ExoMars – Overview and Expected Results for Planetary Entry Probe Engineering and Science

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Presentation Overview

Overview

Project History / Context
Technical and Science Goals
ExoMars Entry, Descent & Landing
Onboard Sensors for EDLS
Science Payload and expected Results
Current Status

Project History / Context

ESA's Aurora Programme

Set up in 2001 with the following goals:

- Create and implement a European long-term plan for robotic and human exploration of the solar system, with Mars, Moon and asteroids being likely targets
- Search for life beyond the earth
- Emphasis is on combination of exploration & technology development

Aurora Missions

- **ExoMars: Exobiology / EDLS and Surface Mobility (started 2003)**
- Earth re-entry capsule / Mars aerocapture demonstrator: technology validation missions
- Mars sample return
- Intermediate lunar mission ?

Technical and Science Goals

EXOMARS is the first mission of the European Exploration Programme in ESA

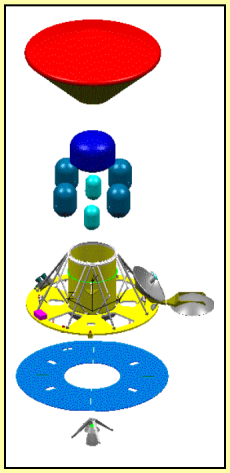
⇒ **It will demonstrate qualification of flight and in-situ technologies that are key to supporting future Exploration missions. These objectives are:**

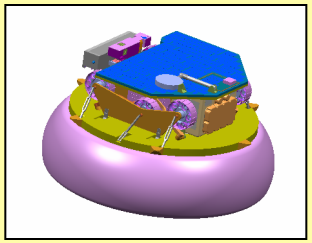
- Safe, entry, descent and landing of a large size payload (Descent Module)
- Surface mobility (Rover) and access to the sub-surface (Drill)

⇒ **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 on the rover (Pasteur Exobiology Payload) and the lander (GEP). The main scientific objectives to be addressed by these science instrument packages are:**

- The search for traces of past and present life,
- The characterisation of Martian geochemistry and water distribution at various locations,
- The improvement of the knowledge of the Mars environment and geophysics,
- The identification of possible hazards before landing other spacecraft or, in the longer term, humans on Mars

