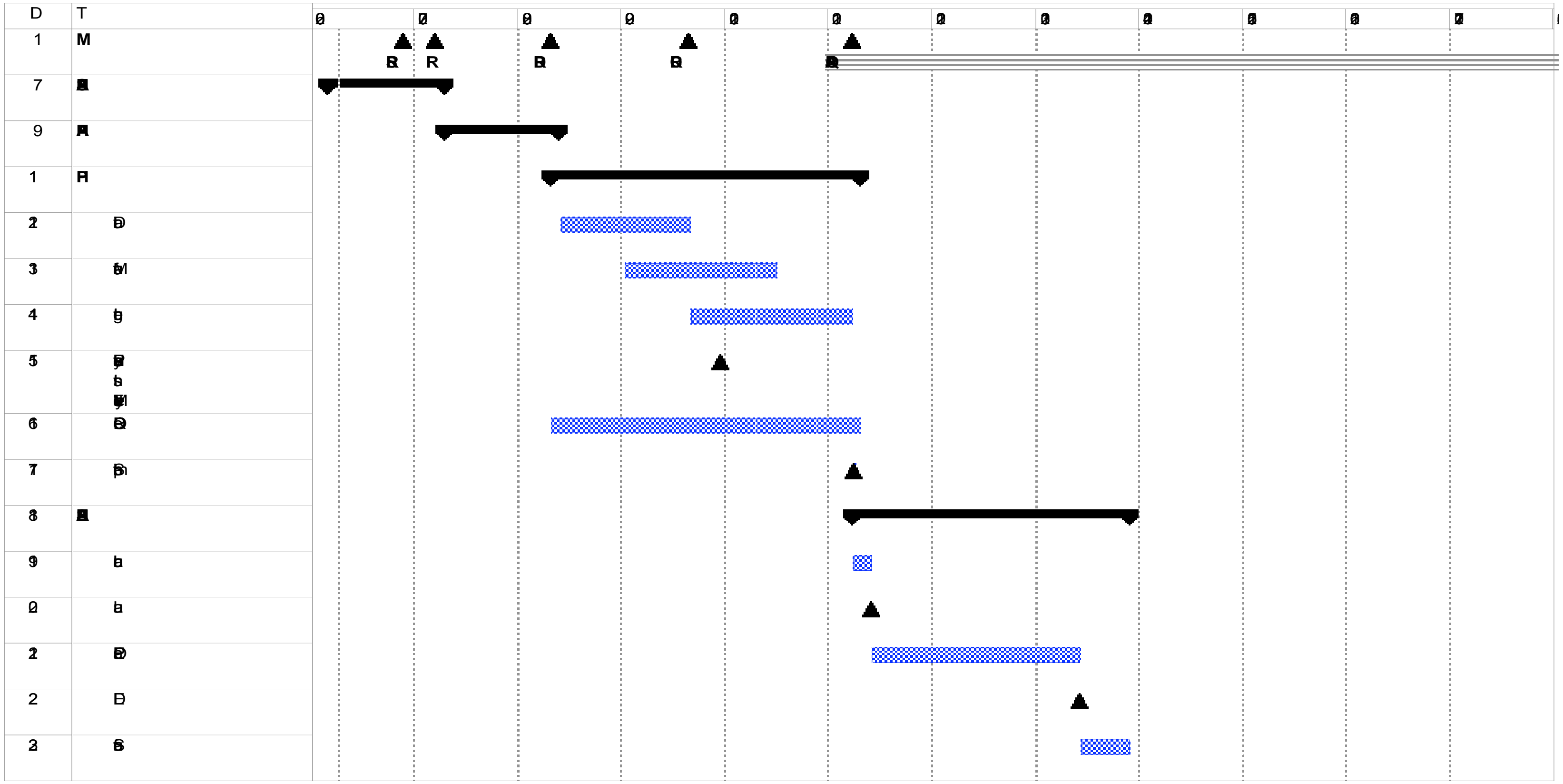
- The Carrier/Orbiter spacecraft operations will be similar to those of many other ESA missions, and will be carried out by ESOC => MOC at ESOC for LEOP, cruise and EDL, Rover egress & checkout (TBC)
  - Use of existing Ground Segment infrastructure as much as possible
  - No science during these phases (except EDL science to be relayed to Earth after landing)
  - MRO coverage during EDL as backup for tracking and tone TM
  - Handover from MOC to ROC for Rover daily surface operations after successful Rover egress and checkout (TBC)
  - Overlap period between MOC & ROC (prior/after to handover) to be further defined and detailed

Mission Operations Concept (2/2)

- ☐ The operation of the Rover with its scientific payload will require a dedicated Rover Operation Centre (ROC) in combination (locally) with a Rover Test Bed and Mars Terrain Simulation (MTS) Facility => ROC at ALTEC for Mars surface operations
  - ➢ to process in near-real time the telemetry data from the Rover, prepare the execution of the daily surface operations and issue the necessary sequence of commands and timelines
  - ➢ to test, on ground, the daily surface operations schedule such to validate the sequence of commands to be up linked and to prepare and validate relevant procedures for reacting to off-nominal situations
- ☐ SOC function to be initially implemented into the ROC (first 6 months operations) and then be moved to ESAC (TBC)
- ☐ In line with the present ESA policy, the implementation of the Science Data Archiving and Dissemination is proposed to be located in ESAC
- ☐ In case of mission option 2 (European Orbiter launched by Ariane 5) a dedicated SOC for the Orbiter science will be established

