Surrey University, september 9th 2008
Guest Lecture :
Air Launch Solutions for Microsatellites

CNES, Launcher Directorate (Evry, France) – C. Talbot, C. Bonnal

- Existing launch solutions and microsats missions and market (10')
- Preliminary ideas for a (conventional) micro LV (5')
- Interest of an airborne solution (10')
- Air Launch Concepts under study (20')
- Aldebaran project (5')

CENTRE NATIONAL D'ÉTUDES SPATIALES

Microsatellites
Missions and Market

Ariane, Vega and Soyuz/G

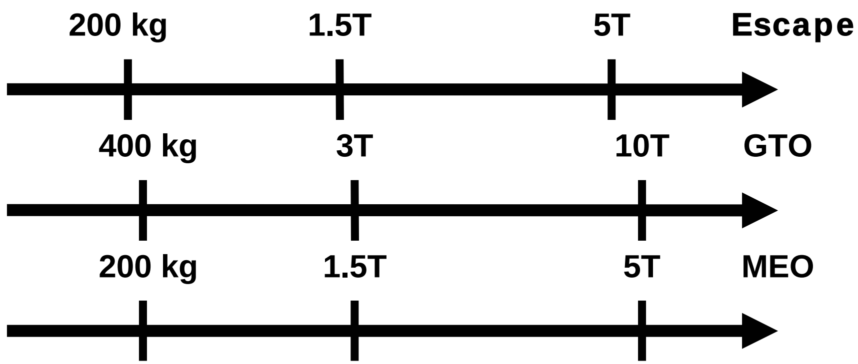
Europe will soon operate from French Guiana a new family of launchers, composed with:

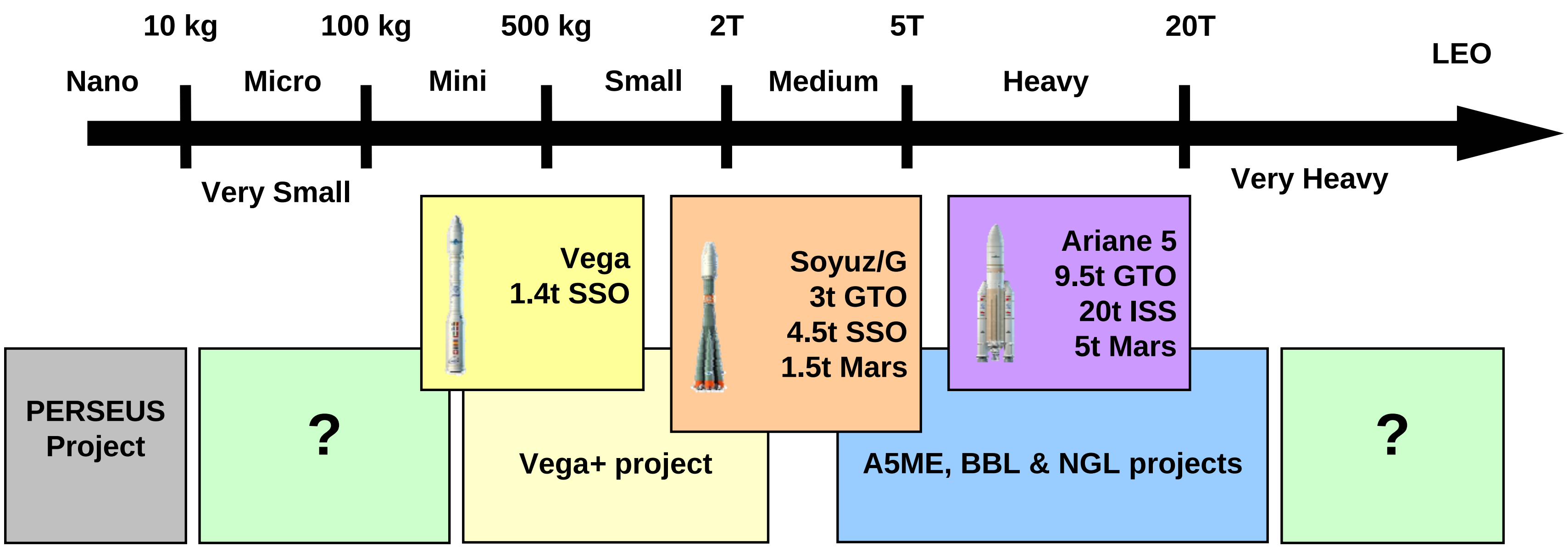
- Ariane 5, in its last version (A5ECA) using a 14t cryogenic upper stage propelled by HM7 (14 successful flights)
- Soyuz, in its “1a” version including an updated electrical system, will be first launched from Guiana in 2009
- Vega, the new developed rocket, will be launched from Kourou by 2009

This family is adapted to European institutional and commercial needs with a complete coverage of the payloads between small to heavy payloads.

Current European offer :

Performance ranges of European launchers and projects in relation to satellite masses.





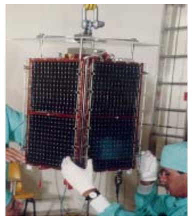
Why a micro launch vehicle ?

The recent multiplication of micro satellite platforms and the increasing success to the associated applications allow us to think about the interest of a dedicated Launch system :

- Numerous successful technology experiences based on microsats, for Science or Defense with gradual increase in instrument performance
- Constant improvement of quality / price ratio
- Rebirth of interest for constellations (Rapid eyes, Orbcomm2, numerous project worldwide…) and formation flying,
- Increasing number of operational applications accessible : communications, intelligence gathering, early warning, space surveillance, different type of observation, etc.,
- Evidence of the vulnerability of the big space systems,
- Increasing interest for the « Responsive Space » approach in the USA and other countries (China, etc.), which prefer small size in order to reduce global costs et delays, and facilitate the implementation of new technologies

Tacsat-1 (USA, ORS)
100 kg, conception & construction for 10M$ and less than 1 year

TopSat (Qinetiq-SSTL, GB)
115 kg, 20M$ all included, with amazing operational performances 2.6m resolution 2.6m, 5 yrs life duration expected, agility, direct user…



Microsat 70-100 (SSTL, GB): more than 20 satellites ordered (70-130 kg), now replaced by a new platform more flexible

Myriade (Astrium/TAS): more than de 15 satellites ordered (100-150 kg) et numerous projects …

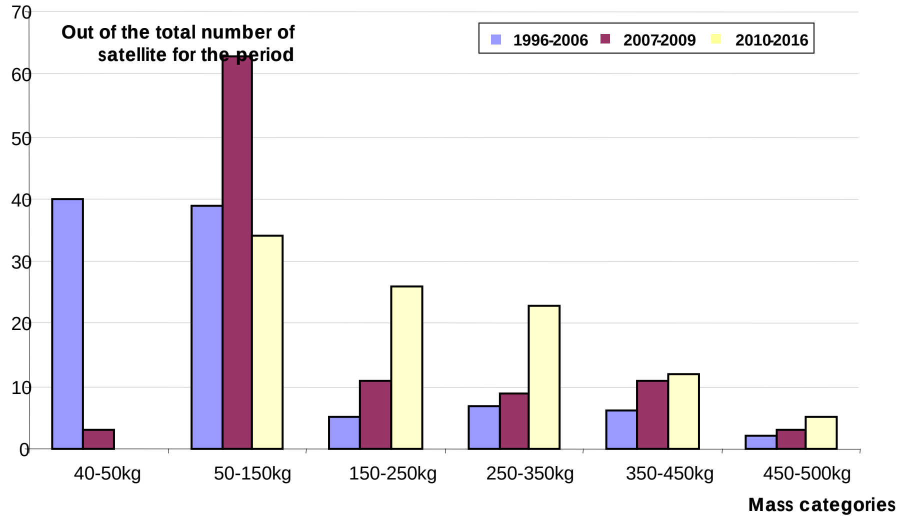
Euroconsult Market Study

The market

The current market for very small satellites (<500 kg) is more active in the microsats range (40-150 kg). Although over the last few years there has been a strong increase in demand for launching of these satellites, for which more and more platforms are available.

This increase in number might also be accompanied by an increase in satellite masses (increase from 150 to 200 kg, or even more) in order to optimise mission yields.

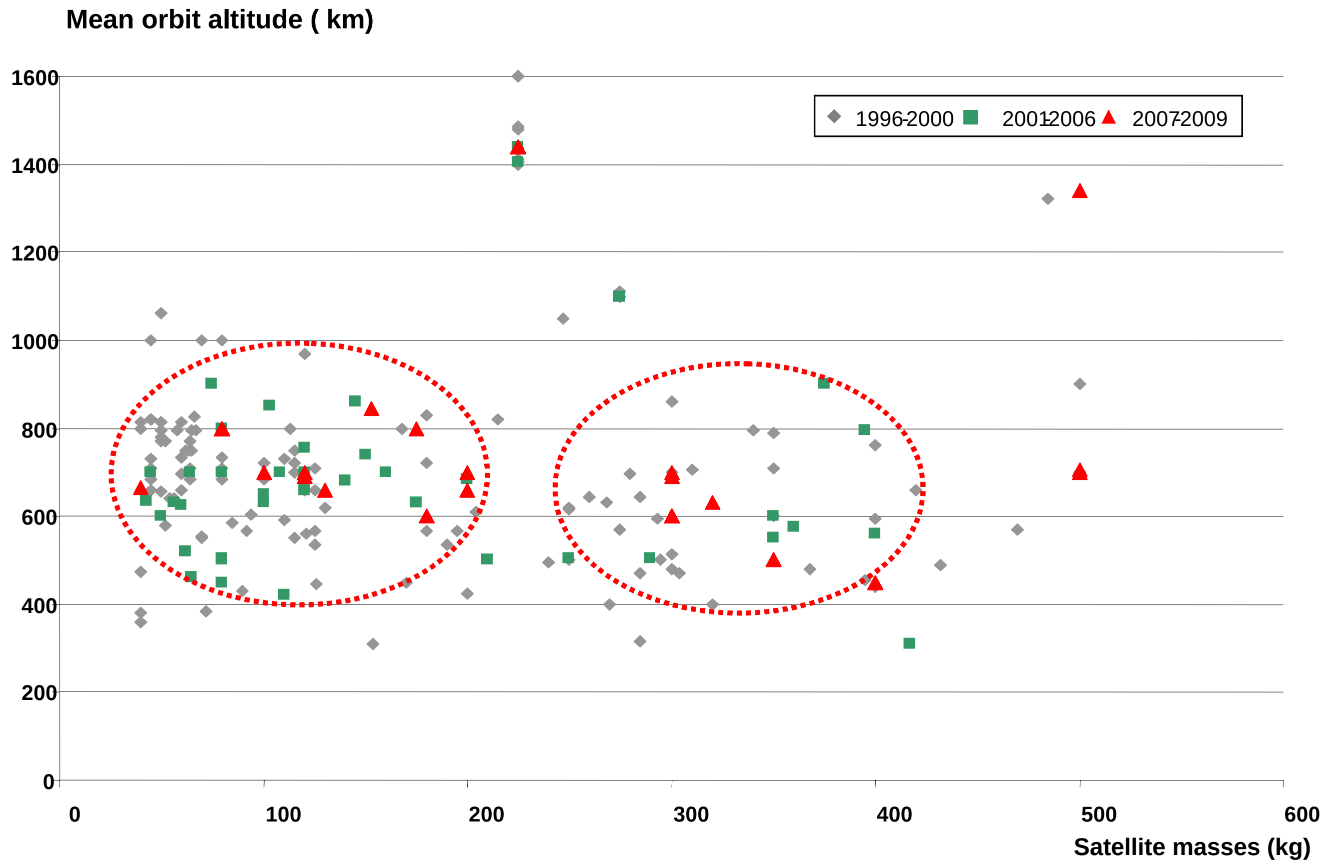
Distribution of small satellites launched (1996-2006) and to be launched (2007-2016) by mass category



Euroconsult for CNES/DLA – Prospective study of world market for small LEO satellites

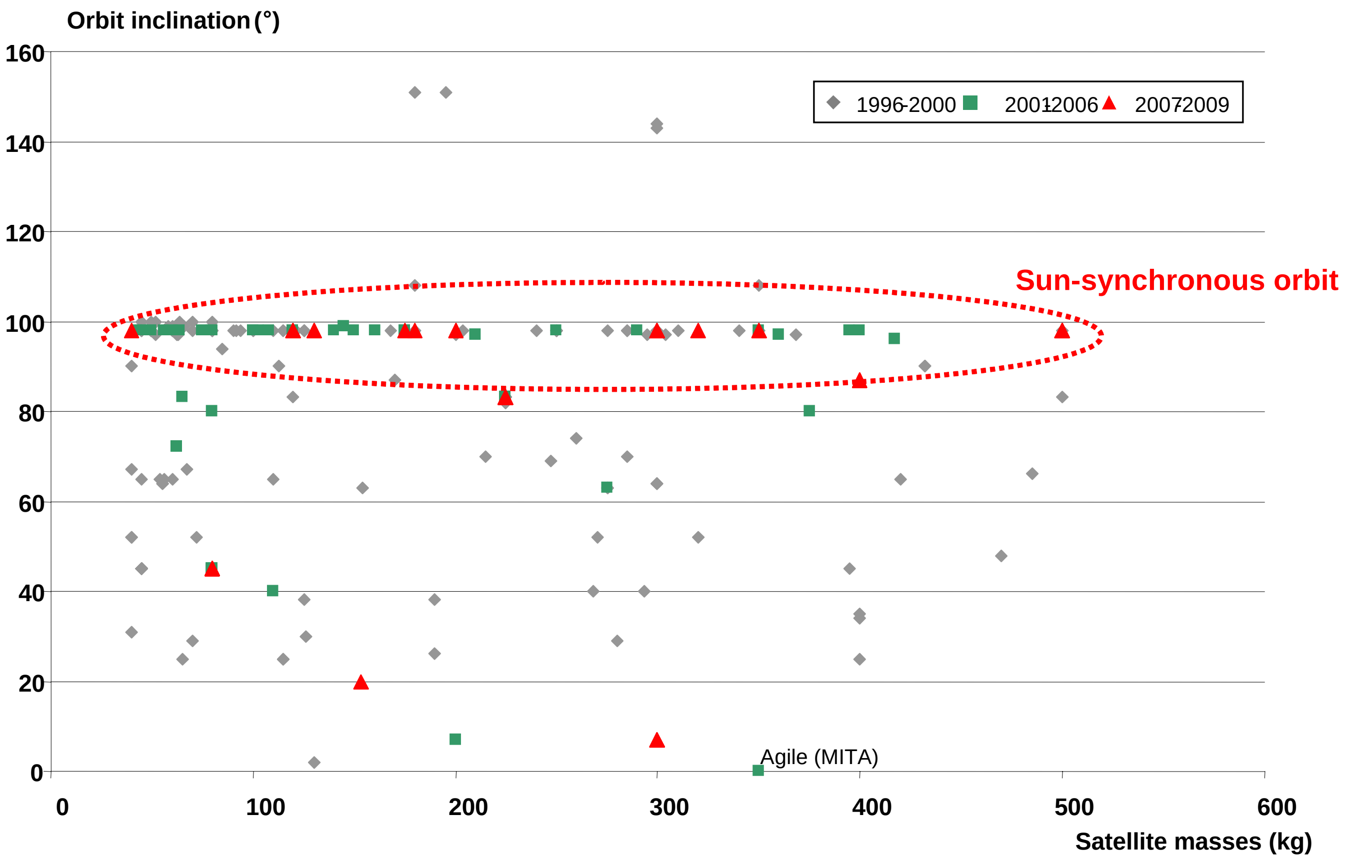
Euroconsult Market Study

Distribution of small satellites launched (1996-2006) and to be launched (2007-2009) by mass and altitude



Euroconsult for CNES/DLA – Prospective study of world market for small LEO satellites

Distribution of small satellites launched (1996-2006) and to be launched (2007-2009) by mass and inclinations



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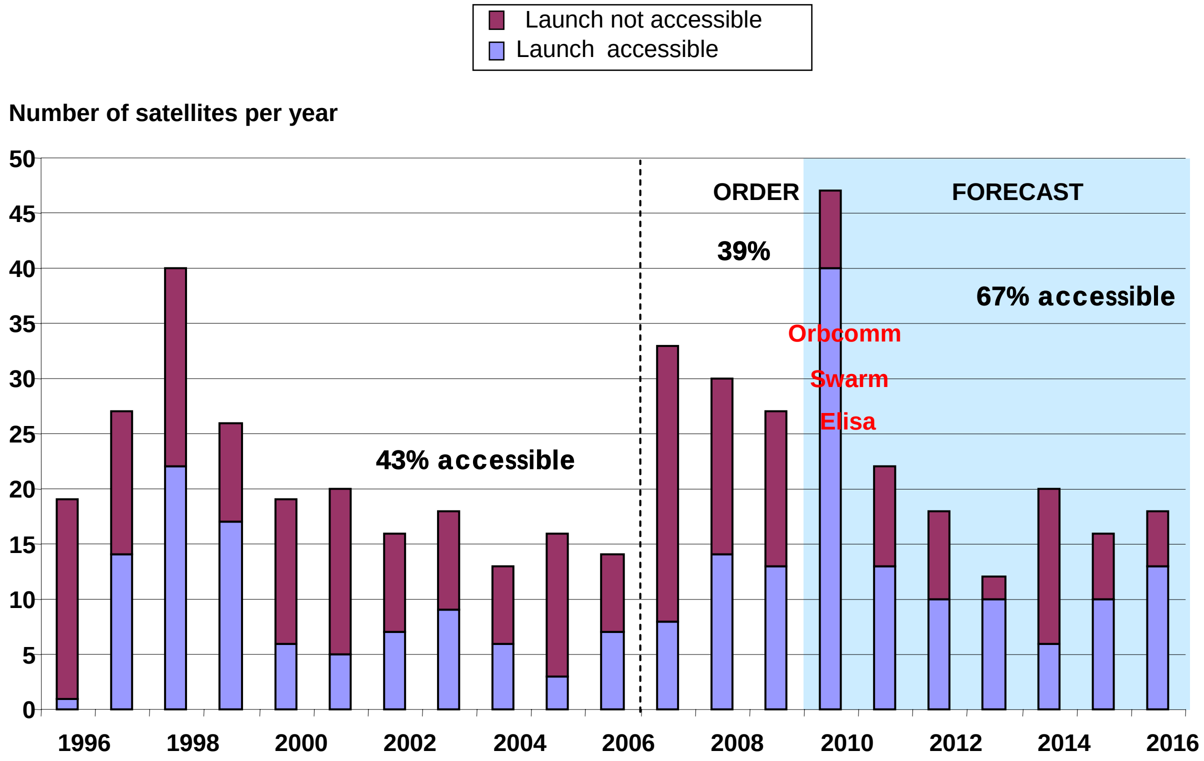
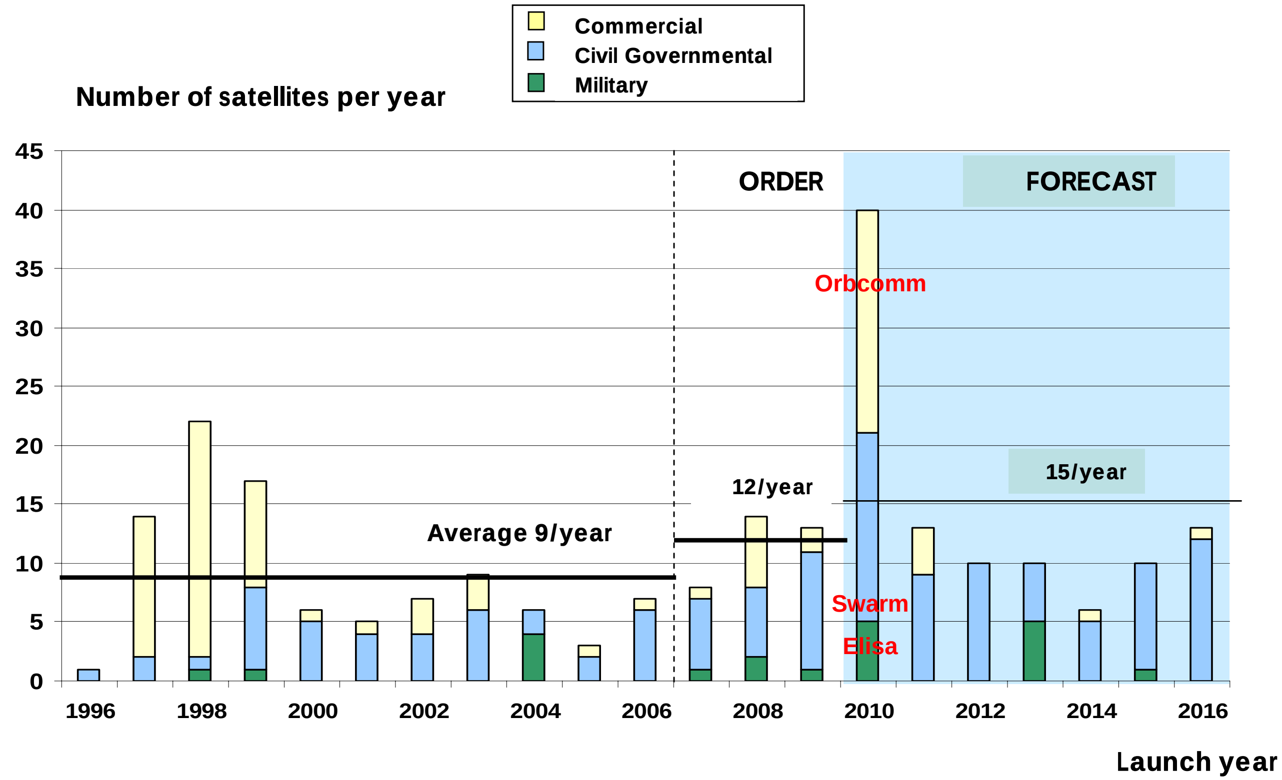
Proportion of accessible satellites launched (1996-2006) and to be launched (2007-2016) in the world



Euroconsult for CNES/DLA – Prospective study of world market for small LEO satellites

Euroconsult Market Study

Number of accessible small satellites launched (1996-2006) and to be launched (2007-2016) in the world by type of customer.