ExoMars S/C Configuration





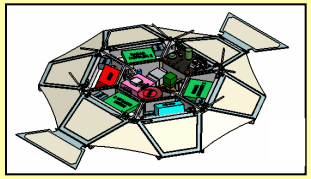
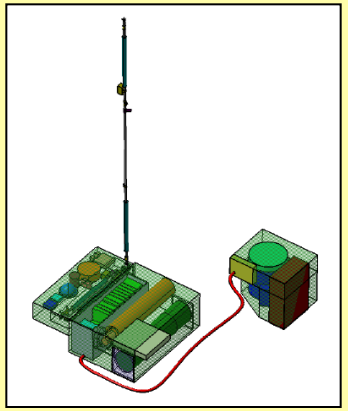
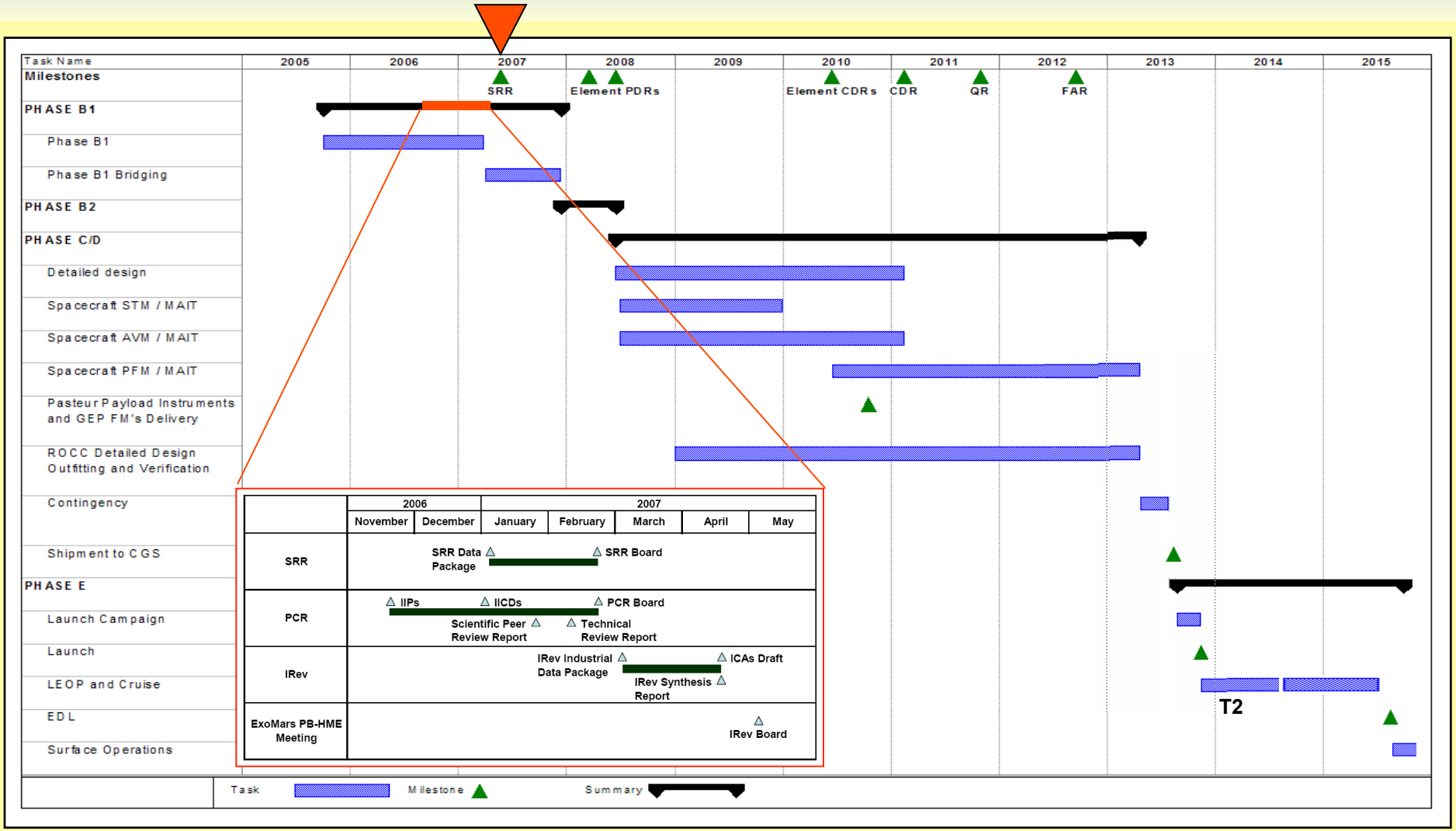


Image credits: ESA / TAS-I

- Launcher: Ariane 5 or Proton
- Carrier module for cruise & orbit insertion
- Entry from orbit – improving flexibility & accuracy
- ~1.13 ton Descent Module (DM)
- EDLS: heatshield ~3.4m dia, parachutes (DGB, Ringsail), retrorockets, vented airbags
- LM with integrated or plug-in ~30 kg GEP
- GEP payload: up to 11 instruments
- 205 kg rover
- Pasteur Payload: 11 instruments



