# AEROFAST

**AEROcapture for Future spAce tranSporTation**

***SEVENTH FRAMEWORK PROGRAMME***

***Activity 9.2 – strengthening the foundations of space science and technology***

***SPA.2007.2.2.02 Space Transportation***

***October, 23rd 2009***

**F. BONNEFOND**

All the space you need

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# Table of contents

# AEROFAST framework

- AEROFAST: AEROcapture for Future spAce tranSporTation
- FP7 – first call - Grant agreement no.: *218797*

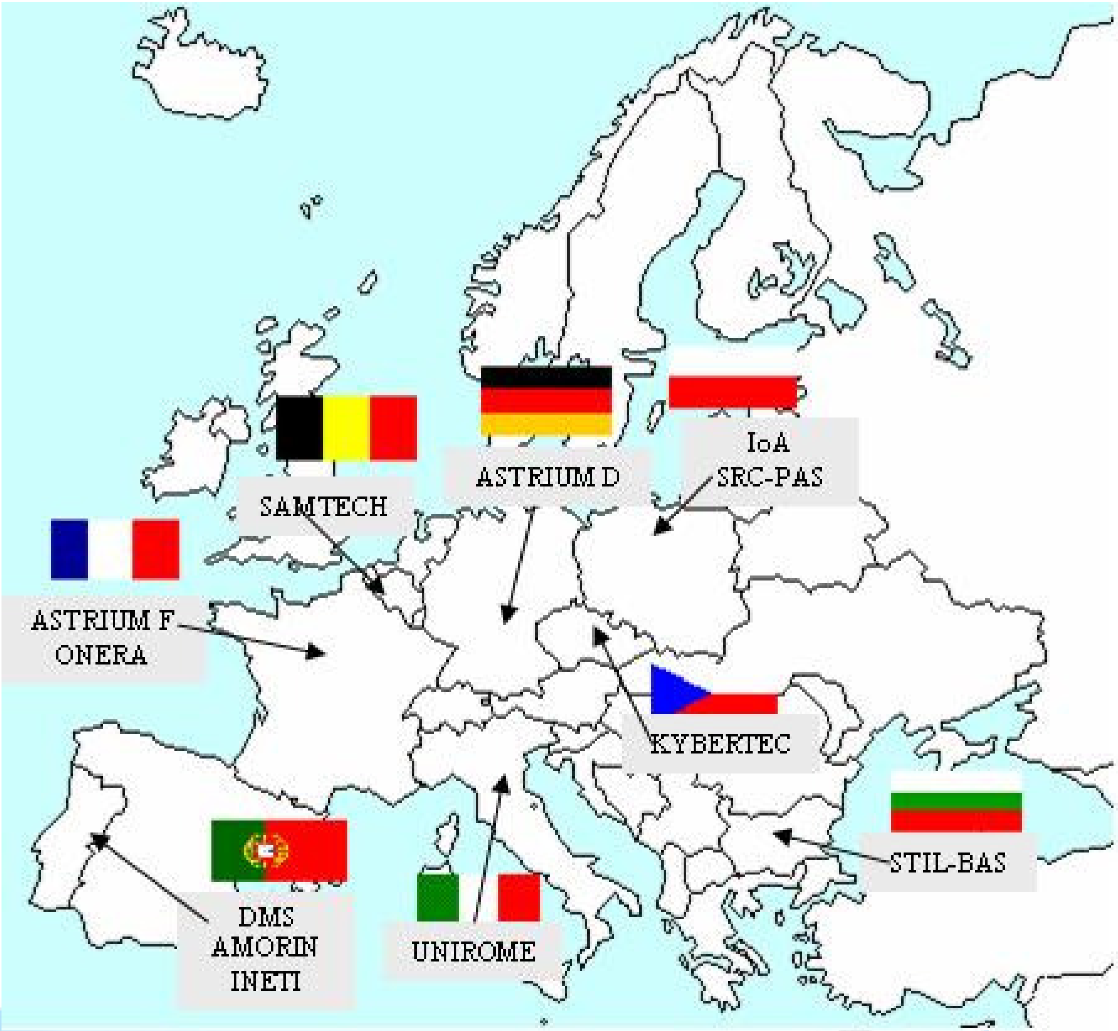
- Planning:
  - Starting date: 01/01/2009
  - Duration: 30 months

