AEROFAST: AEROcapture for Future spAce tranSporTation

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Abstract

AEROFAST is a Mars aerocapture feasibility demonstration performed by twelve European companies leaded by AST-SAS as prime, and funded under seventh framework programme of the European Commission. This study planned over 2.5 years will end in June 2011.
The present paper is dedicated to present an overview of the mission and to point out the improvements and results gained wrt challenging topics:

- A description of the overall mission architecture will be proposed including the pre-aerocapture phase (Earth to Mars transfer), aerocapture phase and post-aerocapture phase (transfer to parking orbit).
- The spacecraft design based on a composite architecture made of several modules will be depicted, aero-shape & aero-thermal behaviours justified, layout & budgets presented.

At the end of the paper, GNC and TPS prototypes activities will be briefly depicted. These activities, key factor for success, are still under progress (NRT & RT tests of GNC algorithms for both pre-aerocapture and aerocapture phases, TPS plasma tests on new cork based materials).

1. Introduction

Aerocapture is a new technology for Solar System exploration that uses a single pass through a planetary atmosphere to decelerate the spacecraft and achieve a targeted orbit (Fig-1).

Such manoeuvre saves a significant amount of mass with regard to a more conventional technique of insertion using propelled braking, and becomes really attractive when the delta-V necessary for orbit insertion becomes greater than 1 km/s, which is the case for most of the future solar system exploration missions (sample return missions, in-situ missions and future manned missions which require spacecraft to enter and manoeuvre in a planet's atmosphere).

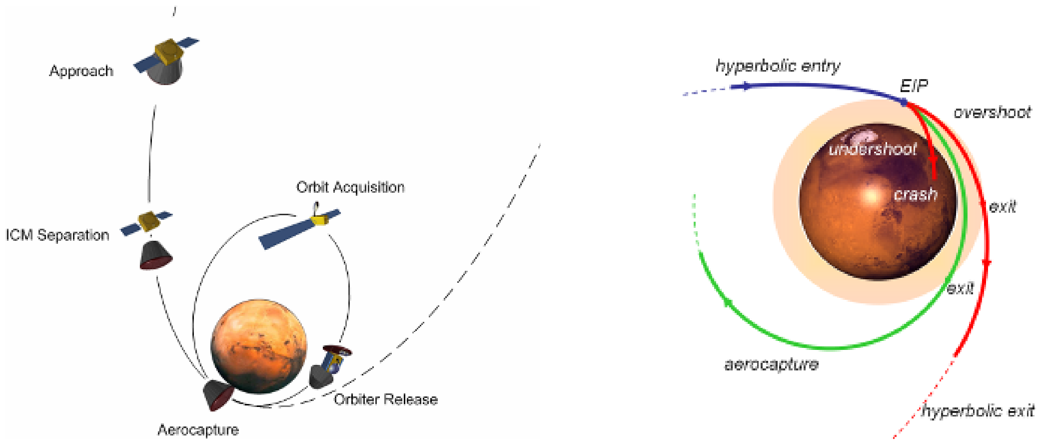

Figure-1: Aerocapture principle

Aerocapture is a very challenging system level technology where compromises have to be found between individual disciplines such as system analysis and integrated vehicle design, aerodynamics, aerothermal environments, thermal protection systems (TPS), guidance - navigation and control (GNC), instrumentation… all these disciplines needing to be integrated and optimized as a whole to meet the mission specific requirements.

Currently, Technology Readiness Level (TRL) of aerocapture technology in Europe is assessed at TRL2 to 3 whereas a TRL6 is mandatory to envisage the aerocapture technology for operational missions while mitigating development risks. The AEROFAST study fits with this goal, being dedicated to increase the TRL level of aerocapture technology up to TRL4 through a complete mission study of a Martian aerocapture.

The objectives of AEROFAST 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 a thermal protection system for such a mission
- OBJ5: Define on-board instrumentation for aerocapture phase recovery.

2. Acronyms

A/C	AeroCapture
AGL	Above Ground Level
AST	ASTRIUM
BC	Back Composite
CAC	Cruise & Aerocapture Composite
DOF	Degree of Freedom
DSN	Deep Space Network
EIP	Entry Interface Point
FC	Front Composite
FPA	Flight Path Angle
GNC	Guidance, Navigation, Control
HGA	High Gain Antenna
IMS	Imaging Multi Spectral
IMU	Inertia Measurement Unit
L/D	Lift-over-Drag
LGA	Low Gain Antenna
LOS	Line of Sight
MO	Mars Orbiter
NRT, RT	Non Real Time, Real Time
OBDH	OnBoard Data Handling
P/L	PayLoads
TCM	Trajectory Change Manoeuvre
TPS	Thermal Protection System
TRL	Technology Readiness Level
wrt	with regards to

3. Mission and GNC

The frame of the AEROFAST mission has been defined as a low cost mission. The launch and transfer orbit injection is supposed to be performed by a Soyuz Fregat departing from Kourou, and able to perform the coast phase needed to get rid of declination limitations.

The complete mission sequence contains the phases of:

- Cruise & Pre-aerocapture phase: Challenge is to master the attitude/position of the spacecraft (S/C) before manoeuvre:
  - Cruise : Several trajectory correction manoeuvres (TCM) are foreseen to allow Martian rendez-vous with the use of star trackers for navigation
  - Approach: Before arriving to Mars, the Deep Space Network (DSN) navigation will be hybridized with an optical + radiometric navigation increasing the accuracy of targeting the aerocapture corridor.
- Aerocapture phase: Used to brake the incoming velocity thanks to the drag exerted by the atmosphere and will insert the spacecraft on the appropriate elliptical orbit.
- Post aerocapture phase: to target a quasi circular sun-synchronous orbit at a low altitude.
  - Science Orbit Acquisition: Before reaching its operational orbit, the spacecraft will perform some transition manoeuvres that, with the help of the drift due to gravitational perturbations, will drive it to its final orbit.
  - Science Orbit Operation: Once inserted in its final orbit, the vehicle will begin its observation mission (swath width of 25km with a resolution of ~1m) and will only perform small orbit adjustment manoeuvres.