ExoMars Schedule



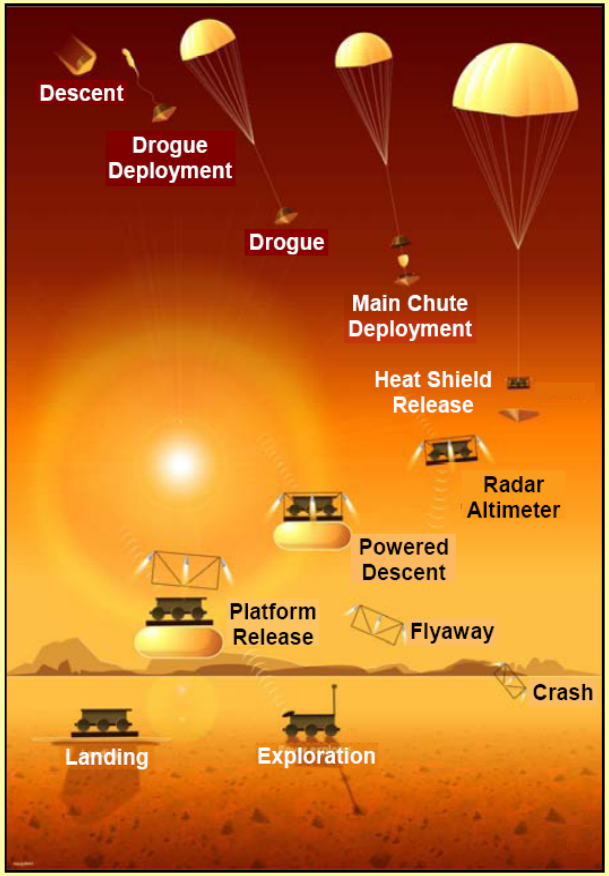
ExoMars EDLS design drivers

- **DM mass – ca.1130 kg**
- **Entry strategy – hyperbolic vs entry from orbit**
- **Entry velocity and angle**
- **Landing site altitude range: a ≤ 0m (MOLA) selected**
- **Landing ellipse size: semi-major axis < 50 km, 3-σ**
  - Needs to be small enough to allow to meet science goals (land in region of interest while avoiding special regions)
  - Tradeoff with entry velocity and -angle, max heat load, navigation accuracy required
- **Deceleration concept: parachute systems, rocket based deceleration and surface wind compensation**
- **Airbag system design: non-vented vs. vented airbags**

ExoMars EDLS: Sequence

- Arrival in orbit (Sept 2014)
- 2 hour coasting phase
- Entry speed 5.41 km/sec @ 130 km alt
- Entry angle -14.8 deg
- Max heat load @ 37 km, Mach 24
- Max g load @ 35 km (10.8g), Mach 18
- DGB drogue deployment @ 7.8 km, Mach 1.9
- Ringslot main deployment @ 5.8 km, Mach 0.8
- Front shield separation @ 4.8 km, Mach 0.3
- Altimeter operation @ 4 km, V_v < 58 m/s
- Parachute offload g-turn @ 450m, V_v = 50m/s, V_h < 30 m/s
- Drop & airbag inflation at E+304 sec, h > 12 m
- Touchdown at E+306.5 sec, V_v < 14 m/s, V_h < 12 m/s
- Backshell fly-away & crash

ExoMars EDLS sequence



ExoMars EDLS: Airbags

Vented Airbag System

- Baselined after IRev
- Allows higher payload fraction as compared to MER type AB
- 6 gas-filled chambers, inflated at 10-15m height
- Impact speed range ~ 8-18 m/s
- Laser / electronics controlled chamber deflation
- Breadboarding phase includes series of tests with varying env. parameters (impact speed, impact angle, surface properties,..)

1st / 2nd ExoMars airbag breadboard test a / b , June 2007

Image credits: ESA / TAS-I / Aerosekur / CIRA

Onboard sensors for EDLS (1)

Planned measurements during EDLS

- ***EDLS requirement for a flight instrumentation package to perform measurements (environment composition, heat flux, temperature and pressure) during entry and descent***

- Temperature sensors (verification of heatshield thermal behaviour)
- Heat flux sensors (flight / model cross comparison, margin optimization)
- Pressure sensors (measuring the pressure field, possibly acq, of attitude information)
- UV-IR Spectrometer (measure flow composition for model verification)

- Sensors on backshield & frontshield
- Important: low mass (<10kg total)
- Minimized risk impact

Allocated masses	Front shield	Backshield
Therm plugs / thermistors	1.7 kg	1.2 kg
Pressure sensors	1 kg	1 kg
UV-IR spectrometer	-	3.5 kg

Onboard sensors for EDLS (2)

Proposed front shield sensors

- **10 Thermal plugs / thermistors**
- **10 Pressure sensors**
- **10 Surface recession gauges**

- Thermal plugs within the TPS: reconstruction of the heat flux considering the TPS behaviour (use of the TPS thermo-chemical model). Classical use on ground and some on flight (MPF, ARD)
  - Risk of introducing weak point on the TPS is very small – same TPS material and same joint -> same procedure as for TPS repair
  - Avionic interface very specific – Not compatible with standard interface – needs to be taken into account for DAQ / DPU interface design

Front shield sensor accomodation (example)