- EU contribution: 1.924.374 EUROS
- Estimated total cost: 2.961.592 EUROS

- Industrial consortium:
  - Coordinator: ASTRIUM SAS, France
  - 12 partners well spread over Europe

# Industrial consortium

| Beneficiary name | Short name |
|---|---|
| ASTRIUM-ST SAS | AST-F |
| ASTRIUM-ST Gmbh | AST-D |
| DEIMOS Engharia | DME |
| Amorim Cork Composites S.A. | AMORIM |
| SAMTECH | SAMTECH |
| University of Roma – La Sapienza | UNIROME |
| INETI | INETI |
| STIL-BAS (Bulgarian Academy of Sciences) | STIL-BAS |
| Institute of Aviation | IoA |
| Space Research Centre-Polish Academy of Sciences | SRC-PAS |
| ONERA | ONERA |
| KYBERTEC | KYBERTEC |



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# Table of contents

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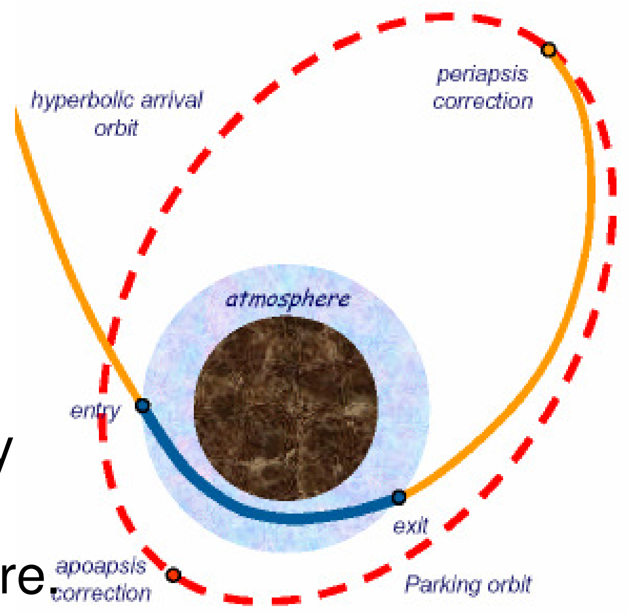
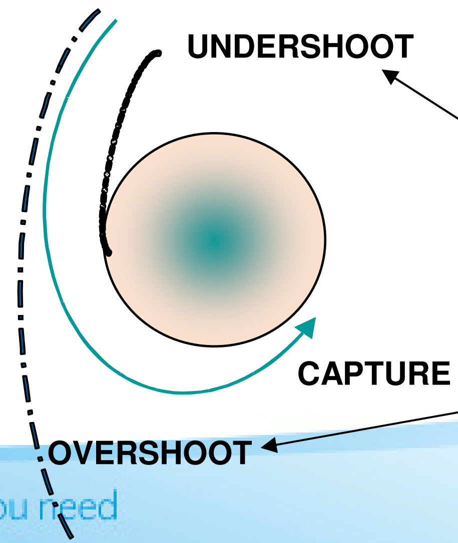
# Aerocapture definition

- Insertion of a spacecraft from a hyperbolic flyby orbit into a planetocentric orbit, through the atmosphere,
  - In a single, aerodynamically controlled, entry pass,
  - Without need of a retro-propulsive manoeuvre.