Master Schedule

- ☐ In the schedule below, it is assumed that the Phase B2 and C/D is authorised for starting by early 2007.
- ☐ As a unique milestone the Implementation Review will conclude the phase B1 and authorise to proceed to phases B2, C/D and E



Orbiter Options

- ☐ In line with the Programme Declaration, two mission options in addition to the baseline scenario are being studied in Phase B1
  - ➢ To add to the baseline scenario a dedicated European communications satellite (to be launched separately with Soyuz
    - ✓ **Option 1: Current ExoMars baseline (i. e. Carrier + DM and Rover - Soyuz launch) plus dedicated telecommunication Orbiter mission – with additional Soyuz launch**
  - ➢ To implement an Ariane 5 based mission having a Mars Orbiter, acting as a communications (and orbital science) node, enabling a more robust mission design and a relatively larger Pasteur Payload
    - ✓ **Option 2: Carrier upgraded to Orbiter + DM (and Rover) – with Ariane 5 launch**

Soyuz Orbiter -Preliminary Assessment

- It only improves the Mars-to-Earth data link (MRO support will be still required as back-up)
- Does not allow for “orbital science”
- The baseline mission configuration (Carrier + DM and Rover) remains unchanged (e.g. mass critical and no DM release from orbit is possible)
- Preliminary internal technical assessment shows that the Orbiter mass is in the range of about 750 kg (including 20% system margin)
  - This is technically feasible only with the Soyuz launch in 2011; for a 2013 launch the mass margin at launch is negative

Ariane 5 Orbiter - Preliminary Assessment

- ☐ **Provides an independent European mission with enhanced Mars-to-Earth data link (MRO support would be only for back up)**

- ☐ **Allows for “orbital science” (30 Kg TBC payload mass allocation on the Orbiter) as follow on of Mars Express**

- ☐ **Could allows for DM release from orbit; Global Dust Storm Season avoidance constraint would be removed, hence a direct transfer trajectory is possible**
  - ➢ This would also provide 6 months (additional) margin in the mission development schedule

- ☐ **Could allow for the accommodation of a larger (16.5 Kg TBC) Pasteur Payload Instruments into the Rover**

- ☐ **Guarantees a robust overall mission design and adequate mass margins**

- ☐ **This option (which is also compatible with a backup launch in 2015/2016) need to be further studied by industry during the course of Phase B1**

Industrial Phase B1

- ☐ Phase B1 started in October 2005 with AAS-I as Prime Contractor
- ☐ Spacecraft Composite Requirements Review completed in Spring 2006
  - ➢ Modification of the S/C elements functional requirements and consequent avionics architecture to comply with baseline mission mass limitations
  - ➢ Adequate mass and power margins commensurate with project maturity (at that stage)
- ☐ Following C-Min (Dec 05) outcome, Phase B1 re-directed and extended to include:
  - ➢ Study of two Orbiter Options
  - ➢ Implementation Review in early 2007
  - ➢ An industrial team reflecting Geo-return targets close to the new scale of contribution for the overall mission
- ☐ System Requirements Review planned in January – February 2007 (TBC)
- ☐ Implementation Review in May 2007 (TBC)

Pasteur Payload Interfaces

- ☐ Implementation of TRL Upgrade Program for selected Pasteur Instruments (up to TRL 4 / TRL 5 as goal) is on-going

- ☐ Good progress achieved in the definition of the Spacecraft to Instruments interfaces:
  - ➢ Pasteur Payload Instruments Interface WS #1 held on 23-24 January
  - ➢ Preliminary Instrument IRD issues and first series of interface meetings completed (April-May) to discuss and consolidate input to Instrument ICD
  - ➢ Pasteur Payload WG #3 held on 20 October
  - ➢ Instrument IRD re-issued to arrive at updated ICDs (December-January)

- ☐ Instrument IIPs and ICDs will constitute the input for the PCR to be performed in preparation of IRev

International Cooperation

- ESA – NASA Mars Program Interface Meeting held early April to consolidate discussion about understanding of cooperation elements for ExoMars

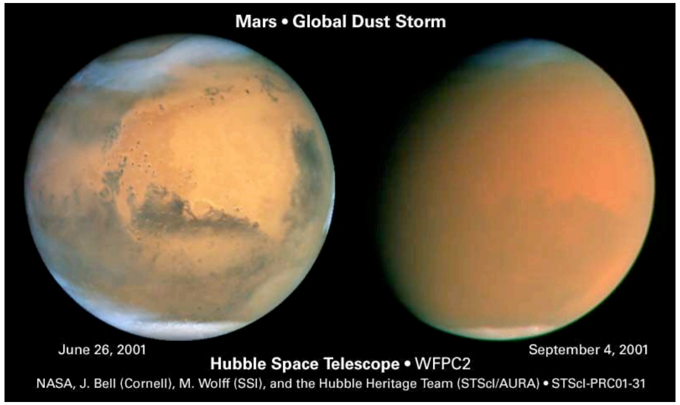
- A (draft) text for an ESA – NASA Memorandum of Understanding for the ExoMars Mission Cooperation has been prepared and (informally) sent to NASA for discussion: next meeting planned in January

