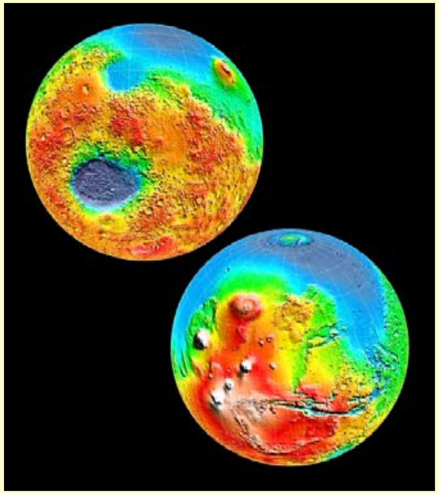
# On the feasibility of a fast track return to Mars

## Mars Lander(s) 2011
## Mars Demonstration Landers (MDL)



# Technology Demonstrators

SMART 1 → Solar Electric Propulsion → BepiColombo / Solo / Cosmic Vision 2015-2025

SMART 2 LISA PF → Drag Free Control → LISA / Cosmic Vision 2015-2025

## Entry, Descent and Landing

- Mars
- Moon
- Mercury
- Europa

# What are the descent options ?

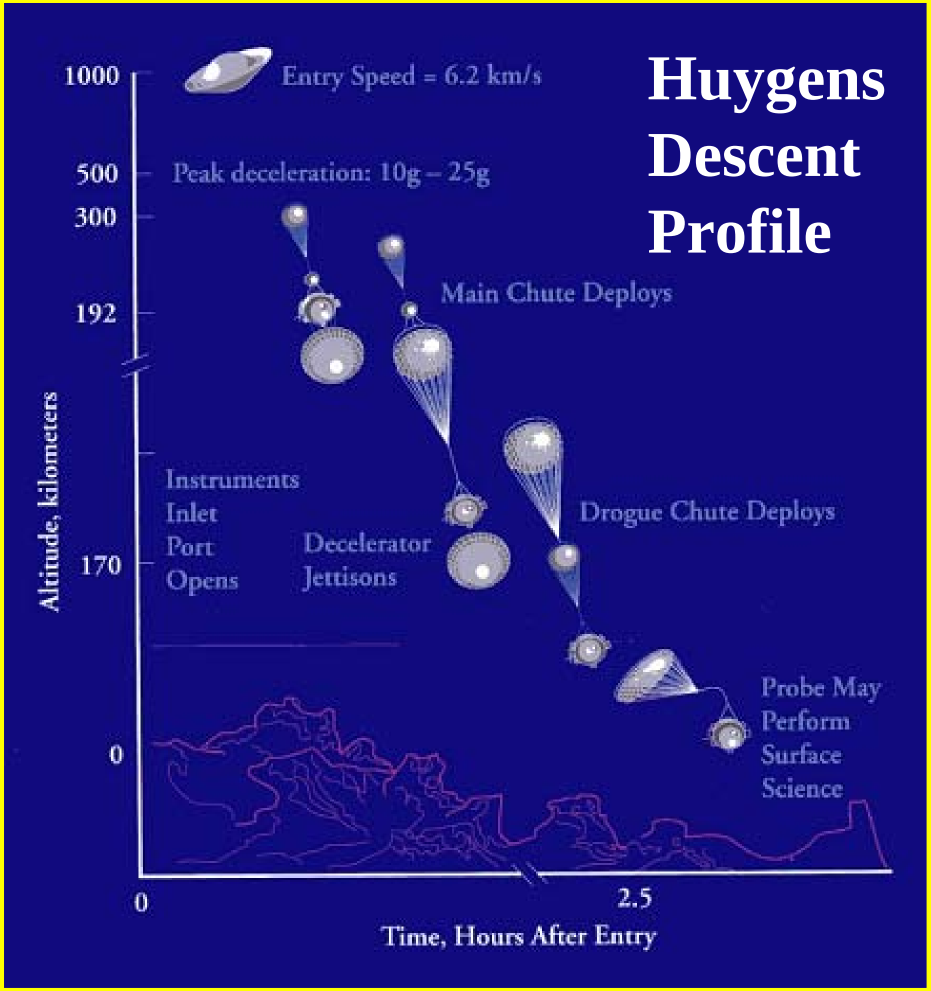
1. **Passive Descent:** Parachute System with Airbags on Landing **(High risk and applicable only to Mars)**

