



## **ALBATROS: Towards a Mach 20+ Hypersonic Glide Vehicle for multi-purpose conventional global missions**

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### **Abstract**

ALBATROS is a five years research project initiated in 2025 by ONERA in order to push the limits of military Hypersonic Glide Vehicles (Mach 20+ velocities, global range, multi-missions capability) in the strict context of conventional payloads. Especially, ALBATROS is planning to develop technologies and methodologies for materials & structures, planning-guidance-optimization of trajectories, aerothermodynamics, MDAO assisted design and to apply them to an optimized preliminary design. This first paper related to ALBATROS is reviewing some past long range boost-glide concepts (Silbervogel, Bell BOMI, Bell BRASS, Bell ROBO, McDonnell-Douglas Rheinberry, X-41 CAV, FOBS systems), describing the possible missions (global conventional strike, global ISR, global payload release) and their flight profiles with a special focus on their technological challenges, and finally presenting some technological orientations (waverider typology, materials & structures based on ceramics and additive manufacturing, schematic arrangement of internal equipment) in the perspective of the first conceptual design of the glider.

**Keywords:** *Hypersonic, Glide, Concept, Operations*

### **Nomenclature**

AFMC – Air Force Material Command

BOMI – Bomber Missile

C4ISR – Command, Control, Communications,  
Computer, Intelligence, Surveillance,  
Reconnaissance

CAV – Common Aeroshell Vehicle

CNRS – Centre National de la Recherche  
Scientifique

FALCON – Force Application and Launch from  
Continental United States

FCC – Flight Control Computer

FOBS – Fractional Orbital System

GG – Gas Generator

GNSS – Global Navigation Satellite System

HGV – Hypersonic Glide Vehicle

HTV – Hypersonic Technology Vehicle

ICBM – Inter-Continental Ballistic Missile

INS – Inertial Navigation System

ISR – Intelligence, Surveillance,  
Reconnaissance

MARHY – Mach Adaptable Raréfié  
Hypersonique

MDAO – Multidisciplinary Design Analysis and  
Optimization

ONERA- Office National d'Etudes et Recherches  
Aérospatiales

PENAIIDS – Penetration Aids

PMS – Power Management System

RABO – Raketen Bomber

RCS – Reaction Control System

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RES – Reaction Engine System

ROBO – Rocket Bomber

RUHTC – Reinforced Ultra High Temperature Ceramics

SAR – Synthetic Aperture Radar

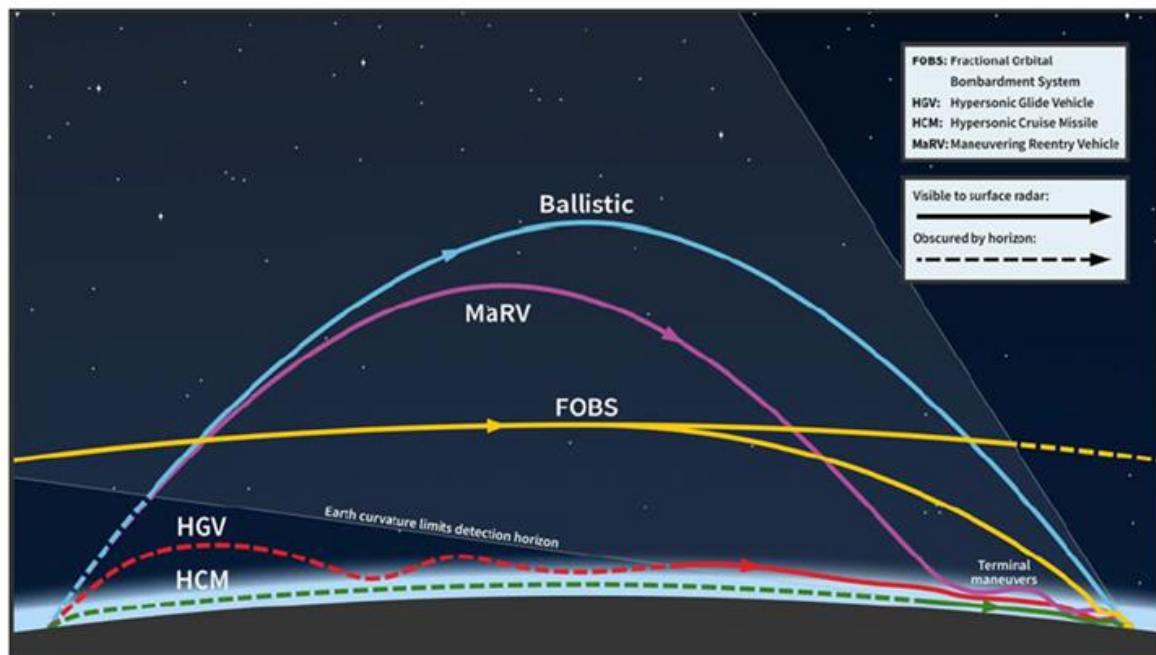
UAV – Unmanned Aerial Vehicle

UHTC – Ultra High Temperature Ceramics

UHTCMC – Ultra High Temperature Ceramic Matrix Composite

## 1. Introduction

During the last ten years, boost glide vehicles commonly designated as HGVs (Hypersonic Glide Vehicle) have become some of the most promising weapons because of their potential capability to penetrate reinforced defenses thanks to their high velocity combined with unpredictability resulting from their capability to perform strong manoeuvres inside the atmosphere. They are also later detected by ground radars because of their low altitude apogee compared to classical ballistic missiles.



**Fig. 1:** Typical HGV flight profile [1]

Mach 10+ HGVs are slowly entering into service for tactical and operational levels, the most famous one being the Chinese DF-17 presented at the military parade of the 50<sup>th</sup> anniversary of the People's Republic of China. But HGVs are also considered for Mach 20+ long range strategic levels characterized by extreme heat fluxes during the re-entry into the atmosphere. In this category traditionally reserved to ICBMs, the most famous program is the Russian "Avangard" glider which is claimed to reach Mach 27 and penetrate any defenses. After several tests, it was announced that it enters in service in December 2019 even if no one has really seen what this design could really look like.



**Fig. 2:** Chinese DF-17 missile and Russian "Avangard" glider (artist view)

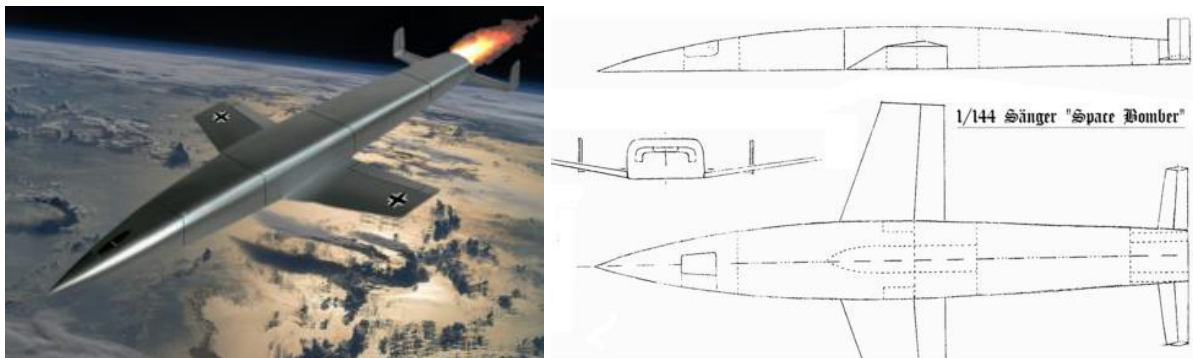
ALBATROS is a five years research project initiated in 2025 by ONERA in order to push the limits of HGV's capabilities (Mach 20+ velocities, global range, multi-missions) in the strict context of conventional payloads missions which are more challenging than non-conventional missions. It is also an opportunity to provide a non-classified generic framework to support the development of new technologies & methodologies of high lift maneuverable re-entry vehicles. Especially, ALBATROS is planning to address materials & structures, planning-guidance-optimization of trajectories, aerothermodynamics, MDAO assisted design and to apply them to a final preliminary design.

