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ALDEBARAN: A "SYSTEM" DEMONSTRATOR PROJECT FOR NEW GENERATIONS OF SPACE TRANSPORTATION, NOW ENTERING IN THE PHASE A.

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ABSTRACT

Aldebaran is the name chosen for a "system" demonstrator project which paves the way for one or more next-generation launch vehicle targets.

The proposed demonstrator comes at a time when it is planned to operate existing European launch vehicles (ARIANE 5, Soyuz, VEGA) until around 2025, with in parallel preparations activities for the development of a new generation launcher. The project is aiming at developing a flight demonstrator by focusing certain activities involved in the preparation of future launch vehicles. The first launch may take place around 2015. It would represent a major contribution to the development of a new-generation launch vehicle.

Several Aldebaran concepts have already been analysed in the "phase 0" during 2008. A selection process have been applied taking into account the benefit of the proposed new technologies for the future launch systems, but also the interest of the partners for instance by taking advantage of research activities already foreseen. An other important selection criteria was the global development cost until the first technological flight. The result of this "phase 0" selection process will be explained.

Three concepts have been retained for the "phase A":

- An airborne solution launched from a military aircraft which will allow to build a dual stages expendable "system" demonstrator, involving the main technological innovations in the frame of the solid propulsion (first stage with new propellants), the liquid propulsion (upper stage with methane), the structures and materials, the avionics and more globally: the "system" activities. The work foreseen in phase A will not only focus on general studies for system and propulsion, but it will also concentrate on some first technological sub-system demonstration tests.

- As a first alternative, an airdropped concept, launched from a cargo aircraft, is kept. It will mainly be studied regarding safety and operational aspects in addition with the "extraction" phase when the demonstrator is airdropped from the cargo bay, and has to be ignited at a safe distance from the aircraft. The technologies involved in this concept are identical to the previous ones.

- As a second alternative, a "more conventional" vertical ground lift-off type of expendable solution is retained. The idea is to push as far as possible the technological choices for a "very low cost" launch system, the propellant choices remaining "open". As for the airborne solution, general studies and sub-system demonstration tests will be addressed during the phase A.

The paper will present the result of the "phase 0" concepts selection process held in 2008. And it will show some of the first technological choices and demonstrations envisaged for the phase A of Aldebaran.

INTRODUCTION AND CONTEXT

Europe will soon operate from French Guiana a new family of launchers, composed with Ariane 5, in the A5ECA version using a 14t cryogenic upper stage propelled by HM7 engine (more than 30 successful flights), Soyuz, in its "1a" version including an updated electrical system, and Vega, the new developed rocket. Both Soyuz and Vega will be launched from Kourou by 2010.

Until 2025, this family is well adapted to European institutional and commercial needs with a complete coverage of the payloads between small (several hundreds of kg) to heavy payloads (see figure 1).

Some adaptations of these launchers to better fit with the evolutions of the satellite markets are envisaged:

- Ariane 5 Mid term Evolution with a new cryogenic upper stage propelled by the Vinci engine developed by Snecma.
- And/or Vega+ with an enhanced performance.

But the development of a new generation launcher for medium class satellites is also envisaged at 2025 horizon.

Among the Europe's priorities is the preparation of the future by developing new technologies.

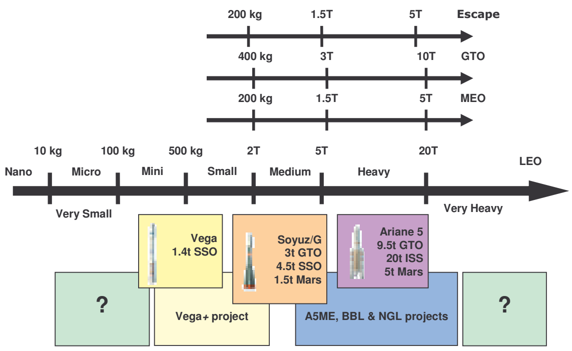

Figure 1: current and close future domain coverage of European launchers

Numerous R&T programs, including those from ESA (FLPP…) and national space agencies, are on-going in the different European countries to define the potential technologies candidates.

Aldebaran project (fig.2) proposes to focus on a system demonstrator which will take benefit of the existing technological elements in construction, adding possibly new ones, and which will be representative of one or several possible final targets.