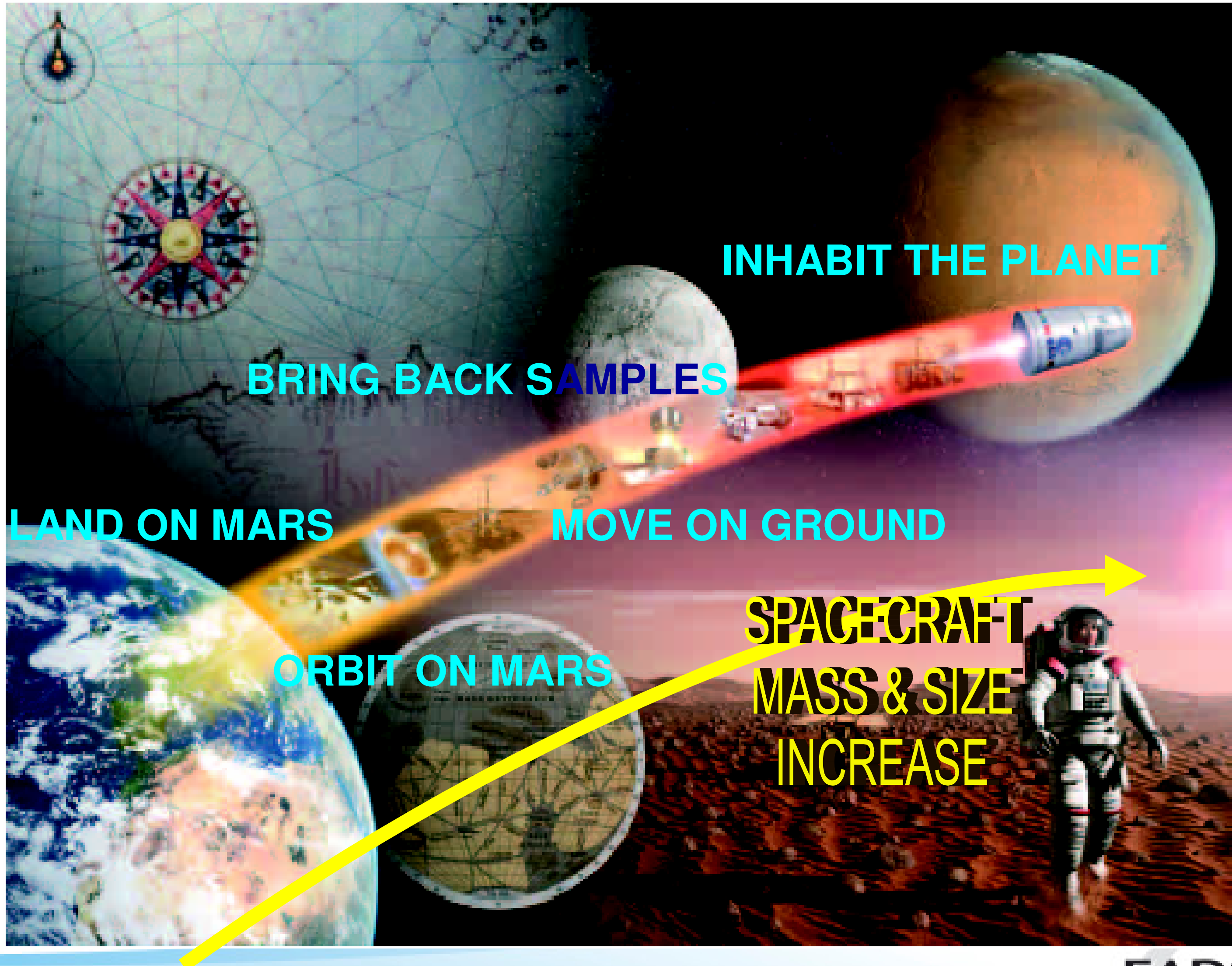



With energy dissipation within a narrow entry corridor :

- Entry flight path angle too steep
  - **Hit of the planet surface**
- Entry flight path angle too small
  - **No capture**

# The steps to pave the Martian exploration



# Why AEROFAST? (1/2)

- Why aerocapture ? One of the core capabilities in the coming years for planetary exploration
  - Large amount of mass saved:
    - **at launch (up to 30 %),**
    - **In low Mars orbit: 41% of the initial mass inserted with propulsion *to be compared* with 82% of the initial mass with aerocapture**
  - Fully adapted to large weight missions:
    - **Sample return missions,**
    - **manned missions**
- Status of aerocapture :
  - New and rather complex technique
  - Never tested in flight, nor used for an operational exploration mission

# Why AEROFAST? (2/2)

- Technology readiness level (TRL) for aerocapture ~ roughly 2 to 3 in Europe

→ AEROFAST main goal:
  - to prepare for a flight demonstration on Mars,
  - to **reach TRL 3 to 4 in the frame of this FP7 first call**.

