Miniaturisation needs of the Mars Network Landers

INSPIRE mission

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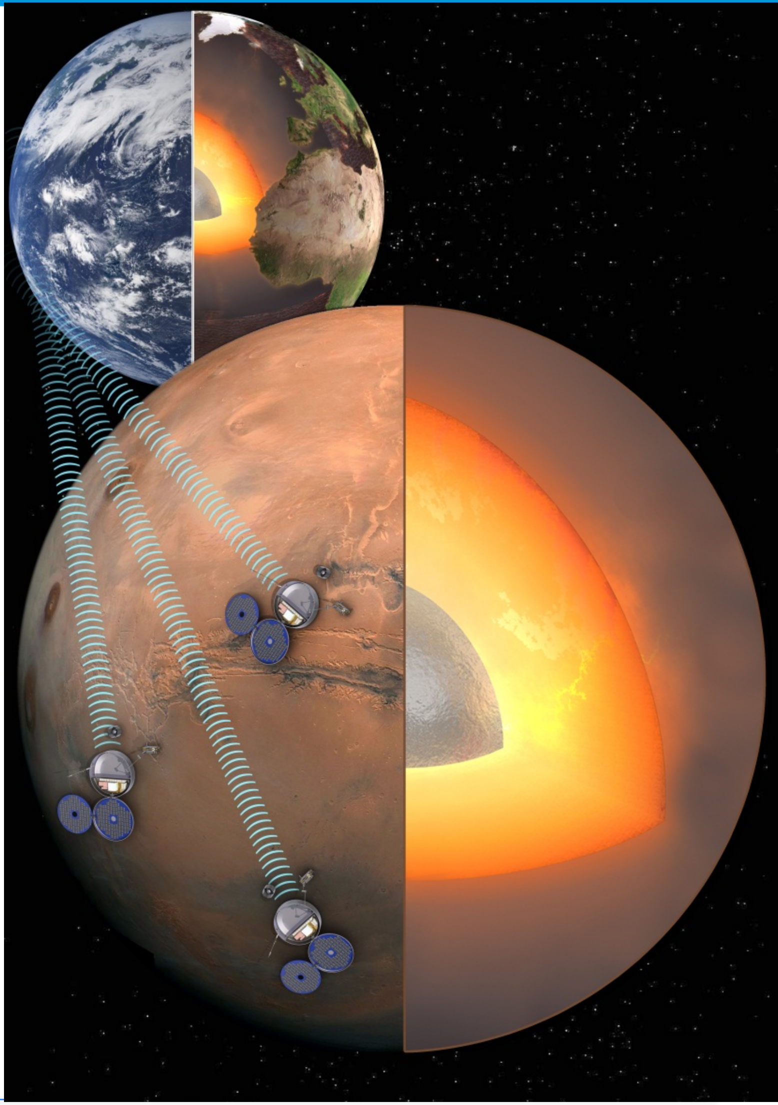


Outline

- Background
- Mission Overview
- Need for Miniaturisation
- Current activities in MREP
- Potential future development
- Conclusions

Background

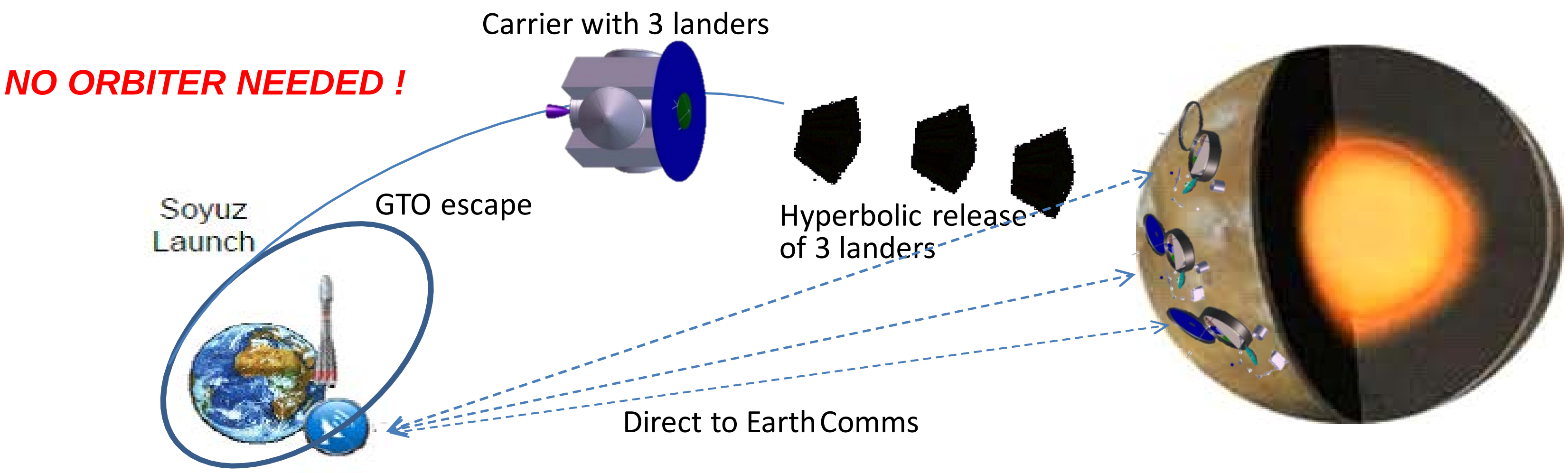
- **Mars Network Science mission proposed within the MREP program**