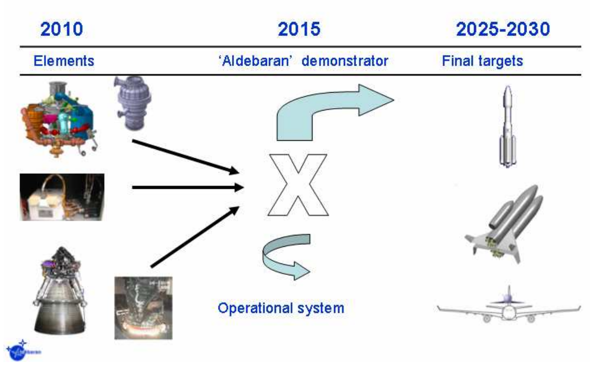

Figure 2: Aldebaran context.

The potential "final" targets that Aldebaran is aiming at can be summarized as follow:

- heavy, medium or small class of expendable launch vehicles (2025+, improvement of present European launchers or new ones).
- Micro expendable launch vehicle (2020+, eventually oriented towards "operational responsive space").
- Future stages and engines envisaged for exploration missions (2025+, Orbital Transfer Vehicle…).

All these different targets are under studies.

Most of the elements of the demonstrator could be tested on ground and separately, but a final objective is to have a full demonstration of the whole system until orbit injection.

And because the demonstrator is one element of the preparation of the future among many others, the investment shall remain reasonable for the participating agencies and industries. Therefore Aldebaran will be of a very modest size (several tons and no more).

A small performance in low earth orbit could however be a secondary objective to catch a potential "niche" of market in the domain of nano or micro satellites. This version is called "operational version" in the present paper.

ALDEBARAN PROJECT

Aldebaran project is co managed by national agencies and institutes (CDTI in Spain, DLR in Germany and CNES in France), and is open to other possible partners.

Main objectives and functions

The Aldebaran demonstrator combines new technologies and techniques, and a new launch system concept, to be build in a flexible organisational structure.

A "new" technique or technology is defined as any improvement made to the launch system (launch vehicle, ground, operations, etc.) or the related development or operating activities that improve both, the management during the development phase, including the coordination between different actors and the service provided to the customer. The launch system improvements concerns life cycle cost, reliability, safety, availability, operational flexibility and flight environments.

The main objectives and functions were presented at Glasgow (ref 2):

Aldebaran will develop the industrial skills and the research centres competencies.

It will pool new or already engaged technologies applicable to future launchers.

It will also provide micro launch capabilities for the dual use (civil, security and defence).

It shall minimise environmental impact and anticipate changes in the regulatory framework.

The development cost shall be below 400 million €.

The launch cost objectives are as follows:

50 kg	€2,5 million EC08
150 kg	€5 million EC08
300 kg	€7 million EC08

The launch campaign shall last less than five days, and the ground means shall be transportable as far as possible.

In the case of an air launched system, a dual source must be possible for the air carrier.

Concepts selection

The first step of the project has consisted in the selection of few concepts compatible with the Aldebaran requirements and which could represent a good receptacle for the candidate technologies. This phase 0 started early 2008 involving Spanish and French industries and research centres, and German DLR institutes for technologies and system studies.

The selection criteria and their relative weights are summarized below:

- Innovation offering a significant gain for launch vehicles
- Scope widest possible (multiple end ‘targets’).
- Pooling as many activities / programmes as possible
- Operational aspect of demonstrator (minimum effort to obtain a derived operational system, and well adapted to the microsat market).
- Minimum demonstrator development cost
- Minimum development risks technical, delays, financial, political, organisation.

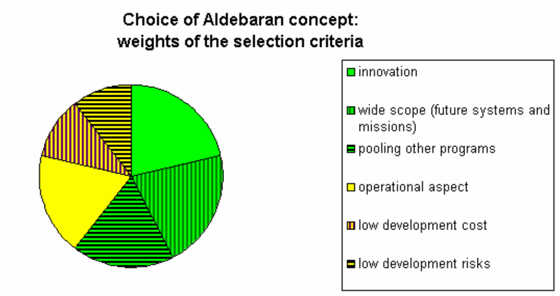

Fig 3: Aldebaran selection criteria.