4. Mission analysis

4.1 Mission constraints

Soyuz from Kourou offers a range of payload compatible with AEROFAST type of mission, and the flexibility to reach different declination with the re-ignition capability of Fregat upper stage.

From the mission analysis, a set of constraints reported Tab-1 has been identified which drives the cruise and pre aerocapture phase.

Table-1: Constraints from mission analysis

	Constraints	Justification
RQ-1	Soyuz performance must be greater than 1450 kg (1250kg spacecraft + 200kg ACU) for the launch opportunity (infinite velocity and declination at departure	
RQ-2	Infinite velocity at arrival must be lower than 4 km/s	To avoid energy dissipation issue during aerocapture (aerocapture design constraints)
RQ-3	The angle between the infinite velocity and the Earth direction must be lower than 90° at Mars Arrival	To have aerocapture phase placed on the side facing the Earth, with the communication link available (even if Mars is hidden by the Sun at space craft arrival), and with operational transmitters during aerocapture phase (pre-aerocapture communication constraints)
RQ-4	The Sun-Earth-Probe (SEP) angle must be greater than 7° from 20 days before Mars arrival	
RQ-5	The angle between the Earth direction and the vehicle velocity has to be greater than 40° during the whole aerocapture	
RQ-6	The angle between the infinite velocity at arrival and the Sun direction must be greater than 45°	To be able to use optical measurements (stars trackers, camera) on Mars moon in the last 20 days before re-entry (pre-aerocapture navigation constraints)
RQ-7	Pre-aerocapture navigation performance and propagation of S/C release down to EIP must be such that FPA errors at entry point are below ±1.24 deg.	To allow re-entry within the aerocapture corridor (aerocapture guidance constraints)

4.2 Cruise & Pre-aerocapture phase

The analysis of the Earth to Mars opportunities has been performed for the whole decade 2020-2030. Considering the constraints reported Tab-1, a set of 21 opportunities has been identified (Fig-2).

The best launch opportunity from Earth has been found in Mai, 11th of 2026, with a Mars arrival expected in June, 11th of 2028 as the best compromise between minimum departure infinite velocity and transfer duration from Earth to Mars (opportunity n°9 among 21).

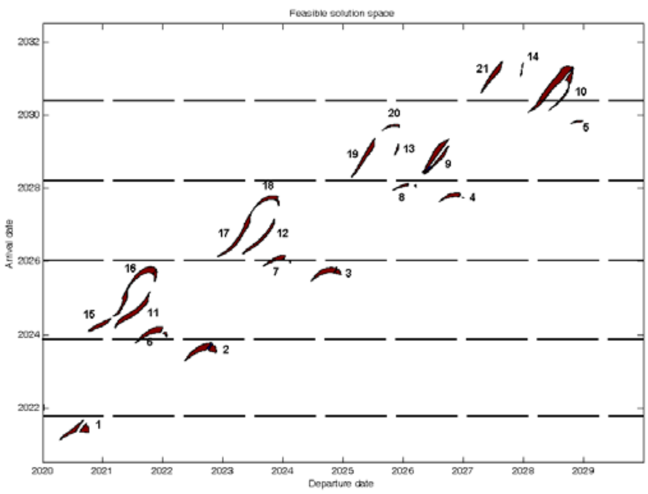

Figure-2: Constraint compliance map (white = no compliance)

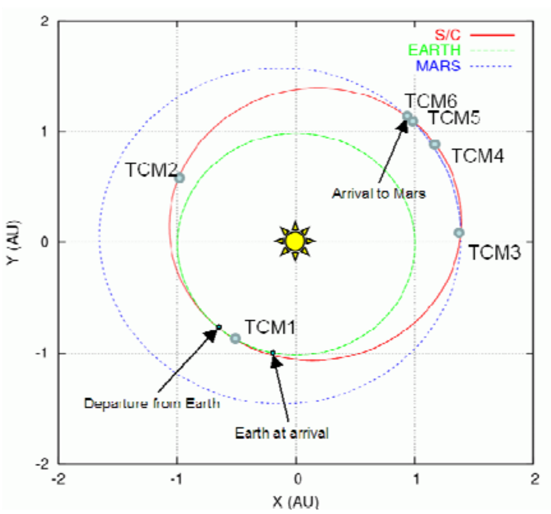

Figure-3: AEROFAST transfer from Earth to Mars

The features of the selected trajectory are:

- A transfer of type T4 which suppose to have more than one revolution about the sun, with 6 TCM to meet the target conditions at Mars arrival (Fig-3). TCM have been optimised wrt the navigation process and the overall delta-V required to be minimized. Last TCM is foreseen not later than EIP -4h
- An injection into polar orbit at Mars by any of the two possible arrival branches (north and southbound)
- An Entry Interface Point (EIP) defined at 120km AGL, with a Flight Path Angle (FPA) of -10.74 deg.