This first paper related to ALBATROS will review some past long range boost-glide concepts, describe the possible missions and flight profiles with a special focus on technological challenges, and finally present the main technological orientations for the first conceptual design of the glider.

## 2. Some past long range boost-glide concepts

### 2.1. Eugene Sänger's "Silbervogel" RABO

The "Silbervogel" RABO (Raketen Bomber) is the famous pioneering work on long range boost glide concepts developed by Eugene Sänger during the 30s and World War II in order to strike the American territory directly from Germany. It was a 28 m long 100 tons weight manned aircraft initially accelerated by a 3 km long railgun and then using its own liquid fueled rocket to reach nearly Mach 18 and an altitude of 145 km. The trajectory continued in ballistic conditions up to an apogee of 165 km and then started the re-entry into the dense atmosphere by performing skipping glide in order to increase the range. The "Silverbogel" was supposed to be able to carry 4 tons of military payload and to travel up to 24 000 km long so that it could theoretically be recovered in the Japanese territory.



**Fig. 3:** Eugene Sänger's "Silbervogel" concept [2] [3]

### 2.2. Bell Aircraft concepts

- Bell "BOMI" concept for MX-2276 advanced study

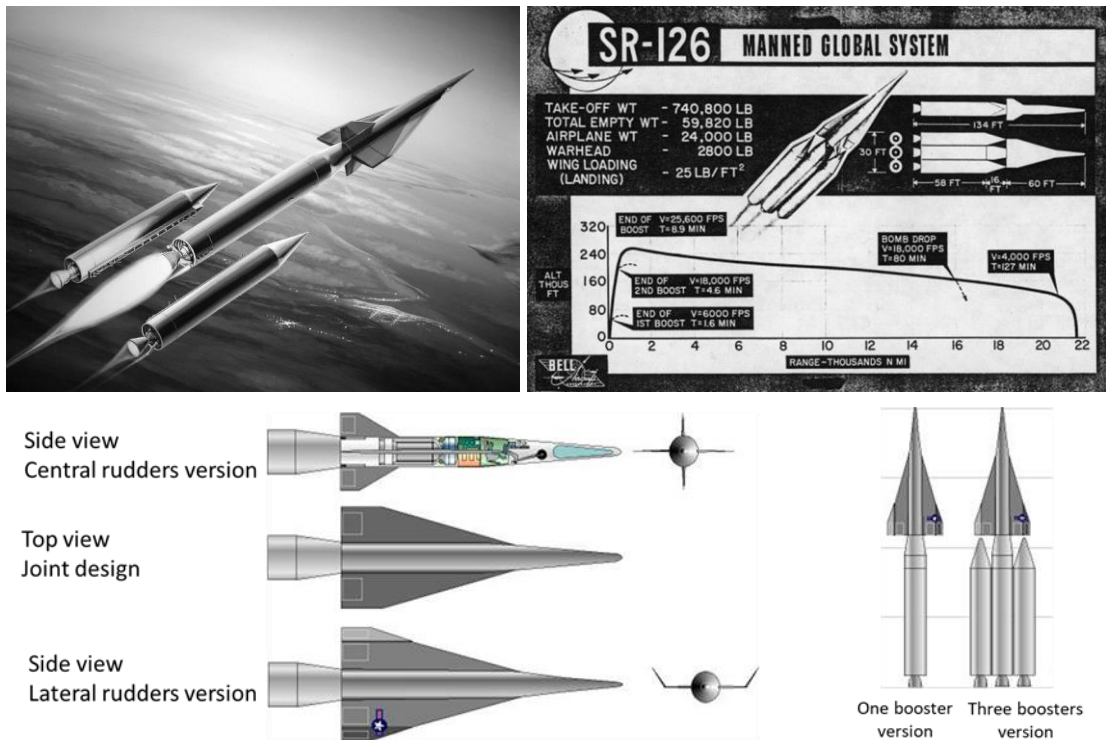
In 1950, the program manager of the famous V2 missiles, major general Walter Dornberger, was hired by the Bell Aircraft corporation. Especially, he continued the works on the most innovative boost-glide bombardment concepts developed during World War II under the name BOMI (Bomber Missile). After some preliminary self-funded works presented to the US Air Force in 1952, a first study named MX-2276 was committed by the US DoD.

The final design [1] proposed in 1955 was a vertical launching horizontally stacked three stages concept: (i) a 36 meters long, 95 tons weight, recoverable rocket-powered manned first stage (ii) a 28 meters long, 70 tons weight, expandable rocket-powered second stage (iii) a 23 meters long, 20 tons weight, recoverable rocket-powered manned third stage including nearly 2 tons of military payload. A typical flight profile was an acceleration up to Mach 22 at an altitude of 80 km, a payload release at Mach 18 at an altitude of 50 km, and a landing after travelling 20 000 km.

Some of the technological hypothesis were considered as too optimistic by the committee review and it was recommended to focus the efforts on an ISR version. The evolution of the design [6] resulted in a vertically stacked concept including an expandable first stage which was proposed in the context of the WS-118P study even if it was funded by the MX-2276 study.



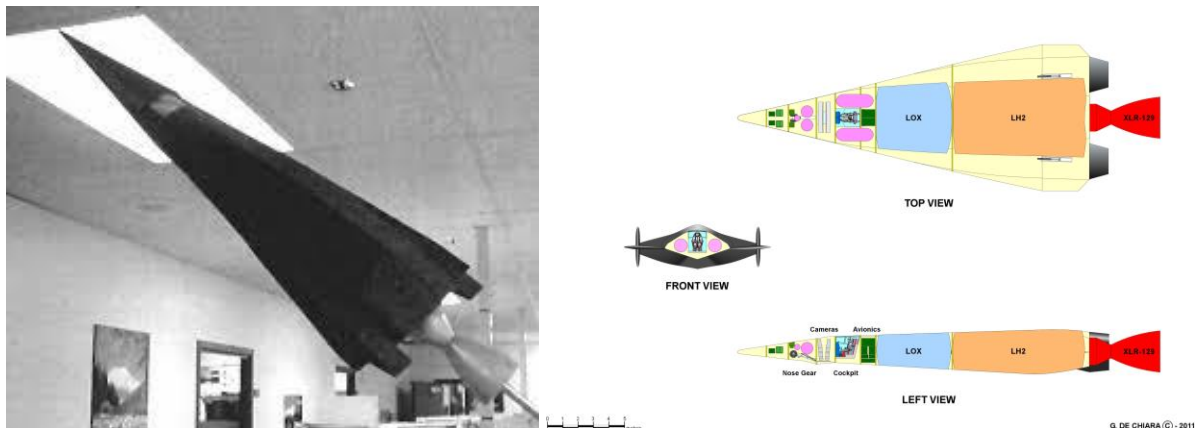
The works performed for the ROBO study were finally merged in 1957 in the proposals for the X-20 "Dyna-Soar" spacecraft which was finally cancelled in 1963.