At the end of 2008, 7 concepts were still in competition.

In the next paragraphs, one can have a brief description of each concept.

The Reusable First Stage (RFS) + Kick stage.

This concept was proposed and studied by DLR (ref 5). The main characteristics depend on the versions:

- Demonstrator Version A: RFS alone with 2 Vinci (Safran/Snecma engines) with reduced expansion as main engine (liquid hydrogen and oxygen propellants)

- Demonstrator Version B: RFS with 2 Vinci with reduced expansion as main engine; Solid rocket motor as upper stage; strap-on Boosters and Kick-stage with simple ceramic demonstrator engine (this version allows to bring about 100kg into low earth orbit).

- Operational Version: RFS with 2 Vinci with reduced expansion as main engine; Solid rocket motor as 2nd stage; strap-on Boosters and Re-ignitable third stage with ceramic engine (P/L > 200 kg).

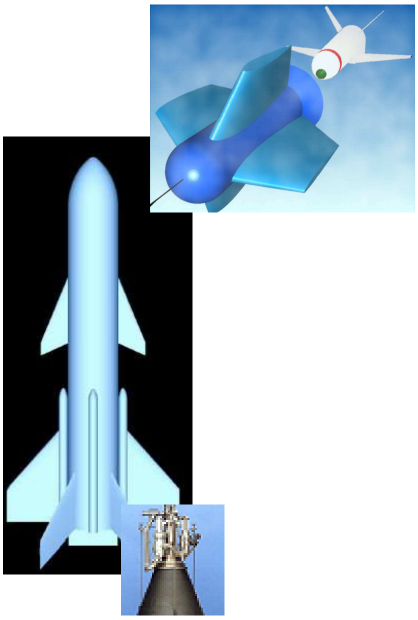

Figure 4 : general view of RFS + Kick stage concept (DLR).

For all versions, an in-air capturing system as shown in the figure 4 (top right) was proposed, which is under investigation by DLR. The main reason for this proposal is the fact that using this advanced method allows saving the otherwise required mass for fly-back propulsion and propellant, and thus increasing payload performance.

The Airborne Concept launched from a fighter aircraft.

This concept was proposed and studied by EADS-CASA and Dassault (ref 1). The main characteristics are:

- A small launch vehicle airborne below a combat aircraft, weighting about 6T for the linear 2 stages demonstrator, and up to 11T for the operational derived version.
- A launch procedure using high energy manoeuvre capability of the carrier aircraft: separation at about 40° flight path angle, Mach 0.8 and above 15km altitude.
- A 2 stages (solid & liquid propellants) demonstrator vehicle compatible with existing combat aircrafts available in Europe (Eurofighter and Rafale).
- An operational version adapted to each potential carrier for a better performance.

This type of concept allows for innovative mission scenarios.

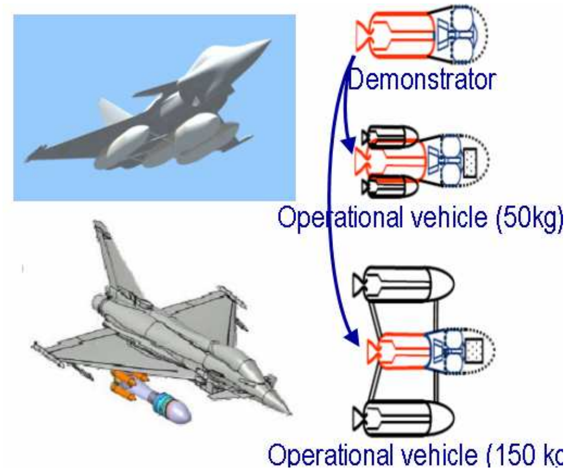

Figure 5: general views (Dassault and EADS-CASA) of the airborne concept launched from a fighter aircraft.

The Airdropped Concept launched from a cargo aircraft.