2. **Powered Descent:** Thrusters (+Parachute System when applicable) **(Horizontal and Vertical Velocity Control)**
   - **Soft Landing → significantly reduce risk at impact**
   - **Very high mass descent system**
   - **Technology learning curve can be applied to airless bodies**

3. **Partially Controlled Descent:** Parachute System + Thrusters **(Horizontal Velocity Control)** with Airbags on Landing
   - **Reduce horizontal velocity → reduce risk at impact**
   - **Higher mass system**

# 1) Passive Descent

- Higher Risk as no control is implemented on descent
- European Heritage - from Huygens Entry & Descent System
  - Similar to Mars entry since Huygens was deployed at a very high altitude where atmospheric density is similar to that encountered on Mars
  - Learning curve from Beagle 2
    - Over-dimension EDLS
    - Extensive ground test and verification programme
    - Telemetry during descent



# 2) Powered Descent (Soft Landing)

- Reduction in velocity for landing reduces risk

  But….

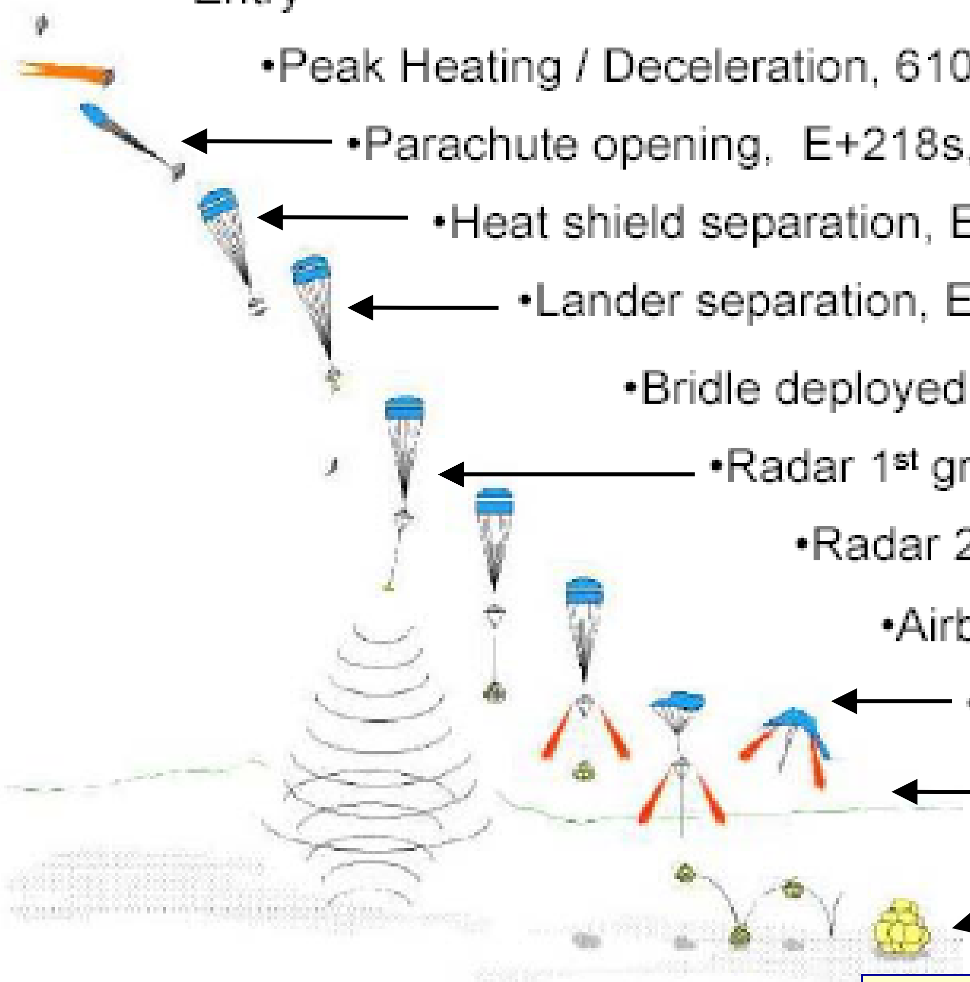
- NO HERITAGE IN ESA or Member States
  - Time constraints for an early launch in the 2011 window do not permit the development of a powered descent system
    - Design phase (including learning curve from other agency's
    - Extensive test and validation phase
- Extremely mass constraining
- Key long term technology for Moon/Mercury/Europa