- Associated objectives:
  - **OBJ1**: Preliminary define the aerocapture demonstration
  - **OBJ2**: Make a significant progress by increasing the TRL of the planetary relative navigation and the aerocapture algorithm up to 5,
  - **OBJ3**: Build a breadboard to test in real time the pre-aerocapture and aerocapture GNC algorithms,
  - **OBJ4**: Demonstrate/prototype the thermal protection system for such a mission,
  - **OBJ5**: Define on-board instrumentation for aerocapture phase recovery.

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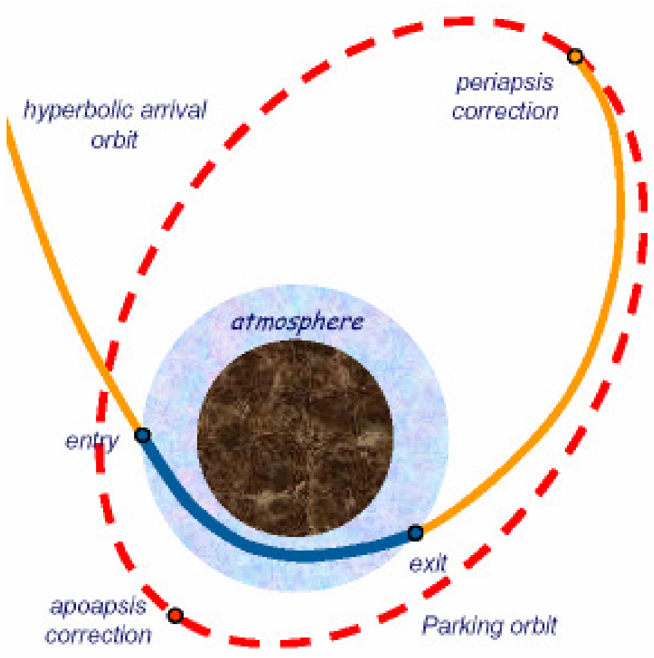
# Table of contents

# Main assumptions

- Low cost mission
- Soyuz-like Launch performance
- Optimized entry conditions at 120 km:
  - Relative velocity: 6112 m/s
  - Flight Path Angle: -10.59°
  - Perigee altitude : 40.9 km - optimized to obtain the targeted apogee altitude after the aerocapture phase.
- Main characteristics of the spacecraft:
  - Three modules vehicle concept (final satellite, aerocapture module and cruise module),
  - Maximum diameter: 3600m

# AEROFAST mission phases

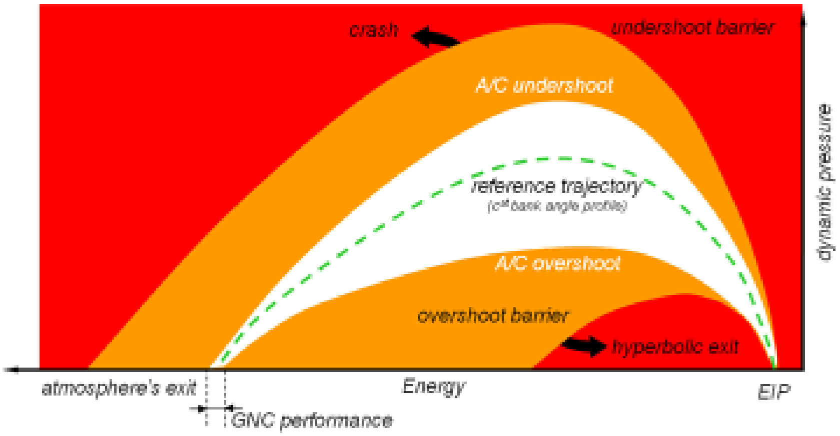



- **3 main phases:**
- **Pre-aerocapture phase :**
  - **Hyperbolic path to the upper atmosphere**
  - **Challenge: master the attitude/position of the S/C before manoeuvre**
  - ⇨ **Navigation needs**
- **Main aerocapture phase :**
  - **From entry point to atmosphere exit**
  - **Goal ⇨ reach an elliptical orbit within a narrow corridor**
  - **Challenge ⇨ to sustain important heat loads**
- **Post aerocapture phase :**
  - **transfer to a parking orbit: to target a quasi circular sun-synchronous orbit at a low altitude:**
    - **Altitude: 350 km**
    - **Inclination: 92.8°**

# Aerocapture corridor

- Considering the following conditions:
  - the optimised Entry conditions
  - the atmospheric dispersions
  - the uncertainties on drag and lift coefficients
  - the GNC accuracy at ±100 km.