This concept was proposed and studied by EADS-CASA and ASTRIUM. The main characteristics are:

- A linear architecture / 3 stages P13.9-P3.6-C1.6 (2 solid and 1 liquid methane + Oxygen propellant stages)
- A demonstrator which could be launched from ground (with shortened Px nozzle)
- Operational version airdropped from A400M
- Payload on SSO 800 km :
  - Demonstrator : 200 kg
  - Operational version : 300 kg

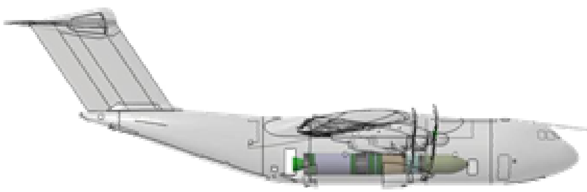

Figure 6: general view (ASTRIUM-ST) of the airdropped concept launched from a cargo aircraft.

Infinity concept.

This concept was proposed and studied by Orbspace. The main characteristics are:

- A 3 stages concept, the first stage being reusable with a high flight rate.
- A Reusable 1st stage with methane + liquid oxygen propellants, pressure fed architecture.
- Vertical Take Off, bottom-first re-entry, Vertical Lift off .
- Multiple Ceramic rocket chambers insuring engine out capability, controllability and high flight rate of the 1st stage.

The technical choices and the organisation were proposed in order to reach a very ambitious recurring cost target even compared to the Aldebaran requirements.

Figure 7: general view (Orbspace) of Infinity concept.

The CATS (Cheap Access To Space) concept .

This concept was proposed and studied by Bertin. The main characteristics are:

For the Demonstrator version:

- A two-stage-to-orbit vehicle C10C3 (Lox + liquid methane for both stages, pressure fed) allowing to bring a 50 Kg payload on 800 km SSO.
- A reusable 1st stage.
- Composite materials for tanks.
- A high commonality level between 1st and 2nd stages (tanks materials, propellants…).
- Mobile ground facilities.

For the derived Operational version:
A family of launchers based on a modular design (common core booster approach), is directly derived from the demonstrator. It includes 3 launchers covering ALDEBARAN requirements.

The Dedalus concept air launched from an UAV .

This concept was proposed and studied by Onera. Two versions are proposed for this air launched multi mission system without any pilot for the air carrier:

.Dedalus version I:

- Development of a new Unmanned Aerial Vehicle. Conventional architecture with two booms and two independent tails.
- Twin engines in nacelles above wing.
- launch vehicle: 3 solid stages in Pendulum support mode under the UAV.
- Separation from UAV at 0° flight path angle.
- Payload mass injected in low earth orbit about 150 kg.

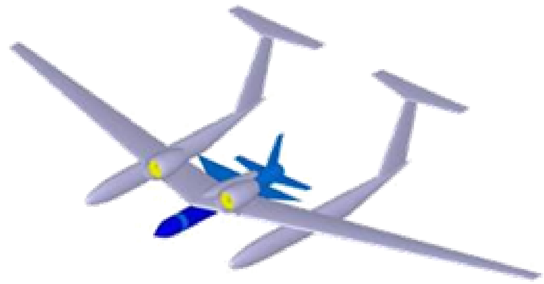

Figure 8: general view (Onera) of Dedalus version I concept.

Dedalus version II:

- Use of an existing UAV (i.e.: GH block 20).
- Launch vehicle: 3 solid stages adapted towards geometrical and mass limitation under the UAV. payload mass limited to around 60 kg in LEO.

The Flexito concept.

This concept was proposed and studied by Astrium_ST. The main characteristics are:

- A linear launcher architecture: 3 stages.
- A Reusable cryogenic 1st stage with 2 Vinci engines (Snecma) H11 + 2 solid propellant stages P3.6 / P0.8.
- A payload capacity on SSO 800 km about 160 kg

No fundamental differences are proposed between the demonstrator and the operational versions. This will finally depend on the Recovery versus the reusability logic and the Launch site mobility.

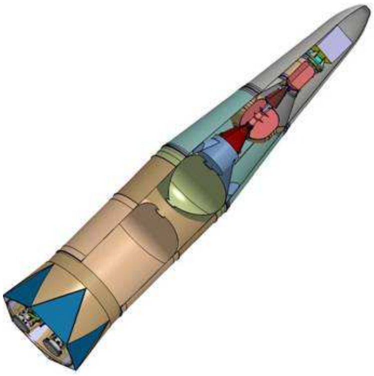

Figure 9: general view (Astrium_ST) of Flexito concept.