**Fig. 6:** Bell "ROBO" concept [8]

### 2.3. McDonnell-Douglas Model 192 "Rheinberry"

The McDonnell-Douglas Model 192 "Rheinberry" is a black program of the 60s which was one of the concepts studied for the successor of the Lockheed-martin Mach 3+ SR-71 "Blackbird". It was a 20 m long manned aircraft developed for global ISR missions. The aircraft was supposed to be accelerated up to nearly Mach 22, to fly over the target in suborbital conditions, and then to come back to the national territory by performing almost one Earth circumference. This program was given up in 1967 due to its complexity with respect to promising satellite solutions.

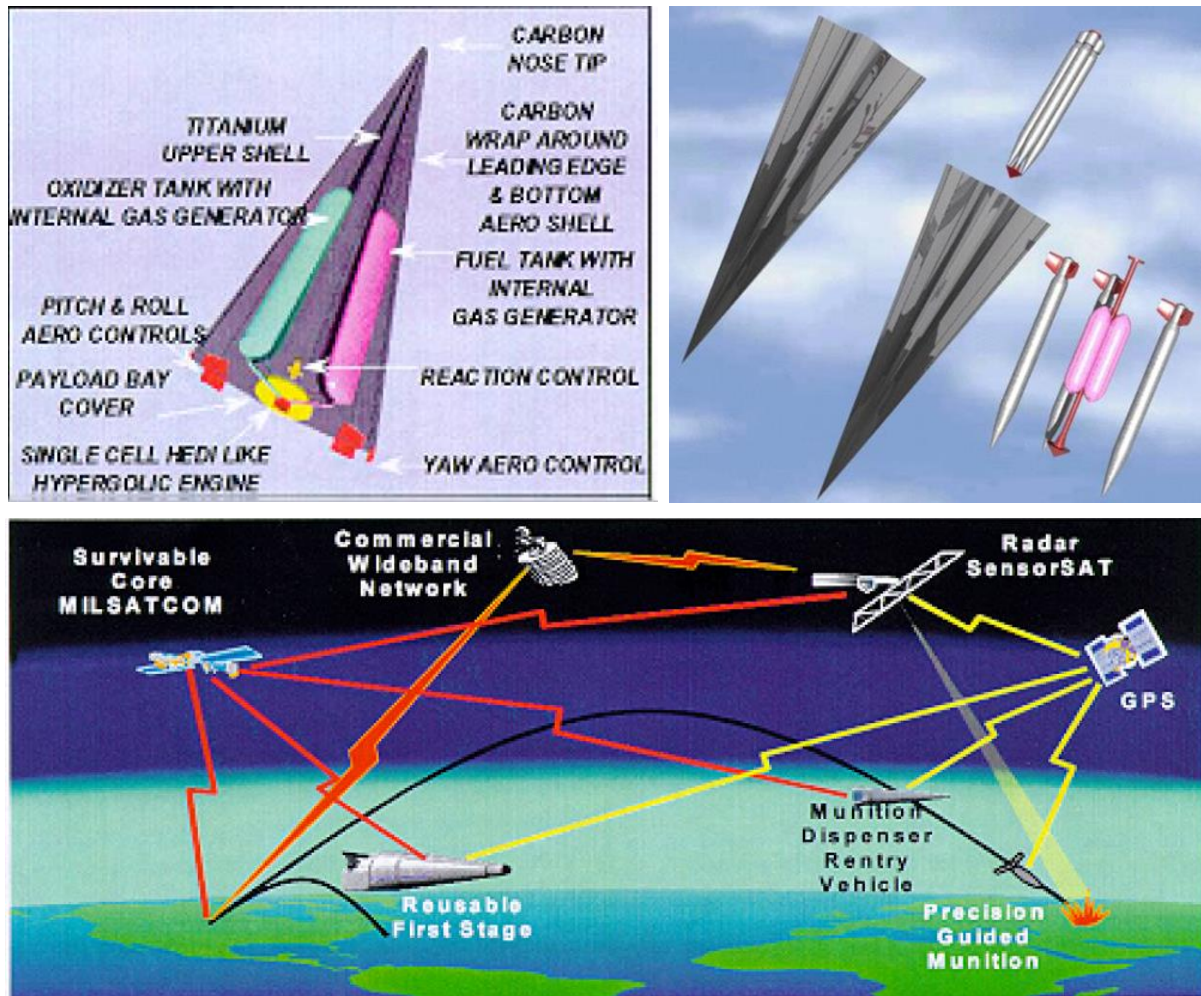


**Fig. 7:** McDonnell-Douglas Model 192 "Rheinberry" [9] [10]

### 2.4. X-41 CAV concept and HTV-2 demonstrator

The CAV (Common Aeroshell Vehicle) [11] [12] proposed by the US AFMC (Air Force Material Command) at the end of the 90s is probably the most interesting concept with respect to the missions considered for the ALBATROS project. It was a boost-glide system which aims at releasing a conventional military payload anywhere on Earth in less than one hour and a half. The HGV was becoming an aeroshell

carrier (nearly 3.6 m long and 1 ton weight) protecting its payload (nearly 500 kg weight) from extreme heat fluxes during the reentry and then releasing it from the rear side when close to the target.



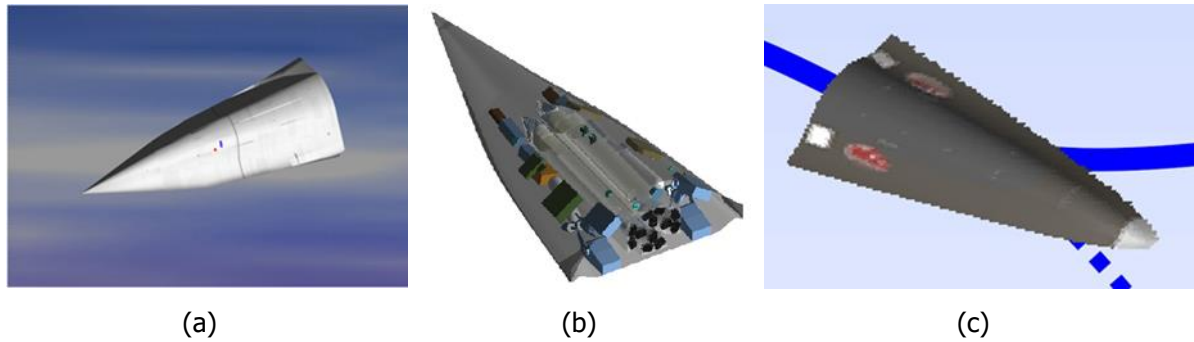
**Fig. 8:** AFMC Air Armament Center CAV concept [11] [13]