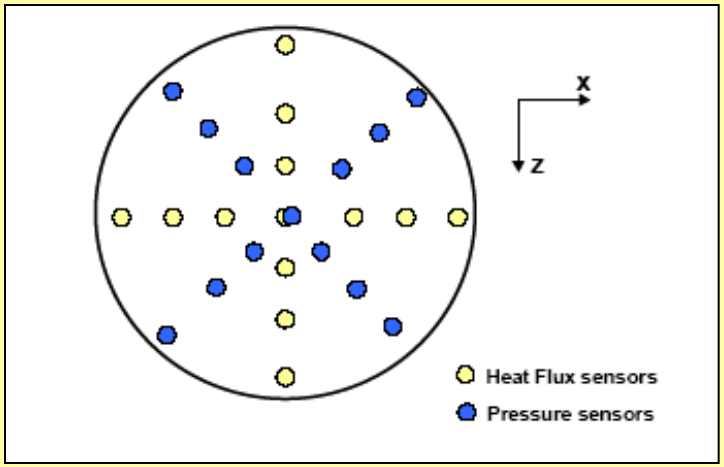
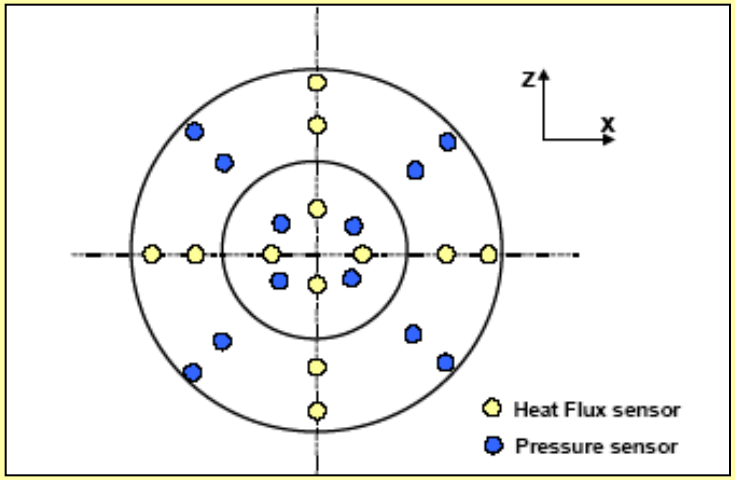


Image credits: TAS-I

Onboard sensors for EDLS (3)

Proposed backshell sensors

- 10 thermal plugs, 10 thermistors
- 10 Pressure sensors
- Re-entry spectrometer candidate: RESPECT developed by IRS Stuttgart for flight on the EXPERT re-entry capsule (planned 2009)



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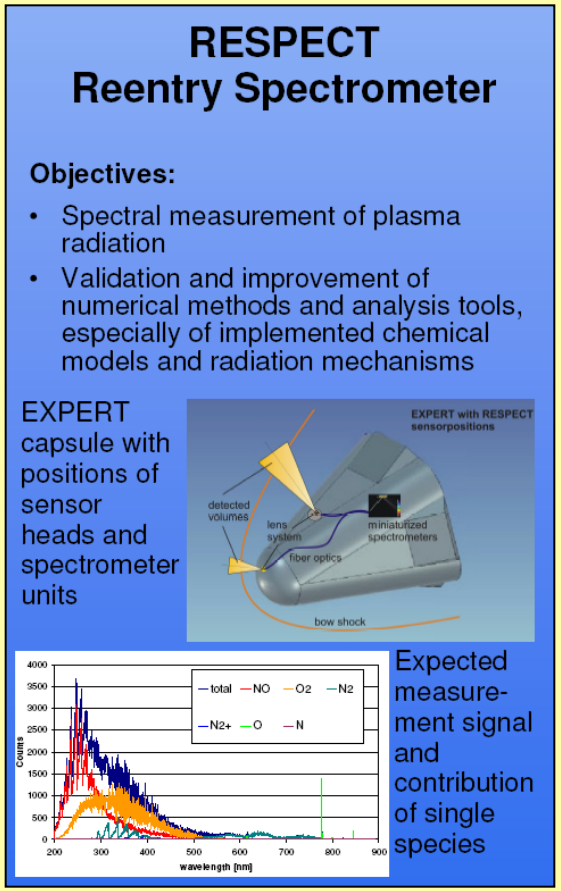