- Coordination with JPL has been pursued in compliance with ITAR. Two Technology Assistance Agreements (TAA's) have been prepared and are currently under final (legal) review
  - one dedicated to the provision of JPL support and services for ExoMars Spacecraft (i. e. Data Relay and telecomm, high resolution images of Mars, project review, EDLS and Rover design, Rover Operation Centre design)
  - the other dedicated to the Urey instrument data exchange
  - TAAs submission to US State Department imminent

- ESA – Roscosmos contacts re-established (meeting held on 13 July) to secure support for EDLS and Rover design and in particular for the provision of RHUs
  - technical meeting also held on 8 September specific for RHUs/RTGs

Back-Up Charts

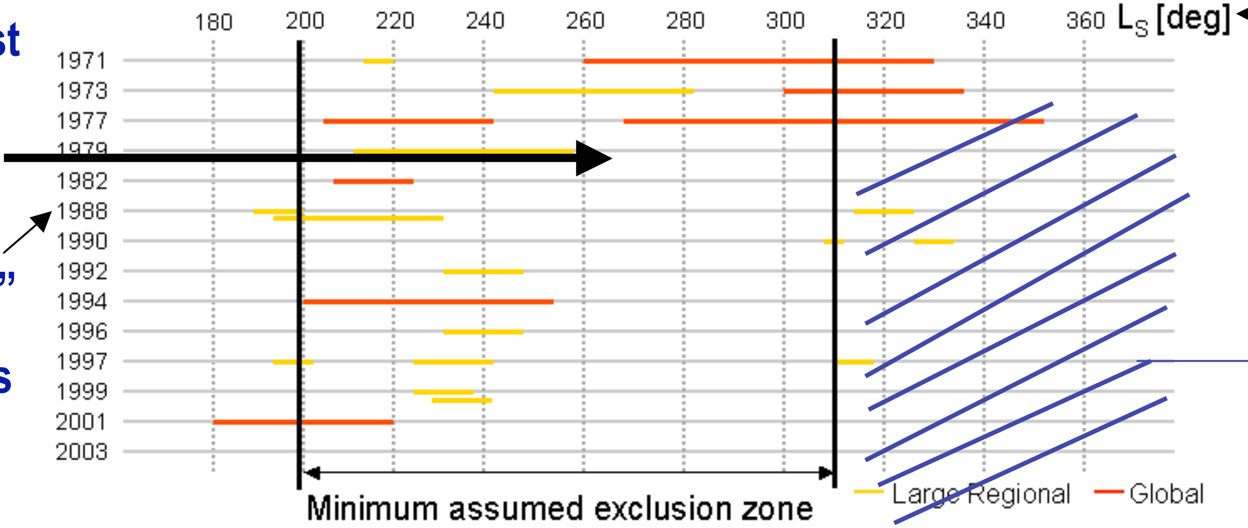
Global Dust Storm (GDS) Season



Mars is subjected to dust storms that cover almost the entire planet: it happens around Mars perihelion and it is unexplained to date

Availability of Solar energy is very reduced and mechanisms may get stuck

A period of about 6 months around it has been assumed for avoidance



Mars orbital position

"Global Dust Storm Season"

"Earth years"