Two types of payloads were considered for the CAV concept:

- Force Application:
  - A single Unitary Penetrator for buried targets
  - A specialized Agent Defeat Weapon joint to a Unitary Penetrator to defeat specific types of biological or chemical weapons
  - Sub-munitions for the dispense of Highly Effective Area Attack on dispersed targets over a broader geographic area
  - Non-lethal weapons such as electronic jammers, pulse generators, sticky foams
  - An Hunter-Killer UAV searching for strategic relocatable targets
- Force Enhancement:
  - Airborne C4ISR sensors deployed on a small UAV
  - Ground deployed mini/micro ISR sensors incorporating a satellite link
  - High value time critical cargo to support military forces or special operations

The most significant challenge of this concept was the final disposition of the CAV. Should it be expendable or recoverable? In the former case, should it be planned an auto destroying system? In the latter case, where and how should it be recovered?

Some companies were asked for the conceptual design of a CAV-L (low performance) and a CAV-H (high performance) in the perspective of a technological demonstrator probably designated as X-41. The following figure is showing some of the proposals for the CAV-H.



**Fig. 9:** Some CAV-H conceptual designs [14]:  
(a) Lockheed-Martin (b) Orbital Sciences (c) Andrews Space

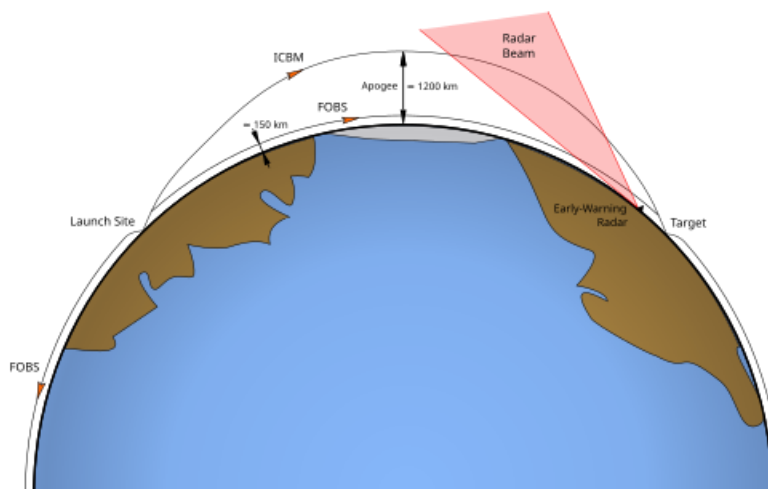
Then, the X-41 CAV was merged in the American FALCON program and the technological demonstrator X-41 finally became the famous Lockheed-Martin HTV-2 vehicle [15] boosted by a Minotaur IV launcher. Two experimental flight tests failed in 2010 and 2011: the first one due to a roll-yaw coupling instability and the second one due to extreme heat fluxes.



**Fig. 10:** Some views of the HTV-2 mock-up

## 2.5. FOBS based systems

FOBS (Fractional Orbital Bombardment System) is an innovative type of ICBM which warhead is following a Low Earth Orbit instead of a predictable high apogee ballistic trajectory. A de-orbiting module is used at the target approach to initiate the re-entry into the atmosphere. This system has many advantages with respect to pure ballistic missiles: (i) later detection by ground based radars (ii) unpredictability of warhead de-orbiting (iii) capability of exotic trajectories (e.g. reverse attack) in order to bypass anti-missiles systems.



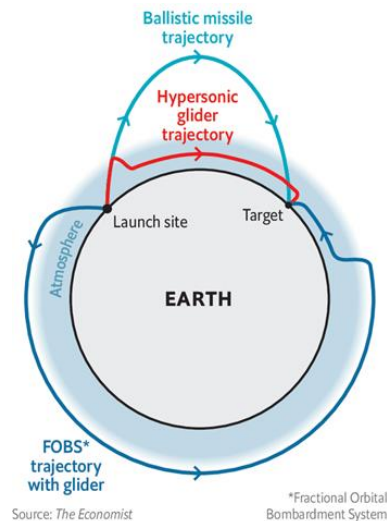
**Fig. 11:** Typical FOBS profile [16]

The Soviet R-36O system was the single operational FOBS system entered in service in 1968 and retired in 1983 due to SALT II military treaty of armament reduction. USA never deployed a FOBS system probably because of two major drawbacks: (i) strong reduction of mass payload due to the necessity to put it on Low Earth Orbit and to add a heavy de-orbiting module (ii) lower accuracy with respect to ballistic missiles.



**Fig. 12:** Soviet R-36O missile [16] [17]

FOBS based systems are regaining a new interest because they can be combined with an HGV guaranteeing accuracy and high unpredictability during the endgame phase. The new Russian ICBM RS-28 "Sarmat" would have the technical capability to put the "Avangard" glider into Low Earth Orbit. Indeed, it was declared by Russian authorities that "Sarmat is capable of a 35 000 km suborbital flight". USA also declared that China has tested a HGV based FOBS in July 2021 even if China claimed that it was a test related to civil applications.



**Fig. 13:** Typical FOBS flight profile combined with HGV re-entry vehicle (source: The Economist)

### 3. ALBATROS missions

#### 3.1. General specifications

For all considered missions, the system (i.e. launcher + hypersonic glide vehicle) should be able to fulfill the following specifications:

- **Range:** The system should be able to perform one Earth circumference so that any location on Earth could be attacked/flied over from any directions (e.g. reverse attack) or so that the vehicle could be potentially destroyed/recovered close to the launch site. NB: It is not necessary to be able to perform more than one Earth circumference because actual international military treaties prevent from using weapons located in space (i.e. performing more than one orbit).

- **Payload effect:** Even if the system is able to reach global range, its payload should strictly deliver only conventional effects (i.e. no nuclear, radiative, biological, chemical effects) so that it cannot be confused with ICBMs and then provokes an automatic nuclear counter reaction.
- **Maximal velocity:** The capability to perform one Earth circumference is inducing that the hypersonic glide vehicle is starting its trajectory in the atmosphere at least beyond Mach 20 and probably close to the orbital velocity
- **Maximal altitude:** The system should not reach high altitude apogee (i.e. several hundreds or even thousands of kilometers) inducing early detection by ground radars and confusion with classical ICBMs. On the contrary, low altitude apogees should be promoted in order to help the penetration of defenses thanks to later detection by ground radars. An order of magnitude of the maximum altitude of the apogee is nearly 100 km but it can be extended up to 300 km for some flight profiles using extra Low Earth Orbit.
- **Launch site:** The capability to perform one Earth circumference is likely to induce large systems which would not fit inside submarines or surface ships silos. So, a ground based launch site is preferred and a military annex of the Kourou Guyana Space Center could be a good candidate for global range capabilities and potential recovering of the system.
- **Launcher:** The launcher should be reactive with storable propellants and able to provide high thrust capabilities so that a quasi-orbital velocity could be reached at nearly an altitude of 100 km.
- **Multi-missions & Recoverability:** A global range capability is inducing high complexity and cost with respect to other short range specialized conventional military systems. So, an extensive multi-missions capability, and even a potential recoverability/reusability, are key points for an economic viability of the development of such a system.

