AEROFAST

GA n° 218797

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AEROcapture for Future spAce tranSporTation

International Planetary Probe Workshop 7 – Session 6B

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FP7 context

AEROFAST – AEROcapture for Future spAce tranSporTation

- **In the frame of EC (European community) FP7 first call**
- Activity 9.2 – strengthening the foundations of space science and technology
- SPA.2007.2.2.02 Space Transportation
- **Duration: 2,5 years**
  - **Jan 2009 – Jun 2011**
- **Status: AST is the coordinator. Team composed of 12 partners**
- **More on www.aerofast.eu**

Partner	Country
ASTRIUM-ST SAS	France
ASTRIUM-ST Gmbh	Germany
DEIMOS Engharia	Portugal
Amorim Cork Composites S.A.	Portugal
SAMTECH	Belgium
University of Roma – UNIROME La Sapienza	Italy
STIL-BAS (Bulgarian Academy of Sciences)	Bulgaria
Institute of Aviation	Poland
Space Research Centre-Polish Academy of Sciences	Poland
ONERA	France
KYBERTEC	Czech Republic
FCUL	Portugal

SEVENTH FRAMEWORK PROGRAMME

EADS astrium

AEROCAPTURE definition and issues

- DEFINITION:
  - insertion of a spacecraft from a hyperbolic flyby orbit into a planetocentric orbit, through the atmosphere,
    - In a single, aerodynamically controlled, entry pass,
    - With only a correcting propulsive manoeuvre (=> circular orbit)
- ONE OF THE CORE CAPABILITIES IN THE COMING YEARS FOR PLANETARY EXPLORATION
  - Large amount of mass saved (up to 30 %) at launch
  - Fully adapted to large weight missions (Sample return missions and manned missions)
- NEW AND RATHER COMPLEX TECHNIQUE
- NEVER TESTED IN FLIGHT
  - TRL low : 2 to 3
  - not used for an operational exploration mission (except for the skip entry of Zond 2 in 1968)

General Objective

- Aerocapture for Mars Exploration

After demo : TRL 6
Ready for use within actual mission (MSR)

Demonstration Mars mission

2011 : TRL 3 / 4

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2009 : TRL 2 / 3
Not studied by space agencies

AEROFAST proposed as a typical R&D project.

Objectives of the project

The different objectives of the project are:

- Obj1: Define a project of aerocapture demonstration
- Obj2: Make a significant progress in space transportation 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.

WORKPACKAGES	**WP leader**	**Participants**
WP1 Aerocapture overall design	AST-F	SAMTECH DEIMOS FCUL UNIROME IoA ONERA
WP2 Spacecraft design	AST-D	AST-F DEIMOS UNIROME
WP3 : Innovative thermal protections	AMORIM	AST-F AST-D
WP4 : O/B GNC function development & validation	DEIMOS	FCUL AST-F
WP5 On-board instrumentation	UNIROME	STIL-BAS SRC-PAS
WP6 Overall coordination & management, and dissemination	AST-F + KYBERTEC	+ WP leaders

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AEROFAST frame and inputs

- Assumptions:
  - Low cost mission
  - Soyuz-like Launch performance
  - Main characteristics of the spacecraft:
    - Three modules vehicle concept (final satellite, aerocapture module and cruise module),
    - Maximum diameter: 3600mm
- Main results from first system loop:
  - Mass characteristics of the vehicle,
  - Aerocapture trajectory to start the thermal protection study,
    → Optimized entry conditions at 120 km:
    - Relative velocity : 6377,6 m/s
    - Flight Path Angle : -10.04°
    - Azimuth of relative velocity : -19.57°
    - Latitude : -77.8°
    - Longitude : 10.6°
    - Perigee geocentric altitude : 27.77 km
  - Set of conditions to be applied to the relative navigation activities.