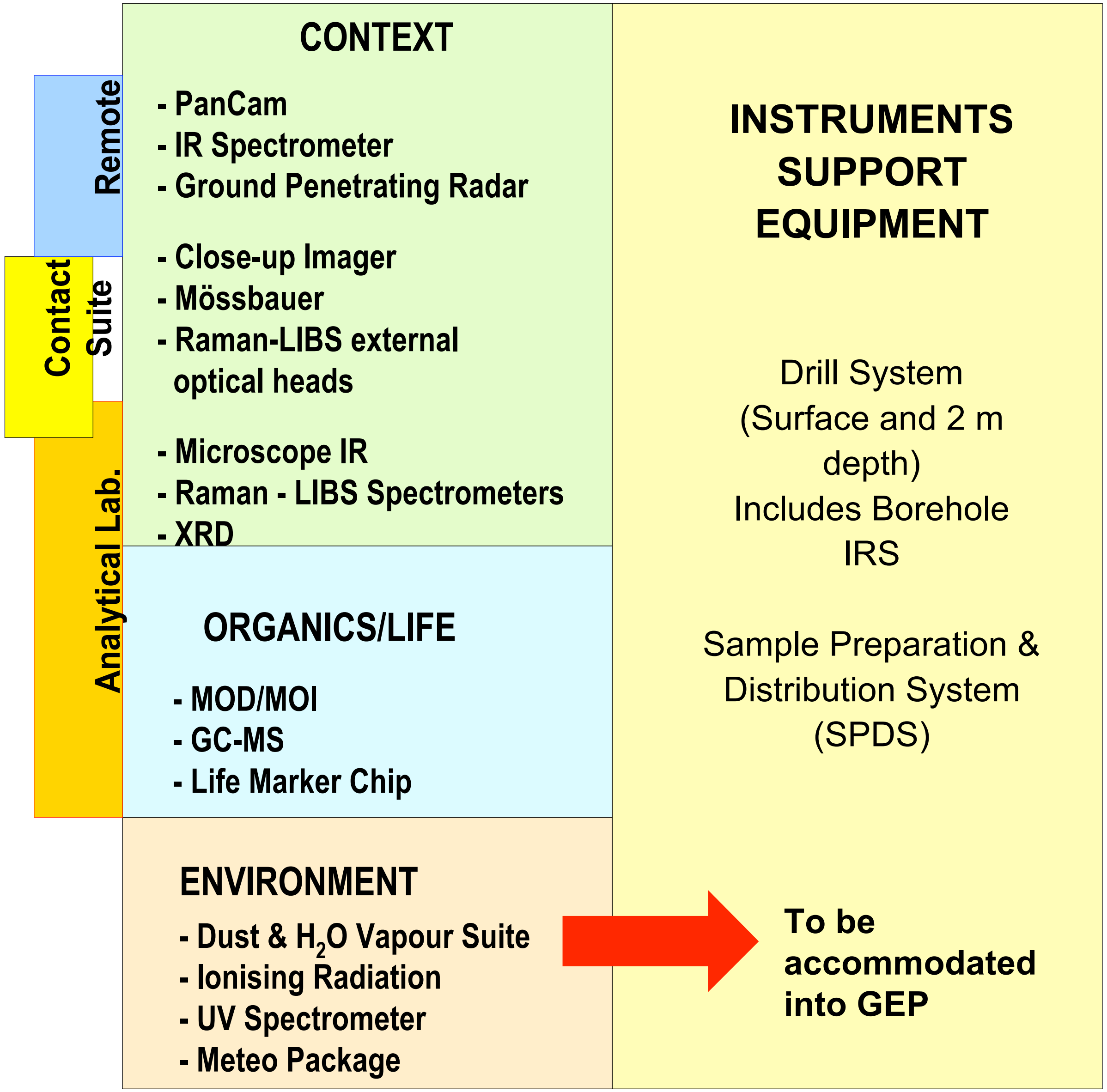
2 Earth years = 1 Martian year

Landing Times

Years for which a GDS did not occur or when no data were available are not showed

Pasteur Payload

- The instruments development is under the responsibility of relevant National Agencies
- The current total mass of the Pasteur Payload Instruments is 12.5 kg, thus exceeding the 8 kg allocation: if necessary instruments de-scoping will be implemented available resources



Remote

Contact Suite

Analytical Lab.

CONTEXT

- PanCam
- IR Spectrometer
- Ground Penetrating Radar

- Close-up Imager
- Mössbauer
- Raman-LIBS external optical heads

- Microscope IR
- Raman - LIBS Spectrometers
- XRD

ORGANICS/LIFE

- MOD/MOI
- GC-MS
- Life Marker Chip

ENVIRONMENT

- Dust & H_2O Vapour Suite
- Ionising Radiation
- UV Spectrometer
- Meteo Package

To be accommodated into GEP

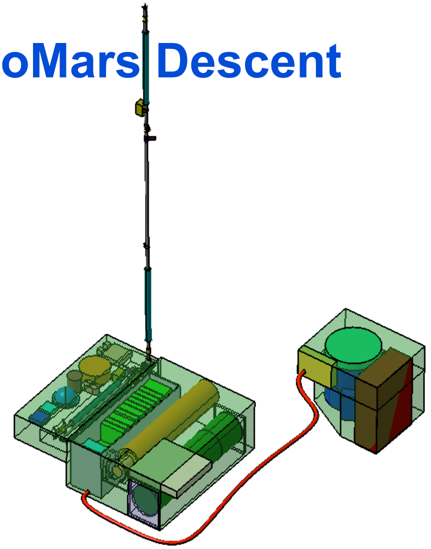
INSTRUMENTS SUPPORT EQUIPMENT

Drill System (Surface and 2 m depth) Includes Borehole IRS

Sample Preparation & Distribution System (SPDS)

Geophysical and Environmental Package (GEP)

- The GEP includes a number of instruments dedicated to investigation of the Mars environment: Seismometer, Mole (to measure temperature gradients), Dust Suite, UV Spectrometer, Ionizing Radiations, Meteo Package (Wind, Humidity etc)
    - The GEP will be accommodated into the ExoMars DM and, following successful landing and Rover egress, will operate autonomously on the Mars surface (e. g. transmitting data and received commands directly via the NASA telecom infrastructure MRO)
    - The design and accommodation of the GEP on the ExoMars Descent Module is at present under review
- The GEP development will be performed by a Consortium (presently led by DLR with participation of CNES)