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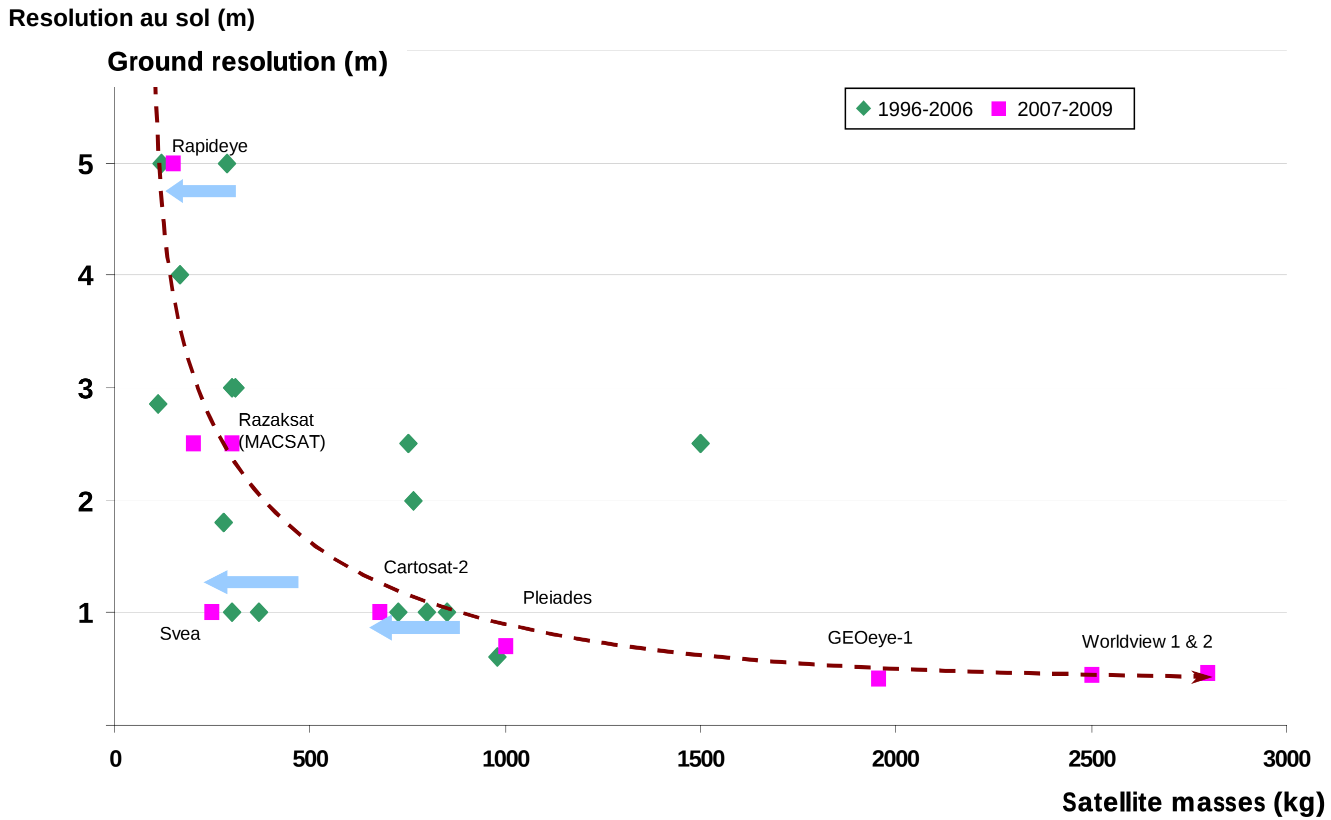
Increasing of observation performances

Resolution of small observation satellites launched (1996-2006) and to be launched (2007-2009) by mass



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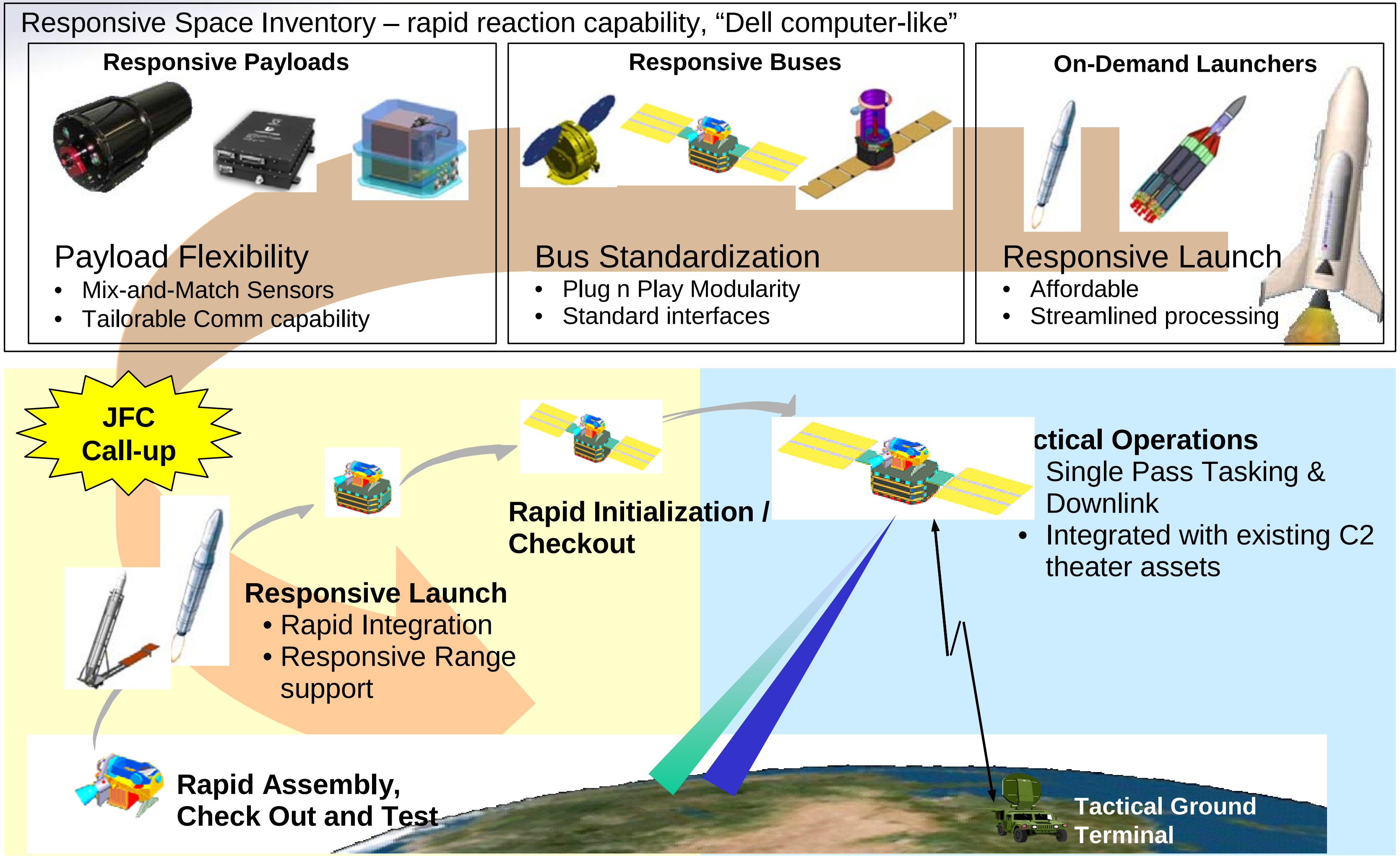
USA : ORS (Operationally Responsive Space)



US ORS office vision

(potentially) Responsive Launch vehicle

Minotaur familly (OSC) : LV derived from decomissioned ballistic missiles (minuteman II, Peacekeeper), operationals (M4&5 in development)

Performances :
M1 ≈ 500 kg LEO
M2 et M3 : « Target LV »
M4 ≈ 1500kg LEO,
M5: GTO compatible

Pegasus familly (OSC) : operational airborne LV (ORS version : Raptor-1). Ground variant (Taurus)

Performances ≈ 200-400 kg LEO (Pegasus-XL)

Falcon-1 (Space-X) : « low cost » launcher in final development phase

Performance ≈ 200-400 kg LEO, and until 700 kg LEO (Falcon-1E)

Falcon-1 price < 7M$ … comparable to ASAP price

Projects of new launch systems (USA)

(potentially) Responsive Launch vehicle

Quickreach (Air Launch LLC, FALCON program): Air launch concept (internally carried in a C-17 globalstar) … in development

Performance : 400 kg LEO

Scorpius (Microcosm) "very low cost" LV (modular and simple conception using advanced technologies)
Performance : 250 kg LEO (Sprite)

Numerous projects more or less ambitious… many airborne ideas.

Lanceurs « réactifs » existants ou en projet (hors US)

Russie

Numerous converted Missiles (SS18), operationnal : Dniepr, Volna, Shtil, etc.

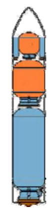
Several airborne projects (internally carried with Antonov, Ishim and MRLV under Mig-31, etc.), some in development ?

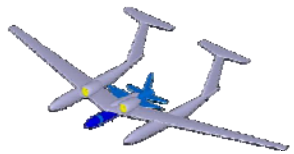
Asie, Israël, etc.

Japan, Korea, Israel : several airborne concepts in project

China : Numerous projects (some in development ?)

Europe





Following presentation ….

Preliminary Ideas of (conventional) LV

Classical micro Launch Vehicle

Typical Requirements :

- ✓ SSO 800 km (i=98.6°)
- ✓ P/L mass = 150 kg
- ✓ Launch Price ~ ASAP

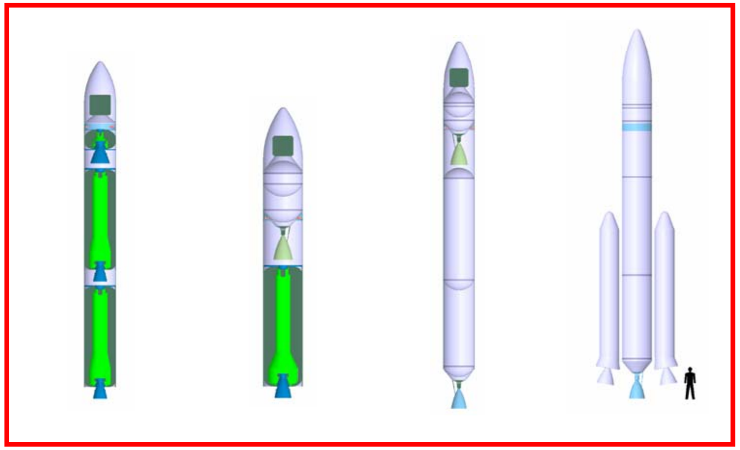
Classical Micro-launchers :

- ✓ Expandable
- ✓ Vertical take off, from ground
- ✓ State of the art technologies
- ✓ Design to cost

Preliminary trade-offs :

- ✓ Solid propellant and Lox/methane retained, Storable propellant only for small upper stage. Elimination of hydrogen and hybrid propulsion.

Conclusion : despite ambitious design to cost assumptions, the costs remain 20% to 100% higher than the requirement.



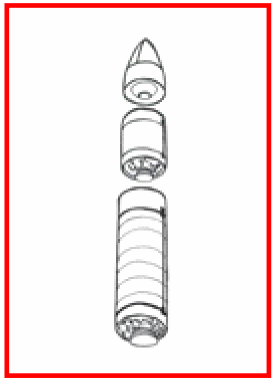
Configuration	Performance	Comments
P9-P9-P2	150 kg	Less expensive
P19-C5	150 kg	
P13-P4-L1	150 kg	Lighter config.
C18-C2	150 kg	New engine
C18-C2 +2 P8	500 kg	Interesting extensibility

BBμL and Missile derivatives

In order to minimize investing costs and development duration, building block have also been considered :
- ✓ Re-use of Vega stages (Zefiro 9 & 23)
- ✓ Re-use of Aestus engine of A5

Configuration	Performance	Comments
Z9-Z9-Lx	< 0 kg	Insufficient thrust
Z23-L5	100 kg	Limited performance
Z23-Z9-L2.5	450 kg	Very high DP
Z23-Z23-L4	600 kg	
P80-L5	500 kg	Very high Acc

M4



Other possibility : conversion of retired M4 (French SLBM)
- ✓ upper composite replaced by a versatile upper stage (i.e. based on an Aestus engine)
- ✓ Replacement of obsolete materials (electrical system, pyrotechnics, etc.)
- ✓ More than 150 kg depending of the upper stage and launch pad position

Only the M4 derivative seems to be compliant with the objective

Airborne Solutions : advantages and drawbacks

Why an Airborne launcher ?

The two main reasons of the lack of competition of classical micro LV are :

- ✓ Scale effect (smaller P/L, bigger Mass ratio ...)
- ✓ Fixed cost (expensive ground facilities, complex operations...)

A solution could be an Airborne Launcher :

- ✓ Use of a re-usable, existing and very reliable first stage : an aircraft,
- ✓ Gain on the total mass of the vehicle due to various DeltaV savings,
- ✓ Reduction of the ground facilities size (elimination of the launch pad) and constraints (safety in close range), and possibility to launch from the European continent (proximity of the Customer).

Performance gains of airborne LV

On the strict performance point of view, an airborne launcher can have multiple gains :

- ✓Gain on the initial velocity : modest for most cases (150 to 200 m/s) and particularly interesting for high supersonic aircraft such as interceptors (300 to 800 m/s),
- ✓Reduction of the gravity losses, angle of attack and drag : particularly interesting if the altitude of separation from plane is high and if the initial attitude is optimized (flight path angle),
- ✓Reduction of the losses due to atmospheric pressure at the output of the engine with the possibility to increase the expansion ratio of the nozzle,
- ✓Reduction of the losses due to safety constraints, flight by protected areas, in close or long range (depending of the autonomy of the plane),
- ✓Reduction of the impacts due to environment on the launcher dimensioning (acoustic, dynamic pressure, etc.).

The total gain is function of numerous parameters and can reach, in certain cases, 2000 m/s (Ishim Project with high supersonic separation form Mig-31 interceptor).

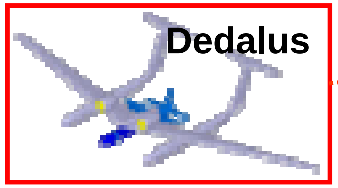
Performance gains of Airborne LV

-25%

-30%

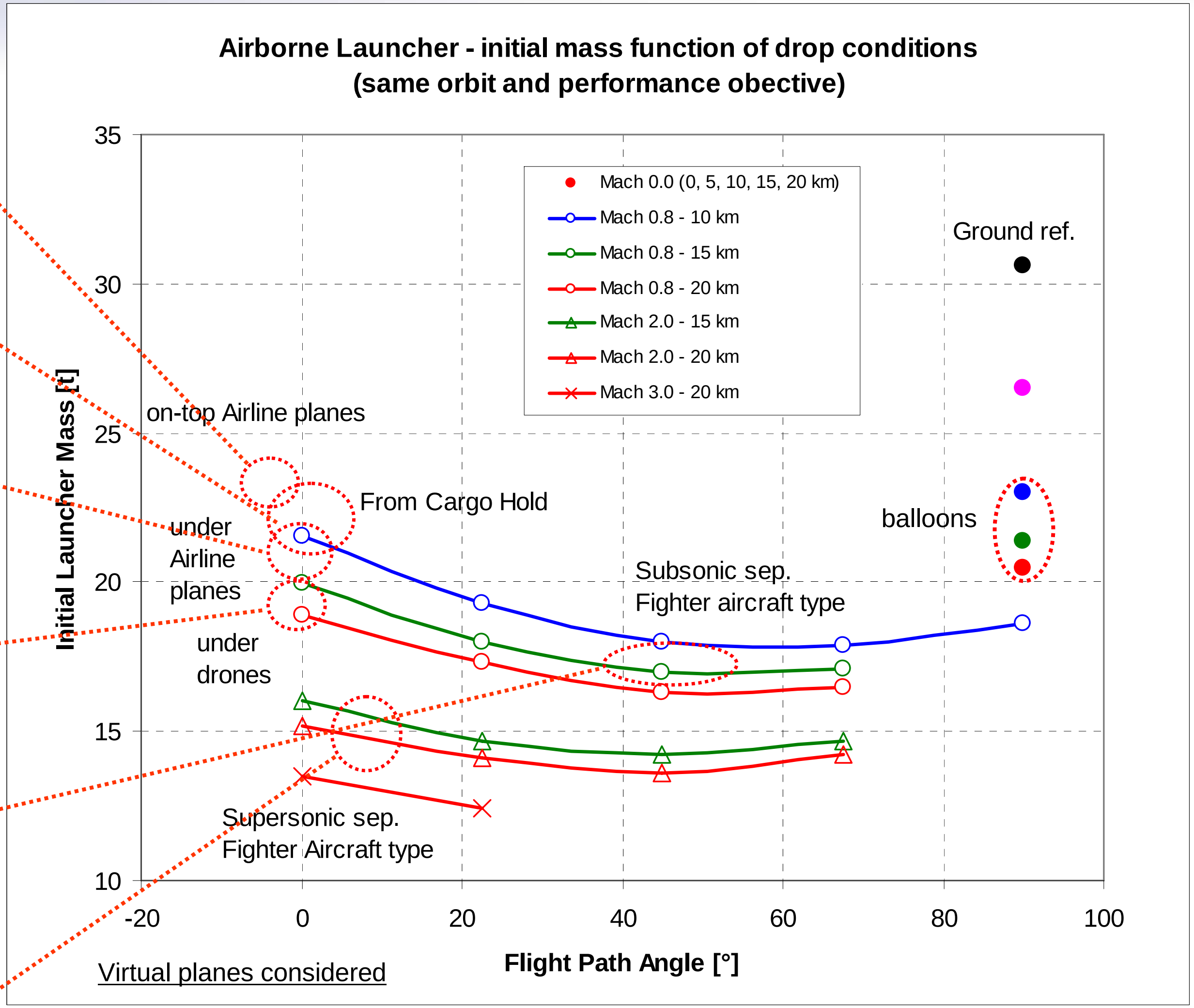
-35%

-40%



-45%

-55%



Gain on the initial mass of an airborne launcher compared to a classical ground take off (objective 300 kg in SSO)

Some drawbacks of Airborne systems

Disadvantages depends mainly of the airborne system and the method of launch (under fuselage, under wings, on top, internal, towed, etc.).

Impacts :

- ✓ Limitation on launcher volume & mass, geometrical constraints for launcher design,
- ✓ Limitation on kinematics conditions at separation (mach, altitude, flight path angle), and geographical point (distance from airport, from ground, etc.),
- ✓ Limitation on propellant category (security and safety considering the type of the plane and the pilots),
- ✓ In certain case, necessity to have additional systems or structures on the launcher (wings, parachutes, etc.) to ensure a good and stable separation, and to wait for the plane distancing, etc.
- ✓ Requirement of specific technologies to ensure autonomous servitudes during the a/c flight (energy, pressurisation, thermal regulation, etc.).