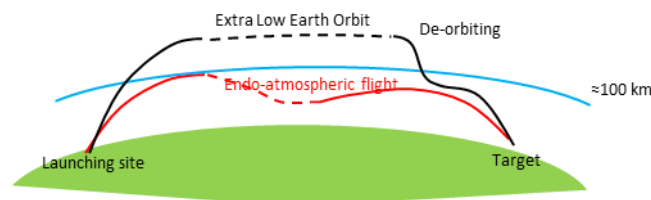
### 3.2. Mission 1: Global conventional strike

The first type of mission is a direct global conventional strike where the destruction of the target is obtained both by the kinetic effect of the HGV and by the explosion of a warhead contained inside the HGV. Potential targets include critical infrastructures that could be possibly buried or reinforced, high value time sensitive targets, mobile large targets like ships (e.g. carrier vessels). The mass of the warhead should be at least 500 kg in order to obtain a significant effect deserving such a mission. The type of warhead could be adapted to each specific targets.

The capability to strike promptly critical targets in nearly one hour anywhere on Earth could deserve special operations. But in the context of international tensions, it could also be thought as a conventional deterrence without reaching extreme pressures characteristic of nuclear deterrence. Especially, it could help the defense of overseas territories which are much less defended than the metropolitan territory.

Another point is that a global HGV solution is likely to be a low cost solution with respect to very complex hypersonic aircrafts carrying missile systems. This cost advantage could even be increased if it is possible to develop a recoverable and reusable reactive launcher.

Two different flight profiles could be considered:



**Fig. 14:** Possible flight profiles for Mission 1

- The first profile is a classical HGV profile where most of the flight is performed in endo-atmospheric conditions with an altitude of the apogee around 100 km. The capability to reach global range from any directions will need a high lift to drag ratio design combined with skip gliding, but skipping will probably need to be assisted by a small additional reaction engine

used intermittently during the lower phases of the rebounds. Such a reaction engine could also help the penetration of the defenses.

- The second profile is the combination of a FOBS profile and a HGV profile. The HGV is put on an extra Low Earth Orbit (e.g. between 100 and 300 km) and when approaching the target an expendable de-orbiting module is used to recover a HGV profile. This concept has the advantages to reach more easily a global range and to keep more velocity for the last phases of the mission so as to perform potentially longer crossrange and stronger maneuvers. But this concept has also some drawbacks with respect to the first profile because it supposes a higher mass to be put at a higher altitude, an earlier detection by ground radars, and a higher vulnerability to exo-atmospheric interceptors.

In any case, the capability to strike accurately small stationary targets and large mobile targets will need the use of a seeker for terminal guidance. The most significant challenge of the mission will be the development of a seeker solution able to keep its performance after experiencing extreme thermal and thermo-mechanical conditions during the crossing of the atmosphere. This challenge could probably be the main constraint for the feasibility and credibility of this mission.

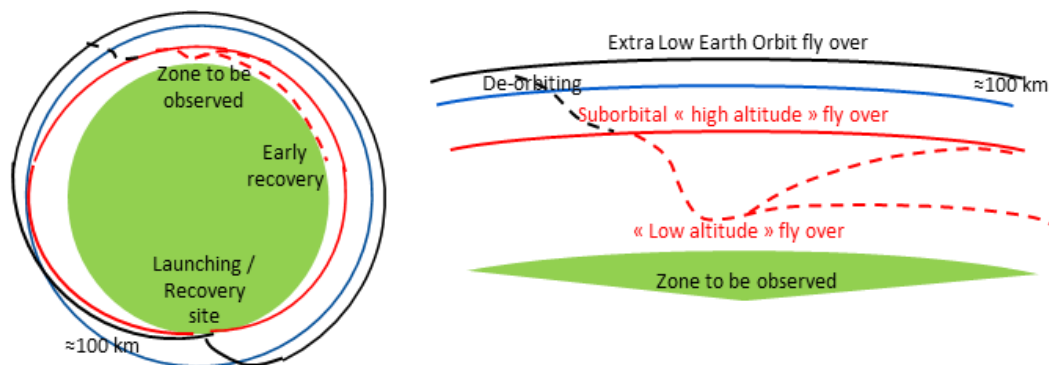
### 3.3. Mission 2: Global Intelligence, Surveillance, Reconnaissance

Global ISR (Intelligence, Surveillance, Reconnaissance) missions are mainly performed nowadays by satellites. They are so efficient that almost all aircrafts devoted to this specific mission have disappeared, like the famous Mach 3+ Lockheed SR-71 "Blackbird" which was never replaced. Nevertheless, the need for reactive ISR missions at lower altitudes has never completely disappeared. Indeed, the U-2 aircraft has not retired and some projects of Mach 5+ successors of the SR-71 are still evoked by the American DoD. Even if satellites are often considered as ubiquitous, they are not exempted of some drawbacks:

- their trajectories are known and predictable by targets that could use camouflage to deceive the satellites during the fly over
- there could be a significant latency before reaching the zone to be observed or between two flies over of this zone that could be used by time sensitive targets
- they need heavy and costly surviving systems to remain in orbit during a long lifetime.
- some of their observation systems cannot penetrate clouds which are often present in the high latitudes of the Earth
- the resolution of images obtain in orbit is lower than the one obtained at lower altitudes

In this context, a global reactive unpredictable ISR system offering an extra high resolution at lower altitudes could be a complement to satellites for specific time sensitive or camouflaged targets. The saving of mass and volume resulting from the removal of long lifetime systems could also be used for more performant sensors or for a more complete mix of optical, radar, and electromagnetic sensors. A global HGV could also be a low cost solution with respect to hypersonic aircrafts if it is possible to recover and reuse it. This cost advantage could even be increased if it is possible to develop a recoverable and reusable reactive launcher.