Table-2: AEROFAST selected trajectory

Zone	Transfer type	Min. depart. velocity (km/s)	Declination (deg)	Departure date	Arrival date	Transfer time (months)
1	T1/T2	4.3057	-10.786	31/07/2020	14/07/2021	11.43
2	T1/T2	3.7219	14.880	15/09/2022	30/09/2023	12.48
3	T1/T2	3.3342	19.735	04/10/2024	13/09/2025	11.30
4	T1/T2	3.1070	32.894	05/11/2026	13/10/2027	11.24
5	T1/T2	3.0002	28.250	10/12/2028	05/11/2029	10.84
6	T4	2.9756	29.130	05/12/2021	02/03/2024	26.87
7	T4	2.9811	19.921	04/01/2024	04/03/2026	25.95
8	T4	3.2276	10.642	29/01/2026	20/02/2028	24.71
9	**T4**	**2.7816**	**-14.641**	**11/05/2026**	**11/06/2028**	**25.03**
10	T4	3.5997	19.114	21/09/2028	27/04/2031	31.15
11	T5	3.1335	-49.399	19/04/2021	29/05/2024	37.32
15	T6	3.4743	6.046	16/02/2021	10/06/2024	39.75
16	T6	3.3289	21.477	06/10/2021	19/09/2025	47.44
17	T6	4.6517	-5.999	27/01/2023	15/04/2026	38.57
18	T6	3.2223	29.179	20/10/2023	17/09/2027	46.92
20	T6	3.1869	32.772	08/11/2025	18/09/2029	46.32

4.3 Aerocapture phase

The aerocapture feasibility is mainly driven by the conditions at the EIP (Tab-3). The aerocapture corridor is bounded by extreme over-shoot (hyperbolic exit) and under-shoot (crash) trajectories. The small width of the corridor leads to maximum FPA errors bellow ±1.24 deg at EIP

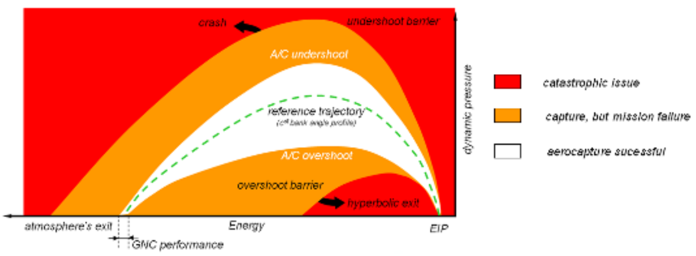

Figure-4: Entry corridor for Aerocapture at Mars arrival

Table-3: EIP features

Entry Interface Point (EIP) at 120km AGL	
Relative velocity:	6377.6 m/s
Flight Path Angle: (local geodetic frame)	-10.74°
Azimuth of relative velocity:	-19.59°
Latitude:	-77.8°
Longitude: (geodetic frame)	10,6°

As depicted Fig-5, the aerocapture phase allows targeting the orbit inclination while exiting the atmospheric phase, but aerocapture doesn't allow meeting all in plane parameters, in particular pericenter altitude of the orbit for science operation (Tab-4).

At the end of the aerocapture at 120km altitude, spacecraft exit parameters (relative velocity ~3500m/s, FPA ~3°) lead to the nominal apocenter altitude (345km AGL) but a too low pericenter altitude (-44km ->crash).

Thus, a fast correction manoeuvre must be performed just after aerocapture to reach the nominal pericenter altitude required (290km AGL).

4.4 Post Aerocapture phase

The orbit for sciences operations must comply with the requirements of the scientific optical payloads. AEROFAST orbit reported Tab-4 has been chosen in order to have an almost global coverage with repeating ground track and constant lighting conditions:

- Repeating orbit condition, which allow to have image at the same location with similar light incidence condition
- Maximum surface coverage, which allow to observe the largest part of Mars
- Sun synchronous condition, which allow to compensate the Mars motion around the Sun to keep same lighting conditions
- Frozen orbit condition, which correspond to an orbit with parameters having small rates of variation in order to reduce the cost of the orbit control

Table-4: orbit features for sciences operations

Semimajor axis	3713,87 km	Pericenter altitude	290.55 km
Eccentricity	7,355e-03	Apocenter altitude	345.18km
Inclination	92,7°	Orbital Period (OP)	6871s = 1.91 h
Pericenter argument	270°	Mars global coverage	1098 OP

5. Guidance, Navigation and Control architecture

The GNC architecture is composed of sensors, actuators and a guidance & control philosophy to meet the navigation requirements of each mission phase. The reference used for GNC studies is the baseline spacecraft (shape, mass) reported §6.

5.1 Cruise & Pre Aerocapture phase

During the cruise phase, the spacecraft is in sun pointing mode. The only changes in spacecraft orientation are for the 6 TCM and the final target orientation.

Spacecraft navigation relies on a class-3 Inertia Measurement Unit (IMU) and star trackers during cruise phase coupled with a deep space network transponder. Sun sensors may also be activated in a safe mode.

Control is done by reaction inertia wheels (for attitude control) and thrusters (for TCM and inertia wheels desaturation). For Mars final approach (EIP-5days), the optical camera is pointed towards Mars (LOS measurements) and radiometric measurements are activated to meet the requirements at EIP.

Monte Carlo simulations, including external perturbations and sensors performances, have demonstrated the robustness of the GNC architecture with accuracy < 3km (3σ) at EIP for a total delta-V < 30m/s for pre-A/C phase.

5.2 Aerocapture phase

Aerocapture phase must be safe (no crash or hyperbolic exit) while being complaint with the mission constraints (pre-A/C) and requirements (post-A/C). The philosophy consists in decoupling in-plane & out-of-plane motions for respectively apoapsis and inclination control, while remaining as much as possible in the aerocapture corridor (semi permeable domain)

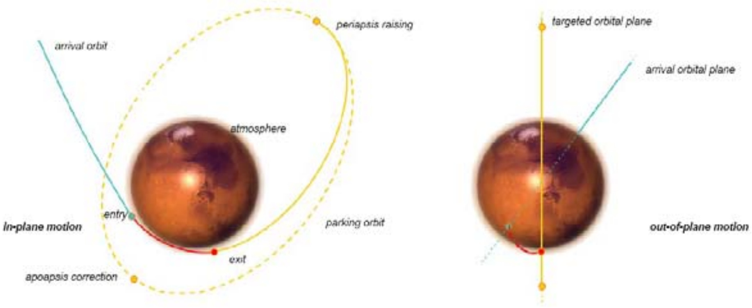

Figure-5: In-plane & out-of-plane required motions

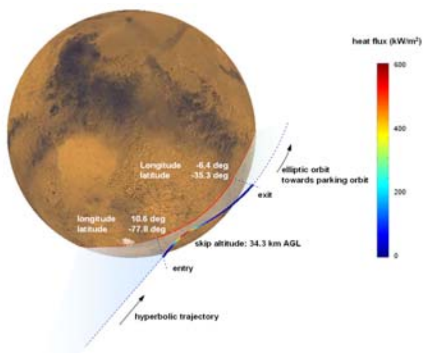

Figure-6: Nominal guided trajectory (not sizing)

Spacecraft navigation during aerocapture relies on the IMU (maximum deceleration about ~4g in worst case), whereas Control is performed by a set of thrusters which maximum torques have been assessed at 200N.m around the yaw axis, 100N.m around pitch and roll axis, with a minimum impulse bit (MIB) < 25ms.