Some solution require to modify the aircraft, which can be problematic for the plane conventional usage.

Finally, advantages are often replaced by new problems, and a precise trade off is required in any case.

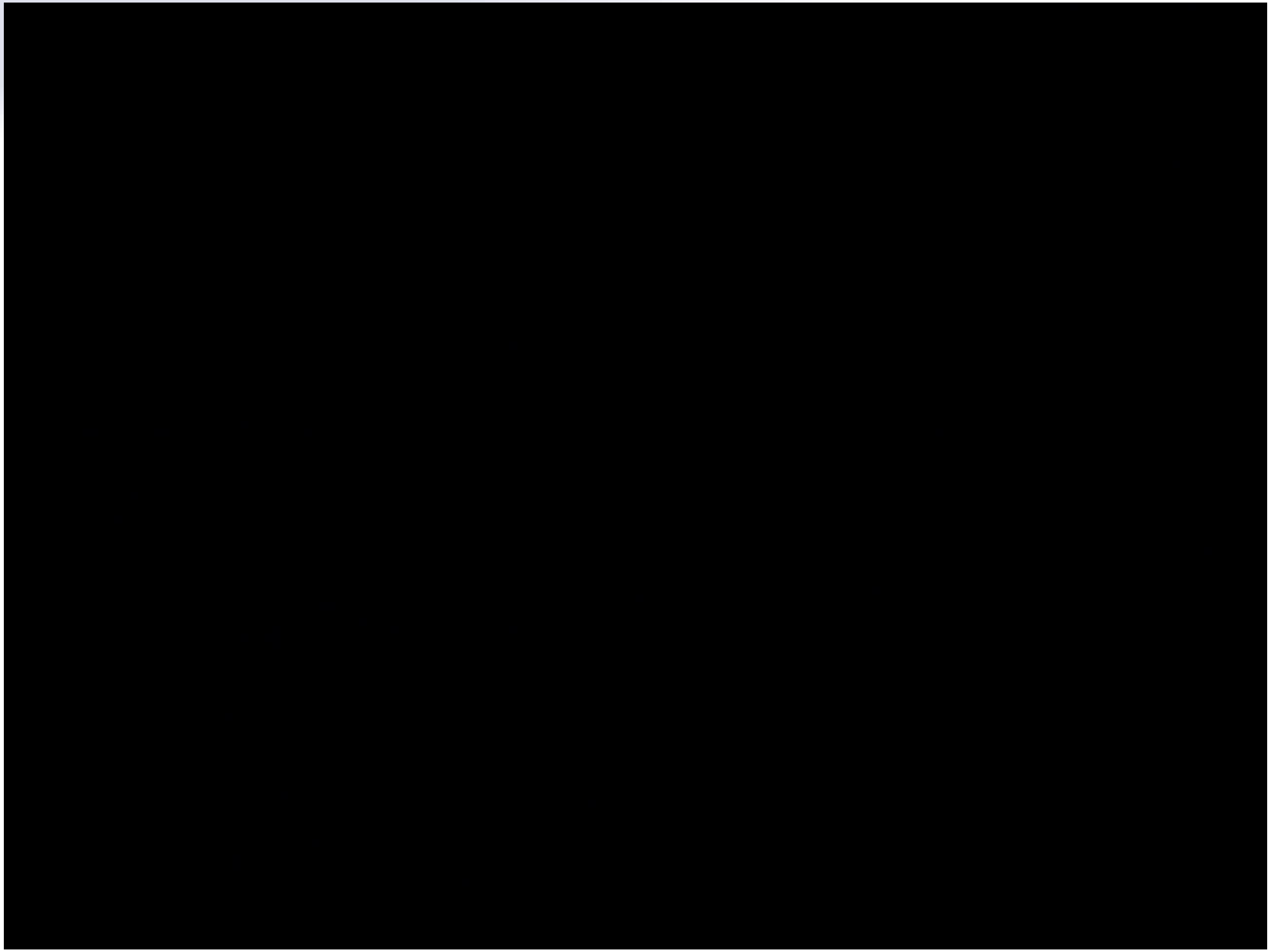
Some examples of Airborne launchers

- ✓ Pegasus : captive on bottom of the fuselage of a modified Lockheed L1011 (or the wing of a B-52). The launcher requires a large wing to limit the losses at separation during the aircraft distancing and to control the first stage. 3-stages with conventional solid propulsion plus an optional little kick stage (HAPS) to correct dispersions at injection : total mass 23t, performance 400 kg LEO (200 kg in SSO).

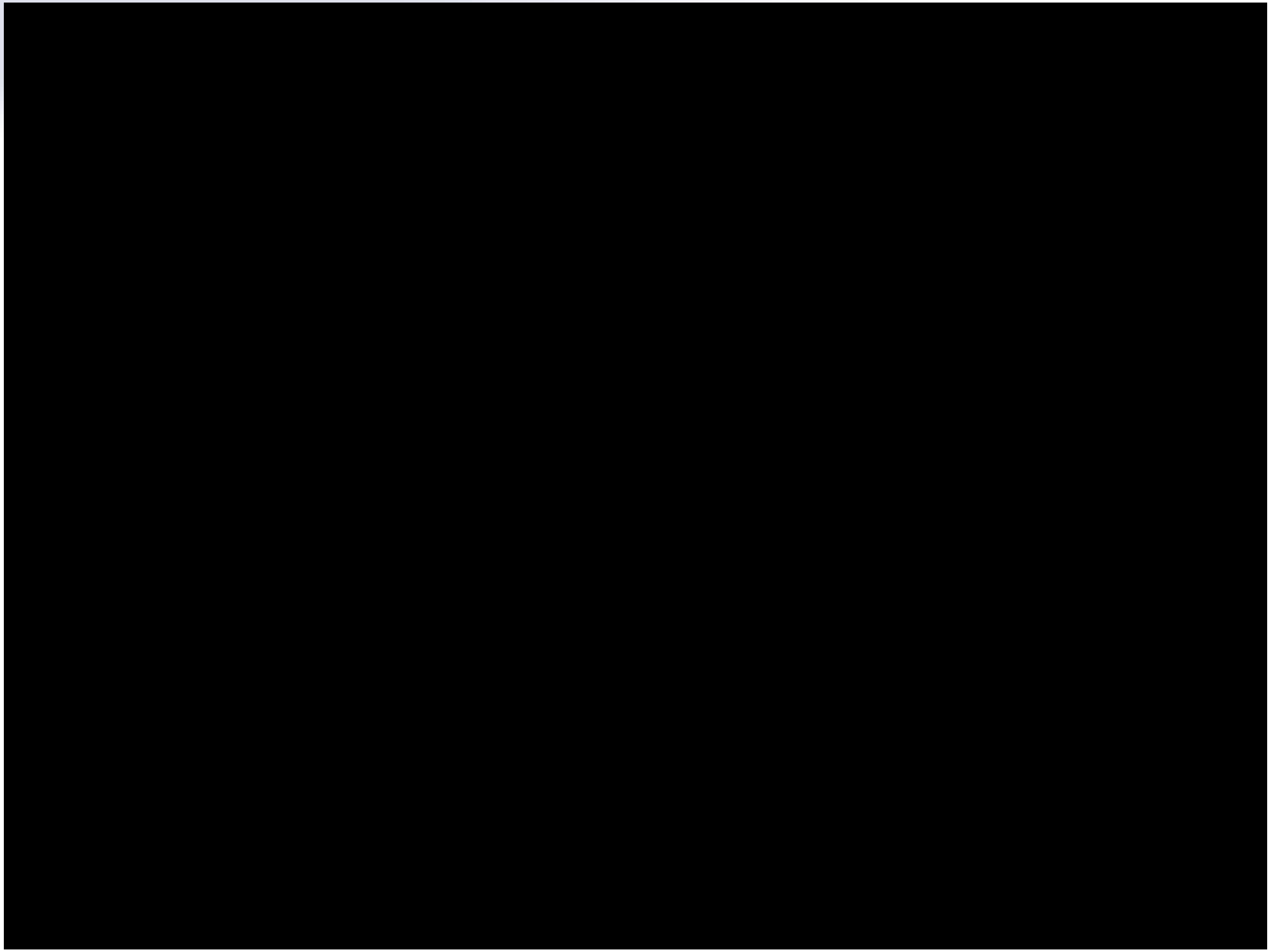
- ✓ Quickreach (project) : The launcher is positioned inside the hold of a C-17 Globalstar. It requires an imported double rail attached to the aircraft made up of inflated rubber rollers. A LV parachute is used to facilitate extraction and stabilisation outside. The first seconds after ignition are particularly difficult with a control at more than 90° of AoA. 2-stages configuration with a propulsion based on Lox/Propane pressure fed engines. Total mass 40t. Performance 450 kg LEO.

- ✓ Ishim (project) : A micro launcher captive under the fuselage of a Mig-31 and separated at more than mach 2, 20km of altitude and a little slope. Launcher mass < 10t, Performance ~250 kg LEO.

Pegasus Example



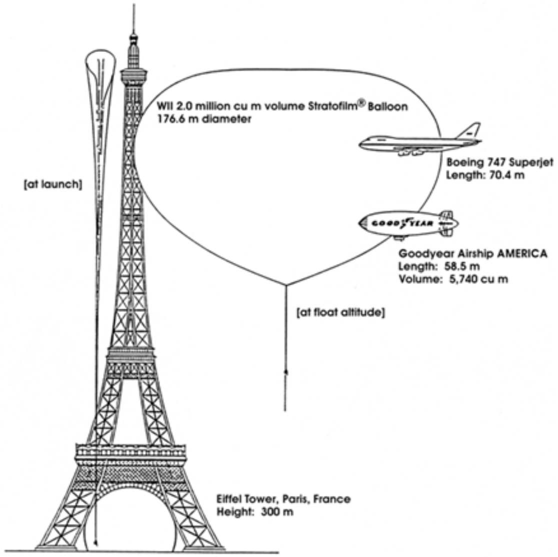
Quickreach Example



Airborne Solutions : concepts under study

Concept not studied

Dedalus for transport mission



NASA balloon size

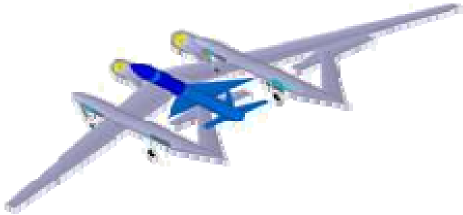
- The balloon solution was rapidly eliminated due to the requirement for very large balloon (for a few tons of LV) and the operational constraints (weather conditions, balloon recovery, slow ascension, etc.)

Aerto-towed

- The main advantages of aero-towed concept are the easy separation, the low-costs modifications of the aircraft and the relatively unconstrained size of the LV.
- Unfortunately the drawbacks are also numerous : complexity of conception (wings and gears required, sophisticated flight control during aerotowed phase, abort mission management)

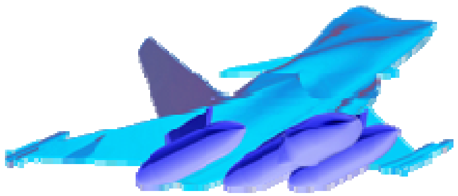
Concepts under study

TELEMAQUE



DEDALUS

HORVS



MLA

On-top concepts (using Air Liner)

- The launch vehicle is positioned on top of a civil transport carrier aircraft (i.e A300 “0g”)
- The separation is ensured by relative lift between LV and aircraft. The aircraft must fly with a 0° or negative flight path angle (descending trajectory). Such solution requires a good lift performance of the LV, i.e large wing (at least 2 or 3 times the wing loading of the Pegasus) or a specific device (catapult)

- Such separation has already been demonstrated (US Space Shuttle, Leduc/Languedoc aircrafts, etc.). Many concepts of this type exist worlwide (Boeing Air launch, Dassault Vehra, etc.).

Leduc / Languedoc

Boeing Air launch concept

Dassault Vehra

On-top concepts : Telemaque

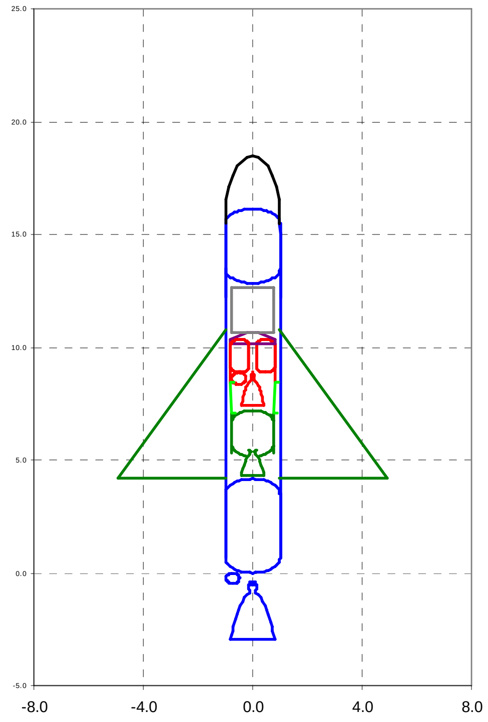
- Due to the large wing required, such concepts are often designed to be partially reusable (first stage uses the wing to facilitate re-entry and landing.

- The Telemaque concept is a relatively ambitious project using a Lox/Methane propulsion for first stage (derived from Vulcain engine) and a cargo with a 2-stage ELV and the spacecraft.
- Staging is C16-P4-C1.2 (total mass > 30t) for 250 kg in SSO.

The main advantage of such solution is the important possible size for the LV.

Main drawbacks concern the complex separation phase (active control of the LV?, management of propellant), and probable requirement for some aircraft modification (attachment on hard point).

CNES Telemaque



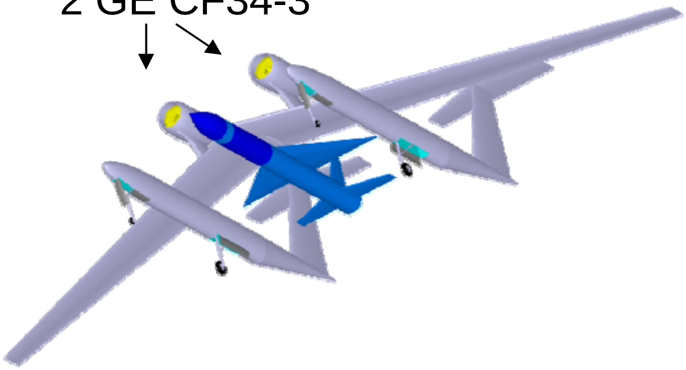
Dedalus - Captive on bottom UAV

- The Dedalus is an original concept considering an UAV to transport the LV. The main advantage is the architecture (2-bodies) of the UAV allowing to easily accommodate a LV. The fact that the carrier is unmanned is also (in a certain way) an advantage.

- A P9-P4-P0.7 LV configuration, separated at high altitude (16 km), mach 0.7 and 0° FPA allows to place 150 kg in SSO.

- The MTOW required for the UAV is around 22t (less than 7t for the UAV alone and 15t for the LV) and a wing area of 37m… the biggest drone ever made !

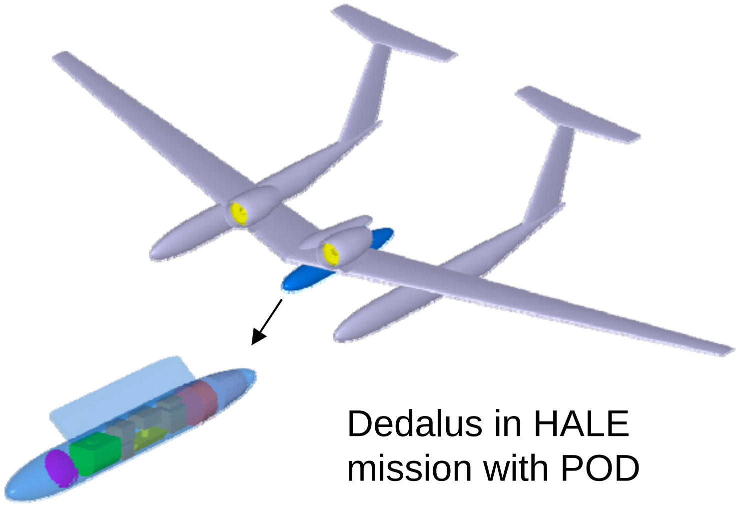
CNES/ONERA Dedalus concept



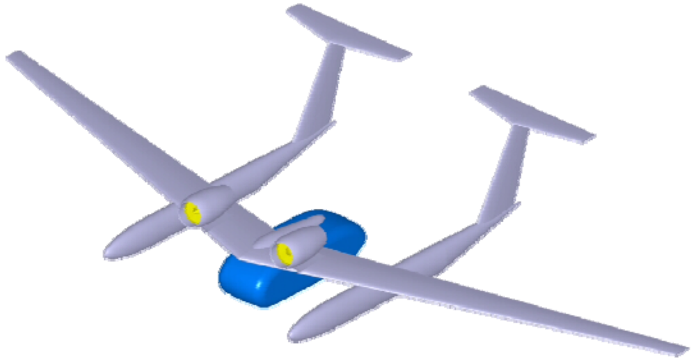
Dedalus - Captive on bottom UAV

- The main difficulty here is the required investment for the conception and construction of such UAV. An idea is then to define it for multimission purpose : classical HALE mission (30h observation with 1.5t pod), long distance fret (7t at more 9000 km), etc.

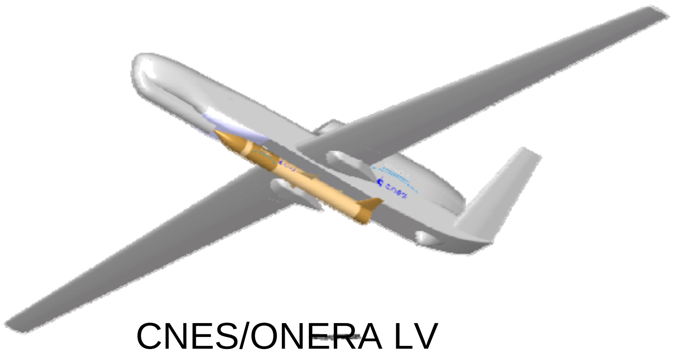
- For comparison the biggest existing UAV (GlobalHawk) has a 14.6t MTOW (65%) and a max P/L of 5t. The difficulty to accommodate a LV under such UAV limit the LV mass to about 2t.