- **Mars Robotic Exploration Programme (MREP/MREP-2):**
  - Mars Sample Return mission is taken as long term objective
  - Target is to contribute to each Mars mission slot (every ~2 years)
  - Prepare post-ExoMars missions and enable decisions at next C-Min (2012)

  - **Mission Studies**: 2 candidate missions for Launch from 2022 onwards for MREP-2
    - Phobos Sample Return Mission – PHOOTPRINT
    - Mars Network Science Mission - INSPIRE

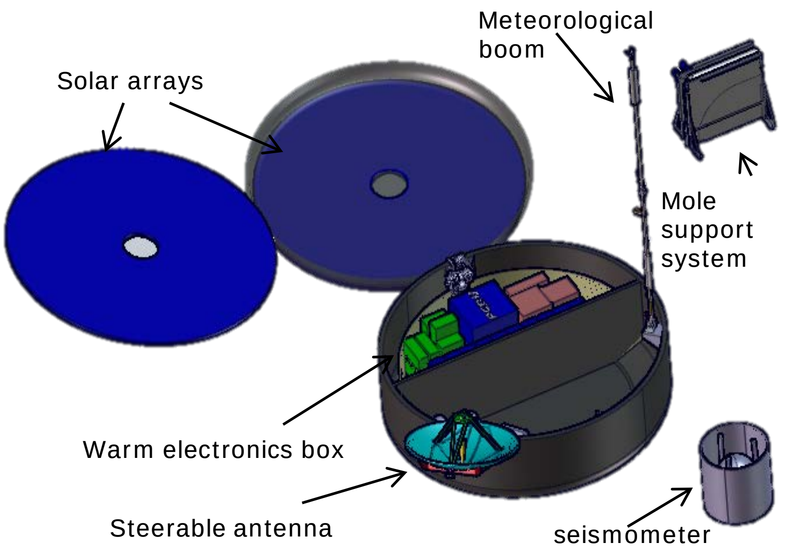
  - **Technology Development**
    - Short term & Mid Term: For 2022 or 2024 proposed missions
    - MSR critical Technologies
    - Long term: strategic and enabling technologies for European Robotic Exploration