The guidance performance has been assessed by Monte Carlo simulation (1000 runs, 3DOF). Results show no crash, no hyperbolic exit, an inclination well controlled and a 100% fulfilment rate of the total delta-V < 170m/s (Fig-7) for aerocapture phase and science orbit acquisition.

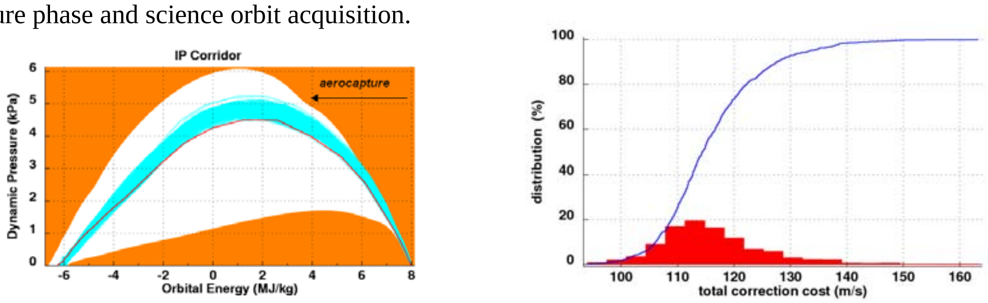

Figure-7: Aerocapture robustness (MtC simulations)

The performance of the control has been assessed (Fig-8) for the nominal trajectory leading to oscillations amplitude below ±5° for both angle of attack and sideslip angle (< ±1° for Pdyn >100Pa), and bank angle manoeuvres performed with accuracy better than 5°.

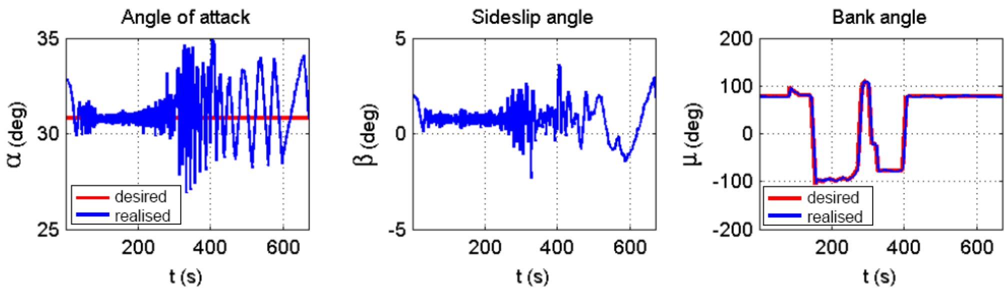

Figure-8: Control performance during nominal guided trajectory

5.3 Post Aerocapture phase

Just after aerocapture, TPS heat shield has to be jettisoned to allow fast correction manoeuvres to target the in-plane parameters of the science operation orbit:

- During the science orbit acquisition, navigation relies on IMU. The two burns which are required at apocenter & pericenter (mainly to shift pericenter altitude from -44km to 290km) are performed by the attitude control thrusters of the Mars Orbiter.
- Once Mars Orbiter placed on the science operation orbit, navigation relies on the star trackers and the IMU. The attitude control is performed by reaction inertia wheels, while the slow decrease of the semi-major axis (Fig-9) is corrected by bi-impulsive corrections done by the thrusters every 61 orbits to limit ground track drift at 30m maximum at the equator wrt the nominal ground track.

The science orbit control requires a delta-V~3.6m/s for 1 period of repetition (1098 nodal periods) corresponding to a full coverage of the Mars surface.

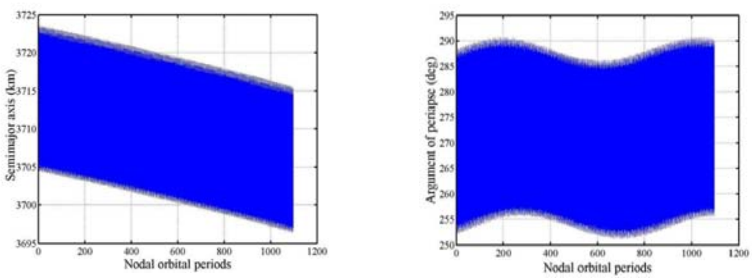

Figure-9: Evolution of semi major axis (if no correction) compared with the stability of the argument of perigee over an entire period of repetition of 1098 nodal orbital periods (frozen orbit conditions)

6. Spacecraft design

Missions with aerocapture phase generally involve spacecraft architecture based on two main modules, an Orbiter module encapsulated within a protective module jettisoned after Aerocapture.