# 3) Partially Controlled Descent

- **Provides Horizontal & some vertical Velocity Control**
- **Reduces Risk on Landing**
  - **Optimizes conditions for airbag impact**
- **No Technology Heritage in Europe →**
  **Immediate Developments Required**
  - **Control Sensors**
  - **Thrusters**
  - **Airbags/parachutes/GNC/ System development**

**→ Recommended Approach**

# MDL- A Possible Descent Profile



- Entry
- Peak Heating / Deceleration, 610 kW/m$^2$, 7.9 earth g
- Parachute opening,  E+218s, 9.3 km, 492 m/s
- Heat shield separation, E+238 s (20s gap)
- Lander separation, E+248 s (10s gap)
- Bridle deployed, E+258 s (10s gap), 6 km
- Radar 1$^{st}$ ground acquisition, L-28s, 4.5 km
- Radar 2$^{nd}$ ground acquisition, L-14s, 3.5 km
- Airbag inflation, L-10s
- Rocket firing, L-5 s, 2100 m
- Bridle cut, L-3 s, 2014 m
- Landing, L-0s, 2000 m

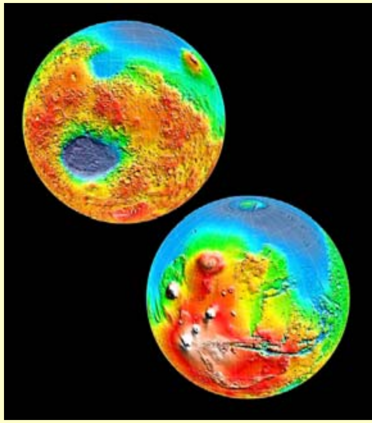
From Aurora Demo Lander Study

# Airbags

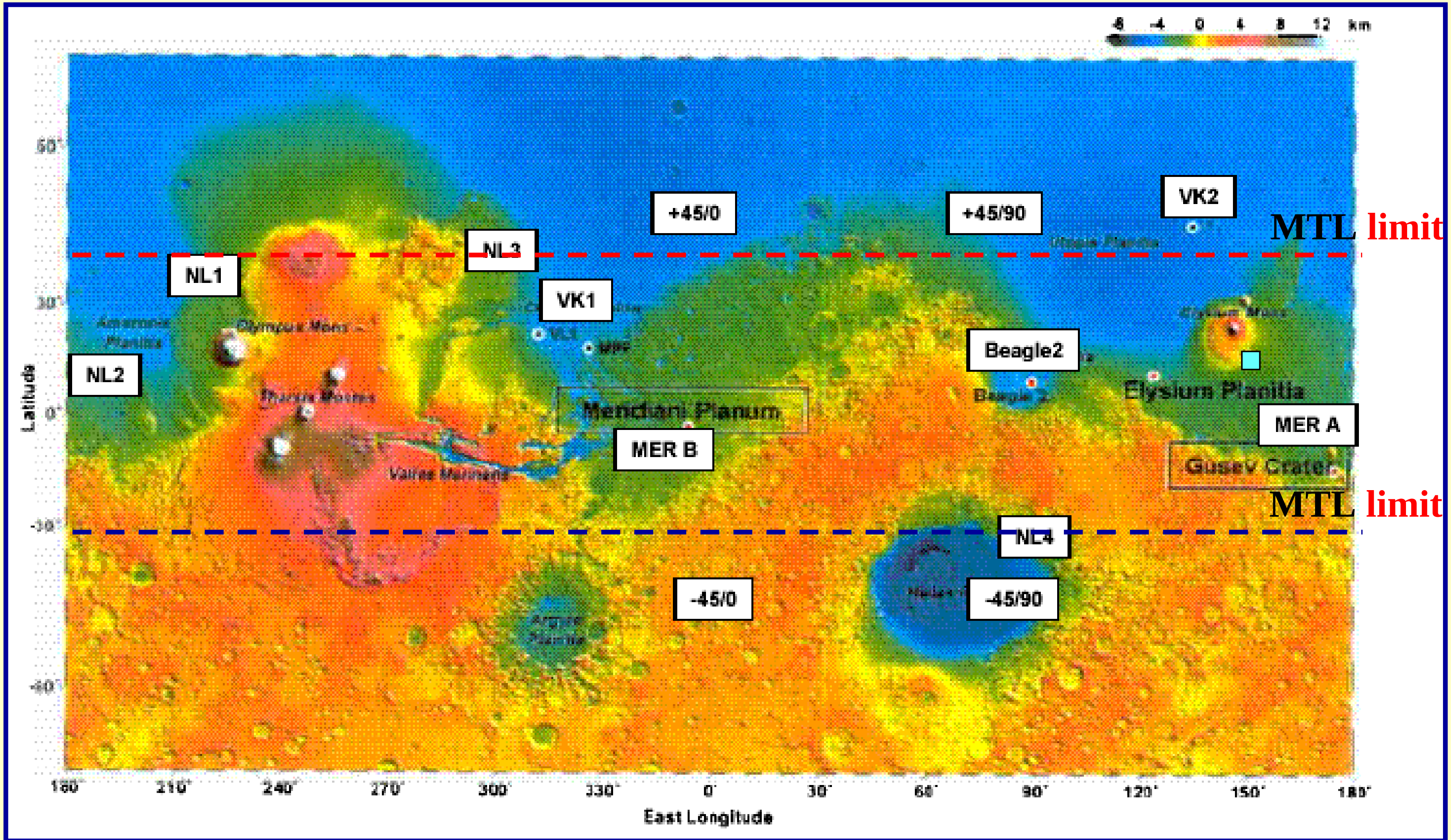
- Permits Hard Landing
  - both Passive and Controlled Descents
- Limited heritage in Europe →
  - Immediate Development Required
  - Extensive ground test campaign required
- Airbags must be released or retracted so as not to impede Lander after impact
  - Vented & sealed airbag tradeoff