Key Enabling Technologies

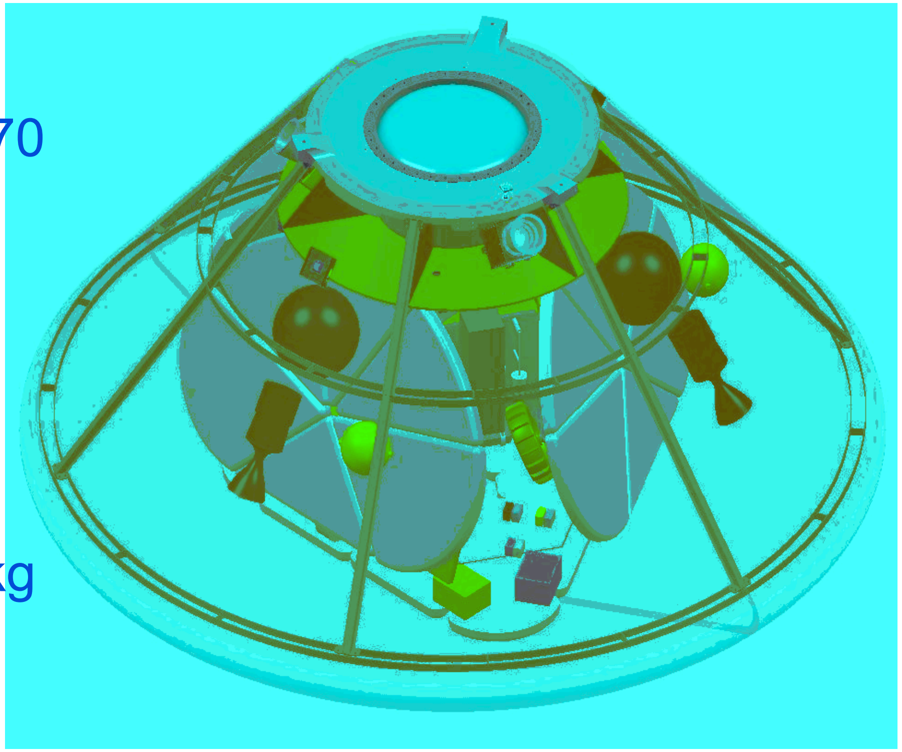
- Before the start of Phase B1, a series of R&D activities (Aurora/TRP) related to ExoMars have been performed. The results of these activities are being considered in the context of the Phase B1

- The development of ExoMars key technologies (namely EDLS, Rover and Drill) are part of the Phase B1. In particular, breadboard models of airbags, Rover navigation and locomotion and the Drill and Sample Preparation and Distribution System will be manufactured and tested to achieve TRL 4/TRL 5 (as goal)

- Continuation of key technology development will be part of following project phases consistent with the main ExoMars Mission objective (i.e. flight and in-situ qualification of new enabling technologies such as the Entry, Descent and Landing System, the Rover and the Drill)

Baseline Mission

DM Configuration: Soyuz – Non Vented Airbags

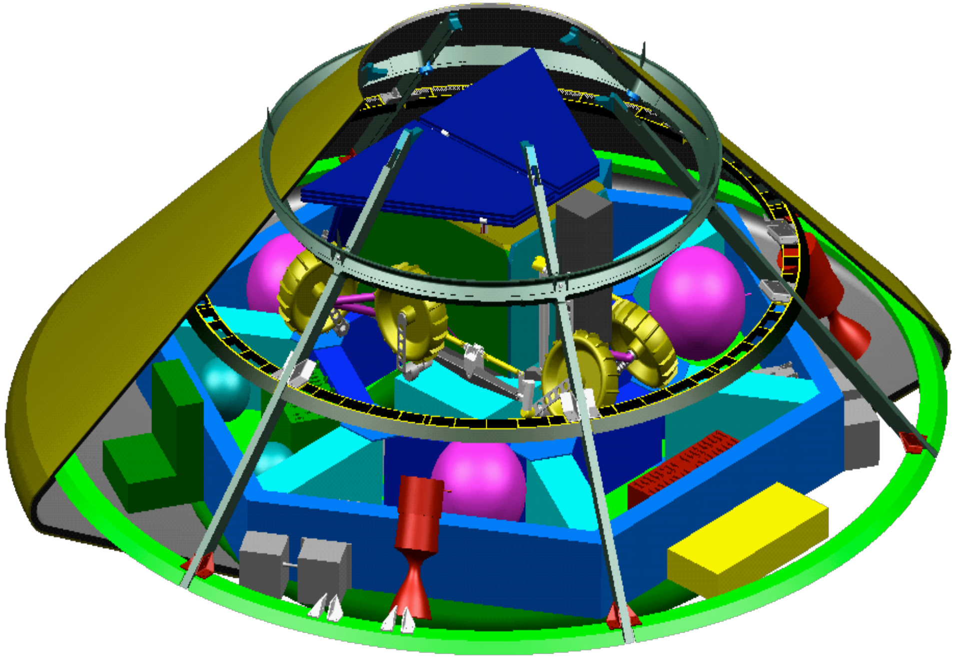


- ☐ Maximum MER-qualified landed mass appears to be 570 kg (to be investigated)
- ☐ Rover volume constrained by tetrahedral shape
- ☐ Instrument mass limited to 8 kg