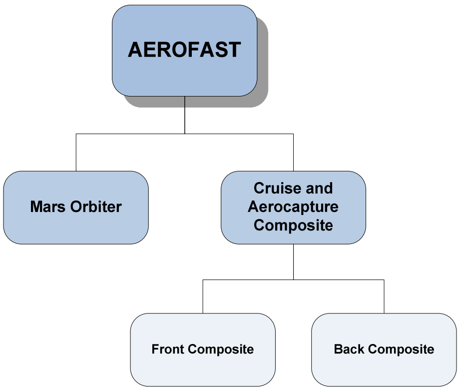

Figure-10: Product tree

AEROFAST spacecraft product tree depicted Fig-10 is based on three different modules, a Mars Orbiter, a Cruise and Aerocapture Composite composed of a Front Composite and a Back Composite (option):

- During pre-aerocapture and aerocapture phase, the Mars Orbiter module is implemented within the Cruise and Aerocapture Composite (Fig-11)
- After aerocapture, prior to post-aerocapture manoeuvres, Front & Back Composites are jettisoned (Fig-11)
- Post-aerocapture manoeuvres for sciences orbit acquisition & operations are performed by the Mars Orbiter (Fig-11)

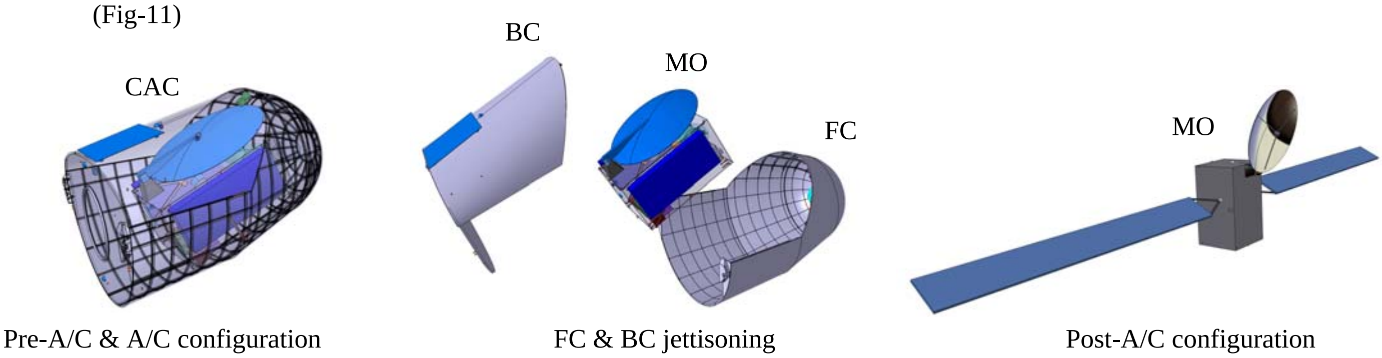

Figure-11: Aerofast different configurations

6.1 Aero-shape trade-off

Aerocapture requires an aeroshape that provides a lift-over-drag (L/D) ratio with sufficient provision (L/D>0.3) and sufficient static stability performances. In addition, the aeroshape must protect the payloads (P/L) from the severe aerothermal environment during the aerocapture, and shall be safely jettison able at the beginning of the post-A/C phase.

In the frame of AEROFAST, a trade-off has been performed considering two configurations:

- A blunt body capsule derived from Apollo, ARD concepts
- A lifting body dealing with bi-conic shape

By considering L/D requirements, payload protection wrt aerothermal heating and layout constraints, the bi-conic shape has been selected.

6.2 Aerothermodynamics analysis of the biconic shape

Aerodynamic performances of the bi-conic shape have been assessed for different angle of attack by Euler calculations, results exhibiting L/D ratio > 0.4 at angle of attack < 40deg (Fig-12).

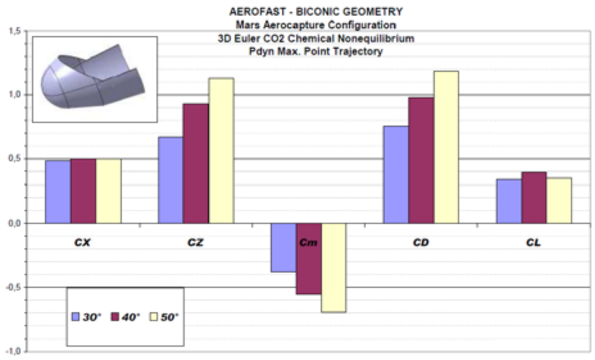

Figure-12: Max dynamic pressure point - Mach 27

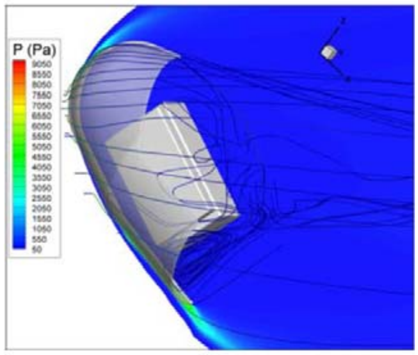

Figure-13: Satellite flow interaction t=91s, 40° angle

Spacecraft-flow interactions (Fig-13) have been analysed, demonstrating (Fig-14) the need of a Back Composite protection for the Orbiter (locally heat fluxes >20kW/m^2 mainly due to flow radiation)

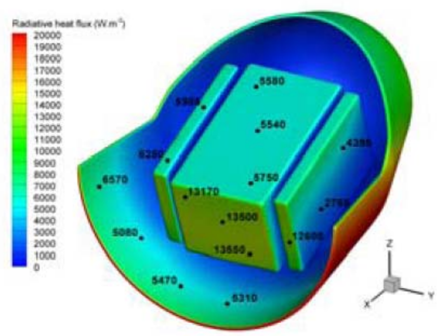

Figure-14: Radiation heat flux on Orbiter at t=91s

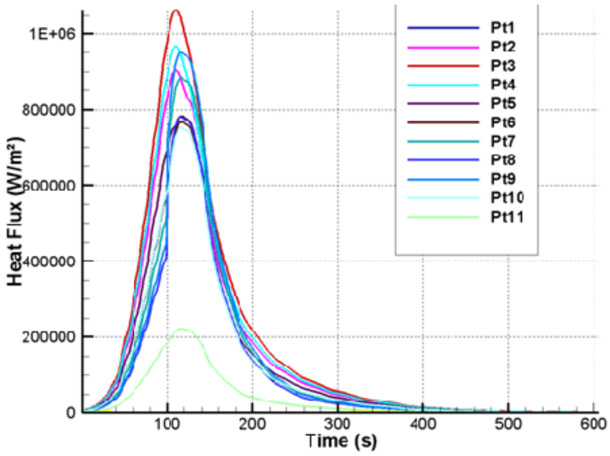

Figure-15: Max heat flux history ($T°_w$=300K)