Image credits: IRS Stuttgart

Pasteur Payload

Instrument Name	Countries	Mass (kg) incl. maturity margin	Instrument Description
PanCam	UK, D, A…	0.760	Panoramic camera system (Rover mast)
Urey	USA, NL, CH…	4.422	Mars Organics Detector (MOD) and Mars Oxidants Instrument (MOI) (analytical lab.)
MOMA	D, USA, F…	4.182	Gas chromatograph / mass spectrometer (analytical laboratory)
WISDOM	F, N, USA…	1.087	Ground-penetrating radar (under Rover)
Raman/LIBS	E, NL, F, D…	1.872	Combined Raman and LIBS (robotic arm and analytical laboratory)
MicrOmega	F, CH, I, D…	1.071	VIS + IR spectrometer (analytical laboratory)
MIMOS-II	D, DK, F…	0.320	Mössbauer spectrometer (Rover's robotic arm)
CLUPI	CH, F, CDN…	0.200	Close-up imager (Rover's robotic arm)
Mars-XRD	I, UK, E…	1.320	X-ray diffractometer (analytical laboratory)
MIMA	I, RUS, E…	1.000	IR Fourier interferometer (Rover mast)
Ma_Miss	I, P, PL	0.414	IR borehole spectrometer (part of subsurface drill)
Total Pasteur		16.65	

- All instruments: TRL 3-4 at PCR (March 2007)
- TRL 5 needs to be reached by PDR (Spring 2008)

Direct atmospheric studies

Surface dust

Geophysics Package Payload

Instrument Name	Countries	Mass (kg) incl. maturity margin	Instrument Description
MiniHUM	D, UK, F…	0.016	Miniaturised humidity and frost point sensor
EISS	F, N, USA…	0.358	High-frequency GPR for deep soundings
METEO-AEP	UK, FIN, DK..	0.474	Suite of meteorological sensors
MEDUSA	I, DK, E…	1.316	Dust instrument suite
LaRa	B, USA, F…	0.820	X-band transponder for radio science experiment
ARES	F, UK, HUN	0.134	Atmospheric relaxation and electric field
UVIS	UK, D, B, I…	0.385	UV-VIS spectrometer
IRAS	D, I, UK, B	0.510	Radiation instrument
MSMO	DK, F, UK…	0.280	Magnetic observatory
HP3	D, P, F, UK..	~ 1.8 kg	Subsurface mole / Heatflow and physical properties package
SEIS	F, UK, S, D	~ 2.3 kg	Seismometer
Total		~ 8.4 kg	

Direct atmospheric studies

Atmospheric electricity

All instruments: TRL 3-4 at PCR (March 2007)

TRL 5 needs to be reached by PDR (Spring 2008)

Current Project Status

Phase B1 (study of several mission options) conducted until May 2007, including

- **PCR: Recommendations on payload complements obtained, TRL assessed**
- **SRR: Successful, RIDs completed / being processed**
- **IRev: Culmination of Phase B1, with selection of final mission configuration**

06 2007

- **PB-HME - Enhanced baseline (A5, vented airbags, 16.5 kg PPL, GEP) accepted**
- **Authorization to proceed with RFQ for B2-C-D-E1 by July 2007 was obtained**

Ongoing & near-term activities

- **Work on RFQ to TAS-I ongoing with high priority, deadline 16 07 2007**
- Proposal from TAS-I expected 08 2007
- Proposal evaluation, negotiations, agreement, B2-C-D-E1 kickoff
- Breadboarding activities (rover, computers, batteries, SPDS, …) ongoing
- Next major milestones: PDRs in early 2008 !

Summary

ExoMars Mission

- Configuration: Heavy launcher, CM + DM, entry from orbit, rover + GEP
- Launch 2013, T2 transfer, arrival late 2014, landing 2015
- Surface mission focused on Exobiology (rover + PPL) including subsurface sampling, plus Geophysics Package (GEP)
- Operations: nominal mission 180 sols

Expected results for Planetary Probe Engineering & Science

- In-flight characterization of environment during atmospheric entry on Mars
- In-flight measurements of heatshield performance
- Detailed characterization of important atmospheric constituents
- Detailed characterization of dust and its effects in the Martian atmosphere
- Accurate meteorological measurements supporting atmospheric modelling