Baseline Mission

DM Configuration: Soyuz – Vented Airbags

- ☐ Maximum landed mass (640 Kg) constrained by S/C composite mass at Entry Point (due to the limitations imposed by the launcher capability/performance)
- ☐ Rover volume is no longer shape-constrained (hexagonal base-plate)
- ☐ Instrument mass requirements of 12.5 kg could be met (TBC)



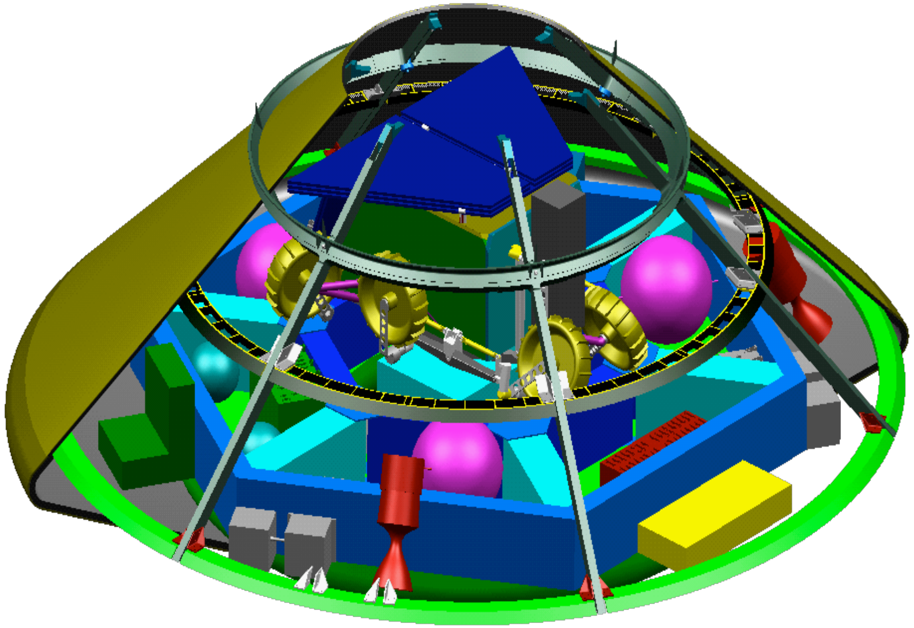
Ariane 5 Orbiter - Vented Airbags

- ☐ Allows for the enlargement of the SES hexagonal base plate and, proportionally, of the whole DM, up to a diameter compatible with the Ariane 5 fairing

- ☐ Rover volume is no longer shaped-constrained

- ☐ A total Instrument mass around 16.5 kg could be achievable

- ☐ The DM shape would be the same of Soyuz Vented Airbags but dimensions would be different