Three different flight profiles could be considered:



**Fig. 15:** Possible flight profile for Mission 2

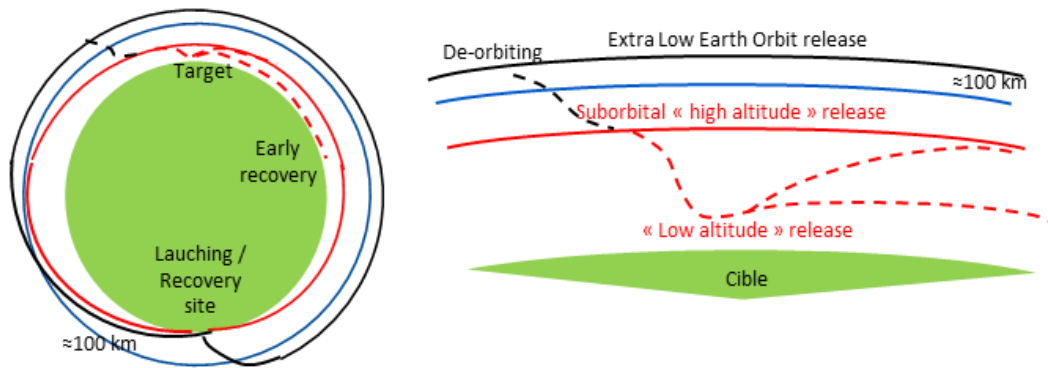
- The first one is a FOBS profile where the fly over the target is performed at an altitude between 100 and 300 km and the de-orbiting is performed after almost one Earth circumference in order to come back to the launch site so as to recover the vehicle. It should be noted that the development of even a simple recovery system will be a significant challenge and will induce major constraints on the design of the vehicle. This profile is not the most interesting one because the resolution of images is not improved with respect to satellites and the trajectory is predictable once the vehicle is detected. Finally, a recoverable HGV is found to be a complex and costly solution for such a flight profile because a cheap short lifetime rudimentary satellite put in Extra Low Earth Orbit by a reactive launcher would be probably a better solution.
- The second one is a suborbital profile where the fly over is performed between the stratosphere and the upper limit of the atmosphere where thermal heat fluxes are limited. Due the presence of a tiny atmosphere which allows lateral crossrange, the trajectory is less predictable. Nevertheless, this suborbital profile does not allow a major improvement of the resolution with respect to satellites. Furthermore, the achievement of one Earth circumference will probably need a complex skipping trajectory assisted intermittently by a reaction engine in the lower phases of the rebounds. It should be noted that a FOBS profile including a de-orbiting at the approach of the target can be combined with this suborbital profile in order to increase more easily the range.
- The third one is a suborbital profile including a dive inside the lower atmosphere during the target approach so that the fly over is performed at a low altitude offering an extra high resolution of the images, a potential penetration of high altitude clouds, and strong lateral maneuvers leading to highly unpredictable trajectories. This profile is probably the most interesting one but it also supposes huge challenges to be solved. The most significant one will be the thermal management of the sensors and the windows because the vehicle will experience extreme heat fluxes inside the dense atmosphere during the dive. The second one will be the recovery of the vehicle up to the launch site because a large amount of propellants would probably be needed by an additional reaction engine in order to regain altitude and velocity after the low altitude fly over. Depending on the altitude and velocity of the fly over, and depending on the distance to be performed between the fly over and the launch site, an early recovery of the HGV in allied nations territories or in national maritime overseas territories should probably be planned.

To conclude, a global range HGV could be an interesting solution for reactive and unpredictable ISR missions in complement to satellites. Nevertheless, it is a complex and costly solution with respect to a cheap short lifetime rudimentary satellite if the flight profile is limited to Extra Low Earth Orbit or suborbital profiles. The use of a HGV is rather deserving the introduction of a low altitude dive so that it can perform extra low resolution images at least similar to the ones performed by hypersonic aircrafts. But this flight profile will induce major challenges in terms of thermal management of sensors, development of a recovery system, performing of long range trajectories up to the launch site, or coordination with other nations or overseas national territories if a recovery up to the launch site is not possible.

### **3.4. Mission 3: Global conventional payload release**

The two previous missions could be strongly limited by the thermal management of the seeker or the ISR payload during the re-entry phase into the atmosphere. Furthermore, it would be interesting to have more diverse military effects of the payloads and to have more flexibility in their deployment. One solution is to decouple the HGV and the payload by releasing it close to the target. In this case the HGV is becoming a simple carrier and protective shell of the payload during the re-entry phase and the payload is the final effector optimized for the desired military effect. This is the concept already proposed for the X-41 CAV.

Three flight profiles could be considered:



**Fig. 16:** Possible flight profile for Mission 3

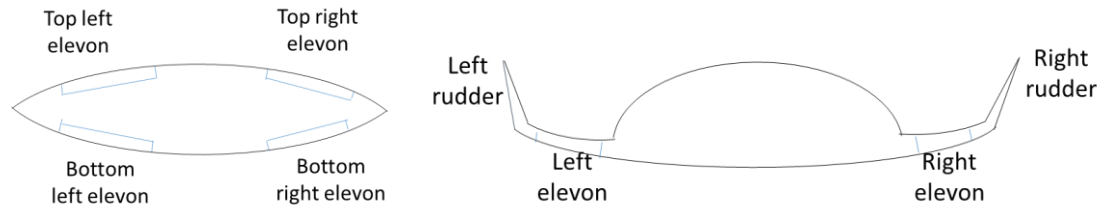
- The first one is a FOBS profile where the payload release is performed at an altitude between 100 and 300 km and the de-orbiting is performed after almost one Earth circumference in order to come back to the launch site so as to recover the vehicle. It should be noted that the development of even a simple recovery system will be a significant challenge that will induce major constraints on the design of the vehicle. This flight profile has a limited interest in a sense that the payload will not have a better thermal protection during the reentry into the atmosphere. Consequently, the potential payloads would be limited to short lifetime sensors platforms into space or to highly thermally protected reentry warheads with a limited impact accuracy due to the absence of a terminal seeker. Nevertheless, this flight profile is allowing easily a global range and it is also slightly unpredictable in a sense that it is impossible to predict the release of the payload. An interesting use of this profile would be the release of several payloads over several targets during one Earth circumference or to release several payloads over a single target so as to add deception to unpredictability.
- The second one is a suborbital profile where the payload release is performed between the stratosphere and the upper limit of the atmosphere where thermal heat fluxes are limited. Due to the presence of a tiny atmosphere which allows lateral crossrange, the trajectory of the HGV is less predictable during the target approach. Nevertheless, this flight profile is the least interesting one because it does not allow a thermal protection of the payloads and it requires complex skipping trajectories assisted by an additional reaction engine so as to come back to the launch site.
- The third one is a suborbital profile including a dive inside the lower atmosphere during the target approach so that the payload release is performed at a low altitude after the extreme heat fluxes experienced during the reentry. The altitude and velocity of the release will depend from the nature of the payload. In this context, a large diversity of optimized payloads can be considered like the ones already quoted for the X-41 CAV concept. This flight profile is probably the most interesting one but it also supposes huge challenges to be solved. The first one is the development of a release system at high velocity in a dense atmosphere. The second one will be the recovery of the HGV up to the launch site because a large amount of propellants would probably be needed by an additional reaction engine in order to regain altitude and velocity after the low altitude release. Depending on the altitude and velocity of the release, and depending on the distance to be performed between the release and the launch site, an early recovery of the HGV in allied nations territories or in national maritime overseas territories should probably be planned.

To conclude, this mission is probably the most promising one if the payload release is performed at low altitude due to the diversity, flexibility, optimization of the potential payloads. Nevertheless, it will induce major challenges in terms of development of a releasing system, development of a recovery system, performing of long range trajectories up to the launch site, or coordination with other nations or overseas national territories if a recovery up to the launch site is not possible.