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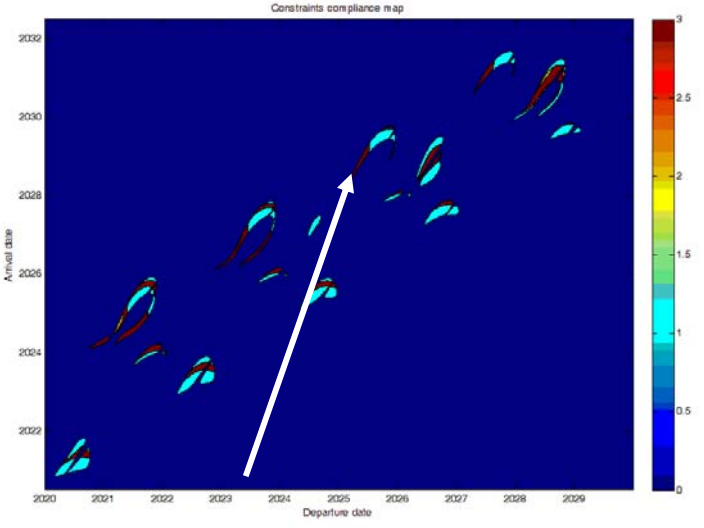
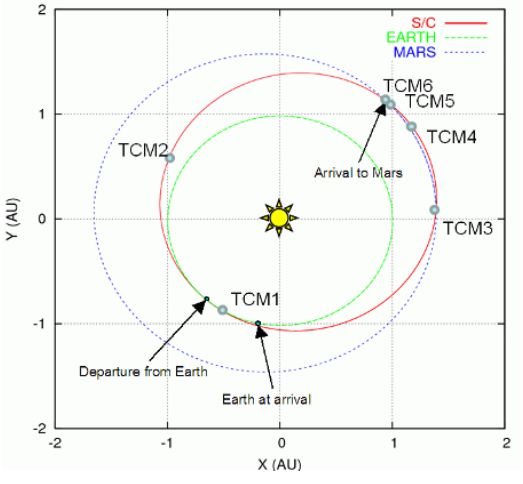
Mission description

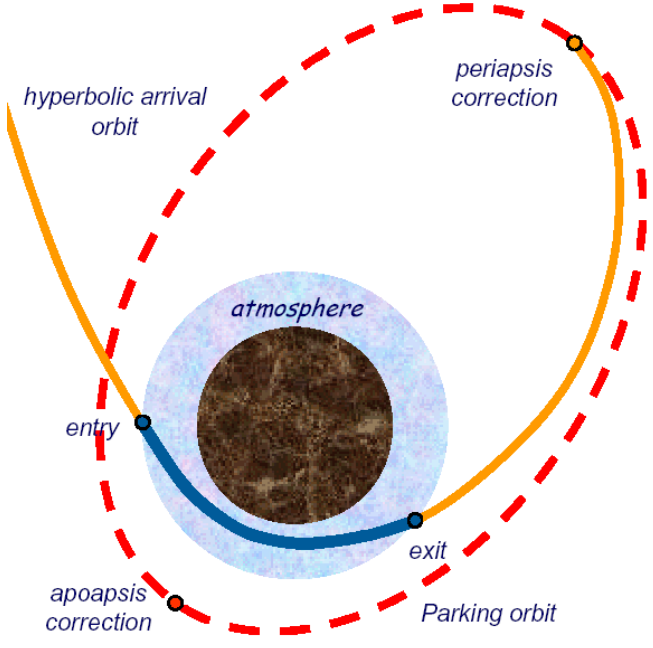
- Earth to Mars opportunities analysed for the decade 2020-2030





- Selection of trajectory: departure in May 2026 and arrival in June 2028 after one and half rev around the Sun

AEROCAPTURE mission



3 main phases:

- **Pre-aerocapture phase (Deimos) :**
  - **Hyperbolic path to the upper atmosphere**
  - **Challenge: master the attitude/position of the S/C before manoeuvre**
  - **⇨ Navigation needs**
- **Main aerocapture phase (Astrium):**
  - **From entry point to atmosphere exit**
  - **Goal ⇨ reach an elliptical orbit within a narrow corridor**
  - **Challenge ⇨ to sustain important heat loads**
- **Post aerocapture phase (Unirome):**
  - **transfer to a parking orbit: to target a quasi circular sun-synchronous orbit at a low altitude:**
    - Altitude: 345 km
    - Inclination: 93°

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GNC concept

- Interplanetary cruise phase
  - Navigation based on DSN and on-board camera
  - Innovative optical navigation allowing the replacement of DSN measurements during last weeks
  - Achievable accuracy of 1 km (1σ) on altitude of periaxis
- Aerocapture phase
  - Inertial navigation
  - Numerical predictor-corrector guidance
  - Simple eigenstructure assignment controller
  - Error on targeted apoaxis lower than 100 km at 96%
- Post-aerocapture phase
  - DSN navigation
  - Reaction wheels control for accurate targeting (<0.01 deg/s)