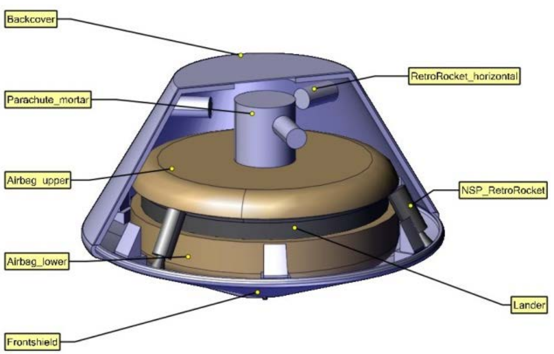
Mission Overview: INSPIRE

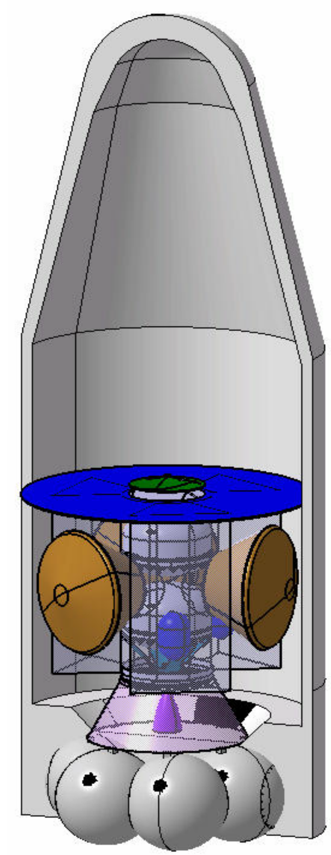


- **Soyuz Fregat** launch from Kourou into GTO (3180 kg spacecraft composite incl adapter).
- 7-12 months transfer with carrier spacecraft providing 1.4-1.7 km/s delta-v.
- Carrier releases in sequence **3 network landers** up to 12 days before Mars arrival.
- Carrier break up and burn up in the Martian atmosphere (Planetary Protection compliant).
- Each lander performs ballistic **entry, descent and airbag landing**.
- Surface platform of ~120 kg deployed on the Martian surface with Direct to Earth comms.
- Deployment of instrumentation, some using **a robotic arm**.
- **Long duration operations** (goal >1 full Martian year) on the Martian surface to investigate the interior of the planet.

The mission elements







Spacecraft Composite in Soyuz

- Most avionics located in Warm Electronics Box protected with several cm of insulation
- Lander avionics used for entry, descent and landing as well as surface operations
- The probe has an instrumentation/payload mass of 5% or the entry mass.

The need for miniaturisation (1/2)

- **Accommodating 3 Mars landers on a Soyuz launch requires avionics with low mass**
  - Large **direct snowball effect on mass**
    - 1 kg on surface per lander
    - → additional 1.5 kg needed for safe landing (2.5 kg penalty per probe)
    - → x 3 probes (7.5 kg penalty)
    - → + increase in carrier structure and propellant for GTO transfer of factor 2
    - ➔1 kg saved per lander (3 kg landed mass) reduces launch mass by 15 kg!
  - Remember: Per lander the payload mass fraction is only 5%, so every kg of avionics could be replaced by payload once launch mass margin is met
  - Volume & power have additional indirect impact on launch mass

The need for miniaturisation (2 / 2)

- **Accommodating 3 Mars landers on a Soyuz launch requires avionics with <u>low volume and power</u>**
  - Volume
    - <u>Direct impact:</u> driver to limit lander size to fit within launch fairing
    - <u>Indirect</u>: Avionics volume increase → increase in surface platform size → increase in aeroshell size → large mass penalty
    - <u>Indirect</u>: Avionics volume increase → increase in warm electronics box volume → increase in thermal power requirement → increase in power system volume and mass
  - Power
    - Avionics power reduction, translates to smaller and lighter power system → launch mass impact
- **For long duration surface missions, there is also a benefit to have low power /hibernation modes and low temperature survivability**

Current Developments in MREP

- **The MREP Technology development plan :**
  - Can be found on: http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=47729
  - Reviewed as a minimum once a year according to mission needs
- **Current activities for miniaturised or compact avionics:**
  - Compact dual UHF/X band Communication Package study
  - Tailored OBC EM for planetary landers
- **Developments needed in coming years**
  - Miniaturised PCDU for Mars landers/rovers
  - Miniaturised Dual UHF X band EM development
  - Miniaturised gyros and accelerometers (IMU), altimeter

