

Abstract

Hyplane: Sub-orbital Easy and Common Access

G. Russo^{1,3*}, R. Savino^{2,3}, D. Pisanti³, M. Saviano³, F. Perrelli³

¹ Trans-Tech srl, via Palizzi 107, 80127 Naples, Italy

² Dip. Ingegneria Industriale, Univ. Federico II, Piazzale Tecchio 80, 80125 Naples, Italy

³ Center for Near Space, via Jannelli 390, 80131 Naples, Italy

*gennaro.russo@trans-tech.it

HyPlane is a new concept of hypersonic transportation system conceived to offer access to stratospheric and space flights as safe, convenient and commonplace as today's commercial air transportation, by integrating state-of-the-art aeronautic and space technologies.

The mid-to-long term perspectives of point-to-point hypersonic flight is based on the availability of winged vehicle configurations, characterized by low wing loading and able to maneuver along the flight trajectory at small angles of attack. These vehicles fly at very high altitudes (when compared to conventional airplanes) in order to reduce the drag and to fly faster across intercontinental distances. In order to promote a commercial use of such kind of transportation, accelerations and load factors must be of the same order of those characterizing the present civil aviation aircrafts (FAA/EASA standards), for the intercontinental point-to-point flight.

From another point of view, the reduction of cost associated with sub-orbital space tourism flight is strongly conditioned by the still small dimension of its market. Therefore, combining this market with the one for point-to-point fast transportation is a clear way to cut dramatically operational costs and tickets price. It implies the utilization of a single vehicle design able to run both missions, even eventually accepting reduction in optimization for each of the two types of flights.

The design consists of a 6 seat ramjet-based hypersonic vehicle for a target trip of 7000 km in the frame of the "urgent business travel" market segment and/or for space tourism perspectives, tagged "HyPlane". A delta wing with relatively sharp leading edges is considered. A turbo-ramjet propulsion system is envisaged to sustain space tourism "multi-jump" flight, and vehicle configurations with relatively high lift-over-drag (L/D greater than 4) and low wing loading (in the order of 80-120 kg/m²) in order to guarantee very low operational load factor (around 1.1) along properly chosen point-to-point flight paths. The very same vehicle will experience acceleration less than 4.2 during the pull-up maneuvers associated with suborbital flight.

The project is fully based on already high Technology Readiness Level (TRL) technologies, in order to guarantee a sufficiently short time to market.

The possibility to provide frequent and affordable suborbital flight experiences can be a way to promote a cultural space-oriented perspective, by developing a more concrete awareness of the opportunities offered by the "Fourth Environment".

A business plan has been studied based of typical industrial approach, considering both the manufacturer and the operator points of view over a typical twenty-year life-cycle scenario. The main results are summarized as follows.

BUSINESS PLAN SUMMARY (conservative)

- Reference time frame: 20 years
- Number of units:
 - ❖ 14500 new BJ, of which 25% SBJ
 - ❖ If the purchasing cost is 80-100 M€, HBJ can take over at least 14% of the SBJ market
 - ❖ A mean of some 1000 passengers captured by Hyplane for space tourism over 20 years
 - ❖ So, HYPLANE will capture 20% of both markets → **102 units** from SBJ/HBJ + **10 units** from space tourism in 20 years
- HYPLANE selling price:
 - ❖ **80 M€** (SBJ=60 M€, BJ=5-55 M€)
- Development cost (NRC) = **2 B€**
- Production cost of one vehicle (RC) = **40 M€**
- Operating cost:
 - ❖ P2P = **28 k€/flight** ❖ TS = **155 k€/ flight**
- Ticket price = 10 (P2P) and 50 (ST) k€ (→ 50-250 k€/day, 6-32 k€/hr)
- Break Even Point between **8 and 11 years** depending of financial approach.

Space Exploration technologies / products / services: *describe which space exploration technologies are being exploited to solve a specific problem via a product or service.*

The project exploits state-of-art airplane aerodynamic and propulsion technologies to obtain a hypersonic vehicle for space tourism and for urgent business travel or fast cargo transportation.