Rating of the concepts

An technical expert working group, independent from the project team, was created in order to evaluate and to rate the different concepts presented before. As general remarks, it was noticed that only two innovations existed at "system level": Air-launching for 3 concepts and Re-usability for 4 (all of which land-launched).

But the technical solutions proposed for the Re-usable systems made them heavier, more complex, more costly and hardly feasible in the frame of the Aldebaran allocated time schedule and budget. In addition, Re-usability as such was not given credit in the general requirement document of Aldebaran. As a consequence, the airborne concepts obtained a better rating compared to reusable ones.

Airborne concepts provides advantages such as an important reduction of the launcher mass compared to equivalent vertical ground launch systems (up to 50%, as shown in the figure below for expendable launch systems), elimination of a launch pad (possible deployment from Europe continent), mission flexibility, etc.

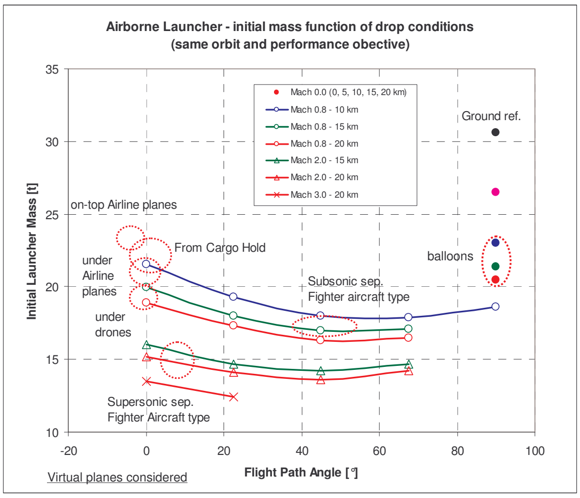

Figure 10: Mass reduction due to air launch method for 300 kg payload on LEO

The expert group could also establish a list of the proposed technologies, giving an assessment on their potential interest, and indicating the TRL (Technology Readiness Level) and the possible final targets on which they can be applied on. This list is covered by 5 main lines:

1st line: System / subsystem technologies:

- Health-monitoring system (HMS)
- In-air capturing for stage recovery
- Engine and vehicle refurbishment
- Air-Drop technology (from large cargo airplane)
- Air-Launch technology (from fighter aircraft)

2nd line: Liquid-propulsion technologies

- Ceramic combustion chamber with effusion cooling
- Methane (CH_4) propellant and combustion
- Other storable LOX/HC propellants (C_3H_8, H_2O_2+Ethanol)

3rd line: Solid-Propulsion technologies

- Improved solid propellants (Oxalane, Butalane-X, HMX)
- Continuous mixing processes for solid propellants

4th line: Structure &materials technologies

- Al-Li tanks & structures and friction stir welding
- EB curing & fiber placement & Resin Transfer Molding

5th line: Equipments/Avionics Technologies

- "High-density" and light weight avionics
- "Middleware switch" (I/F for flexible network of avionic components)

In agreement with the project team, for "CATS" which was considered as attractive without the reusability capacity, it was decided by the expert working group to evaluate an "expendable" version. This version is simply named "vertical ground lift off expendable" concept in the following paragraphs.

The final rating is presented in the graph below:

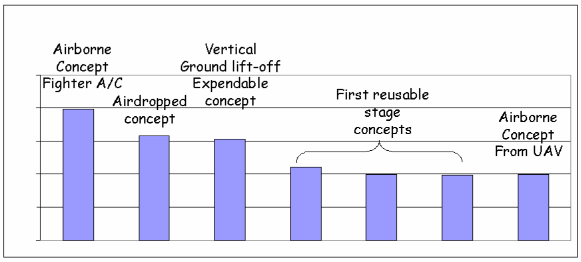

Figure 11: final ratings of Aldebaran concepts

For the 3 first concepts:

- Airborne and airdropped concepts are well adapted to the current Aldebaran requirements, covering all of the five interesting technology fields (liquid and solid propulsion, avionics, structures, system). Thanks to the help of the aircraft, they are the smallest systems identified as able to reach orbit. Remark: the concept using an UAV air carrier obtained a bad rating due to the lack of availability of such system in relation with the objective of planning and cost dedicated to Aldebaran
- "CATS" (Cheap Access To Space concept - expendable type) was surprisingly well rated. It is interesting to pursue the general studies at system level, also "critically" analyzing the technological choices proposed for a possible "very" low cost access to space concept solution.