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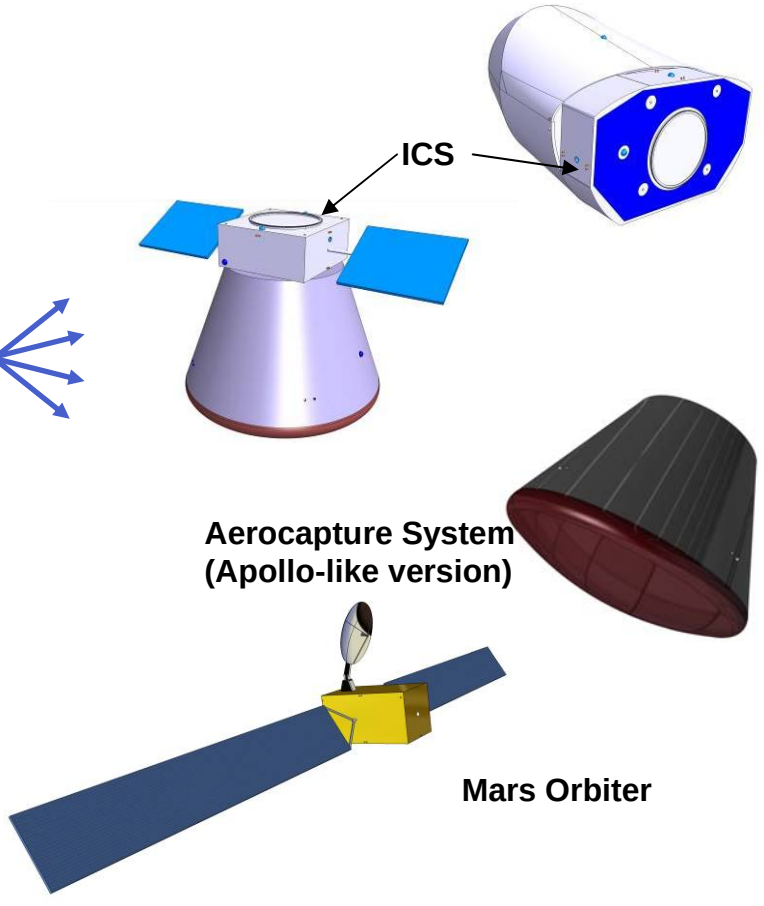
Spacecraft design

- 3 modules vehicle concept
  - Interplanetary Cruise Stage (ICS)
  - Aerocapture System (AS)
  - Mars Orbiter (MO)
- 4 configurations
  - Launch configuration
  - Interplanetary cruise
  - Aerocapture configuration
  - Mars orbit
- Maximum diameter: 3.60m
  - (Launcher compatibility)



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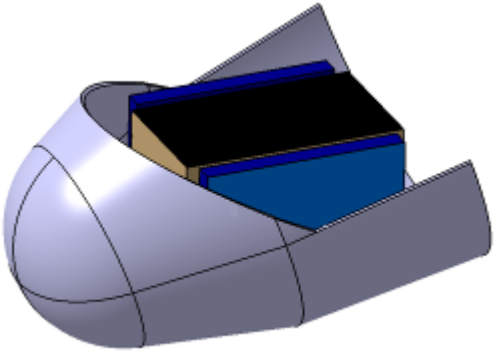
Aeroshape concepts

Aeroshape selection → Mid 2010

Apollo/ARD - like

Main advantages :
•High P/L protection efficiency wrt ATD heating
•Heat-shield manufacturing simplicity,
•Flight-proven aeroshape
Main drawbacks :
•Possible mass penalty (back-cover)
•Minimization of resources/sensor sharing with the carrier module during cruise,
•More complex heat-shield jettisoning

Truncated biconic



More advanced concept, already considered in past Astrium studies (ESA, CNES…)
•Very promising in terms of payload protection (back-cover eventually not needed)
•L/D requirements can be easily achieved
•Compliant with lay-out requirements and protection wrt aerothermal heating.
The shape is currently under study by Astrium-ST with the support of ONERA.
•Need of a back-cover being assessed

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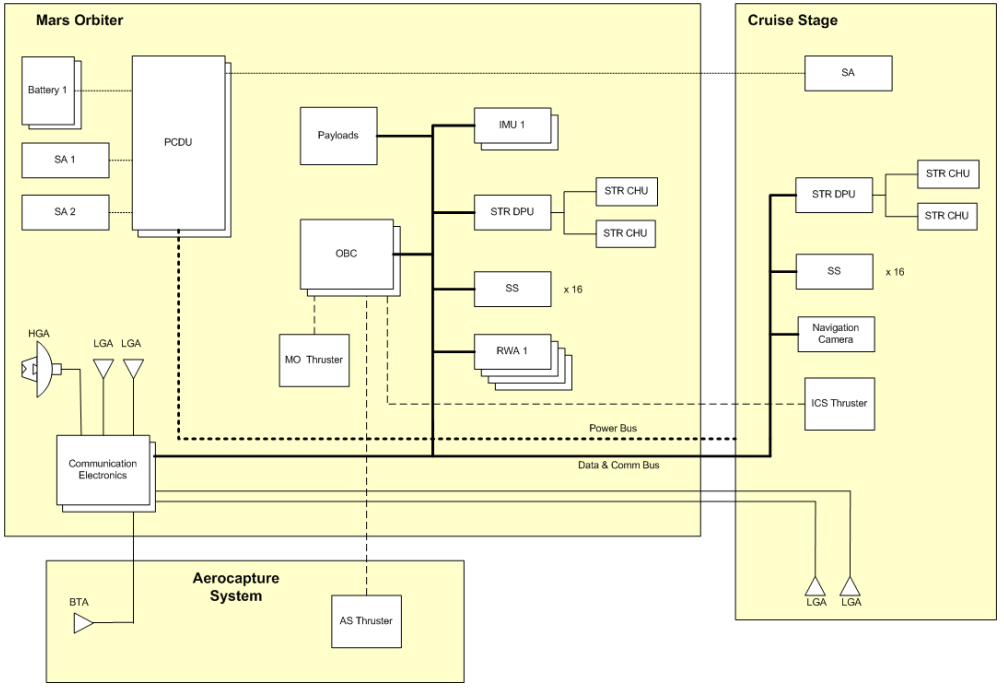
Spacecraft design