- Corridor width:
  - Overshoot ~50 km
  - Undershoot ~20 km
  
  ➔max entry FPA error < 0.8°

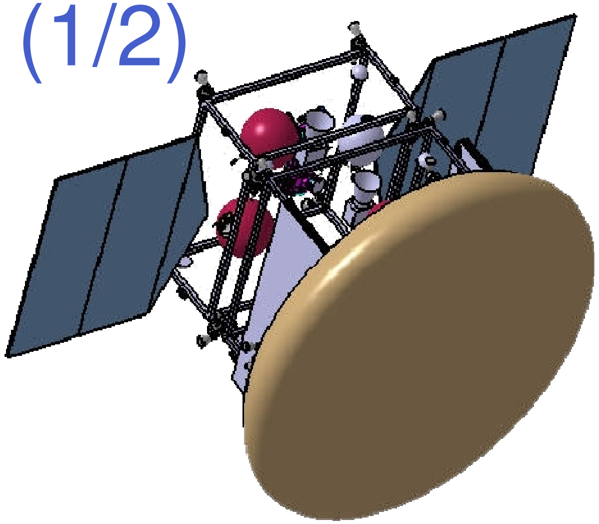



**Driver for pre-aerocapture navigation**

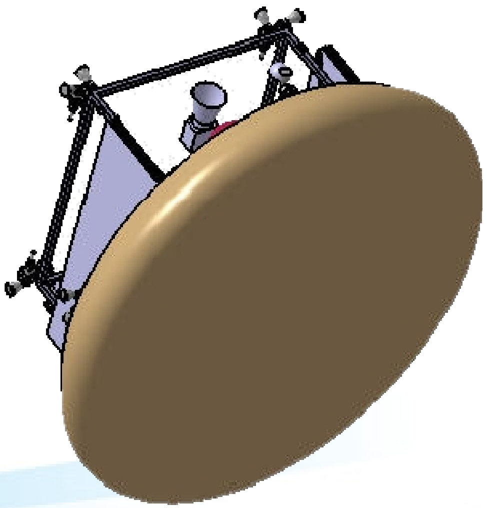
# Spacecraft preliminary design (1/2)