Dedalus in HALE mission with POD

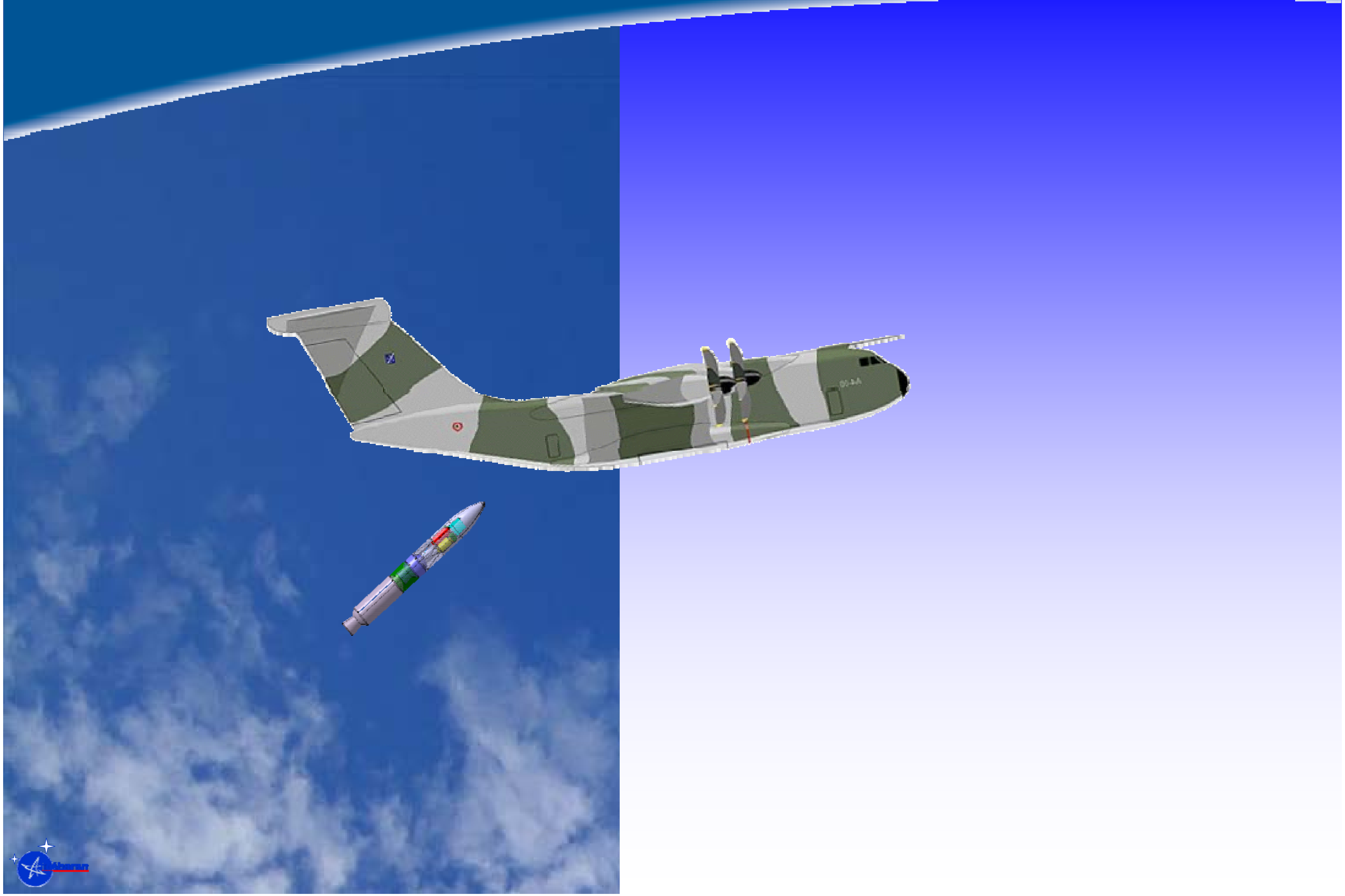


Dedalus for transport mission



CNES/ONERA LV under GlobalHAwk concept

The HORVS airdrop launcher



HORVS – Use of the A400-M (carrier plane)

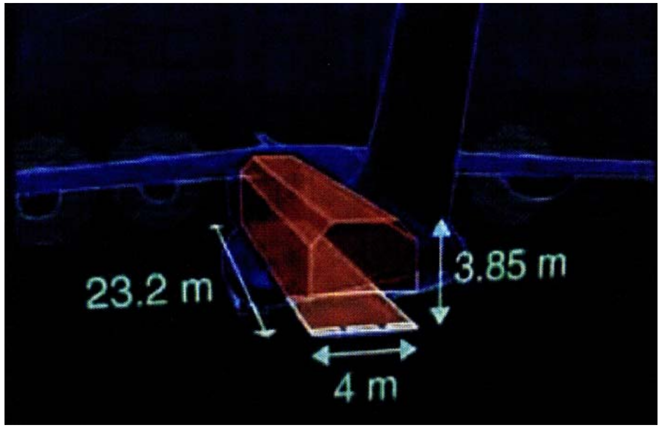
➢ An Airborne LV with an A400M aircraft

The A400M presents interesting characteristics for an airborne system.

It has a large cargo bay (comparable to C-17) with a large opening allowing to transport and jettison a big launcher.

PHOTO AIRBUS MILITARY

- Maximum payload: 37 T
- Range with 20T: 6950 km
- Hold: 17.7 X 4 X 3.85 m
- Max velocity: Mach 0.72
- Length: 45.1 m
- MTOW: 136.5 T



HORVS definition

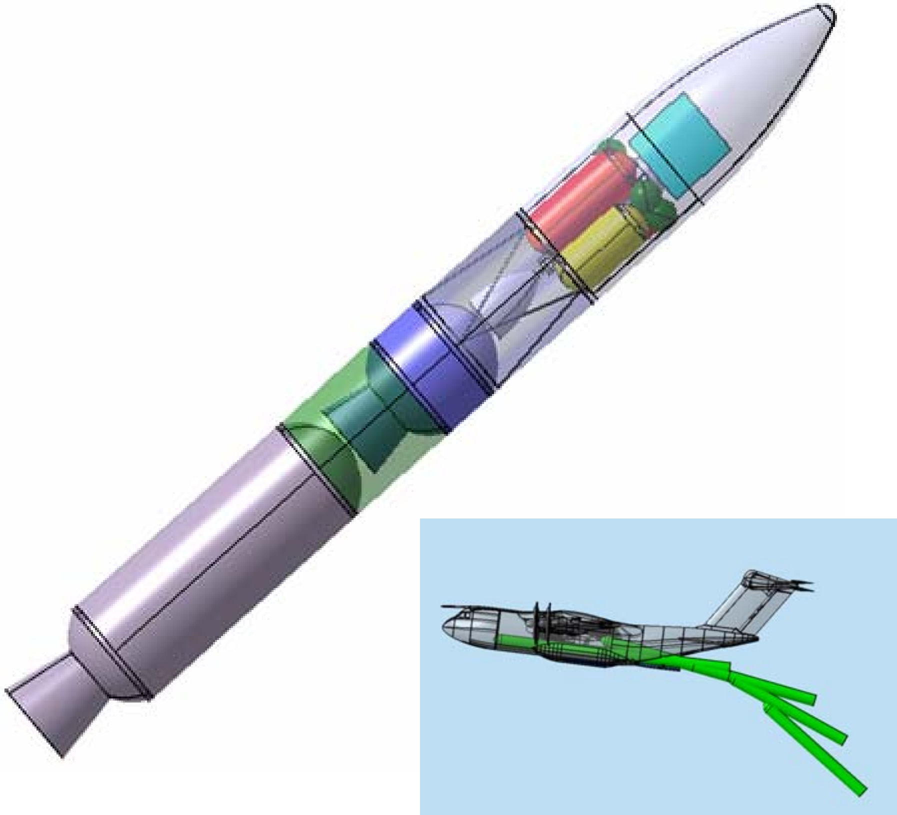
➢ HORVS : High Operational Responsive and Versatile System

Horus is the Greek appellation for one of the oldest Egyptian divinity, the Falcon God, which name means *The one whose is above* or *The one whose is far away*.

Horus is the son of ISIS and OSIRIS

Here, in the HORVS launch system, ISIS and OSIRIS are the stages :

- OSIRIS : Orbital Storable, Innovative and Re-Ignitable Stage
- ISIS : Innovative Solid Stage



HORVS (technology concepts)

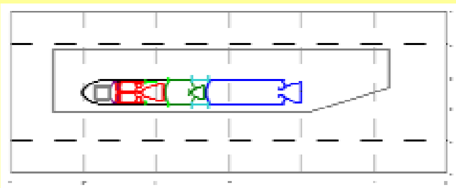
Performance objective is 300 kg in SSO 800 km

Configuration « state of the art » : < 2015

- Standard propellant (P80 type), filament wound CPN
- Storable upper stage with a classic NTO/MMH engine

Ex: P14-P4-L1.4 (8kN Sybil)

Total Mass ~24t

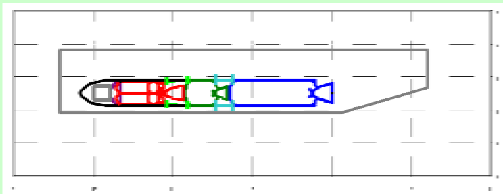


Configuration "green and doped propellant" : 2015-2020

- Butalane with HMX
- New upper stage engine (Fuel Propane / Propylene, Oxyd. : N_2O or H_2O_2 or N_2O_4)

P14-P4-G1.4 (10kN N_2O_4) Mt ~22t

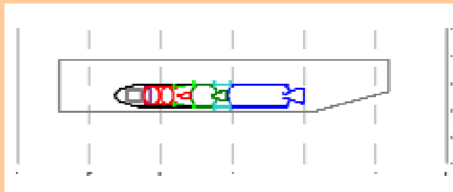
P15-P5-G1.7 (12kN N_2O) Mt ~26t

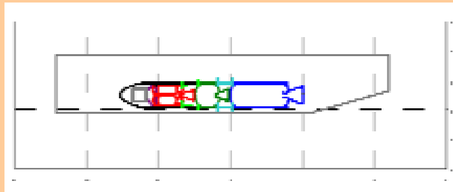


Advanced Configuration : 2020

- Butalane with active binder
- Upper stage with cryo or semi cryo propellant Lox/HC (CH_4 or C_3H_8/C_3H_6) high performance stage (pressure fed or micro TP, use of composite, etc.)

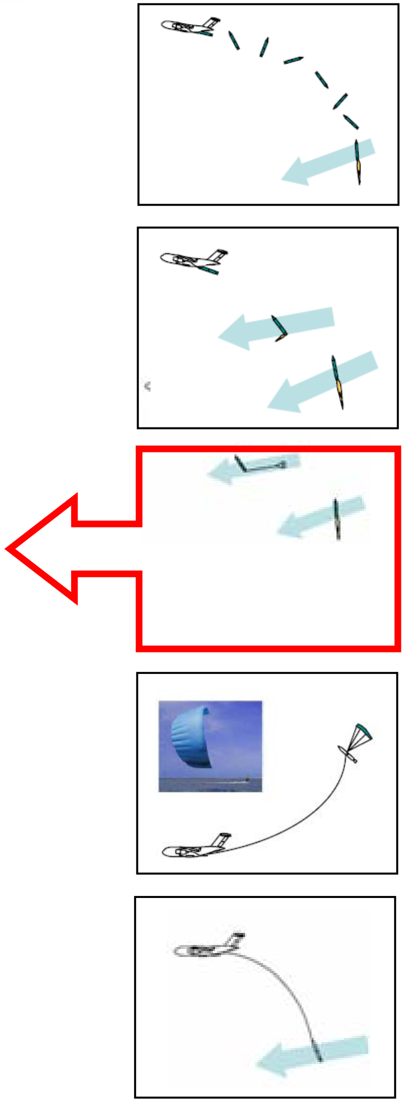
P12-P3.5-C1.2 (12 kN) Mt ~20t





An interesting method is the one proposed by Air Launch LLC (QuickReach concept, Falcon Program of the DARPA):

- Take of a slight flight path angle by the plane (+5°) to initiate the fall down of the launcher by gravity (extraction is helped by a parachute deployment),
- Natural tilting outside the aircraft slowed by the parachute,
- Fall down during several seconds and ignition of the first stage,
- Flight with very high angle of attack (>90°) during the first seconds to orientate the velocity vector in the main inertia direction,
- Classical flight of a launcher



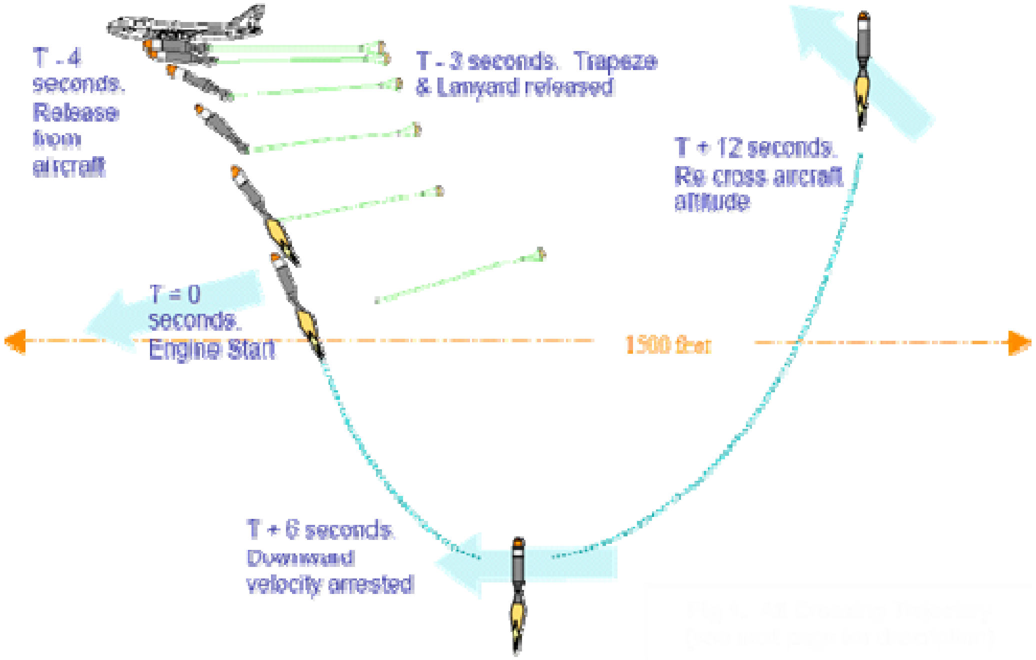
Hypotheses considered for the airdrop point with A400M :

- Mach 0.45 to 0.6, altitude 6 to 10 km depending of the mass of he LV, FPA 5° (such capabilities has been reviewed with Airbus considering open ramp)

HORVS – Launch method

➢ Beginning of the trajectory

The more the titling motion is important, the more the launcher will take angle of attack. The size of the parachute allows to slow this take on AoA.



The objective is to ignite the launcher as soon as possible for performance reasons, while guarantying the security of the plane (re-cross of the aircraft altitude at a certain distance).

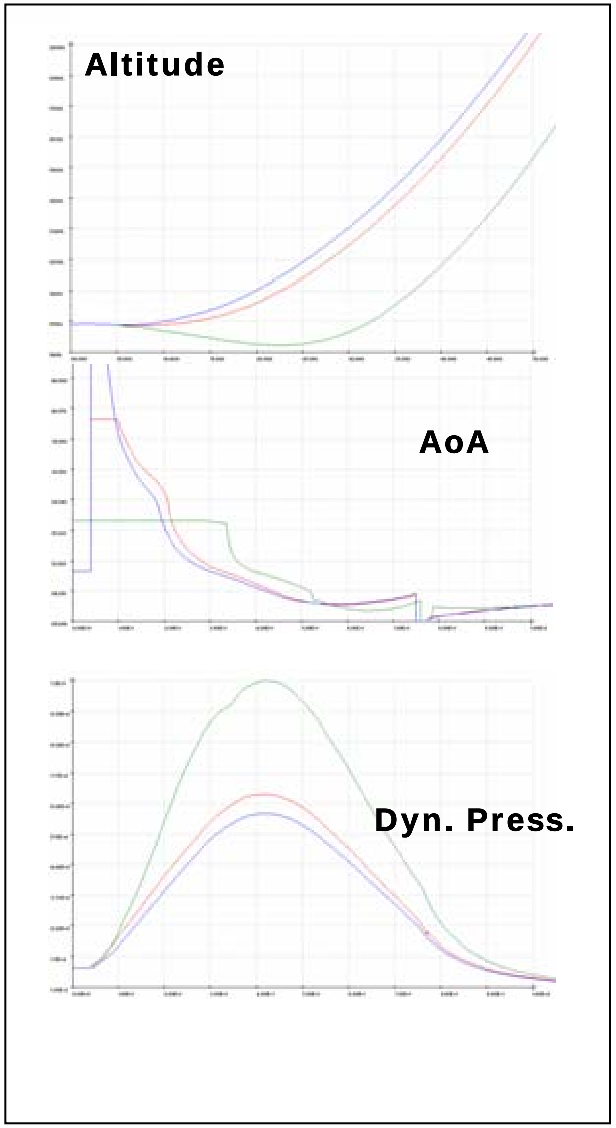
In the QuickReach case, the ignition occurs 4s after Hold extraction. The re-cross aircraft altitude occurs at a distance of about 500m, 12s after ignition.

➢ Control with high AoA

The more the launcher takes AoA during the first seconds after extraction, the more the trajectory would be vertical, which allows :

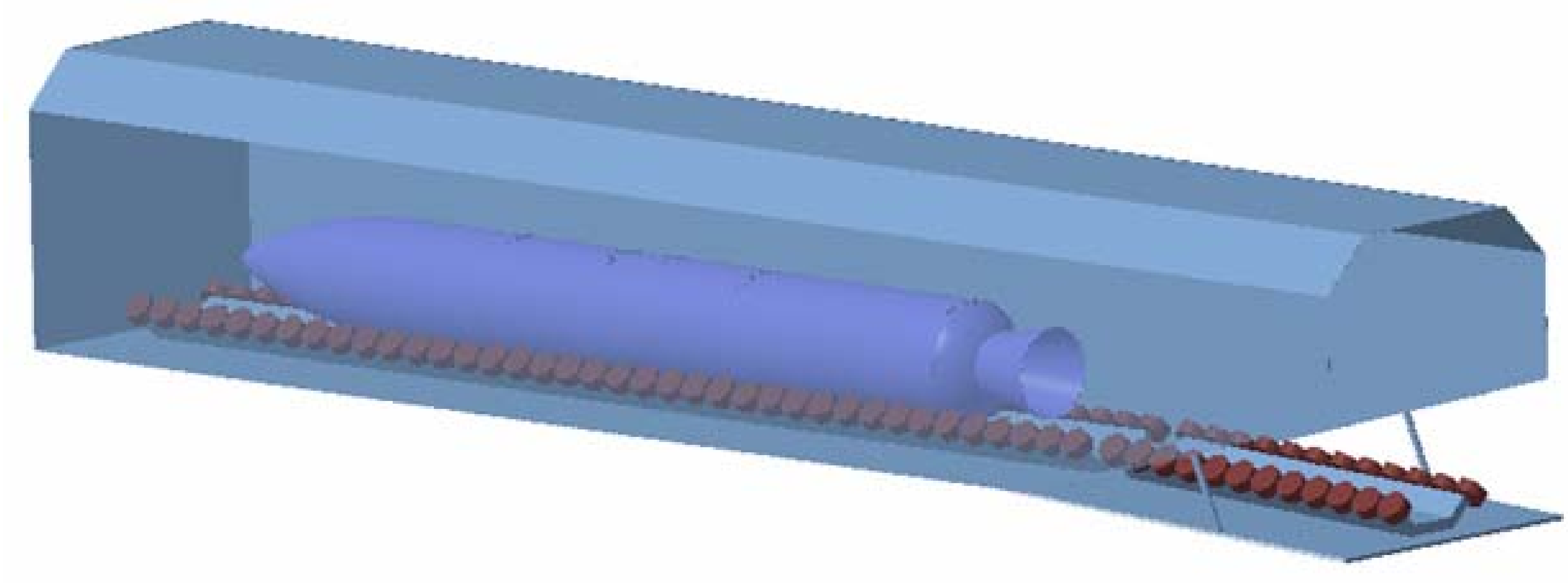
- A re-cross of the aircraft altitude on the rear,
- A reduction of the trajectory losses (gravity, etc.),
- A important reduction of the dynamic pressure and Q.α (dyn. Pressure x Angle of Attack),
- A important reduction of the steering efficiency required (conventional needs)
- A important gain of performance (10 to 15%, at 160 m/s)

Note : this is an opposite procedure compared to Pegasus system.