## 4. Some first technological orientations

### 4.1. Aerodynamic configuration

A high lift-to-drag ratio is needed so as to perform a large part of the global range thanks to gliding and consequently a high performance waverider configuration will be selected. Two topologies are assessed for the control of the vehicle: (i) a compact highly blended configuration with two elevons on the windside and two elevons on the leeside (ii) a slightly blended configuration with two elevons on the wings and two lateral rudders at the extremities of the wings.

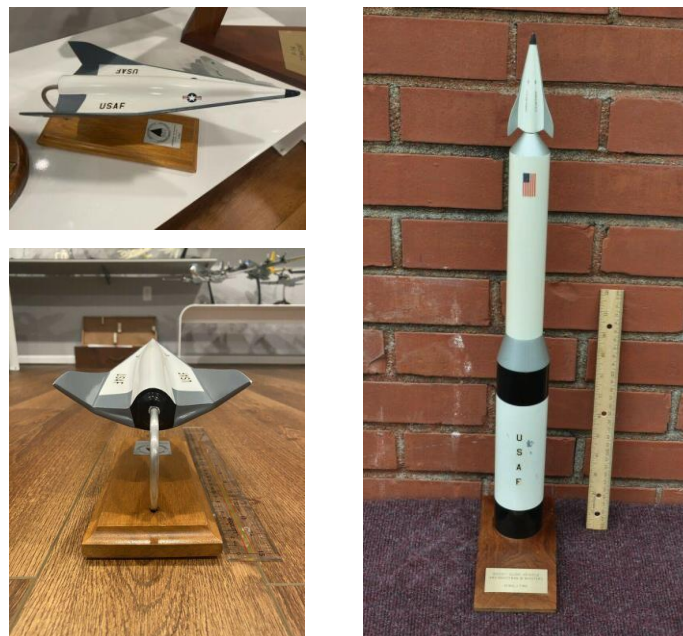


**Fig. 17:** Assessed aerodynamic topologies (rear view)

Nevertheless, a waverider configuration has also some drawbacks with respect to more classical configurations (e.g. flat nose with small available volume, larger span at iso-volume, difficulties to obtain static pitch stability without a heavy forward ballast) that should be compensated by specific solutions:

- Introduction of a flat SAR antenna inside the nose (the electronics of the antenna is deported)
- Removal of fairing during the boosted phase so as to relax the span limitations (the same configuration was used for the HERMES vehicle)
- Assumed unstable configuration along the pitch axis which control can be assisted by RCS

The following figure is showing an old HGV project from General Dynamics Convair Division mounted without fairing at the top of a Minuteman III booster. It could be a source of inspiration for the second assessed topology.



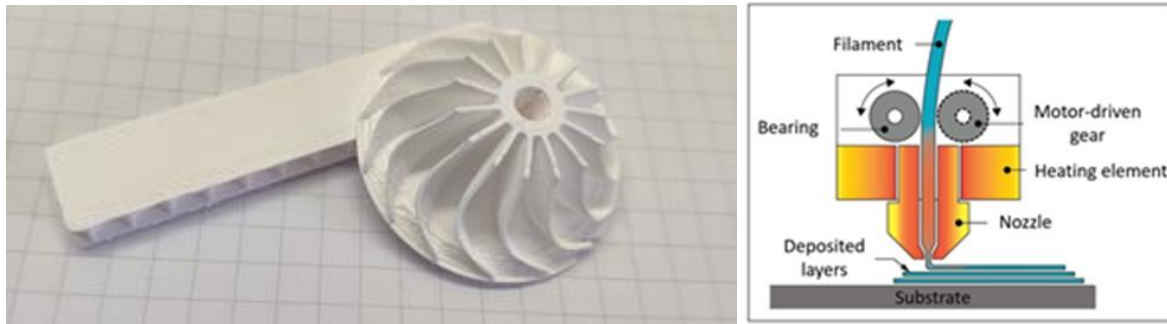
**Fig. 18:** HGV project from General Dynamics Convair Division [18]

### 4.2. Materials & Structures

The thermal and thermo-mechanical strengths of materials & structures are historically known as the most limited factors in terms of velocity-altitude corridor and thermal endurance. Some major innovations are planned to be developed in the ALBATROS project so as to cope with those issues.

The nose, leading edges, and control surfaces need to be very sharp so as to promote high lift to drag ratio. Such low curvature radius design will induce significant thermal issues but also machining issues. Furthermore, in the context of strong manoeuvres and thermal cycles induced by the different potential missions, high mechanical and thermo-mechanical strengths are required. And of course the mass still needs to be as low as possible

Recent UHTCMC materials are probably the best candidates for such applications but classical machining and coating of complex sharp geometries could be very difficult. So, UHTC materials reinforced by short fibers (RUHTC) and coupled with additive manufacturing could be a very interesting solution to obtain the requested specifications without machining constraints. Such works based on the fused filament method are currently ongoing at ONERA to manufacture complex large parts made in RUHTC.



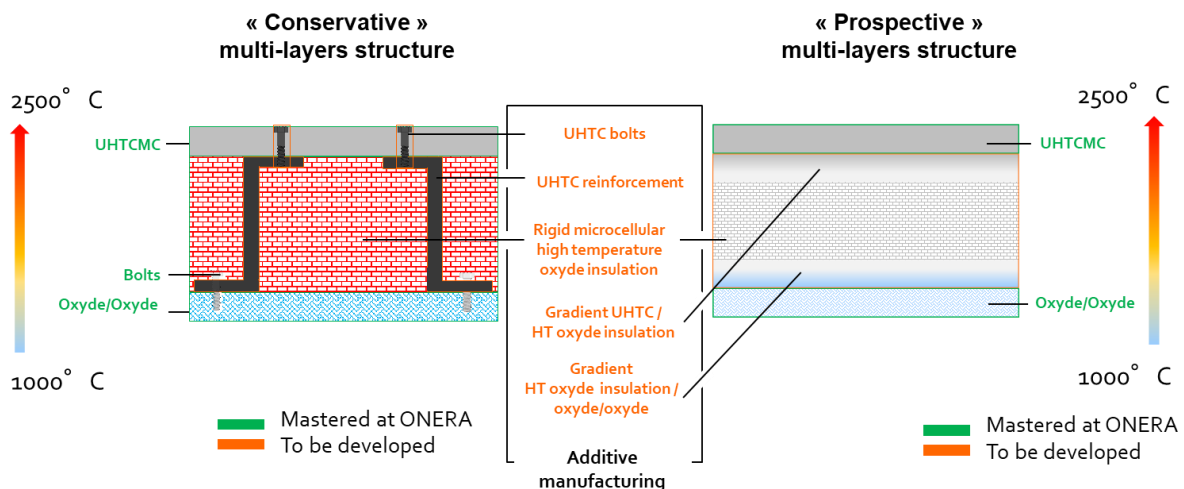
**Fig. 19:** Examples of aeronautical parts made in additive manufacturing

The fuselage itself is the second major issue because it should be able to hand with most of the mechanical stresses and to delay the penetration of heat fluxes inside the internal equipment, while working at high temperatures even if they are not as extreme the as the ones reached by nose, leading edges, and control surfaces. A typical three layers stack is proposed for the fuselage:

- Outer hot structure: UHTCMC (or RUHTC for complex geometry)
- Thermal insulation: Rigid micro cellular structure of high temperature oxide
- Inner cold structure: Oxide/Oxide ceramic composite

Two main structural variants are planned, differing from the mechanical links between the outer and inner structures. The conservative variant is based on classical reinforcements but the second one is based on chemical & structural normal gradients at the transitions between the different layers so as to better cope with thermo-mechanical stresses.