# Selection of MDL Landing Sites

- Landing Site Selection is Critical to Ensure Successful Descent and Landing of the MDL's
- Elevation limited due to the requirement for a thick enough column of atmosphere to allow sufficient deceleration and safe landing
  - MER A, MER B, elev. < -1 km & Viking 1 /2, elev.< -3km)
  - Lower landing elevation leads to greater margin in EDLS (but may bias science)
- Latitude limited by power requirements
  - constrained by use of solar cells
  - preliminary limit : -35 deg to +35 deg
- Landing sites should be scientifically important for
  - Exobiology
  - Geophysics

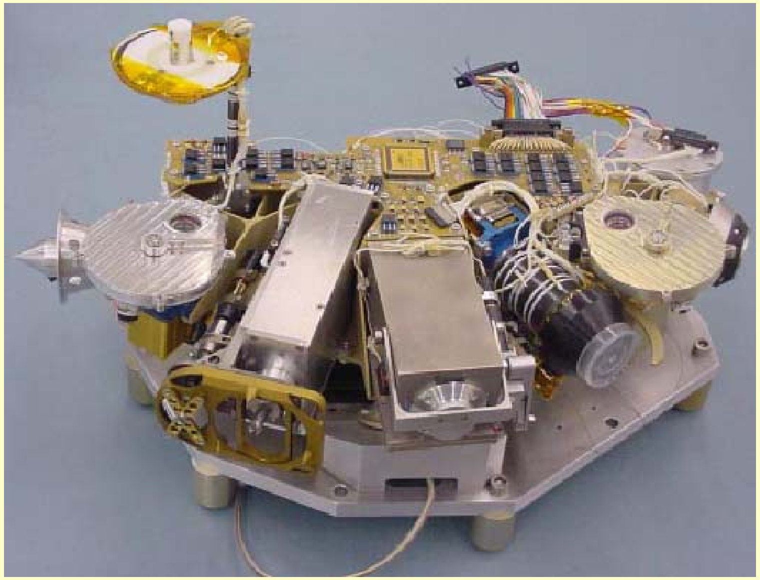


# Current or Attempted Landing Sites



# Possible Payloads (1): Beagle 2

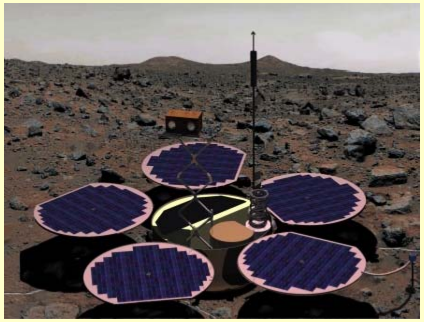
| Instrument | Mass [g] | Power [W] |
|---|---|---|
| Gas Analysis Package | 5740 | |
| Environmental Sensor | 0.156 | |
| Two Stereo Cameras | 350 | 1 |
| X-ray spectrometer | 154 | 3.9 |
| Microscope | 205 | |
| Mössbauer Spectrometer | 540 | 3 |
| Rock Corer Grinder | 348 | 6 |
| PLUTO (incl. deployment unit) | 890 | 3 |
| **Total** | **8.2 kg** | |