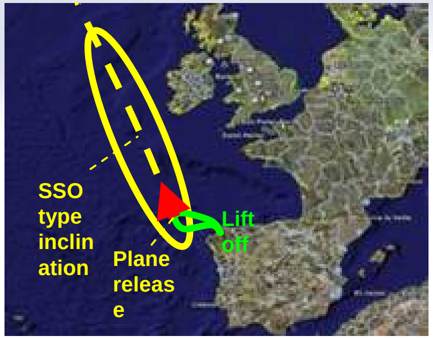


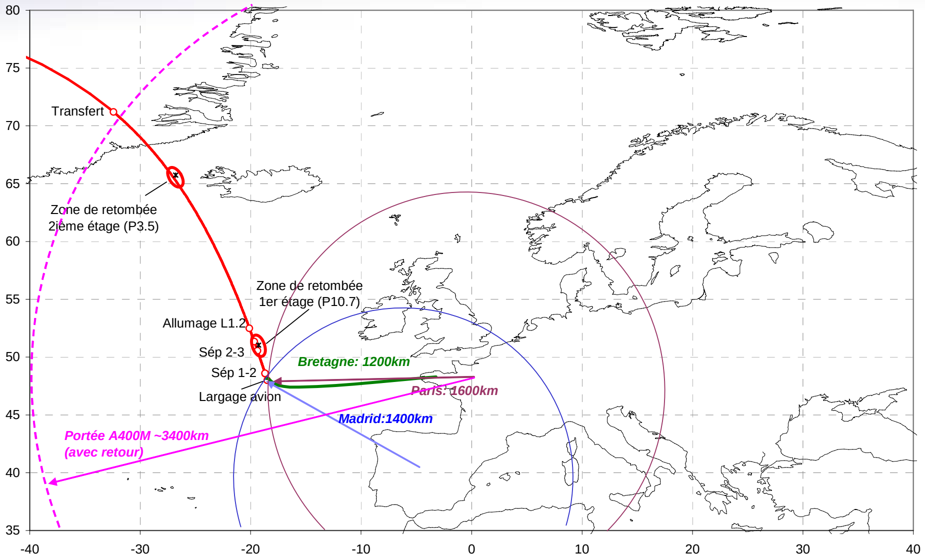
HORVS

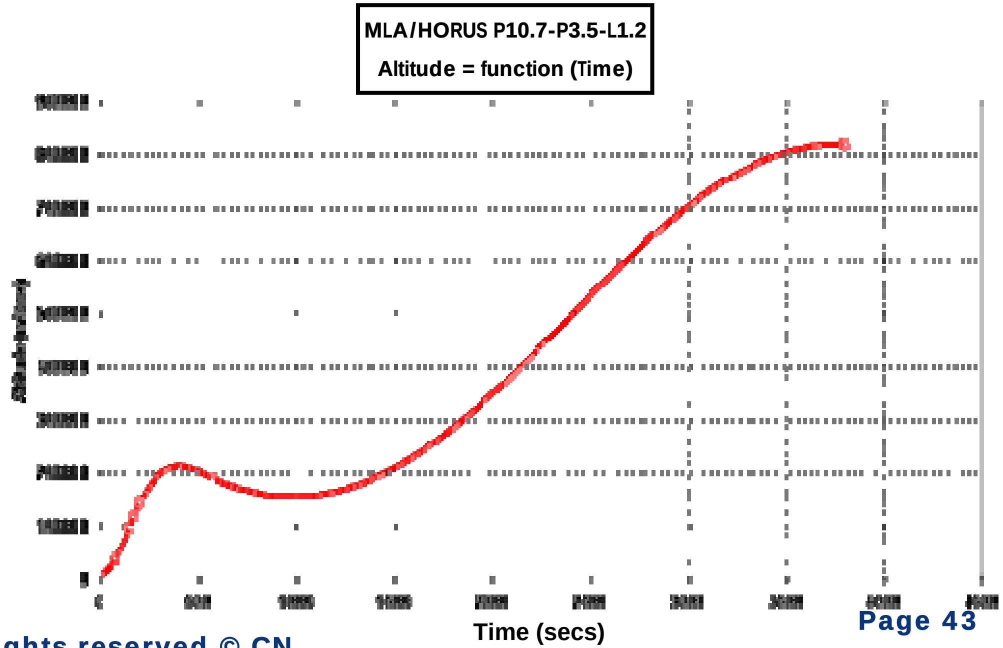
Views of the launcher in the hold. Support and guidance during jettisoning are provided by a double rail attached to the aircraft, made up of inflated rubber rollers.



HORUS – Mission profile







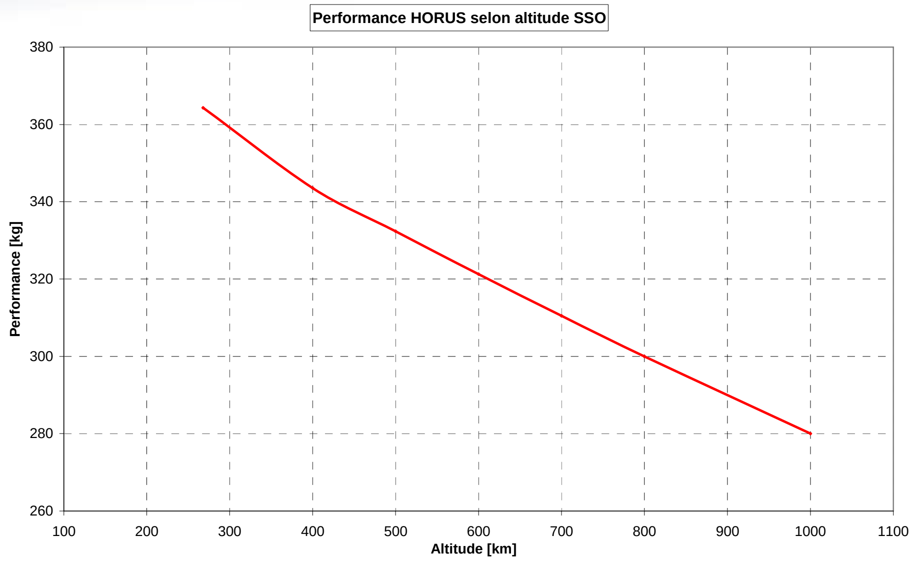
Mission sequences

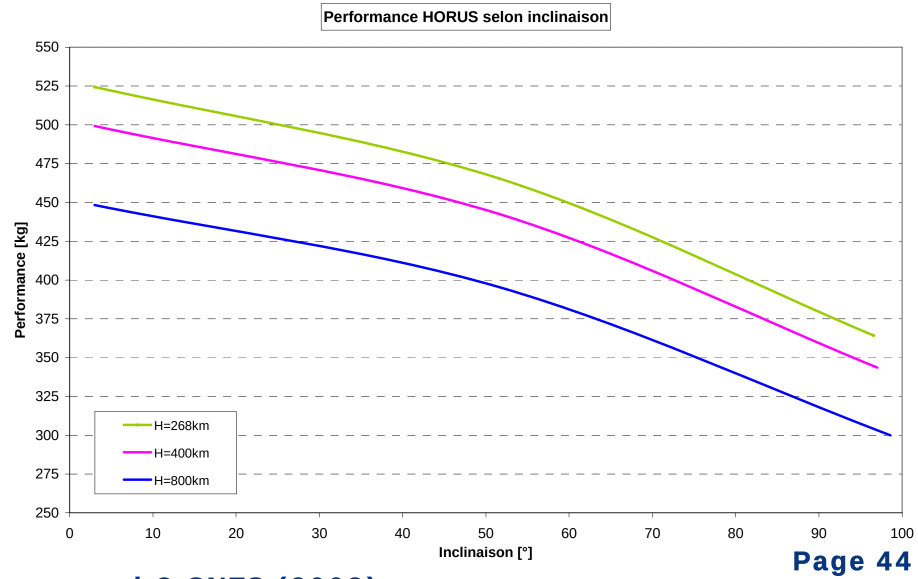
- Take-off from Spain
- Release off south-west Ireland
- Stage fallback:
  - 1st stage: into Atlantic
  - 2nd stage: off Iceland
  - 3rd stage: orbital
- Injection into SSO visible from Australia

HORUS – Performance

Performance

- SSO 800 km/98.6° : 300 kg
- SSO 268 km/96.5° : 365 kg
- EQU 268 km/0° : 525 kg





HORVS from ground

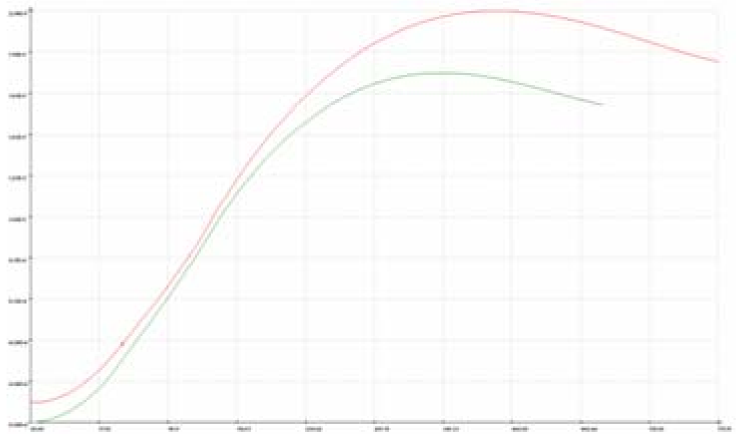
Gain in comparison with a conventional (ground lift-off) LV :

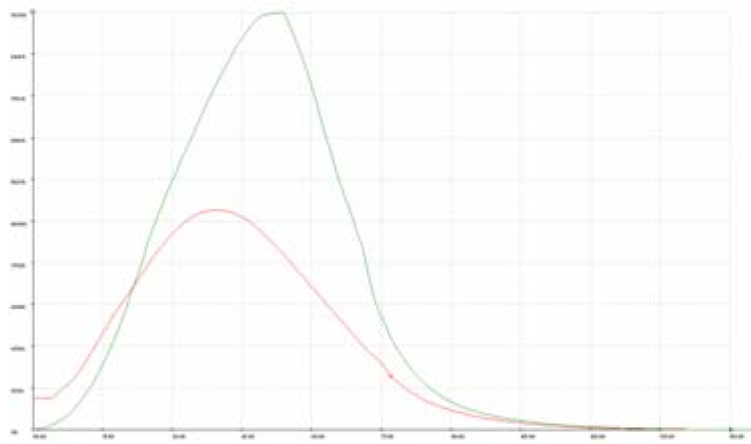
With the current definition, HORVS is able to lift-off vertically from the ground.

- ✓Performance from A400M : 300 kg (SSO 800 km)
- ✓Performance from Ground : 130 kg (-57%).

Moreover, the dynamic pressure in such case increases significantly : 94 kPa (instead of 50 kPa). Separation 1-2 is also passing from 10 to 24 kPa. This will have an impact on the vehicle dimensioning.

A re-staging of the launcher to reach the 300 kg, with iso technologies and design hypothesis (same diameter, etc.) would increase the launcher mass by 28%





The MLA (Airborne Micro Launcher)

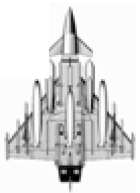
Introduction to MLA

The MLA (Airborne Micro Launcher), is a concept supported by a fighter aircraft, which has the ability to maximize the gain due to airborne launch thanks to the dynamic capabilities of the aircraft (optimization of the kinematics at separation : altitude, velocity and flight path angle).

Such capabilities also offer the possibility to imagine a simplified sequence of jettisoning and a launcher without important aerodynamic support (big wings like Pegasus, parachute like QuickReach, etc.).

Drawbacks are the limited mass of the launcher depending of the aircraft capability, and the affordable volume due to the generally small size of the plane and any constraint such as the train trap deployment, aerobrakes, ground clearance, etc.

Potential Aircraft for MLA in Europe

Aircraft		Max P/L	Comments
Rafale – M (Navy version)	 	> 9.5t (12t*)	Limited length under fuselage. Interesting diameter (navy version) with tall and strengthened landing gear. * With 1/2 kerosene loaded
Euro fighter	 	> 7.5t (10t*)	Limited volume under fuselage due to front landing gear deployment and rear gear traps. * With 1/2 kerosene loaded
Gripen Viggen	 	3.6t 7.0t	Limited external loading for Gripen. Viggen out of service (2005).
Tornado		9.0t	Limited height under fuselage. Interesting volume under wing. Availability beyond 2010 ?.

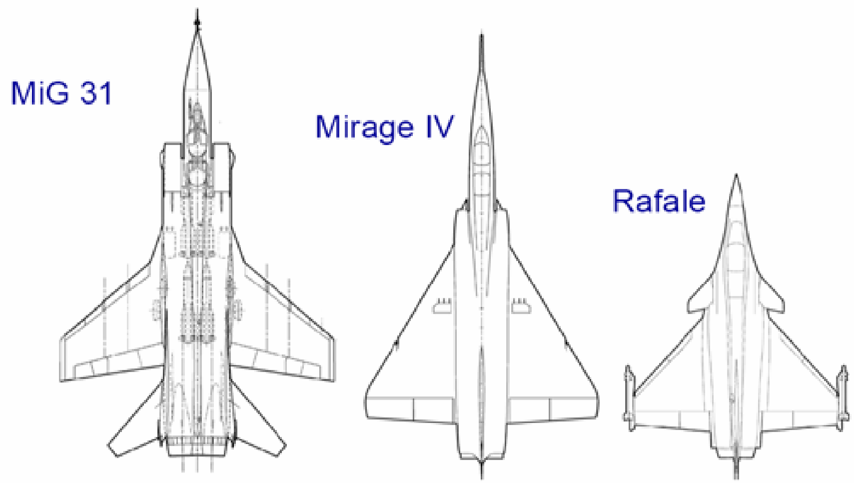
Other potential aircrafts for MLA

Aircraft		Max P/L	Comments
F-18	  	7.0t (>8.0t for F/A 18E)	Limited length due to rear landing gear traps. Available in Spain (Hornet version)?
F-4		7.3t (9.0t)	Large underwing Volume for a linear version of MLA. Availability TBC (Germany, Greece) ?
Mig-31 (Mig-25)	 	>> 10t	Top performer (~20 km, Mach 2.5). Volume to be checked due to landing gear deployment. Not available in Europe.
Others	Mirage III, IV, V, 50, F1, 2000, F-15E : >10t (not available in Europe), F-16		

Firsts studies with Rafale Choice

CNES has realised with Dassault Aviation several studies of MLA using the Mirage IV, a large 2 engines fighter. This aircraft is no more available in France.

To replace it, preliminary studies were performed with the new Rafale and with a Russian Mig-31 (for comparison)

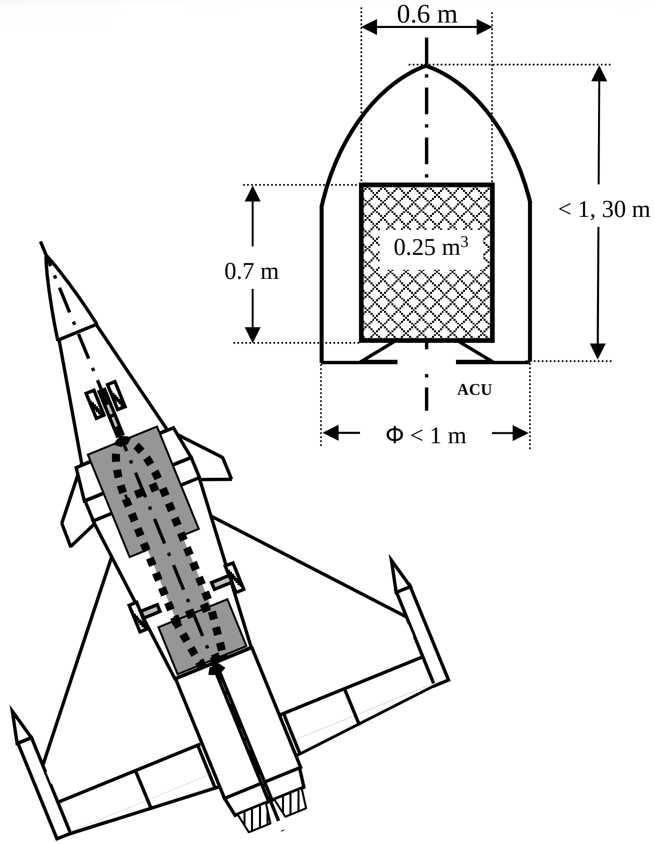


The Mig-31 was of course better in many ways … but despite its very small size, Rafale offers an interesting volume and an increased energy when compared with Mirage IV.

Affordable volume under Rafale

Affordable volume under Rafale

MLA Concept « linear »



Architecture : Linear configuration under fuselage.

Constraints : front landing gear, height of the gears, lateral gear traps, ground clearance, etc.

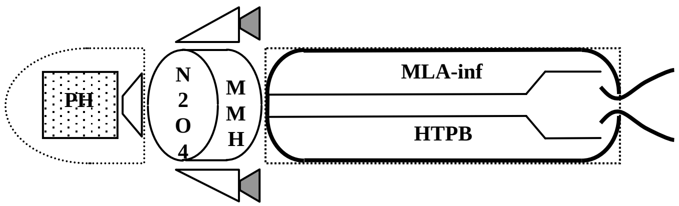
Main difficulty : affordable volume under fuselage would not allow to reach the maximum payload capability of the aircraft.

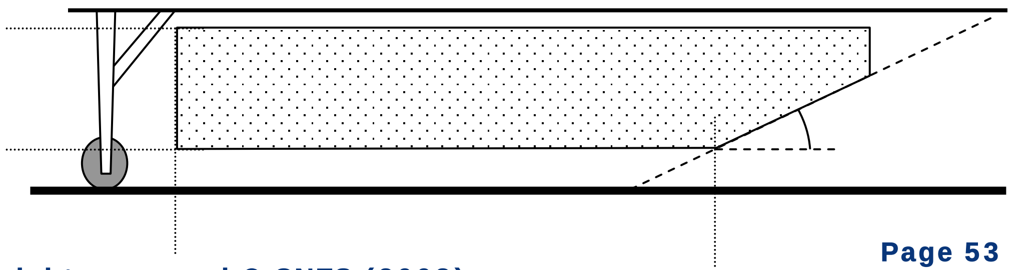
Optimisation of the staging (with a Rafale) :

- 2-stages configuration,
- Density as important as Isv : solid propellant (standard HTPB) for first stage and storable propellant (NTO-MMH) for upper stage

Best configuration = P3-L0.6

Launcher mass < 4.5t (~1/3 of the A/C capability)

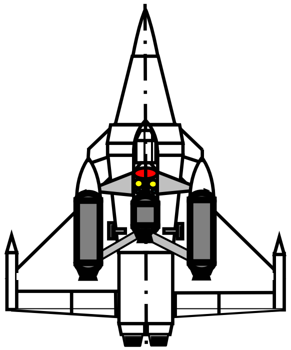




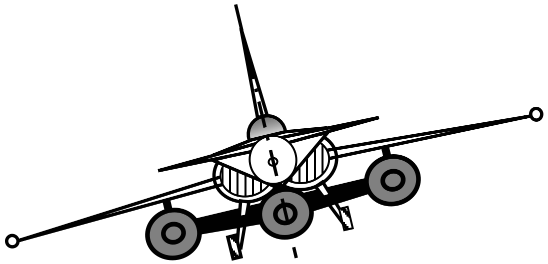
MLA Concept « Trimaran »

Objective : to be compatible with biggest microsats (i-e SSTL Microsat-100 or Myriade family : 120 to 150 kg LEO)

Architecture : 3-bodies configuration, able to reach the maximum external loading capability of the aircraft. Attachment under 3 pylons (fuselage and wing point “1”). Each body are globally equivalent in volume to the external fuel tanks of the aircraft.



Main difficulty : geometric and dynamic constraints due to distance between each body, lateral gear traps movement, etc.