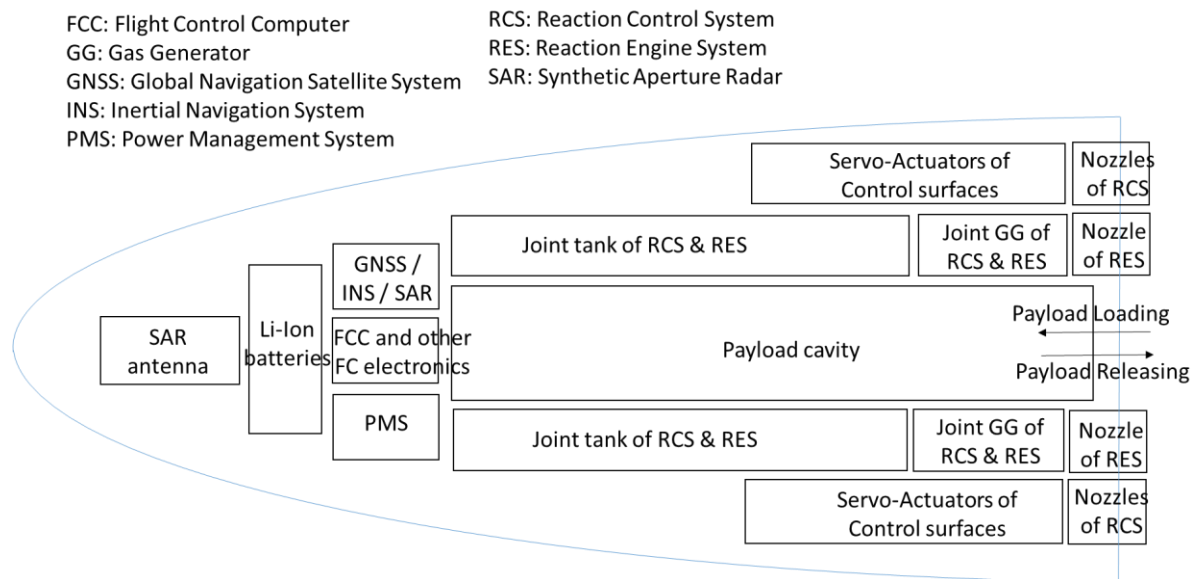
For both variants, additive manufacturing will be extensively used for bolts, reinforcements, micro-cellular insulation. Especially, additive manufacturing will be essential for the development of the second variant including chemical & structural gradients inside a single part composed of different layers.



**Fig. 20:** Multi-layers structures proposed for the fuselage

### 4.3. Equipment and internal arrangement

The following figure is presenting a schematic view of the selected equipment and its arrangement inside the waverider typology.



**Fig. 21:** Schematic arrangement of internal equipment

Here is a short description of the internal equipment from frontwards to backwards:

- **Seeker:** The front region of the vehicle will become very hot for a Mach 20+ vehicle and consequently it seems unfeasible to use an optical seeker during the endgame in those conditions. Furthermore, the geometry of this region will be slightly flat in the case of a waverider typology and it is likely that there will be no room for a classical electromagnetic seeker. So, a flat SAR antenna (Synthetic Aperture Radar) with deported backward electronics is proposed for terminal guidance during the endgame but also for assisted navigation during the target approach. The thermal management of the antenna and the development of a specific high temperature CMC material transparent to electromagnetic waves will be huge challenges for the maturity of this solution.
- **Batteries:** Li-Ion batteries are found as the best compromise between power, mass, and compactness. They are located at the front of the vehicle due to their significant mass concentrated in a small volume. This frontwards location of mass is helping pitch trimming.
- **Electronics:** Three boxes are composing the electronic segment of the vehicle
  - **Sensors box:** It is composed of GNSS (Global Navigation Satellite System), INS (Inertial Navigation System), and deported electronics of SAR (Synthetic Aperture Radar).
  - **Flight control box:** It is composed of the main FCC (Flight Control Computer) and possibly the specific deported electronics of flight control actuators: RCS (Reaction Control System), additive RES (Reaction Engine System), Control surfaces.
  - **Power box:** It is mainly composed of the PMS (Power Management System).
- **Payload:** As described in the missions section, many potential payloads could be considered. So, the payload segment is a closed structural large cavity that could welcome many military systems. Those systems are load on board from the rear side of the vehicle and they could also be potentially released during flight from this same side for the Mission 3 concept. Some PENAIDS (Penetration Aids) like decoys could also be released for the Mission 1 concept. A hard constraint of this loading/releasing system is that no other equipment could be located backwards of the payload cavity.
- **Reaction Systems:**

Two different Reaction Systems are planned:

- RCS (Reaction Control System): It is the classical reaction system needed for the control of the vehicle during the exo-atmospheric phase of the flight. For an unstable design around the pitch axis, it could also be used during the atmospheric phase as an assistance to control surfaces so as to manage efficiently the instability.
- RES (Reaction Engine System): This is two small additional hot gas reaction engines located at the lateral sides of the payload cavity and emerging from the rear side so as to help the penetration of defenses for the Mission 1 concept or to be able to regain velocity and altitude after low altitude dive for the Missions 2 & 3 concepts.

In order to reduce masse and complexity of the vehicle, it is preferable to use the same propellants for the two Reaction Systems. The additional reaction engines are imposing to consider storable hot gas propellants technology. Joint tanks and GGs (Gas Generator) located at the lateral sides of the payload will be designed. The nozzles of the RES will be in the prolongation of the GGs by emerging from the rear side. The nozzles of the RCS will be rather located on the extreme lateral parts of the rear side.

- Actuators of Control surfaces: The actuators of the control surfaces will be electromechanical actuators which electronics could be deported inside the Flight Control electronic box. They will be located at the extreme lateral sides of the vehicle.

## 5. Conclusion

The first months of ALBATROS project were dedicated to a review of past concepts, a high level definition of potential missions including an assessment of their interest and technical challenges, and an introduction to main technological choices.

The next year will be dedicated to a deeper definition of the different missions by detailing the potential payloads, their specifications, and their constraints. A similar work should be performed for the internal equipment so as to refine the mass and volume of the items to be carried. This conceptual phase will end with a first conceptual design of the HGV allowing the generation of simplified trajectories for the different missions.

After the conceptual phase, it is planned to continue with an optimized preliminary design resulting from a MDAO process. But this process will need to be enriched by fundamental and applied researches in three disciplines:

- Development and assessment of high temperature materials & structures including experimental characterization in representative environments
- Development of fast methods of planning, guidance, and optimization of trajectories
- Multi-fidelity aerothermodynamics including experimental tests in the high enthalpy hot shot wind tunnel F4 in ONERA Le Fauga and the cold rarefied continuous wind tunnel MARHY in CNRS Orleans

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