## General design

- Interplanetary cruise
- Aerocapture configuration



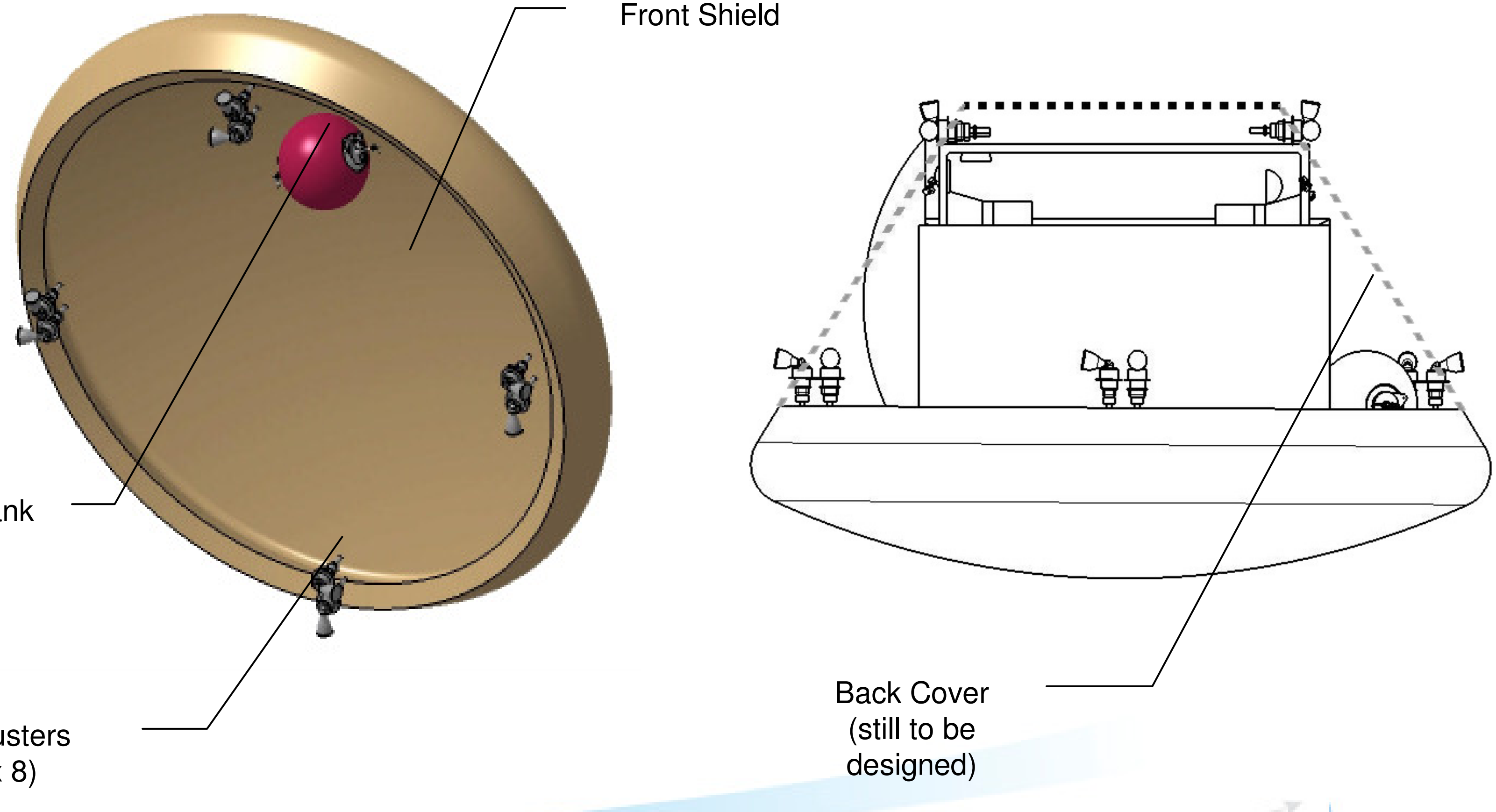
- AEROFAST composite: 1260 kg
  - **Interplanetary Cruise Module 270 kg**
  - **Aerocapture Composite 990 kg**
    - **Mars Orbiter 730 kg**
    - **Aerocapture System 260 kg**



- Max diameter: 3600 mm

# Spacecraft preliminary design (2/2)

- General design – Aerocapture system



# Table of contents

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# Next steps

- Further assess the design of the composite:
  - Best aerodynamic shape for aerocapture


  - Need of a protection for the rear part of the composite to protect the equipment behind the heat shield
  - Overall design and lay-out
- Identify the instrumentation needed during the aerocapture phase
  - What phenomena shall be observed in the aerocapture path?
  - Add scientific objectives when the spacecraft is on the final orbit

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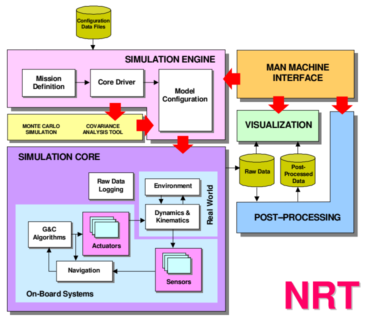
# Next steps

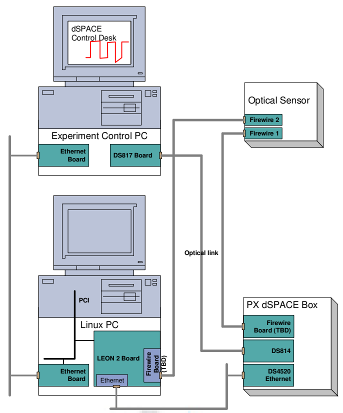
- Identify innovative thermal protection systems (TPS): low density while sustaining high heat loads
  - Assessment of TPS options based on Cork
    - **New high temperature resins**
    - **Possible fillers to use**
    - **Moulding possibilities**
    - **Surface treatments**
  - Assessment of non-ablative TPS