Optimisation of the staging (a priori) :

- 3-stages configuration (1st stage composed of the 2 lateral bodies, central body is equivalent to linear version)
- Use of Solid Propellant for first and second stage and liquid bi- propellant for third one

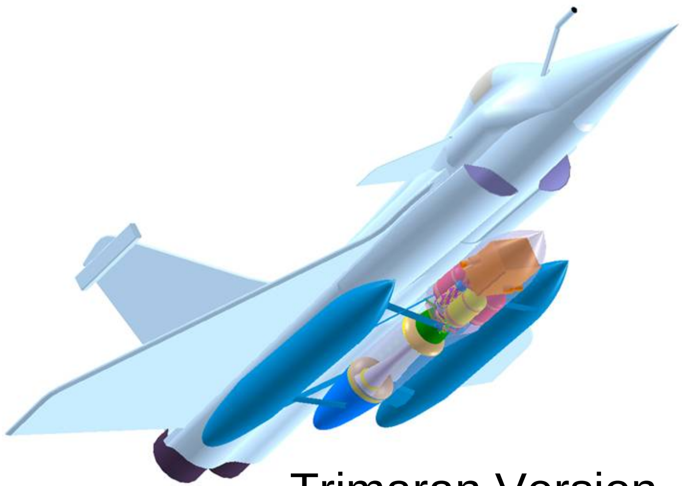
Best configuration = 2xP3.5-P1.7-L0.6 (11.5t)

Comparison Rafale+Tanks / Trimaran

MLA – general specifications

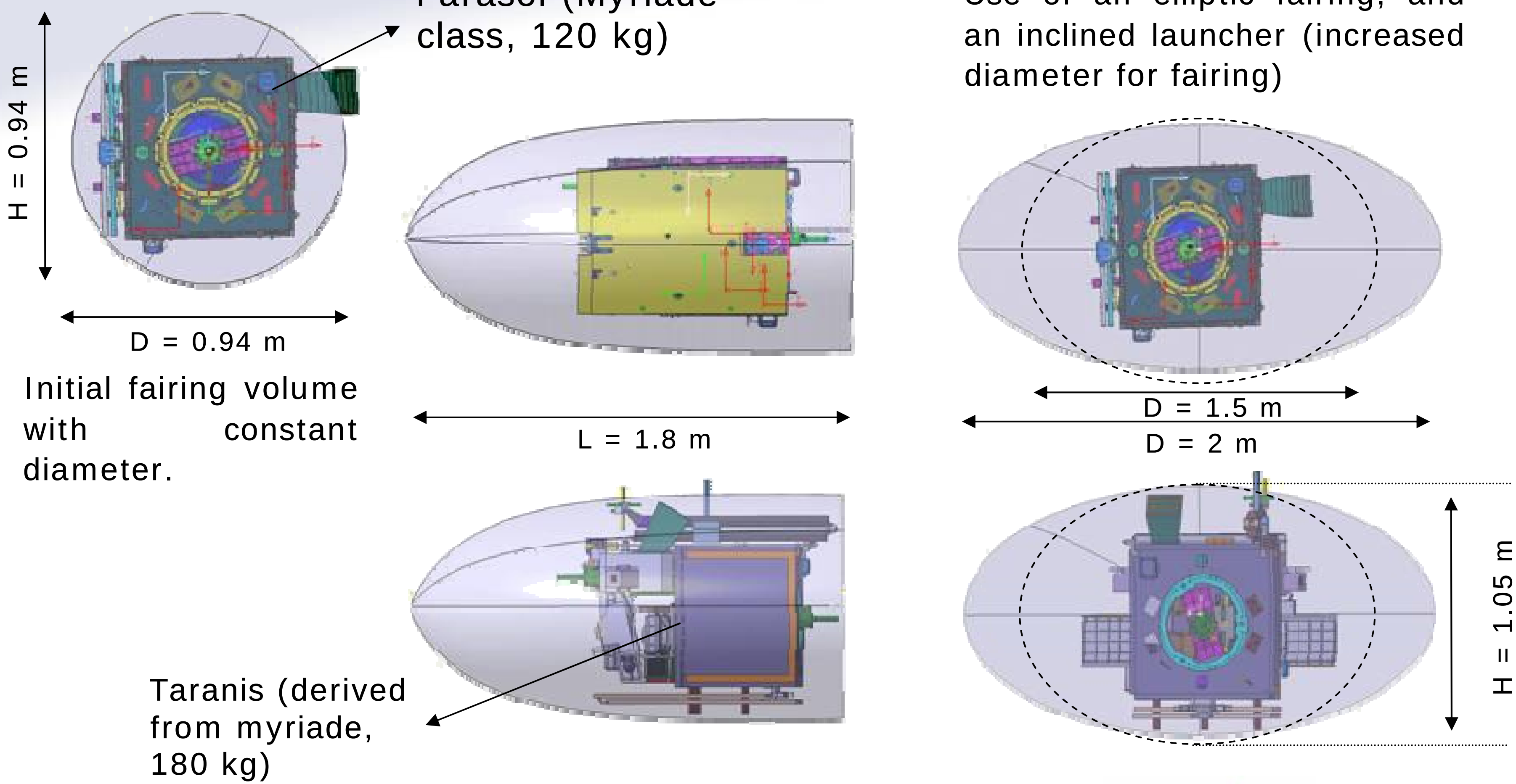
- Performance:
  - Single-bodied version (Linear) : 50 kg SSO
  - Three-bodied version (Trimaran) : 150 kg SSO 800 km
- Launch rate: 2 to 8 per year
- 1st flight: 2014
- Responsiveness: satellite positioning < 2 weeks
- Reliability and availability: 0.99/0.99
- Storage 10 years, re storage 1 month after removal from storage (reversible)

Linear Version



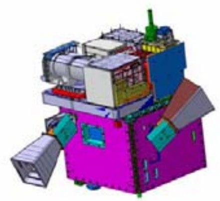
Trimaran Version

MLA - Installing the payload



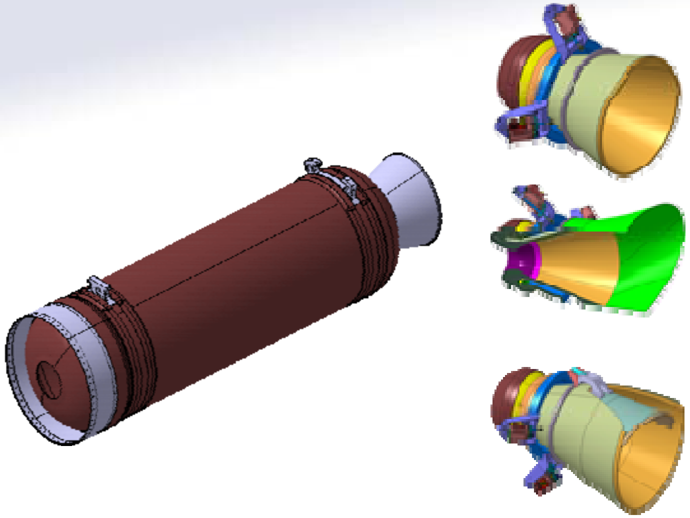
Choosen volume: 1.8m (L) x 1.05m (H) x 1.5m (D)

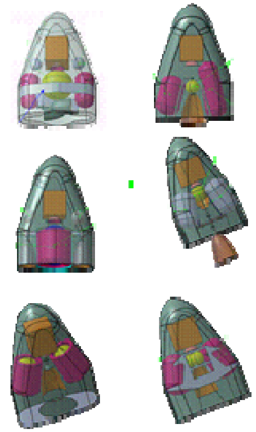
Compatible with Picard (max. Myriade volume, 150 kg)



Picard

MLA linear - architecture





Upper stage :

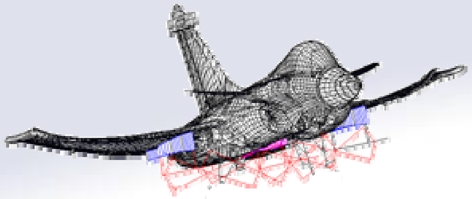
Lower composite :

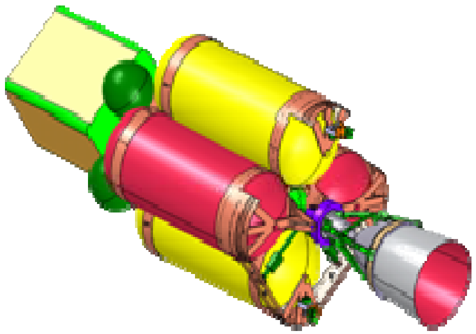
- Reference loading of about 3000 kg, with standard HTPB (Ariane) and option for doping propellant (HMX, RDX) or advanced propellant (Oxalane with active binder)
- Length 3.5m, diameter > 0.9m
- Structure in carbon (monolithic)
- Throat 4D, possible use of a optimized nozzle for Isv
- Steering by movable nozzle and electro-mechanical actuators

- Reference loading 600 kg, architecture as compact as possible (2 lateral engines)
- NTO+MMH propellant (storable, hypergolic)
- Sybil engines issued from French national R&T, at the origin of manoeuvred stages for strategic missiles (many tests in the 90's) :

  Pressure fed cycle, MR 1.65 (iso volume for tanks), 2x4kN, re-ignitable
- Cold gaz for pressurization and attitude control
- Stage using a large amount of composite materials to reduce structural index. Tanks sealed in factory

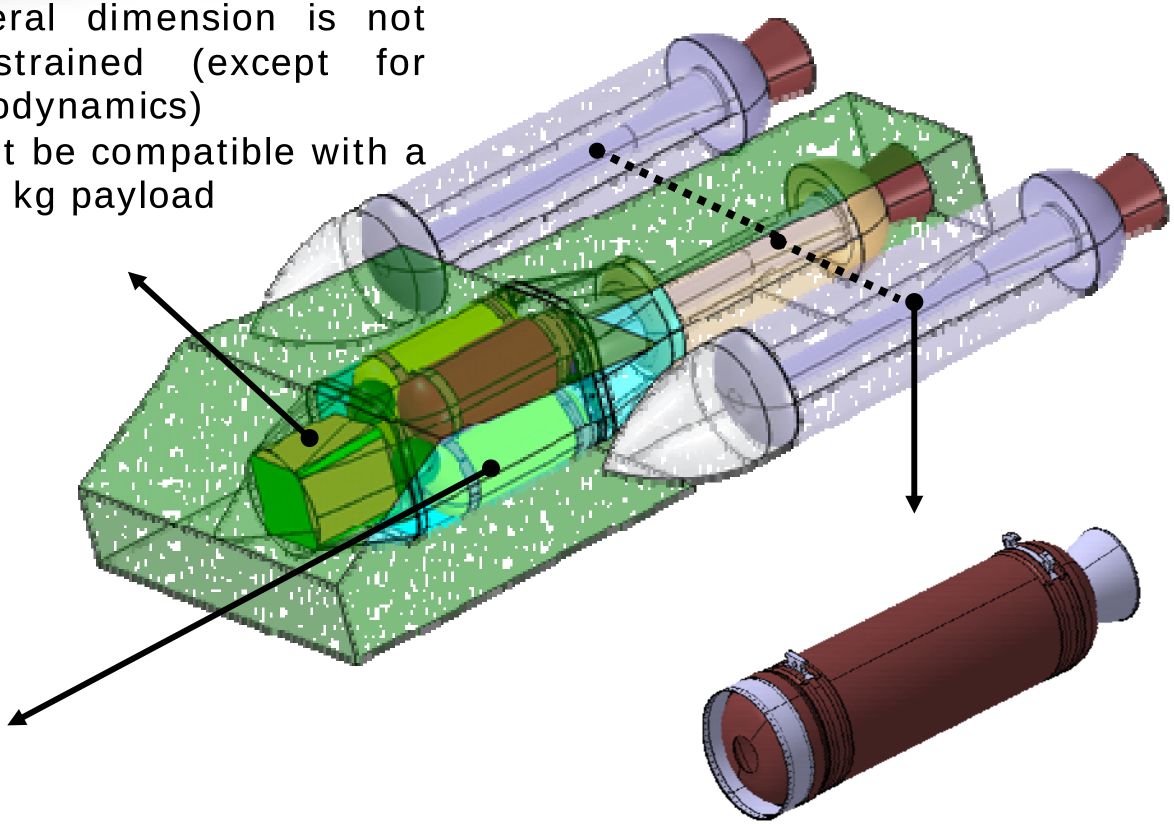
MLA Trimaran - Architecture





Payload and Fairing

- Lateral dimension is not constrained (except for aerodynamics)
- Must be compatible with a 200 kg payload



Compact and Versatile Upper Stage :

- Same technology and loading as the linear configuration
- Architecture as compact as possible, Single 8 kN engine with extendable nozzle

High Performance 1st and 2nd stage

Compact architecture and research for low structural index

Up to 3500 kg for each boosters and 2000 kg for 2nd stage

Up to 200 kN per booster, 100 kN for 2nd stage

Some MLA variants

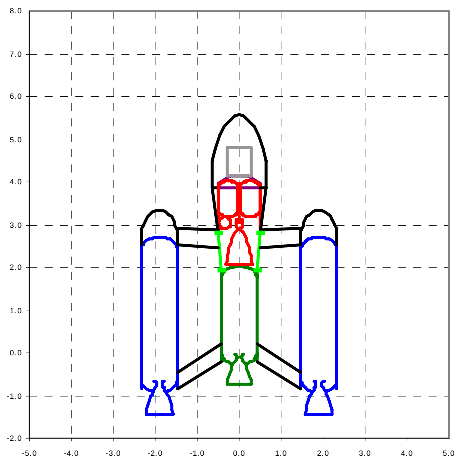
<u>«Standard» MLA</u>

11t launcher

Standard Solid propellant

Upper stage based on Sybil

Max Perfo = 150 kg



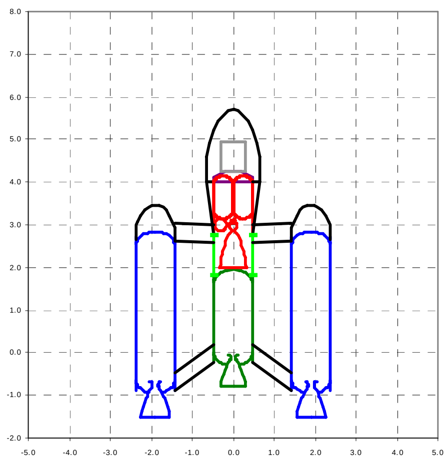
<u>MLA «12t»,</u>

12t Launcher

Standard Solid propellant with HMX

Upper stage based on Sybil

Max Perfo = 180 kg



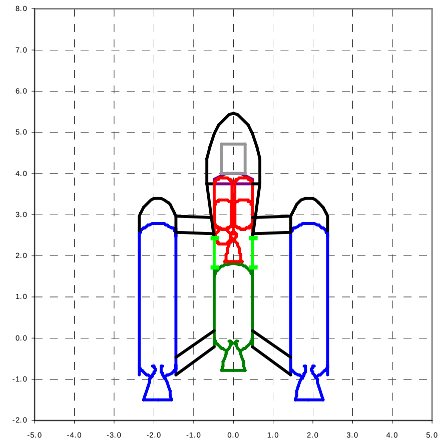
<u>MLA «new storable»,</u>

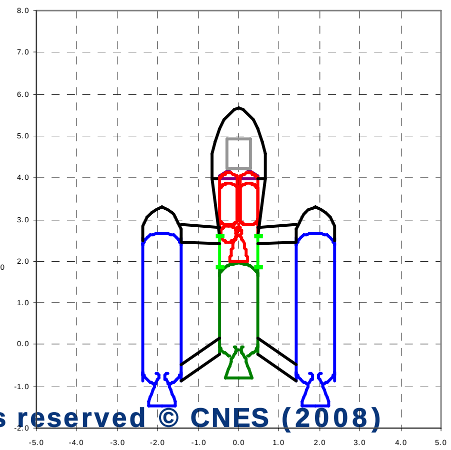
12t launcher,

Advanced solid propellant,

new Upper stage engine optimized for performance (MMH or C3H6)

Max Perfo = 200 kg





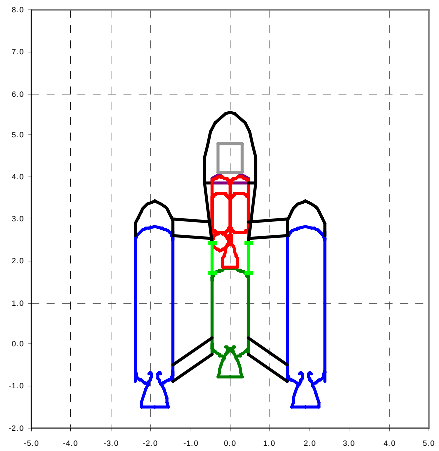
<u>MLA «semi cryo»,</u>

11t launcher

Advanced solid propellant

New and very high performance upper stage engine (cryo or semi cryo) with advanced insulation techniques

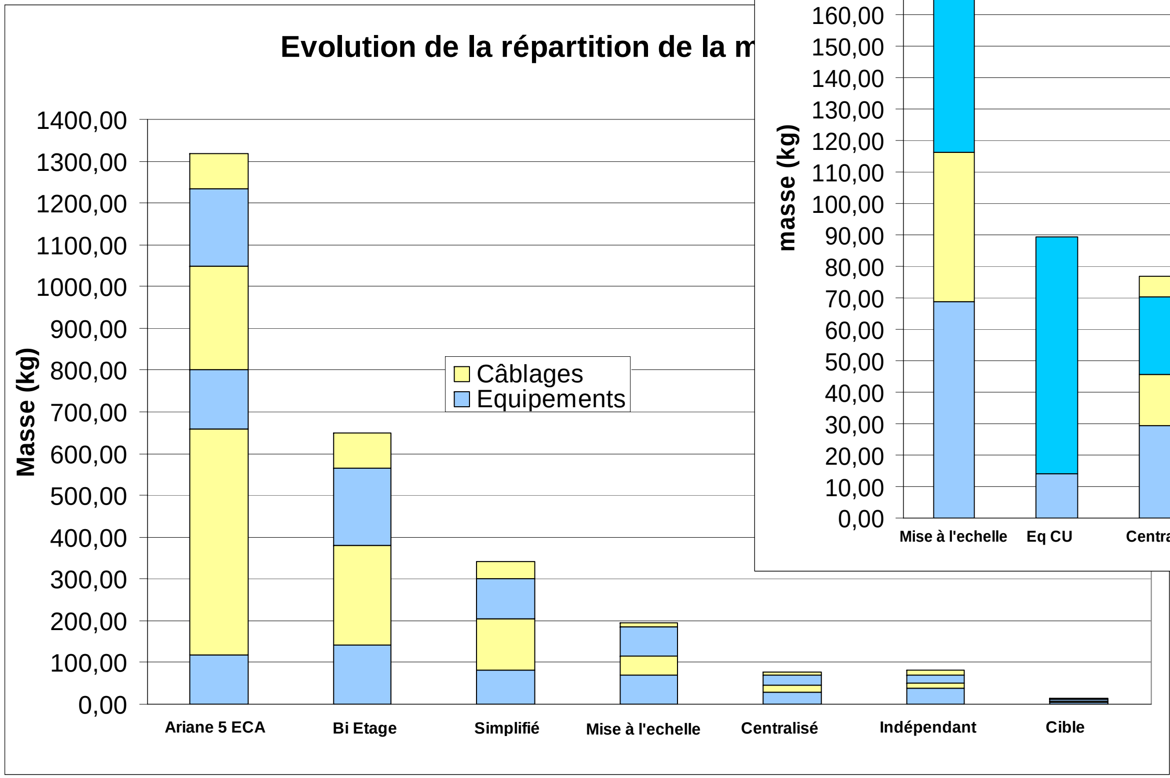
Max Perfo = 160-200 kg

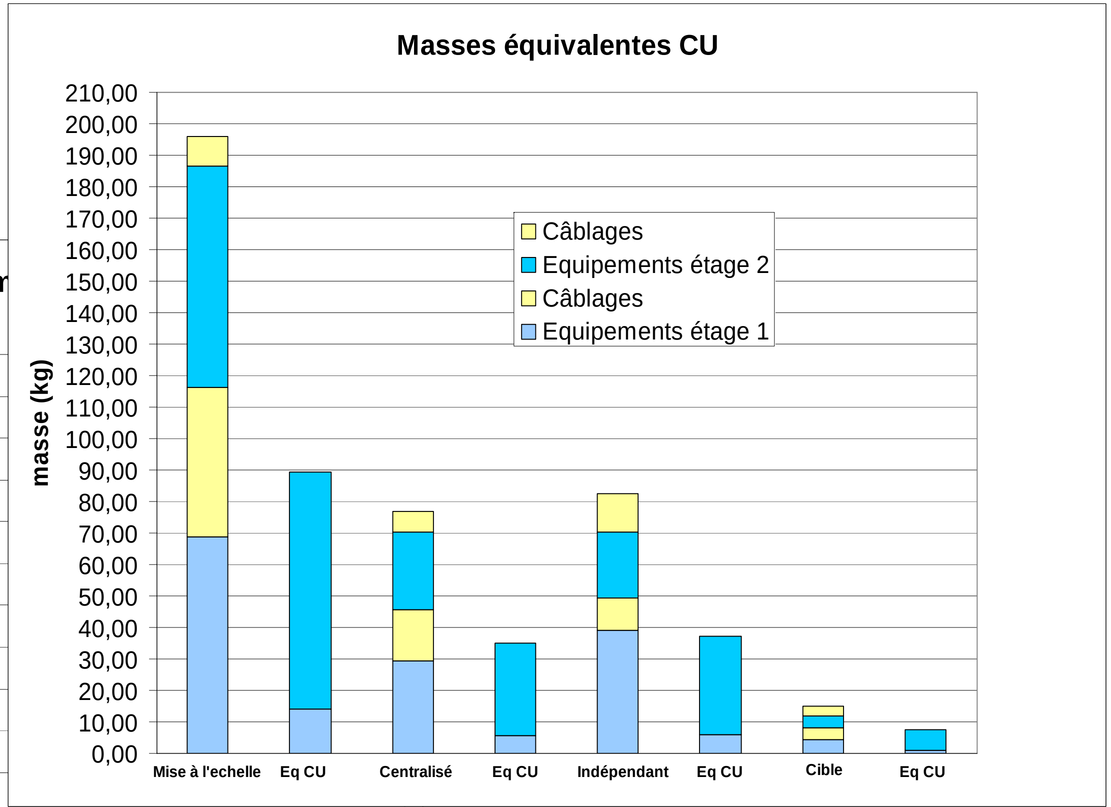


MLA – Avionics mass breakdown

Miniaturised avionics

- State of the Art ~ 35 kg (P/L equivalent)
- Objective : 15-20 kg (new instruments required)