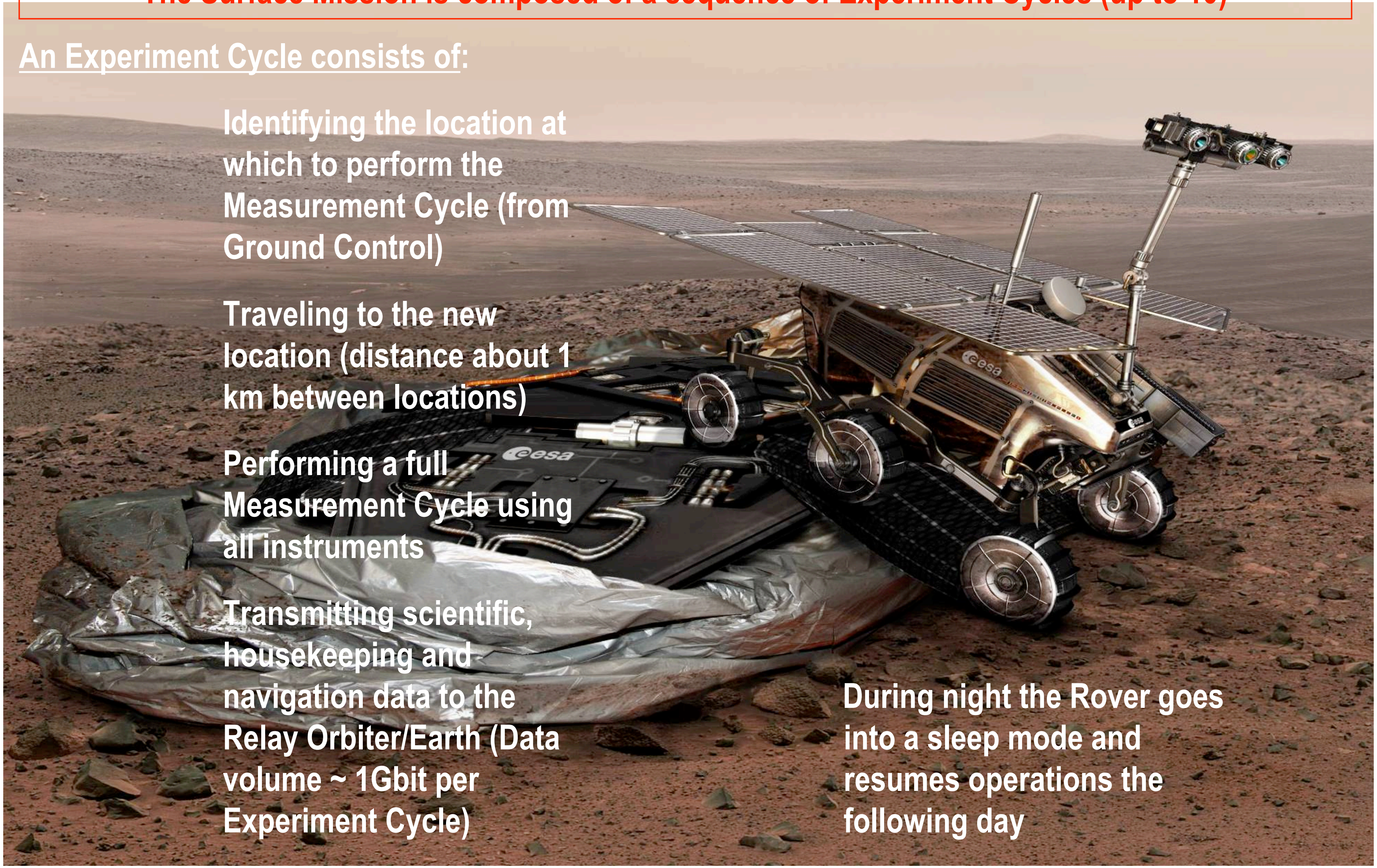


EDLS Components

- Rigid Front Shield with ablative material (Norcoat-Liege) and “cold” substructure (Aluminium shell)
- Back shell in Aluminium
- Flight instrumentation in the aeroshell for EDL Science measurements
- Disk Gap Band single parachute assembly (trade-off on going for dual stage parachute)
- Vertical and Horizontal Solid Retrorockets or Combined Vertical-Horizontal Liquid Retrorockets (possibility for thrust modulation is being considered)
- Airbags Assembly; two concepts are currently being studied, non-vented airbags and vented airbags,
  - It is planned to continue this parallel development until the end of Phase B1, when the results from the breadboarding tests will provide evidence for selecting the most suitable technology

Rover Surface Operations

The Surface Mission is composed of a sequence of Experiment Cycles (up to 10)



An Experiment Cycle consists of:

- Identifying the location at which to perform the Measurement Cycle (from Ground Control)
- Traveling to the new location (distance about 1 km between locations)
- Performing a full Measurement Cycle using all instruments
- Transmitting scientific, housekeeping and navigation data to the Relay Orbiter/Earth (Data volume ~ 1Gbit per Experiment Cycle)

During night the Rover goes into a sleep mode and resumes operations the following day

Rover Vehicle

❑ Locomotion

- ➢ 6 wheels, **RCL-type** chassis

❑ TTC

- ➢ X-band for DTE
    - 2 redundant transponders
    - 2 redundant SSPA
    - 1 RFDN
    - 1 Small HGA (30cm dish, 24dBi gain)
- ➢ UHF band for data relay with MRO
    - Internal redundant Proximity-1 compliant transponder
    - 1 LGA (quad helix)
    - 1 RFDN

❑ Power

- ➢ Solar Arrays
- ➢ Battery (Rechargeable, Li-Ion)
- ➢ PCDU

❑ Thermal Control System (TCS)

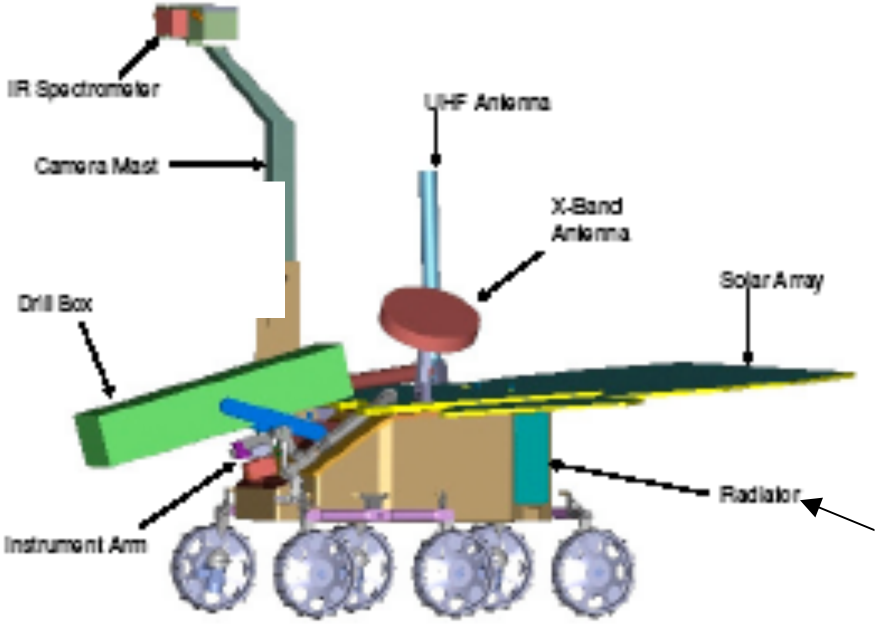
- ➢ Two options under trade-off (with without RHUs)
- ➢ Loop Heat pipes, Radiators, The Switches