Heat fluxes histories (Fig-15) have been assessed along the two worst case aerocapture trajectories identified by Monte Carlo analysis:

- overshoot trajectory corresponding to the maximum heat flux trajectory, with a maximum flux ~1064KW/m^2 found at stagnation point (turbulent regime applied over the whole surface wrt Reynolds criteria)
- undershoot trajectory corresponding to the maximum energy trajectory

The baseline TPS foreseen to protect the spacecraft is the Norcoat liège material (used on ARD, Beagles), glued on Front & Back Composite structures. The TPS thickness is driven by maximum temperature at the interface with the structure ($T°_{max}$ ~450K driven by the silicone based glue).

The results of the 3D computations considering Norcoat pyrolysis/charring and ablation lead to:

- thickness from 19mm to 6mm over the Front Composite surface, with a maximum ablation of 10mm
- thickness of 3.3mm uniform over the Back Composite surface

6.3 Spacecraft architecture

Spacecraft architecture results from trades-off performed at system level, with permanent drivers for saving mass and increasing robustness by selecting principles as simple as possible.

A trade-off has been conducted about the Cruise Stage. Several options were assessed: 2 configurations with external Cruise Stages jettisoned before aerocapture and 1 configuration with an integrated Cruise Stage. At last, the integrated Cruise Stage has been selected has the best compromise between mass saving and robustness (no additional separation mechanism).

The baseline architecture of the spacecraft (CAC and MO) is depicted Fig-16.

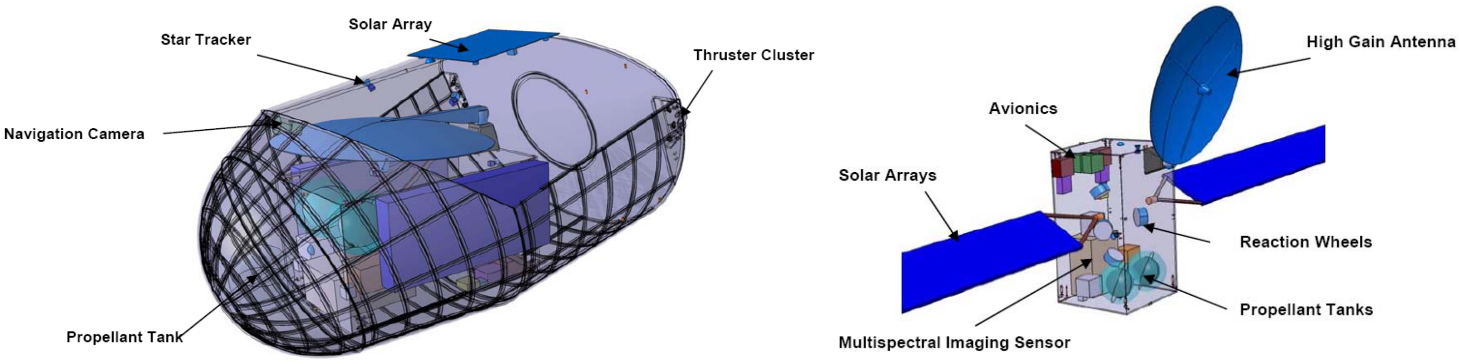

Figure-16: Baseline architecture of AEROFAST CAC and MO

The design and the layout of the spacecraft are driven by the mission sequence:

- Spacecraft must comply with the launch vehicle fairing and interplanetary orbit injection mass capability (Soyuz from Kourou)
- Power generation & storage, communication link to Earth must be available during cruise phase and science orbit acquisition & operation phases
- Autonomous guidance, navigation and control must be available along the entire mission from cruise, approach, aerocapture, post aerocapture phases.

The functional architecture of the spacecraft depicted Fig-18 has been established with the desire to make re-use of components as much as possible, and to fulfil redundancy requirements.

6.4 Spacecraft layout

Most parts of the power, On-Board Data handling (OBDH) and communication systems are integrated within the MO. The equipments which are solely needed during cruise and aerocapture phases are installed within the CAC. The equipments required for the entire mission which need to have outside access have been duplicated and implemented both within CAC and MO (solars array, communication antenna and attitude thrusters).

The specifications of the onboard equipments (measurement accuracy, torques, power budget etc…) have been established wrt the system studies, and by considering the worst cases identified by the Monte Carlo analyses.

Attitude & orbit control subsystem

Navigation:

- Star trackers and sun sensors both on CAC and MO
- IMU (NG LS-200S) for aerocapture and orbit acquisition within MO
- Navigation camera for approach phase on CAC

Control:

- Reaction wheels for cruise and orbital phase within MO
- Thrusters:
  - 6 aerojets MR120 (90N) on CAC for aerocapture + 4 CHT-5 (5N) for reaction wheels desaturation during cruise
  - 12 CHT-20 (20N) on MO for science orbit acquisition, attitude control, and inertia wheels desaturation
- 1 tank of Hydrazine (N_2H_4) is required within CAC to cover cruise, pre-A/C and A/C needs (113kg propellant), whereas 2 tanks are required within MO to cover post-A/C needs (~28kg)