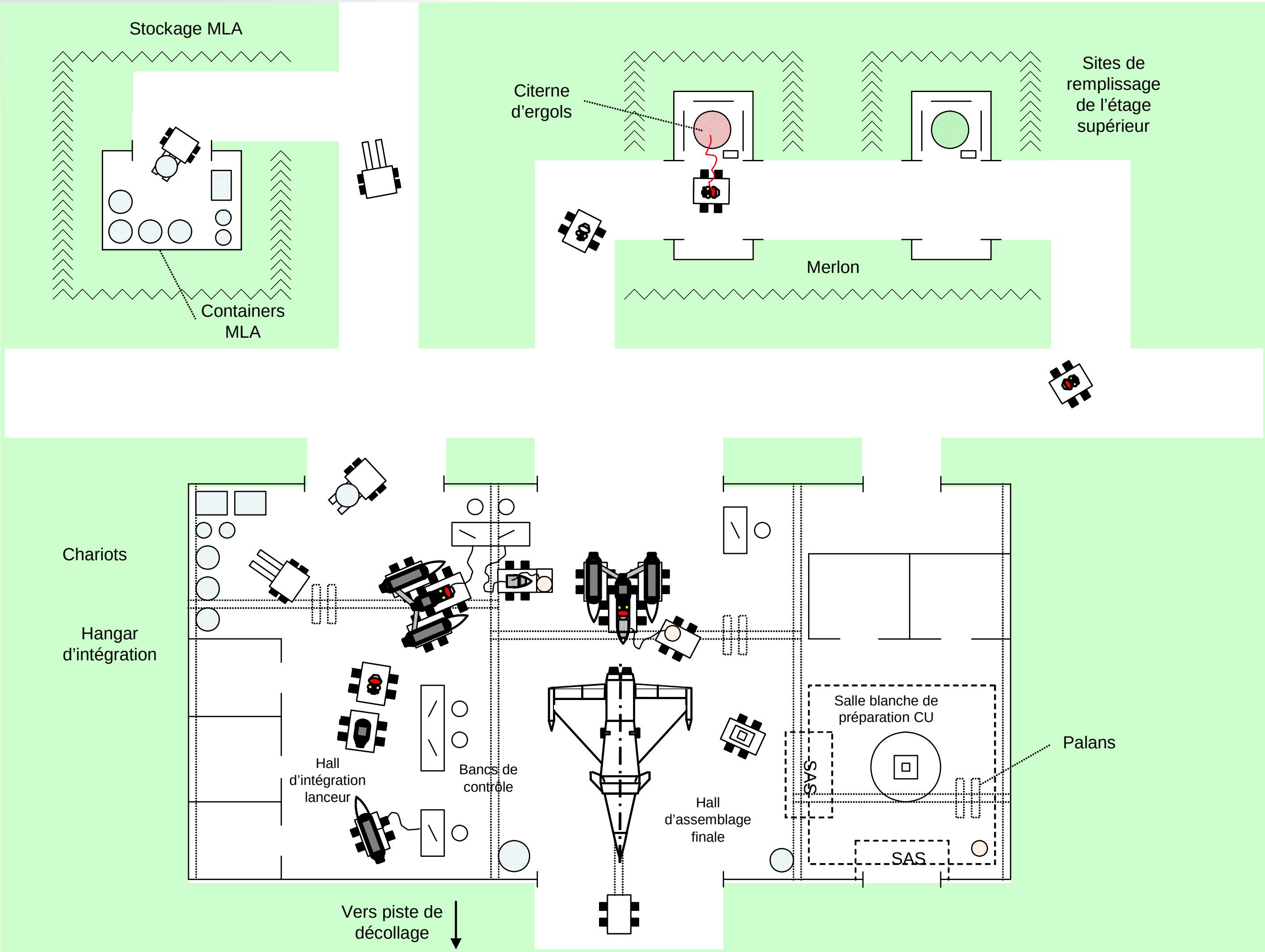


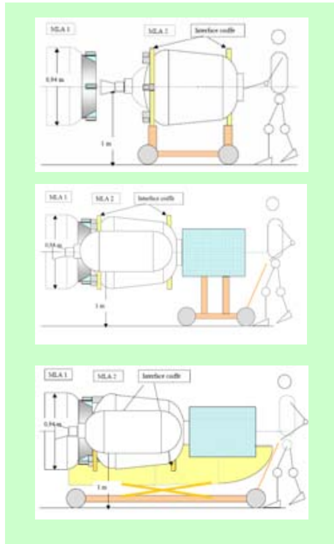


P/L Equivalence

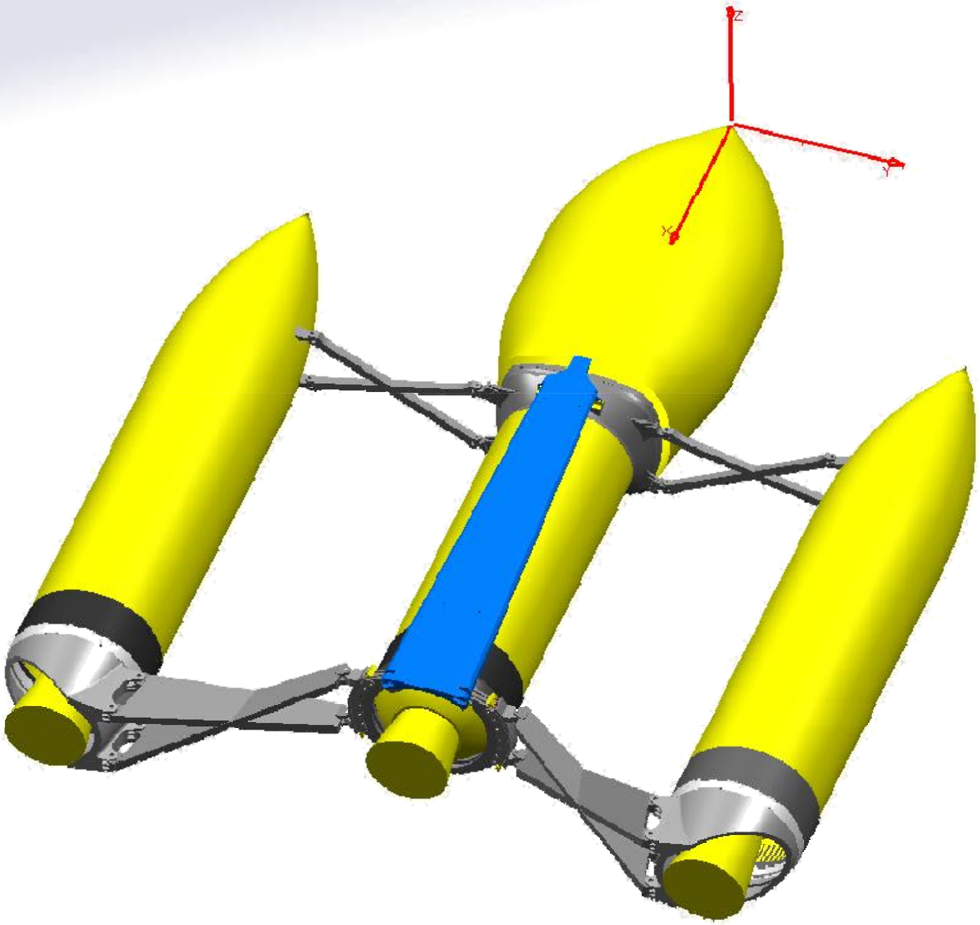
Equipments / Wires

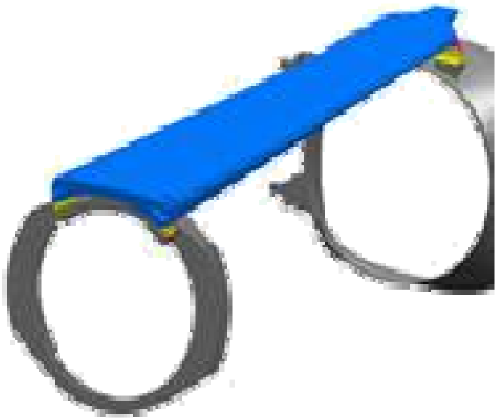
MLA – Ground Installations and operations

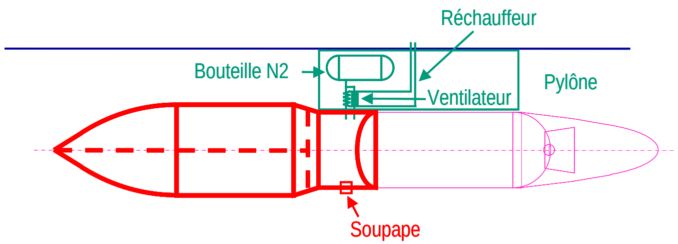




MLA – attachment under aircraft



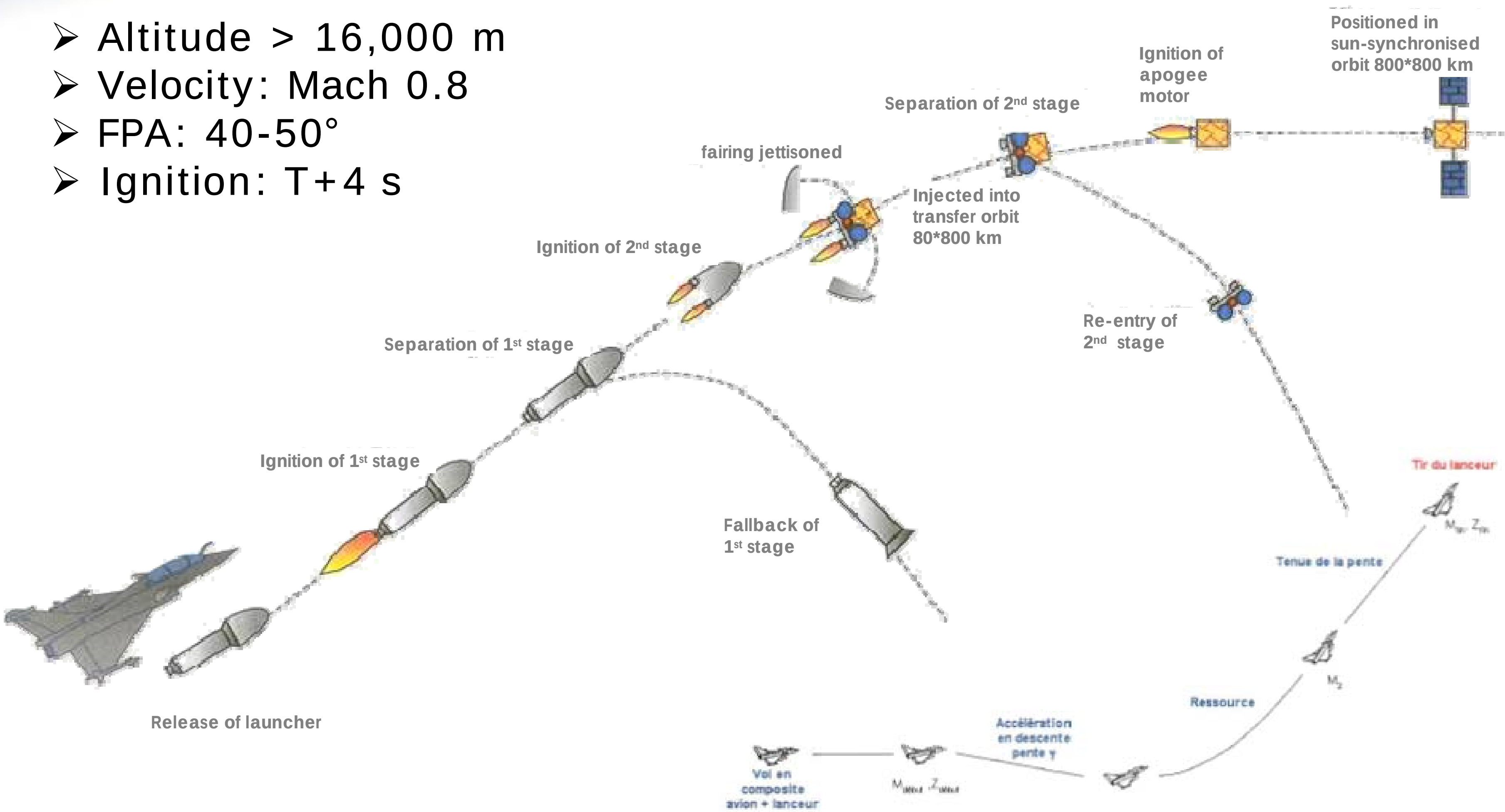




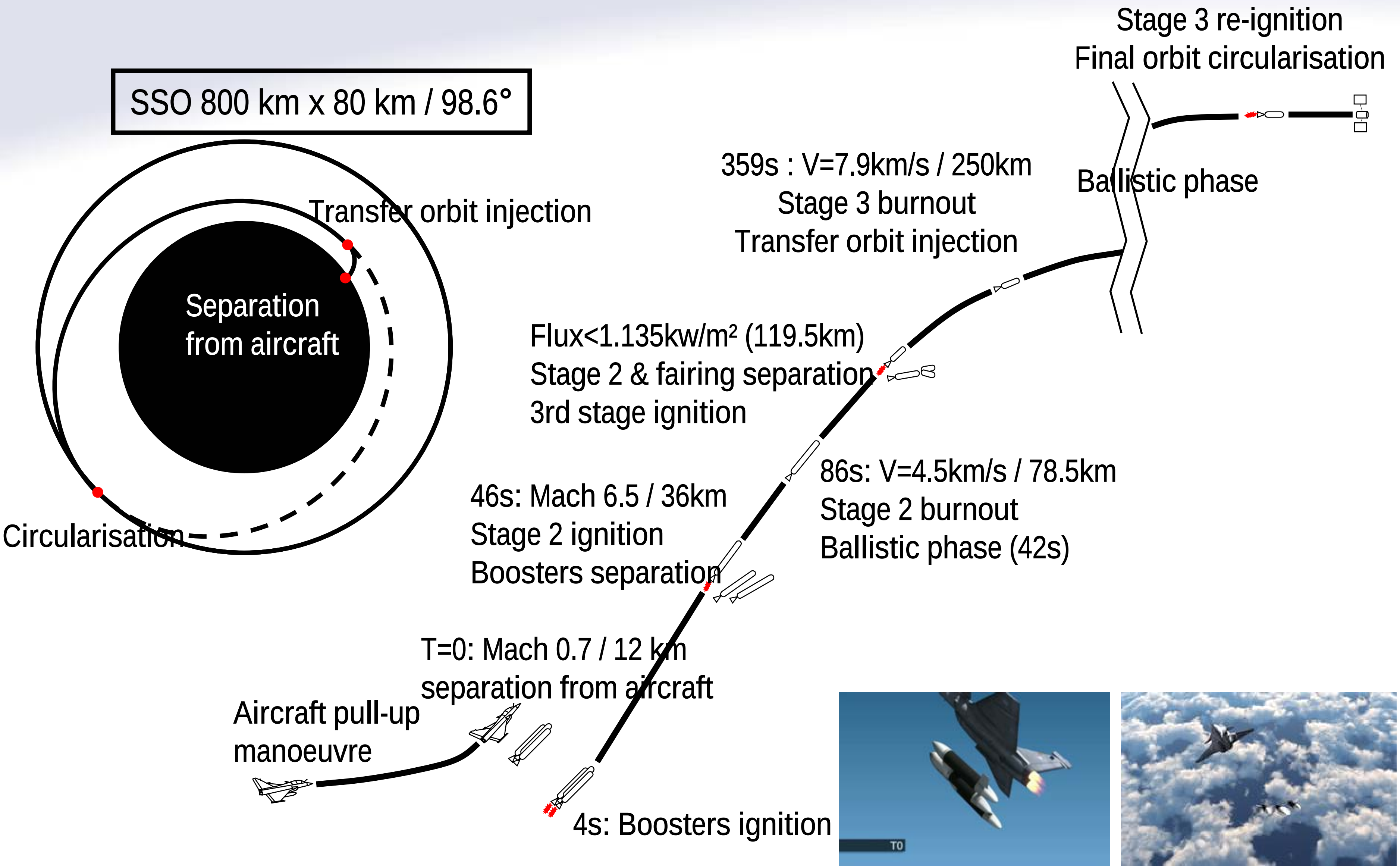
MLA – Mission profile

<u>Linear configuration :</u>

- Altitude > 16,000 m
- Velocity: Mach 0.8
- FPA: 40-50°
- Ignition: T+4 s

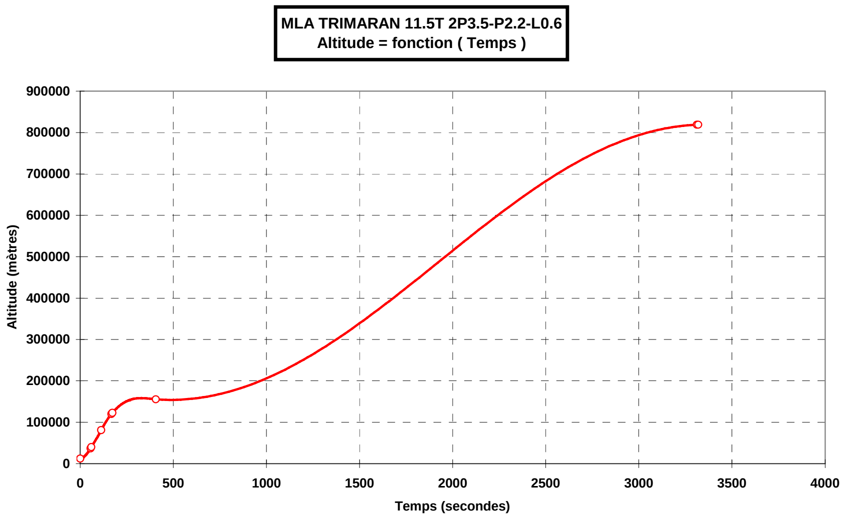


MLA – Mission profile



Typical aircraft mission

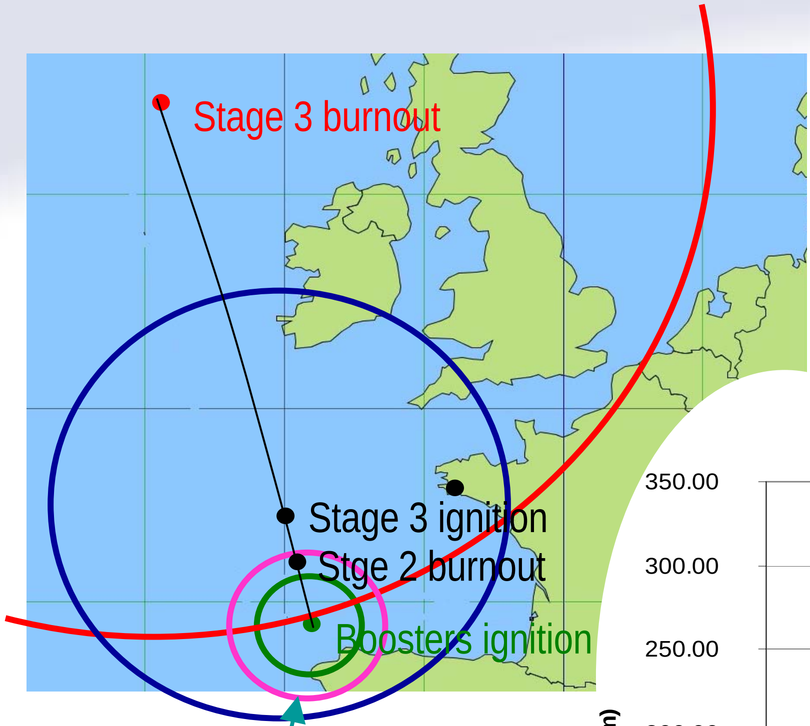
- Take-off from an airfield with the suitable ground segment for launcher and payload preparation
- Cruise flight of the Rafale to the launch position
- Return to base or to another airfield, even in case of aborted launch
- Use of in flight refuelling if necessary (possibly by another Rafale with "buddy-buddy" refuelling pod)