Functional Design

- Focus on “re-usability” of components in other spacecraft stages
- Redundancy of functions derived from criticality of failure
- Blow-down thrusters directly operated via propulsion drive unit within on-board computer



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Spacecraft design

- Mass budget
  - Literature data for “out of the shelf” components
  - Preliminary evaluation for specific components (for instance through main dimensions for the structure)
  - So this mass budget has to be considered as a first set of **mass targets** for the components

	Total Mass [kg]	
	Apollo-like	Bi-conic
Interplanetary Cruise Stage	228	228
Aerocapture System	336	357
Mars Orbiter	598	598
Total	1162	1183
Resulting system margin [%]	15.3	13.3

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Innovative TPS

Key selection criteria

- Thermal Protection Performance
- Withstand heat flux, low ablation
- Process compatible with design requirements
- Long term availability

Enhanced solution, relying on heritage use of Norcoat-Liege for ARD, Beagle or ExoMars

- Advanced cork-based TPS
- Lighter solution wrt existing Norcoat-Liege
- More robust solution (limited ablation)
- Compliant with environment rules (REACH)

Following steps are implemented, relying on Amorim capabilities

- Inclusion of appropriate fillers
- Assessment of production processes
- Evaluation and characterization

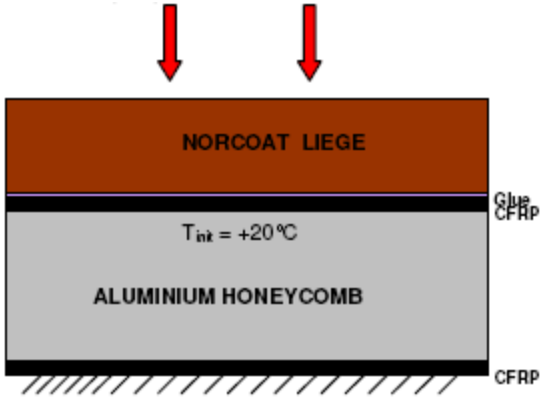
Sample with various formulations (Amorim)

TPS design

- TPS : one of the subsystems defined within the overall spacecraft design
  - Preliminary design mid-2009 (inputs for system analyses)
  - Update planned after aeroshape selection and corresponding revision of ATD data.
- Classical TPS concept:
  - Sandwich structure covered with thermal protection
  - Norcoat-Liege used as reference
  - Then update considering results obtained for enhanced formulations.

Beyond the TPS sizing itself

- Opportunity to develop a 3D thermal/pyrolysis/ablation code (as a module of SAMCEF)
  - Highly valuable outcome of this WP



Aeroshell concept (preliminary iteration)

Front shield	Structure	TP	Total
Thickness	30 mm	14 mm	~45 mm
Mass	4 kg/m²	5.5 kg/m²	~10 kg/m²
Back-Cover			~5 kg/m²

Estimated values used as inputs for system analyses

Next Steps

Obj 1	•Aeroshape Selection •Detailed Spacecraft Architecture
Obj 2 & Obj 3	•Definition of prototype algorithms, •Definition of the camera requirements, •Validation of the algorithms with a non real time numerical simulator, •Final validation with a real time simulator, including a navigation camera breadboard.
Obj 4	•Selection and characterization of the most promising TPS candidates
Obj 5	•Identification and definition of the sensors necessary to perform measurements during aerocapture flight.

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Conclusion

- AEROFAST is a typical R&D project
  - Part of European Community Framework Programme n°7 (FP7)
- Objective to increase the TRL of aerocapture technology from 2/3 to 3/4
  - and propose a demonstration mission as further step (TRL 6)
- Frame of the mission has been defined
  - Low-cost mission, Soyouz-like launcher, 3-module spacecraft
- Remaining steps until end of study will allow completion of overall project objectives
  - Completion mid 2011

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THANK YOU
FOR ATTENTION