Figure-17: Equipments considered

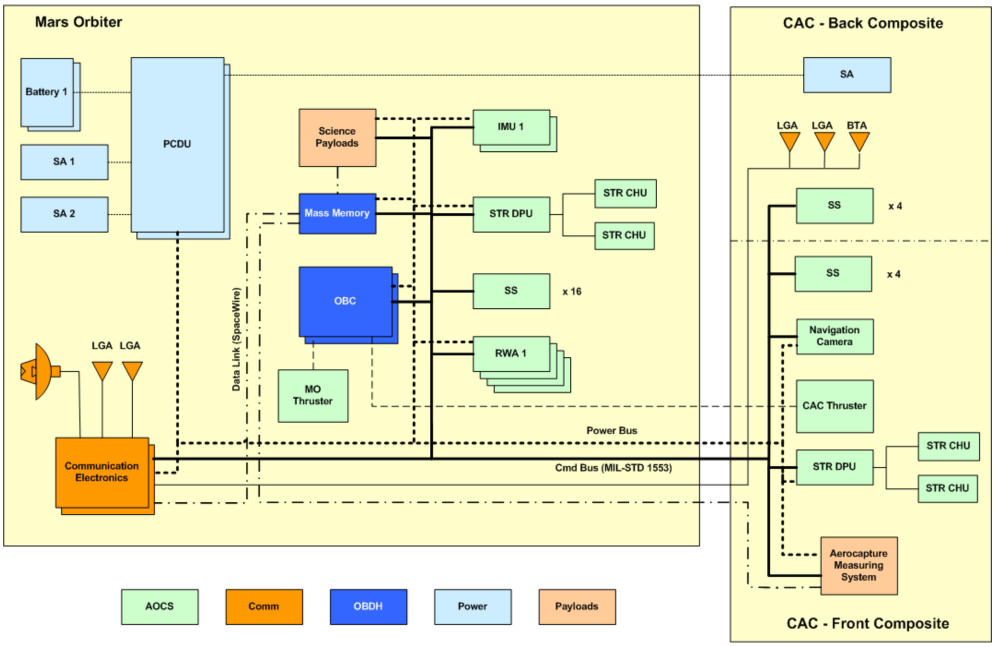

Figure-18: AEROFAST functional architecture

Power subsystem

The power architecture is based on a hybrid approach, a Direct-Energy-Transfer (DET) for cruise phase which is quasi permanently sun illuminated and a Peak-Power-Tracking (PPT) for orbital phase which is dominated by alternative eclipses/daylights in short period:

- During cruise & pre-A/C phases, power needs are in average ~115W which are provided by solar cells of ~1,23m^2 fixed on the CAC surface.
- For orbital phase, power needs vary from 143 watts (eclipse) to 562W (needs for observation and transmission during daylight) provided by 2 solar arrays of 5,6m^2 each on MO.

Batteries (8x VES 140 cells) are implemented within the MO with a total capacity of 39A/h at 28,8V.

Mission Phase	Capacity Requirement [Ah]
LEOP	29.7
Cruise	0
Aerocapture	23.5
Orbit	14.2

Figure-19: Batteries and capacities

Communication subsystem

The communication subsystem provides a data link for housekeeping, telemetry/telecommand and transmission of scientific data.

- 4 Low Gain Antennas (LGA) are used for telemetry/telecommand during cruise and for orbit acquisition phases. LGA are implemented both within CAC and MO, and in a redundant way (mission critical).
- 1 High Gain Antenna (HGA) is used for transmitting scientific data to Earth. Antenna diameter is foreseen to be 2.1m diameter, with a transponder operating in Ka-band at minimum data rate of 594kbit/s. HGA is implemented within MO.

Scientific payload

Science payload is assumed to be 125kg maximum, with a maximum power consummation of 100W.

For the moment, an Imaging Multi Spectral (IMS) sensor is foreseen (87,5kg, 55Watts) dedicated to take pictures for a global observation of Mars surface (panchromatic scanner: 500-800 nm; multispectral scanner: 3 channels: Green, Red, NIR; Spatial resolution, IFOV: 1m (Pan); 4m (Multi) in NADIR position; swath ~23km)

Instrumentation is also foreseen for environment characterisation and TPS analysis during aerocapture phase.

6.5 Mass breakdown and geometry

Mass breakdown, geometry and centring are depicted Fig-20 and Tab-5.

Table-5: AEROFAST mass breakdown

Composite	Mass [kg]
Spacecraft Composite at TOI (wet mass incl. system margin)	**1358.40**
Cruise & Aerocapture Composite - Back Composite (wet mass incl. system margin)	**125.28**
System Margin (20%)	20.88
Cruise & Aerocapture Composite - Back Composite (dry mass incl. maturity margin)	104.40
Cruise & Aerocapture Composite - Front Composite (wet mass incl. system margin)	**444.99**
Propellant & Pressurant Mass	32.00
System Margin (20%)	68.83
Cruise & Aerocapture Composite - Front Composite (dry mass incl. maturity margin)	344.16
Mars Orbiter (wet mass incl. system margin)	**788.18**
Propellant & Pressurant Mass	115.20
System Margin (20%)	112.16
Mars Orbiter (dry mass incl. maturity margin)	560.82

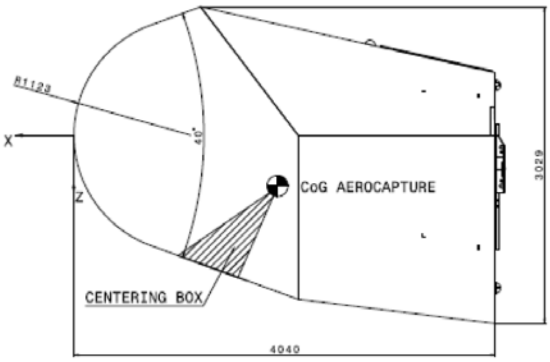

Figure-20: CAC shape and centring box

7. Next steps

End of January 2011, the Test Readiness Review (TRR) has been conducted with all the AEROFAST partners, demonstrating the coherence of the studies performed at mission, system and design levels.

The mission, architecture and general design of the spacecraft are now frozen.