Aldebaran Phase 0 conclusions.

3 concepts were retained at the end of the Aldebaran phase 0.

First, the airborne system under a military aircraft. More details will be shown is the next paragraph concerning the system demonstrator version proposed for the next phase.

Second, the concept airdropped from the back door of a cargo aircraft. This concept presents higher risk and complexity due to the method of extraction and the safety rules. But compared to the fighter option, the mass and the geometry are less constrained, allowing an increased performance. The technologies will be similar therefore it will not be studied in detail during the phaseA.

Figure 12: Astrium-ST airdropped concept

Third, a more conventional concept with a vertical launch method using a classical launch pad. The definition of this concept will be fixed during the first part of the next Aldebaran phase. For that reason, it is not presented in this article.

One of the main orientations for the next Aldebaran phase is to focus on the system demonstrator definition, and the identification and justification of the related technologies.

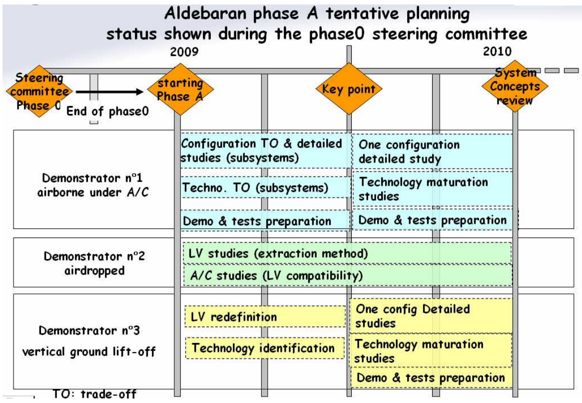

Figure 13: general logic for Aldebaran next steps

The figure above gives an overview of the general logic proposed during the Aldebaran phase 0 steering committee who approved the general conclusions and orientations in 2009.

The following paragraph gives some more details about a possible definition of the first selected concept.

MLA-Demonstrator description

The MLA-D (ref 3) is a 2-stage demonstrator system attached under the wing or the fuselage of a fighter Aircraft.

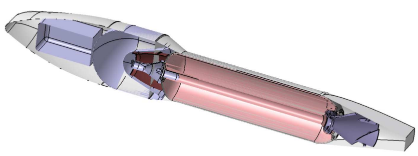

Figure 14: a possible MLA-D definition (Astrium_ST)

The main characteristics are: 6.5m long, 0.9m diameter and a total mass of 4t.

A dual compatibility is obtained with two European aircrafts: the Eurofighter (EADS, BAE Systems and Finmeccanica) and the Rafale (Dassault Aviation). Depending on the aircraft, the attachment mode differs as shown in the figure 15.

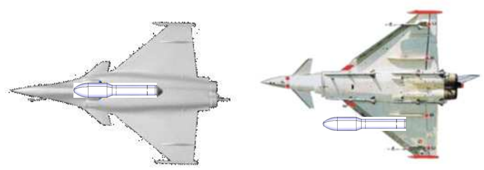

Figure 15: MLA-D under Rafale & Eurofighter

In order to demonstrate the feasibility of the concept, some wind tunnel tests (1/7th scale) have been performed. One objective was to check the aerodynamic flow in the air intake of the aircraft when the demonstrator is placed under the fuselage. No show stopper was found considering the possible layout and geometries of the MLA demonstrator, and considering the flight domain (Mach, angle of attack…).

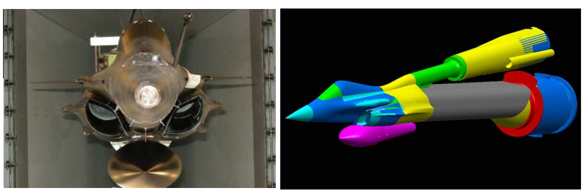

Figure 16: MLA-D + Rafale air intake wind tunnel tests (Dassault + ONERA)

Many subsystems or elements of the demonstrator are investigated to propose innovation (first and second stages, avionics, fairing, pyrotechnics, attitude control, etc.).