**Payload available ~ 10 kg**

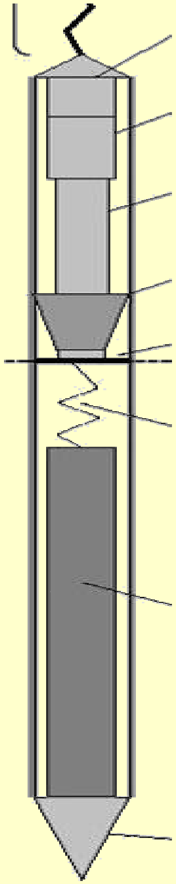
# Possible Payload (2) : Netlander Payload

| Instrument | Mass [g] | Power [W] | Status |
|---|---|---|---|
| ATMIS: Atmospheric Sensors | 855 | 0.43 | Beadboard |
| SEISMO: Seismometer (VBB+SP) | 1700 | 0.5 | Breadboard |
| PANCAM: Panoramic Camera (incl. boom) | 1860 | | Breadboard |
| ARES (ELF): Electric Field | 100 | 0.3 | Study? |
| MAG: Magnetometer | 210 | 0.25 | Flight unit |
| GPR: Ground Penetrating Radar | 460 | | Study |
| Microphone | 50 | | |
| NEIGE: Ionosphere & Geodesy Experiment | 300 | | |
| SPICE: Soil Properties | 50 | | Breadboard |
| **Total** | **5.6 kg** | | |



**Payload available ~ 10 kg**

# Possible Payload (3): Sub-surface sampler



- **Mole available by 2011**
  - Can be configured for geophysics or exobiology
- **Mole carrying the HP3 (Heat Flow and Physical Properties Package)**
  - HP3-TEM (Thermal Excitation and Measurement Suite)
  - HP3-DEN (Densitometer)
  - HP3-DACTIL (Depth, Accelerometry and Tilt Measurements)
- **Mole carrying exobiology package**
  - ATR (Attenuated Total Reflection Spectroscopy)
  - Optically stimulated Luminescence dating
  - Raman spectrometer