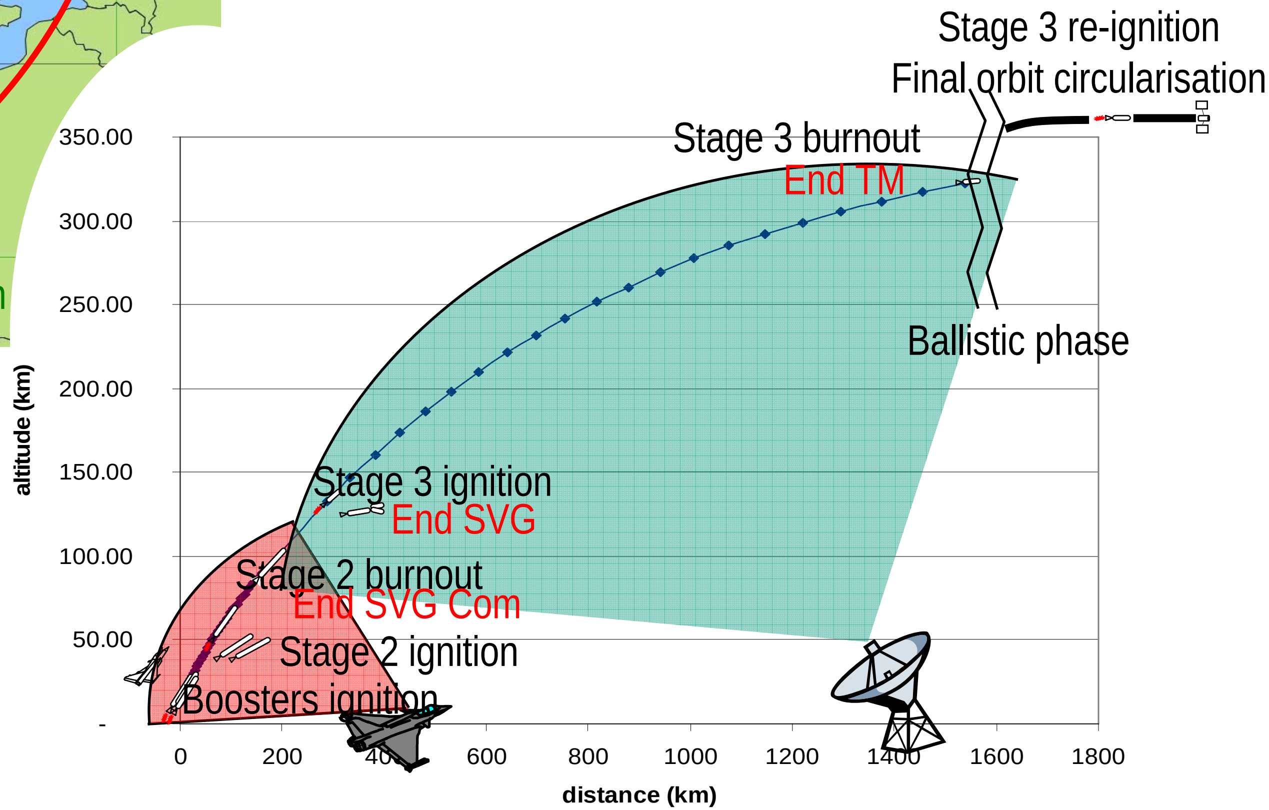
Typical ground segment coverage

Potential solutions for TM reception:

- Existing ground station (e.g.: Pluguffan)
- Ship with mobile TM station
- Mobile TM Kits
- Airborne TM/TC pod (e.g. on a Rafale)



Airborne TM/TC Pod



MLA – Performance (Trimaran version)

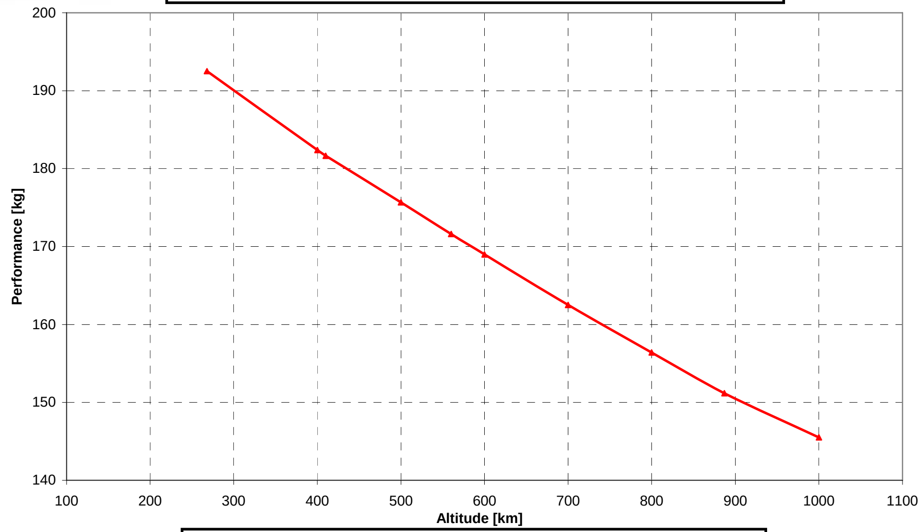
Trimaran version with standard technologies :

✓SSO 800 km/98.6° : 156 kg

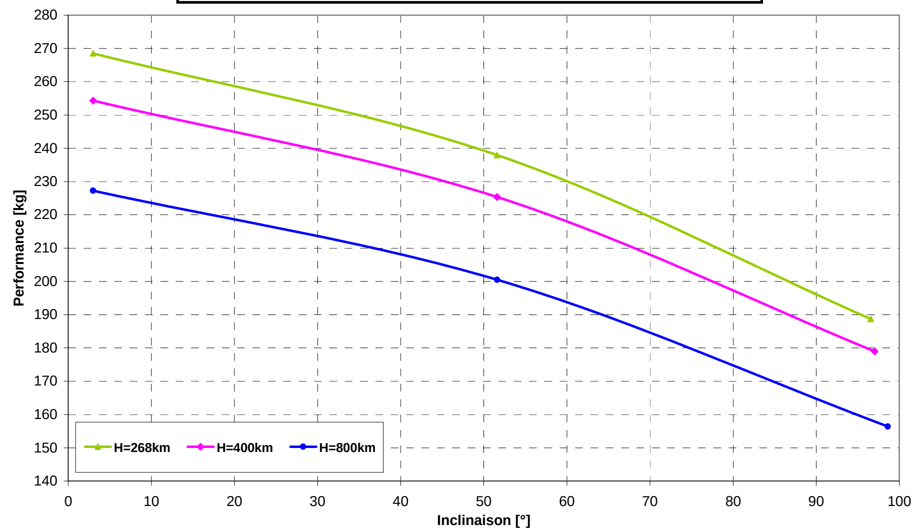
✓SSO 268 km/96.5° : 189 kg

✓EQU 268 km/0° : 268 kg

MLA TRIMARAN 10.5T performance relative to altitude (SSO)



MLA TRIMARAN 10.5T performance relative to inclination



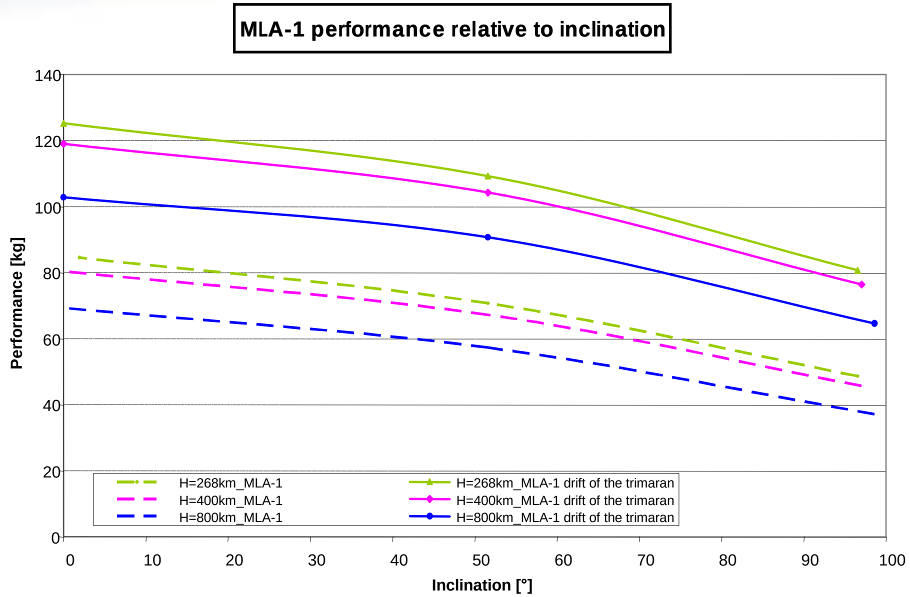
MLA – Performances (Linear version)

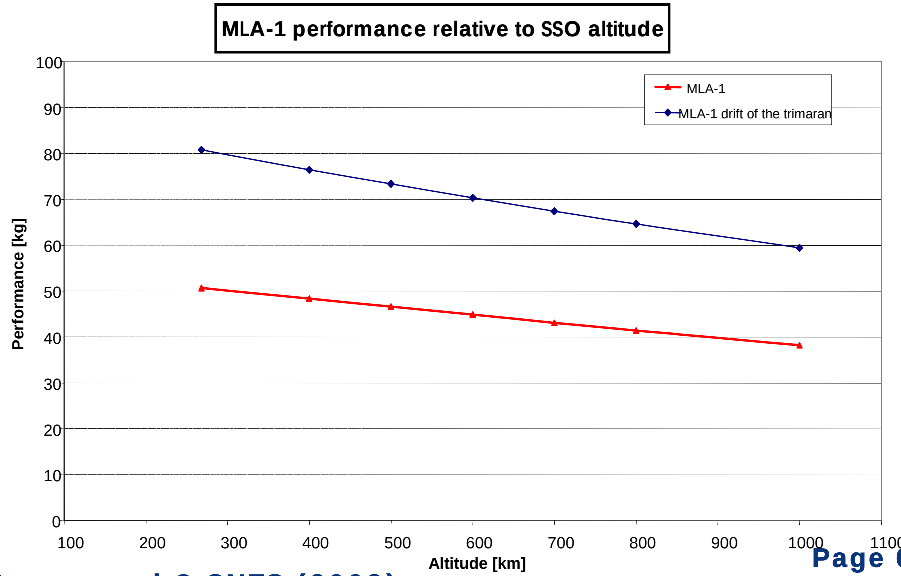
Single-bodied - P3-L0.6

- ✓SSO 800 km : 40 kg
- ✓SSO 268 km : 49 kg
- ✓EQU 268 km : 85 kg

➢ P3.5-L0.6 (advanced technologies)

- ✓SSO 800 km : 65 kg
- ✓SSO 268 km : 81 kg
- ✓EQU 268 km : 125 kg





Aldebaran

ALDEBARAN STUDY PRESENTATION

Sub-Directorate for Future, Research and cooperation with Russia

CNES/DLA

Introduction

- ALDEBARAN is a study conducted by a WG involving french and spanish space agencies (CNES and CDTI), German DLR institute, and numerous industrials*, dedicated to the definition of an in-flight technological demonstrator for Future Launcher.

- ALDEBARAN could be a part of the European activities to be conducted in the [2010, 2015] time frame to prepare the New Generation Launcher.

- ALDEBARAN is not a commercial project: the primary goal is to focus technologies on a flight test bed and to deduce from it an operational system if possible.

- ALDEBARAN studies will be pursed until end of 2008 in order to consolidate the project and select 2/3 concepts for a phase A study.

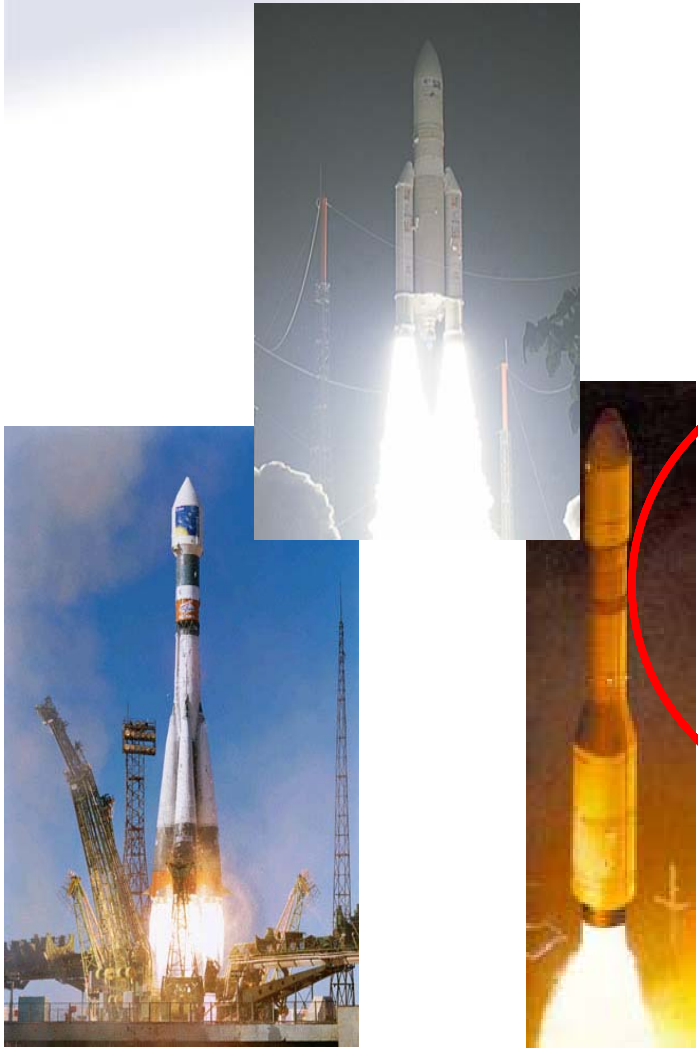
* Aernnova, Astrium-ST, Bertin, Dassault Aviation, Deimos, EADS-CASA, GMV, GTD, Safran, SNPE

Context

- From year 2009 to years 2020-2025, existing European Launchers with market adaptation (ARIANE 5, Soyuz, VEGA) will be able to cover all missions, except …
  - Smaller Payloads as:
    - Small (300 kg) and nano (50 kg) satellites
    - Specific missions: reactivity, flexibility
  - Heavy Payloads as:
    - Exploration missions
    - Manned Flights
- New Generation Launchers (NGL) for medium and heavy missions are probably not needed before 2025 / 2030 (but will take 10 years to develop) except in case of market or technological breakthrough.

Today

2025-2030



Activities for Future Preparation

Existing Launchers Improvements

or

New Generation Launchers

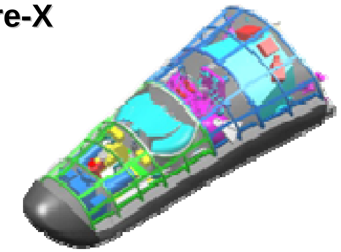
Objectives for Future Preparation activities

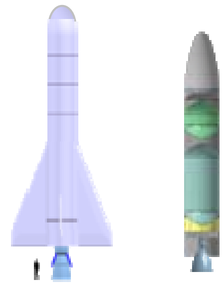
- CNES main goals for future preparation activities are:
  - Consolidation and improvement of existing Launchers (Ariane 5 Mid-Life)
  - Technology Maturation and Simulation means developments
    - R&T
    - MINOS (simulation)
    - Technology Demonstrators
  - Exploration of Market segments not yet covered by existing Launchers range
  - New Generation Launchers Studies: long term

Demonstrator types and objectives

Pre-X

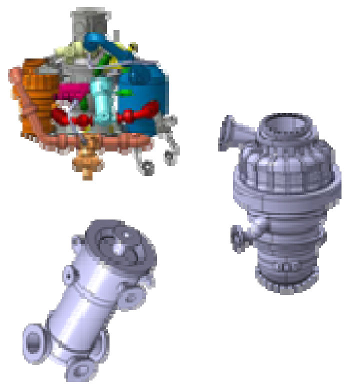
System / Vehicle





Propulsion

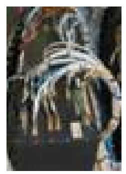
Vulcain-X



Structure / TP

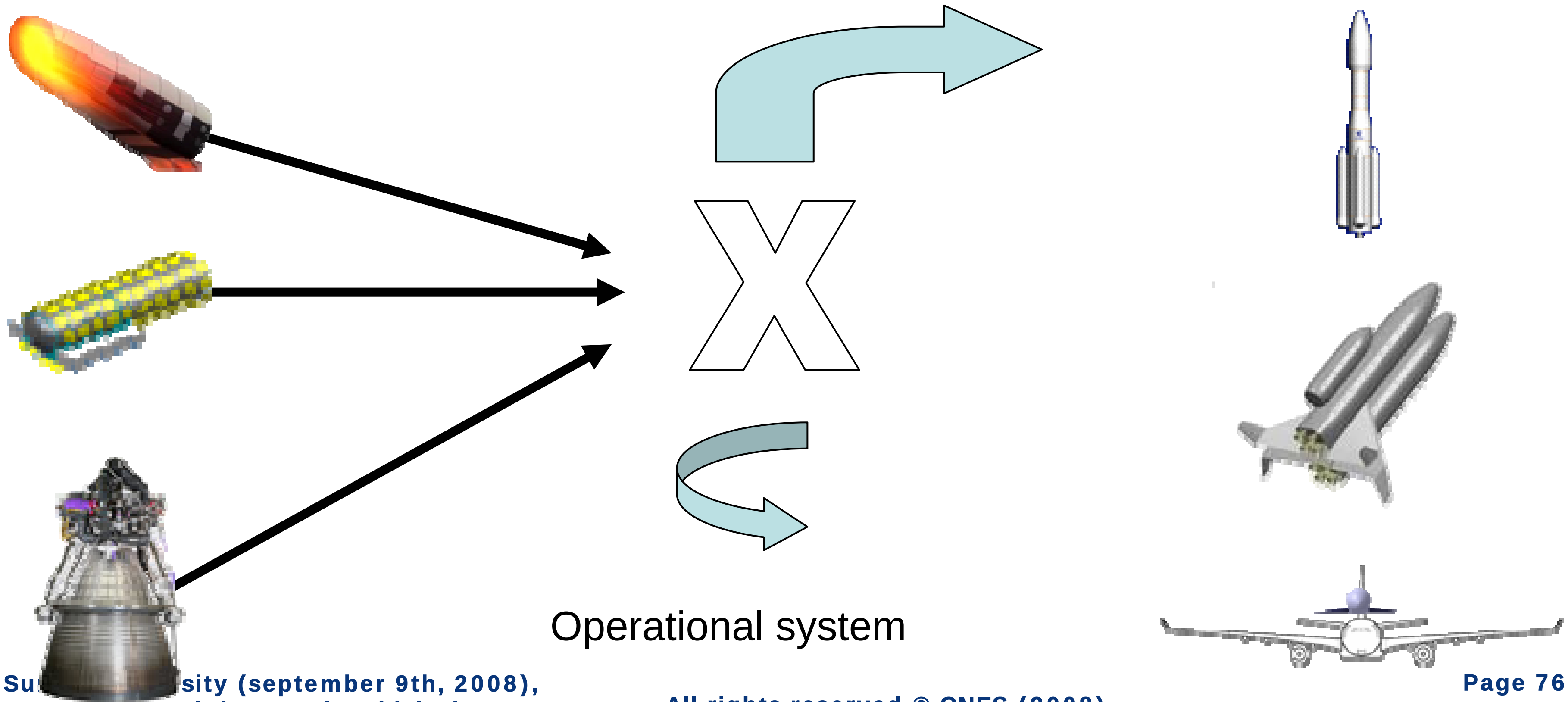
H-X

Electronics



Objectives of Aldebaran

2010	2015	2025-2030
Elements	‘Aldebaran’ demonstrator	Final targets



Why a flight demonstrator?

- On a flight system, to federate activities (which are dispersed at the present time) for preparing future launches.
- Test the usefulness of a new concept over a ‘reasonable’ timescale.
- Develop skills (methods, concepts, technologies, operations).
- Provide launch missions for satellites which are not well covered for by the performances/costs of current launchers.
- Cover defence launch requirements (confidentiality, responsiveness).

Technological and system demonstration

- The purpose of the ‘system’ demonstrator is to demonstrate in flight, a new concept and/or technologies which can be applied to one or more of the following targets:
  - “NGL”: new disposable launcher to follow Ariane 5
  - Average-sized launcher to follow SOYOUZ in French Guiana
  - Small launcher for nano satellites
  - Specific launcher on request
  - Manned vehicle or a sample-return vehicle