Depending on the final technologies (propellant, cycle, structures, etc.), the MLA-Demonstrator will bring about 200kg in low earth orbit, including the inert stage and the unusable propellants. This will allow to perform demonstrations in orbit.

The first stage (ref 4) uses about 2 tons of solid propellant either conventional type (ammonium perchlorate with HTPB), or using new formulations (HMX, Oxalane - ®SNPE). The final choice will depend on the real interest for the next evolutions of launcher systems. It will also depend on the technological maturity which could be demonstrated prior to the development of such systems. The processes of loading will also be taken into account in the technology selection.

Other technological improvements are foreseen for the casing (high strength carbon fibre or shock resistance material), for the thermal protections (low density insulation material), for the nozzle and activation system (low cost and low erosion CC composite throat, extra light structures, EMA activation, etc.).

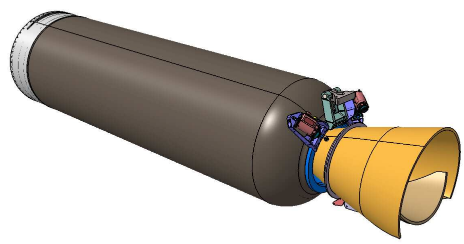

Figure 17: SPS solid propellant motor

The upper stage of MLA-D can use a bi-liquid propellant engine of 5 to 10 kN (Lox/Hydrocarbon). One can add that hydrogen is not well adapted to the constrained volume under the aircrafts; therefore, it was not retained at the end of phase0 for the MLA concept. The evaluated options were methane, propane, ethanol, and kerosene.

when using methane, such upper stage is loaded with about 500kg of liquid propellants. The figure below shows a possible candidate. But, the Aldebaran phase A will allow identifying the better choices in term of architecture, materials and sub systems (pressurisation system…).

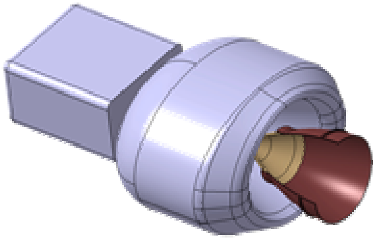

Figure 18: liquid propellant upper stage (Astrium_ST)

For the upper stage engine, several candidates are under study in SNECMA and DLR institute. The current trade off concerns the engine cycle (pressure-fed with film or effusion cooling vs turbo pumped expander cycle). Numerous technological challenges and innovative solutions have been proposed for the engine subsystems (ceramic chamber, mono injector, small size turbo machines, extendable nozzle, etc.).

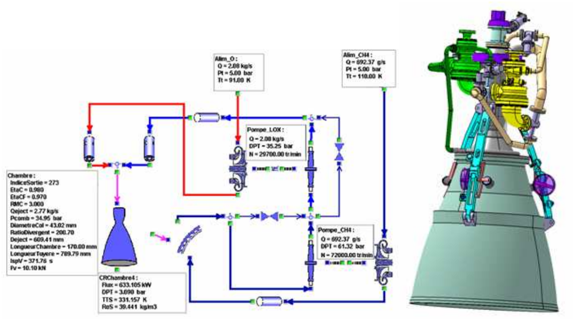

Figure 19: 10kN Lox/Lch4 expander engine (Snecma)

CONCLUSION

Aldebaran project is focusing on the maturation and the development of technologies in preparation for the future launch systems. It is a flying system demonstrator. After a selection process, the phase 0 held during 2008 and beginning 2009, retained 3 concepts:

- an airborne solution under 2 possible military aircrafts.
- An airdropped concept launched from a cargo aircraft.
- A more conventional vertical ground lift off solution.

The present paper roughly presented the phase 0 selection process and conclusions. It also provided some details related for a possible definition of the first selected concept named MLA-demonstrator. It gave some indications about the technologies envisaged in the concept. The Aldebaran phase A is now initiated focusing on the new technologies to be maturated in order to better prepare the evolutions of the European launcher systems.

For what concerns the third concept (conventional lift off type), and in order to reach the same level of definition compared to the MLA-D, some complementary system studies are carried on, in the frame of a so called “bridging phase 0/A”.

The next main step will be the end of the phase A around end 2010 with the selection of a single concept.

Acknowledgements

To industry and research centres involved in ALDEBARAN studies.

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