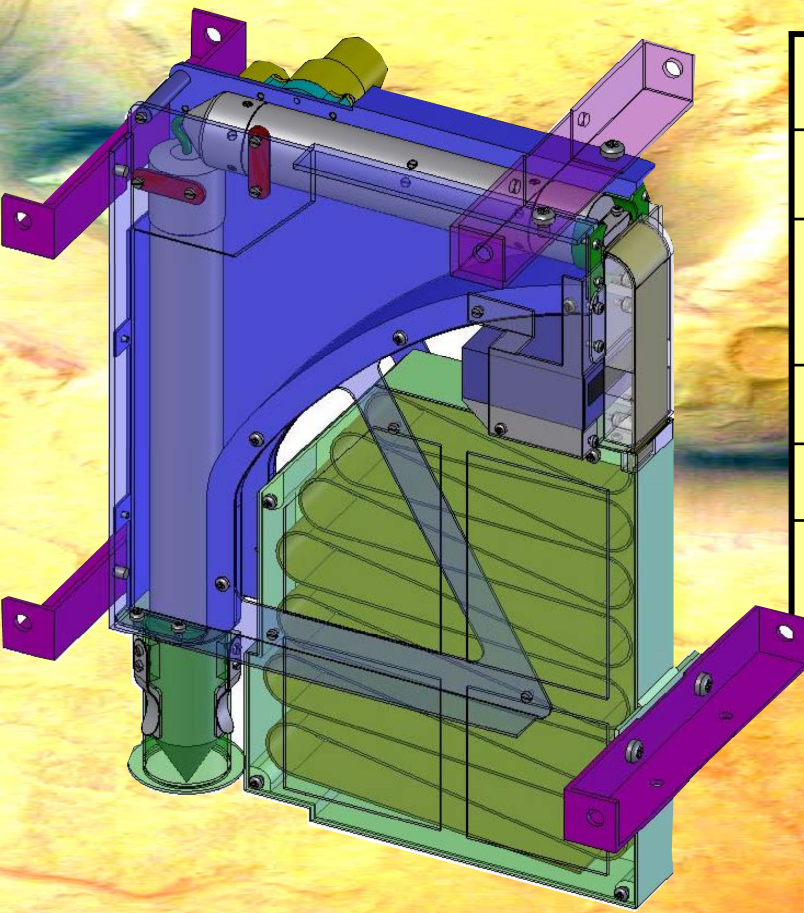
# The only way is down

## Comparison between PLUTO and the new Instrumented Mole System (ISM)

| | PLUTO | ISM |
|---|---|---|
| Purpose | Sample Collection | Instrument Carrier |
| Retrievable | Yes | No |
| P/L | No | Yes |
| Mass, Power, Size | 890 g, 3 W, 280x20mm | 1110 g, 3W, 330x25mm |
| Penetr. Depth [m] | 1.5 | 5 |
| Penetr. Speed | 1.5 m in 1.16 h | 5 m in 5.7 h |
| Status | Flight Model (Beagle 2) | Functional and tested Breadboard in 2005 |

# Subsurface Measurements

## Instrument Packages for the ISM



| | HP$^3$ | ATR | µRaman | XRS |
|---|---|---|---|---|
| **Phys. Prop.** | X | | | |
| **Mineralogy Chemistry** | | X | X | X |
| **Exobiology** | | X | X | |
| | | | | |
| ***Development Status*** | active dev. BB in 2006 | | study | |

**HP3 – Heat Flow Physical Properties Package**

**ATR – Attenuated Total Reflection Spectroscopy**

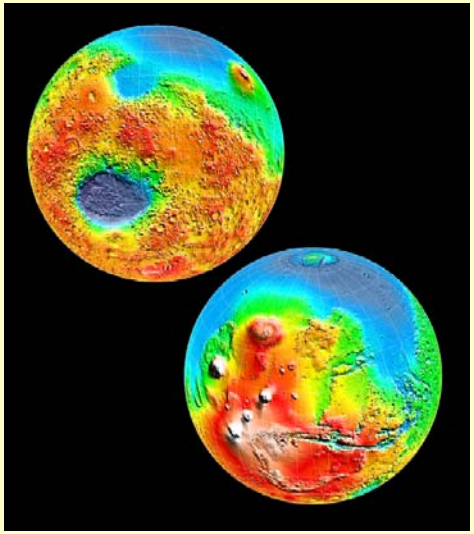
**µRaman – Front end in ISM, main instrument on Lander**

**XRS – X-ray spectrometer**

# Mars Demonstration Lander Study Heritage

- **Two relevant studies**
  - **D-Sci Mars Network Science study**
    **(4 Landers, 92 kg with improved EDLS, hyperbolic insertion)**
  - **Aurora Mars Demo Lander**
    **(1 Lander 250 kg, partial controlled descent, hyperbolic insertion)**
- **Mars Network Science Study looked at the re-use of MEX technology to deliver a set of Landers to Mars & provide communications. Limited study of EDLS & Landers**

# Mars Demonstration Lander Proposed Approach



- **Top level assumptions**
  - → **Soyuz Fregat SF2b from Kourou**
  - → **Launch to Highly Elliptical Orbit prior to Earth Escape (to maximize mass)**
  - → **Adapted and Optimized MEX carrier**
    - → **Provide communications relay and possible orbiter P/L**
- **Lander assumptions**
  - → **for 2 Landers, ~150 kg each**
  - → **Released from Mars elliptical orbit (comm. during descent)**
  - → **40 kg surface element including a 10 kg payload**
  - → **Design significant margins to over-dimension the EDLS**
  - → **Communications during descent and landing**
  - → **Landers released independently in a phased manner to two different landing sites**
- **2 Landers**
  - ➢ **Increases probability of a successful landing**
  - ➢ **Increased landing test data**
  - ➢ **Increased Science return (consider subsurface science)**