Conclusions

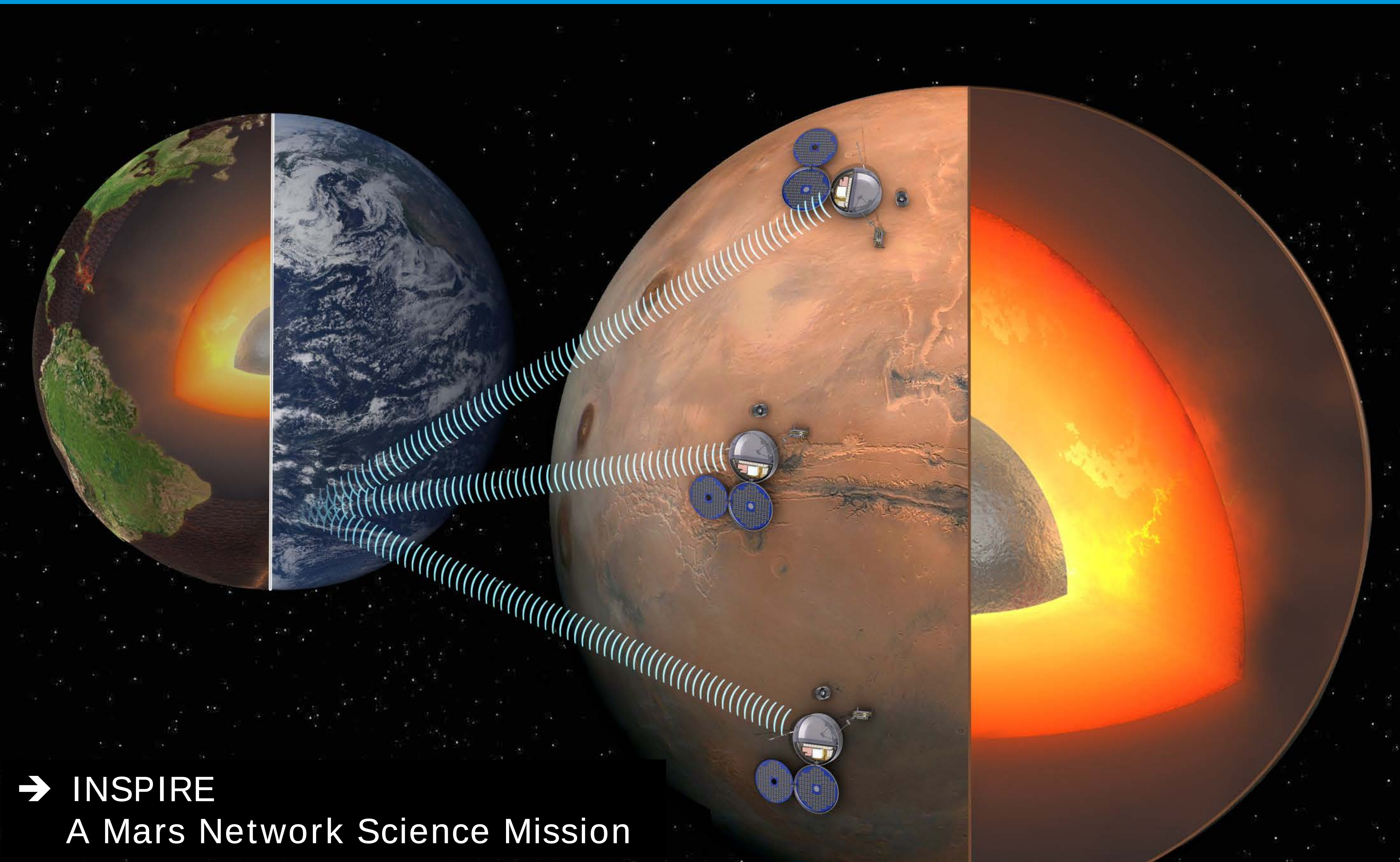
- **Exploration missions in general have large mass snowball effects and tight volume constraints, due to the large amount of propellant required and entry, descent and landing system for planetary landers**

- **Miniaturising avionics is essential!**
  - Can enable missions (meet launch margins)

  And/or

  - Increase science return by increasing the payload mass.
- **Miniaturised avionics identified as enabling building blocks within MREP-2 Technology Development Plan**

Questions ?

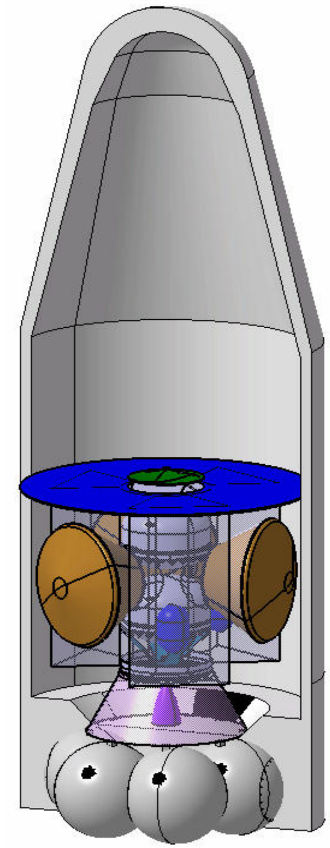


➔ INSPIRE
A Mars Network Science Mission

Carrier Spacecraft

- "Smart" carrier design totally independent from the landers:
  - No subsystems shared with the landers
- Launch mass: dry 516 kg, wet 1915 kg