For the few months remaining, studies will focus on:

- Assessment of GNC algorithms performance for Pre-A/C and A/C phases through 6DOF simulators tested with Non Real Time (NRT) and Real Time (RT) breadboards.

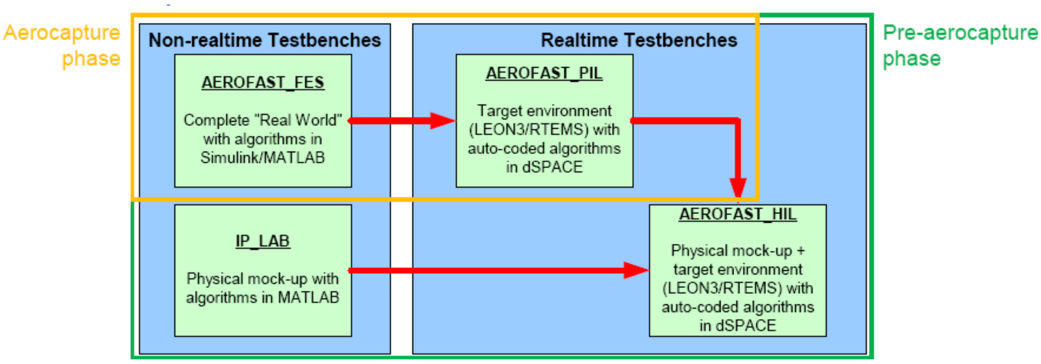

Figure-21: development flow

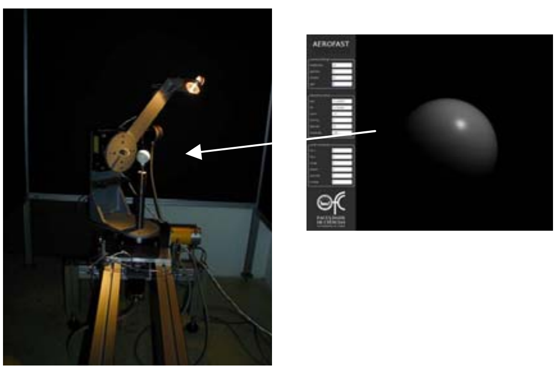

Figure-22: IP lab (Mars/Sun unit)

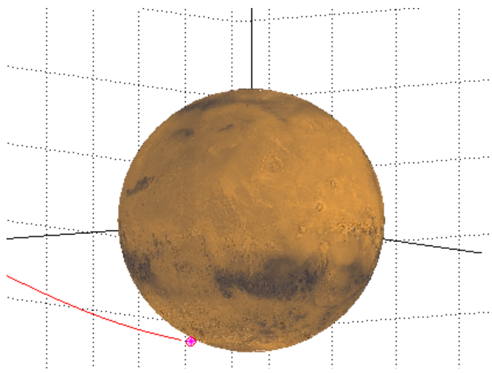

Figure-23: Pre Aerocapture NRT simulation (FES)

Preliminary results are very promising. For pre-A/C depicted Fig-24 & Fig-25, conditions at EIP are met even by considering worst case (initial position and velocity errors, pessimistic misalignments) which validates pre-A/C GNC architecture. Analyses are under progress for A/C phase (NRT & RT)

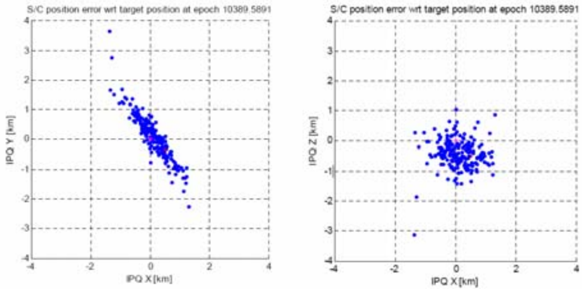

Figure-24: Spacecraft position dispersion wrt target position at EIP (XY and XZ view)

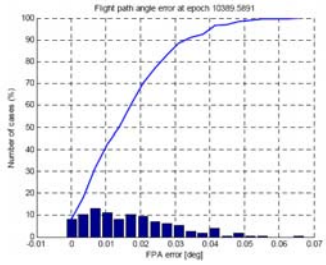

Figure-25: Statistic on FPA dispersion wrt target FPA

- TPS assessment of new cork based materials [R3]. Samples have been manufactured for plasma tests (Comete facility). TPS improvements are dedicated to mass and ablation reduction.

Figure-26: Plasma tests on Cork based material

8. Conclusions

AEROFAST is not dedicated to perform a phase-A, but to prepare for such a mission demonstration by increasing technology maturity to TRL4 (mainly GNC & thermal aspects).

After two years of studies, the overall mission has been defined and the conditions (EIP…) required to perform each phase (cruise, pre-A/C, A/C, post-A/C) established. Mission and systems studies have contributed to generate specifications towards the sub-systems (GNC, communication, power, etc...). The spacecraft architecture has been optimized accordingly leading to a coherent design wrt all disciplines.

Next month until mid-2011 will be important. The spacecraft performance is under assessment through an end-to-end mission simulation. GNC algorithms have been implemented within a simulator for NRT and RT tests within a laboratory environment. If preliminary results are confirmed, AEROFAST main goal to reach a TRL4 will be fully achieved.

9. References

[R1]: AEROFAST – Aerocapture GNC design and performance – P. Vernis AST-SAS – 3rd international ARA days – Arcachon – May 2-4, 2011

[R2]: AEROFAST – Aerocapture for future space transportation – H. Requisiton, F. Bonnefond – IPPW7 – Barcelona – June 12-18, 2010

[R3]: AEROFAST– Development of cork TPS material and a 3D comparative thermal/ablation analysis – G. Pinaud, AJ van Eekelen – IPPW8 – Portsmouth – June 6-10, 2011

AEROFAST CONSORTIUM

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