NRT

- Improve the navigation sub-system for the pre-aerocapture phase and test all algorithms through real time and non-real time breadboards

RTBB




EADS astrium

# Back-up slides

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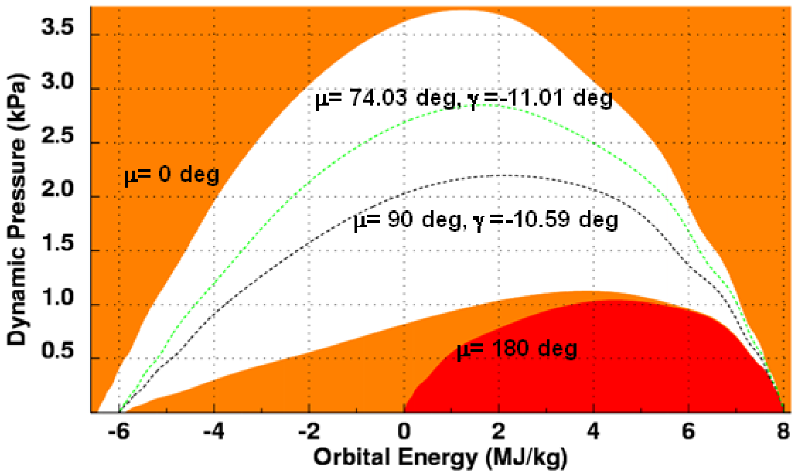
# WBS

| OBJ | WORKPACKAGES | WP leader | Participants |
|---|---|---|---|
| **OBJ1 & OBJ2** | **WP1**<br>Aerocapture overall design | **AST-F** | **SAMTECH**<br>**DME**<br>**INETI**<br>**UNIROME**<br>**IoA**<br>**ONERA** |
| **OBJ1** | **WP2**<br>Spacecraft design | **AST-D** | **AST-F**<br>**DME**<br>**UNIROME** |
| **OBJ4** | **WP3**<br>Innovative thermal protections | **AMORIM** | **AST-F**<br>**AST-D** |
| **OBJ2 & OBJ3** | **WP4**<br>O/B GNC function development & validation | **DME** | **INETI**<br>**AST-F** |
| **OBJ5** | **WP5**<br>On-board instrumentation | **UNIROME** | **STIL-BAS**<br>**SRC-PAS** |
| | **WP6**<br>Overall coordination & management, and dissemination | **AST-F + KYBERTEC + Work package leaders** | |

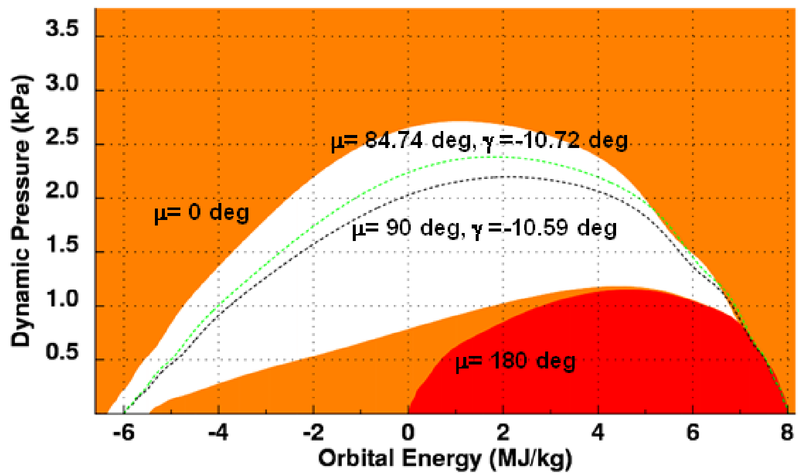
# Aerocapture corridor

## Results

- Case 1 (15% on ATD)




- case2 (30% on ATD)




- width of corridor:
  - **case 1: ±1.06 deg**
  - **case 2: ±0.79 deg**
- max entry FPA error < 0.8°

| *trajectory* | *Case 1* | *Case 2* |
|---|---|---|
| *overshoot* | *50.1 km* | *50.4 km* |
| *undershoot* | *17.4 km* | *26.5 km* |

**Driver for pre-aerocapture navigation**