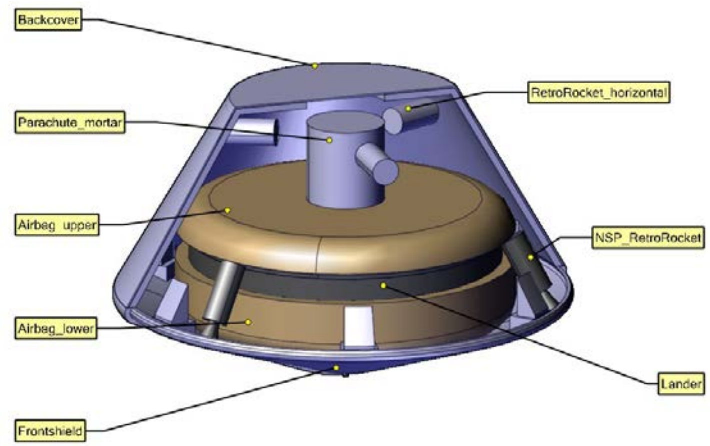
Configuration	• Standard interface of 937 mm diameter • Central cylinder accommodating tanks • Circular top panel to accommodate solar cells • 1m HGA integrated in top panel • 3 landers spaced by 120 degrees on side panels
Propulsion	• Bipropellant (Isp =322 s), 400 N main engine • Maximum 1400 kg of propellant in 2 large tanks
Thermal	• Standard passive thermal control design
Power	• Total area of 10.2 m^2 for the fixed solar panel • MPPT in an unregulated bus • Rechargeable Li-Ion battery
Communications	• X-band communications to ESA DSN • 1m fixed HGA • 65 W RF power • 8 kbps downlink @2.6 AU
AOCS	• 3-axis stabilised • 12 x 10N RCS thrusters • 2 star trackers, 2 IMU and sun sensors
Mechanisms	• 3 spin up and eject mechanisms for the landers

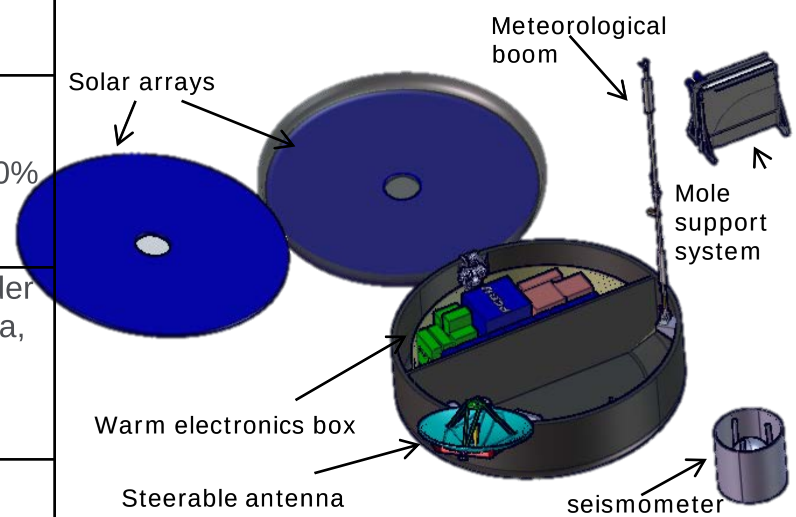


Spacecraft Composite in Soyuz

Surface Platform

Configuration	• 1.15 m diameter clamshell lander • Solar panel deployed from lander lid
Landing Site	• Latitude: -15 to +20 degrees • Altitude: < 0 km MOLA • Accuracy: ~100 km
Lifetime	• Goal >1 Martian year
Data Handling	• Based on “Tailored On-Board Computer for planetary landers” MREP development • ~5 Gbits of mass memory to store data during solar conjunctions
Thermal	• Warm electronics box (WEB) with aerogel insulation up to 10 cm • Potential use of RHU to enhance mission lifetime • Loop heat pipe connecting WEB to radiators
Power	• Solar array of ~2 m^2 sized for 550 Wh/sol at optical depth of 2 • 6.2 kg Li-ion battery sized to deliver 550 Wh with 60% DoD • Dust removal system to extend lifetime
Communications	• MREP development of dual UHF-X band transponder • X-band direct to Earth link, 40 cm steerable antenna, >1.4 kbps @2.6AU • Data relay capability compatible with any existing orbiter using proximity-1 protocol
Mechanisms	• Self-righting hinge • Robotic arm for instrument deployment





Entry, Descent and Landing

Coast Phase:

- From Carrier separation to entry

Entry:

- (1) Entry into Martian Atmosphere detected

Descent:

- (2) DGB Parachute opens at Mach 1.8
- (3) Front Shield is jettisoned
- (4) Lander with its Airbags system is lowered along a bridle from the Back Cover
- (5) Airbags are inflated
- (6) At predefined altitude, the retrorockets are ignited.
- (7) Bridle is cut ; the Back Cover is propelled away from the Lander;

Landing:

- (8) Lander free fall to the surface
- (9) Lander protected by its airbags bounces several times
- (10) Lander stops and comes to rest
- Airbags system is separated from the lander;

Clamshell lander is opened and surface operations begin