HyPlane is a 6-8 seat small size spaceplane, whose design is defined by the interplay of aerodynamics, atmospheric heating, materials and structures, propulsion, fuel selection, cabin, tank and subsystems sizing.

The cabin environment is designed to maintain a comfortable temperature and pressure for the passengers, while providing an excellent view of the Earth from Space. The cabin will have an automatic changing system to guarantee easy transformation from a typical top-class business to a fully free for buoyancy configuration.

A 140 m² aerodynamically efficient double swept delta wing with relatively sharp leading edges and a vertical tail are considered to provide good flight characteristics both in subsonic and super/hypersonic regimes. The aerodynamic configuration is characterized by high lift-over-drag ratio ($L/D > 4$) and low wing loading factor (80-120 kg/m²) in order to guarantee very low operational load conditions along properly chosen stratospheric point-to-point flight paths.

The high performing large surface wing represents a great advantage with respect to similar spaceplanes by allowing the vehicle to take off and land at relatively low velocities. It also reduces the aerodynamic heating and the effect of the sonic boom that still represents one of the main problems associated with high speed flight, so the overall environmental impact of the vehicle is minimized.

HyPlane, powered by two Turbine Based Combined Cycle engines, will perform Horizontal Takeoff and Horizontal Landing on short length runways (less than 1000 m), by exploiting the lift forces resulting from the relatively large wing surface.

The spaceplane design is consistent with both:

- hypersonic cruise transportation over more than 7000 km transcontinental distances with a cruise speed of Mach 4.5 and a peak velocity as high as Mach 5;
- point-to-point suborbital parabolic flights, to exploit suborbital space tourism “multi-jump flights”, during which the vehicle will experience max accelerations around 4.2g during the pull-up manoeuvres, thanks to a new approach characterized by relatively low flight path angles, providing the sensation of weightlessness for some minutes.

Business opportunity: *describe your business model in a nutshell: what is your competitive advantage.*

Most of the available hypersonic spaceplanes studies and designs refer to very large aircraft (even as long as 150 m) with a significant mass (3-4 hundreds of tons) and able to carry about hundred passengers, needing thus to take off and land from spaceports. Today only a limited number of spaceports are operating and others are in the developing phase. Due to the complexity of the technology systems, these projects seem to require very long time to be completed and introduced into the market.

The development of a small-sized spaceplane can represent a more viable solution towards comfortable civil hypersonic systems, also as the most adequate intermediate step towards future development of larger and most powerful vehicles. One of the HyPlane key advantages is the utilization of ordinary runways since spaceports need huge investments to be built that consequently lead to high fees and charges for the operators. It means that HyPlane operators will have significantly lower costs.

The correct potential marketplace for HyPlane is the combination of two markets: those referred to supersonic/hypersonic transportation and suborbital space flight. The first one is addressed in large part to the segment of urgent business travel for passengers as well as fast cargo transportation for special goods/products such as mail and express, pharms, valuables live, perishable, transcontinental organ transport. The latter refers to cheap and short duration microgravity activity as well as astronauts training, to which the leisure space tourism is added.

The combination of these two markets is a clear way to dramatically cut operational costs and ticket prices. It implies the utilization of a single vehicle design able to run both missions (point-to-point fast transportations and suborbital space tourism flights), even eventually accepting reduction in optimization for each of the two types of applications.

With a price of €80M (around \$100M USD) per vehicle, a potential demand of 507 supersonic / hypersonic jets in a time period of 20 years is estimated. On the bases of present supersonic and hypersonic jet proposals, it is assumed that around 20% of the market will be captured by HyPlane, that means 102 vehicle deliveries during a period of 20 years.

For space tourism missions a demand by operators of 10 vehicles in 20 years is prospected.

Target customer base: *describe the profile of your potential customer: public or private sector? organization or individual? local or global?*

About the potential buyers of a supersonic/hypersonic business jet (SSBJ/HSBJ) as HyPlane, several groups can be identified.