❑ Navigation

- ➢ Cameras (Nav. Cam, Haz. Cams)
- ➢ Navigation sensors
- ➢ Autonomous Navigation Software

❑ Structure

- ➢ Integrated units
- ➢ Deployable mast for Cameras, IR Spectrometer and sensors
- ➢ SA support and mechanisms

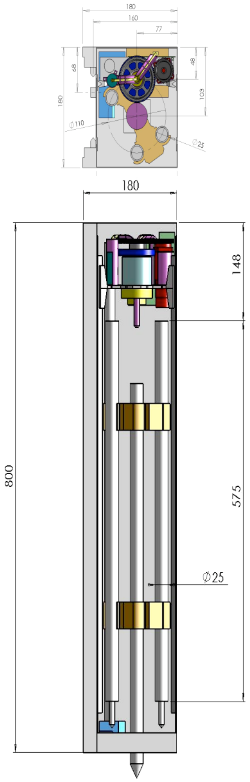


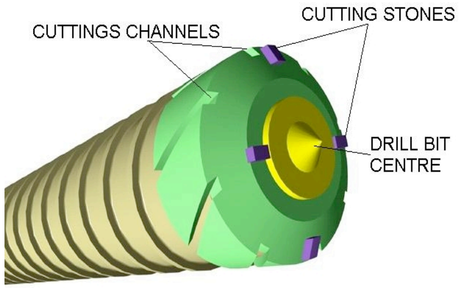
Radioisotope Heating Units

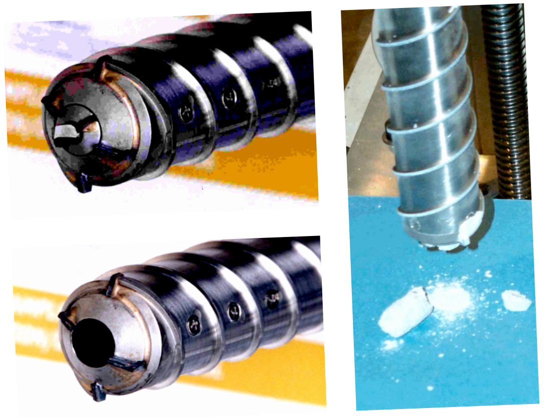
- Radioisotope Heating Units (RHUs) are needed on the Rover in order to provide 30W (TBC) overnight heating power
- 4 Angel units (from Biapos, Russia), each providing 8.5 W of heating power, are presently considered for the Rover design
- Accommodation/location inside the internal enclosure is subject to trade-off between easy late access, proper heat distribution and interfaces with the Rover TCS

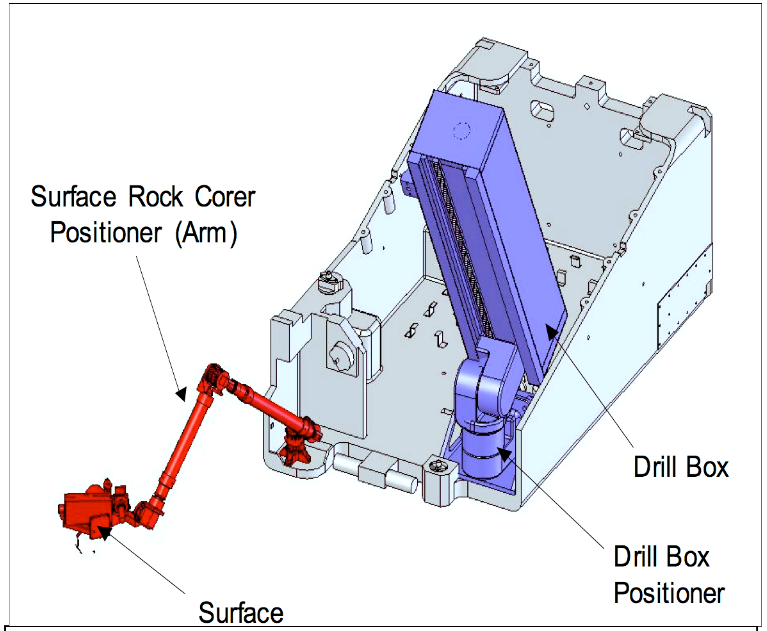
Drill and SPDS

- ❑ **DRILL SYSTEM – To obtain surface and subsurface samples for analysis; includes drill tool, rod exchange and positioning mechanism, sample delivery mechanism**
- ❑ **SPDS – To prepare and present samples to all analytical lab instruments; includes distribution mechanism and milling station**









Subsurface drill includes miniaturised IR spectrometer for borehole investigations