***Study needs to be conducted urgently to ensure schedule !***

# Mars Demonstration Lander Status & Needs

- **Status:**
  - No demonstrated European capability of a safe landing on high-gravity planetary body with low atmospheric density
  - Demonstration required of the EDLS before taking the next logical steps for any strategic phased exploration programme
    - Surface networks
    - Surface mobility
    - Deep subsurface studies
  - Improved Lander (Beagle 2/NetLander-class) is logical first step
- **Development needs:**
  - Robust system with partial descent control, to cope with the uncertain environment (pressure, temperature, wind, terrain)
  - Telemetry of critical EDLS parameters during Descent & Landing
  - Consolidate end-to-end European EDLS, with priorities (in order):
    - Airbags, Descent Thrusters and GN&C, Parachutes, Front Shield,
    - System validation (qualification, test & analysis) over a wide range of external parameters

# Mars Demonstration Lander Development Needs

| Item | | Needs |
|---|---|---|
| EDLS | Spin-up & Eject Mechanism | • Increased accuracy<br>• Huygens-derived design, with lower mass |
| | Back Cover | • Increase in size |
| | Front Shield | • Increase in size |
| | Parachutes | • Optimisation and test |
| | Thrusters | • Thrusters for velocity control during descent |
| | GN&C | • Camera and Radar or LIDAR for descent control |
| | Airbags | • Optimised sizing and pressure<br>• Inflation, drop, long-term storage testing<br>• European development<br>• Russian expertise (Netlander connection) may be exploited |
| | System Validation & Testing | • EDLS Analysis and Test<br>• Analysis and delta testing of all mechanisms<br>• Software independent validation<br>• End-to-end functional testing on ground model |
| Surface Module | Structure | • Increased size, ruggedisation and repackaging |
| | Power | • Larger batteries and battery charging (Tx powered during descent, Rx permanently powered) |
| | Avionics | • Redundant electronics to improve overall system reliability<br>• External antenna for transmission during descent |
| | Payload | • Additional European instruments **(sub-surface package)**<br>• Core payload (on both landers) plus add-ons |

# Mars Demonstration Lander Mission

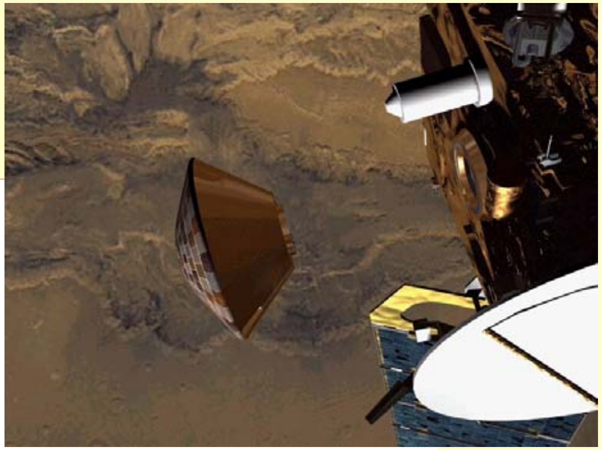
- Launch: November 2011 (Backup 2013)
- Intermediate Earth HEO
  - ❑ Provides Increase in Available S/C + Lander(s) Mass
- Ballistic Mars Transfer (transfer time ~ 10 months)
- Mars Elliptical Orbit
  - ❑ Needs optimization for mass/communications/power
  - ❑ Lander(s) will be released in a phased manner from Orbit
    - – Reduce Entry Velocity
    - – Better Control of Entry Conditions
    - – Ability to Analyze Atmosphere Prior to Descent.
    - – Orbit Insertion in Good Weather
    - – Permit Communication During Descent and Landing

# Mars Demonstration Lander : S/C Orbiter Design

- Mars Express Heritage
  - Propulsion Subsystem
  - Thermal Subsystem
  - Avionics and Data Handling
  - Power Subsystem (with updated solar array – (increased efficiency low mass)
- New Design
  - Adapted Structure for 2 Landers
- Other
  - Tanks

From Mars Network Science Study (D-SCI)

# Recommendations from Beagle 2 Inquiry Board



- **Robust Design Margins**
- **Telemetry during critical phases (entry, descent,..)**
- **Stringent testing process for all systems (parachutes, airbags, release mechanisms, etc.)**
- **Redundancy for entry detection event**
- **…**