- **Fractional owner companies:** this way of acquisition consists in purchasing a “share” of the aircraft. The share of an owner corresponds to a determined amount of flight hours (consider 800 flight hours per year). In general, the owners pay a monthly fee to a company for the maintenance and management of the vehicle.
- **Governments:** it is common that the governments buy a fleet of jets for time saving reasons and prestige.
- **Private individuals:** they can buy a jet mainly for prestige reasons and for leisure travels. The vehicle efficiency is less important for them than other characteristics.
- **International/multinational companies:** large companies are interested in acquisition of a SSBJ/HSBJ in order to reduce the time for management transport with more direct access to the sites of companies and, in addition, they can use the business jet for meetings during flights. In addition, a business jet represents an element of prestige for the company and increases the company employees’ satisfaction of travel.
- **Research institutions:** customers could be research centres or University willing to exploit the HyPlane capability of being able to offer repeated suborbital microgravity conditions during one single flight, without limitation on launch site that is typical of other systems (launchers, sounding rockets and balloons, for examples). In fact, by taking-off and landing from some 80% of worldwide available runways (with length less than 1000 m), reaching a 30 km cruise altitude at Mach number 4-4.5 and realizing either up to three 70km suborbital parabolas or a single flight to the Karman line (100km), the spaceplane will guarantee easier and more frequent access to the “Fourth Environment” (i.e. the Space).

Development status and necessary enhancements: *what is the status of the development of the product of service? Are there any key alliance necessary? What improvements are to be made when it comes to the space exploration technologies?*

HyPlane analysis team includes a large number of Italian and European experts from Universities, research centres, small and medium enterprises as well as large industries, involved in system engineering, aerothermodynamics, propulsion, trajectory and performance analysis, materials and structural analysis.

The project is fully based on already high Technology Readiness Level (TRL) technologies in order to guarantee a sufficiently short time to market. By combining academic education, industry expertise and creative thinking, the HyPlane team carried out all necessary iterations to preliminary define vehicle configuration and performance, through the implementation of appropriate models and simulations.

In particular, CFD (Computational Fluid-Dynamics analysis) was carried out to determine preliminary aerodynamic performances of the HyPlane for different flight regimes and the engineering codes have been validated against experimental and numerical aerodynamic results available in literature over hypersonic configurations, including NASA experimental vehicles.

A reduced-scale model (1:25) has been realized too, by using additive manufacturing technologies, and it has been used to conduct wind-tunnel tests in the subsonic regime.

It is the case to mention that the Hyplane Project was already presented worldwide and defined as the Italian proposal for Space Tourism (see Treccani Encyclopedia, for example)

Benefits for citizens: *please describe how citizens will make us and benefit from your idea in their daily lives by providing concrete user stories.*

Point-to-point hypersonic transportation represents a key element for urgent business travel involving fast transportations of pharms, valuables live, perishable and transcontinental organ transport.

Regarding the space flight, HyPlane will be able to conduct specific mission profiles executing a series of 70km height suborbital jumps, each providing up to two minutes of reduced gravity. Alternatively, Hyplane will be able to reach the Karman line at 100 km altitude. During this period, passengers will be able to experience weightlessness conditions and to have a beautiful view of the Earth from the high stratosphere.

HyPlane will be also the only HTHL (Horizontal Takeoff and Horizontal Landing) sub-orbital vehicle able to provide users with the opportunity to execute microgravity research under repeated, relatively long duration conditions of weightlessness, offering ideal opportunity for precursor human, biological or physical research in preparation for long-duration missions onboard orbital space laboratories. In particular, this suborbital platform will be uniquely offering relatively extended duration of low-gravity conditions, typical of sounding rockets, together with a more flexible research approach, i.e. using typical laboratory-type instrumentation, participation of the research team on their experiments during flight, reusability. Moreover, Hyplane could develop in a mother suborbital spaceplane able to launch a payload to orbit with a small second stage rocket.

By taking-off and landing from some 80% of worldwide available runways, small reusable airplane-like vehicles for sub-orbital missions, such as HyPlane, could represent a first step towards a safer, more comfortable and less expensive Access to Space in the near future, therefore promoting the widespread of Civil Astronautics and Space Tourism. The possibility to provide frequent and affordable suborbital flight experiences could constitute a chance to enforce a cultural space-oriented perspective with the aim of developing a more concrete awareness of the opportunities offered by the "Fourth Environment".