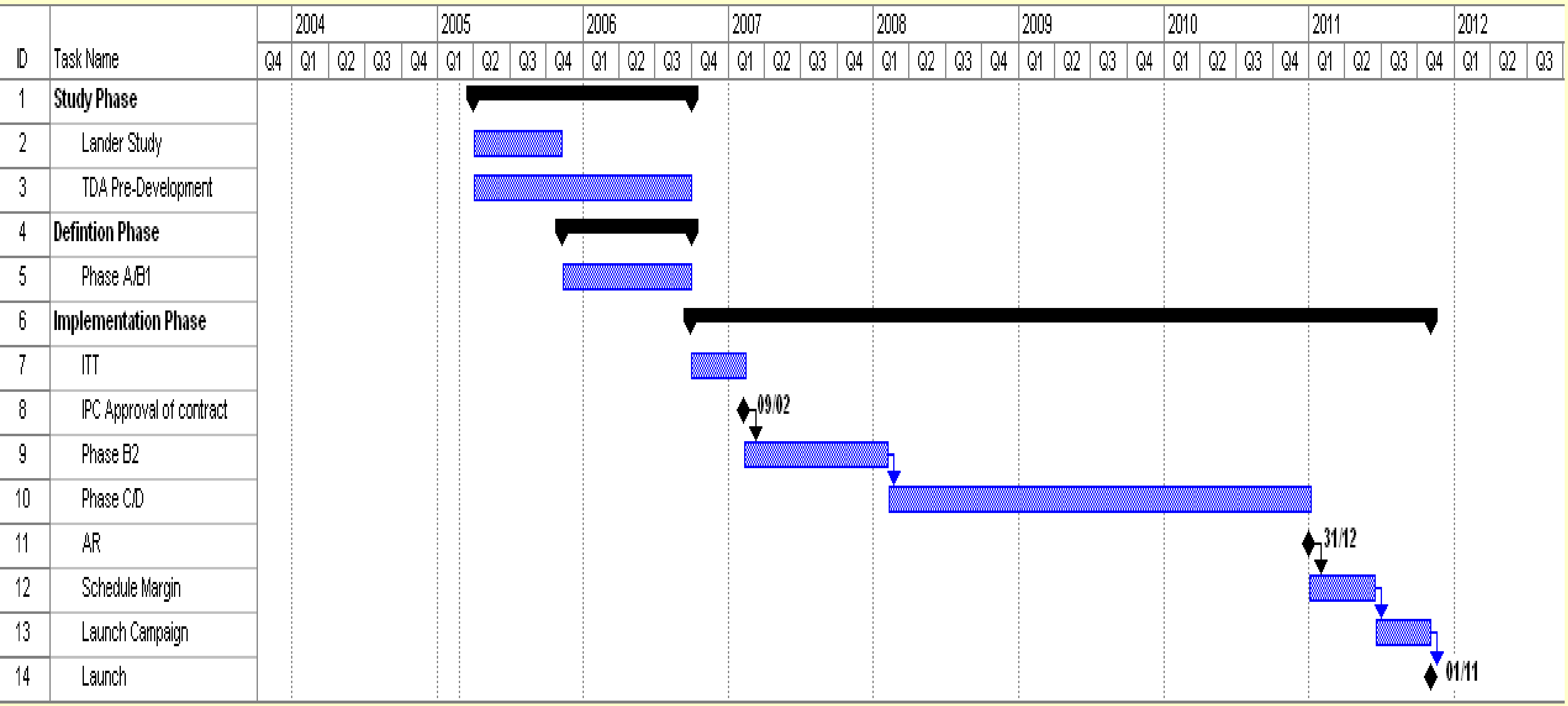
# Immediate Steps and Development

- Detailed consistent Lander study with Technology Development Plan (TDP)

  → **Start ASAP, Complete by Q4 2005**

- Key TDP items to initiate now:
  - Airbag System
  - Controlled Descent System

# Activities & Schedule
## (Launch in 2011)



# Conclusion

- A European Lander Mission to Mars appears:
  - Doable in 2011 provided work start immediately
  - Could prepare the road for larger European endeavors to Mars – Rovers, deep subsurface studies
  - Would provide serious Martian scientific return
  - Could sample subsurface down to 5 m
- The Mars Demonstration Lander would allow:
  - A phased technology development for future Mars exploration
  - Longer term spin-off on other science missions
  - Important step for ESA Science, Exploration & Technical Directorates