SEZIONE ROMADUE
LUIGI BROGLIO
ASSOCIAZIONE ARMA AERONAUTICA

Hypersonic Bizjet: A multi-mission technology demonstrator

G. Russo (speaker), DAC Campania Aerospace District

G. Fusco (Aerosoft), M. Visone & M. Lanzetta (Blue Engineering), M. Giuliani (Caltec), M. Amato (CIRA), P. Ferraro & V. Pagliarulo (CNR-ISASI), G. Russo & C. Voto (DAC), V. Pisacane (Euro.Soft), A. Moccia & P. Dell'Aversana (Lead Tech), R. Vitiello & R. Molitierno (MBDA), G. Di Paola (Protom Group), A. Caraviello & D. Borrelli (Sòphia High Tech), S. Cardone (Tecnosistem), F. Monti (TSD Space), A. Viviani & G. Pezzella (Univ Campania «L. VANVITELLI»), R. Savino (Univ Napoli «FEDERICO II»)

3rd International Symposium on Hypersonic Flight

Air Force Academy (Pozzuoli), Italy, May 30-31, 2019

DAC Campania Aerospace District

DAC
Distretto Aerospaziale
della Campania

Content

BRONZE
Cluster Management Excellence
STRIVING FOR CLUSTER EXCELLENCE

- *Our Identity Card*
- *Working Group on Hypersonics*
- *Mid-to-long term perspectives - WG reference target products*
- *A possible mid-term solution*
- *Competence Maps and Development Roadmap*
- *Demonstrator, Research Infrastructures*

EACP
European Aerospace Cluster Partnership

CTNA
Cluster Tecnologico Nazionale Aerospazio
Italian Cluster for Aerospace Technology

SPIN-IT.EU
Space Innovation In Italy

SEZIONE ROMA DUE LUIGI BROGLIO
ASSOCIAZIONE ARMA AERONAUTICA

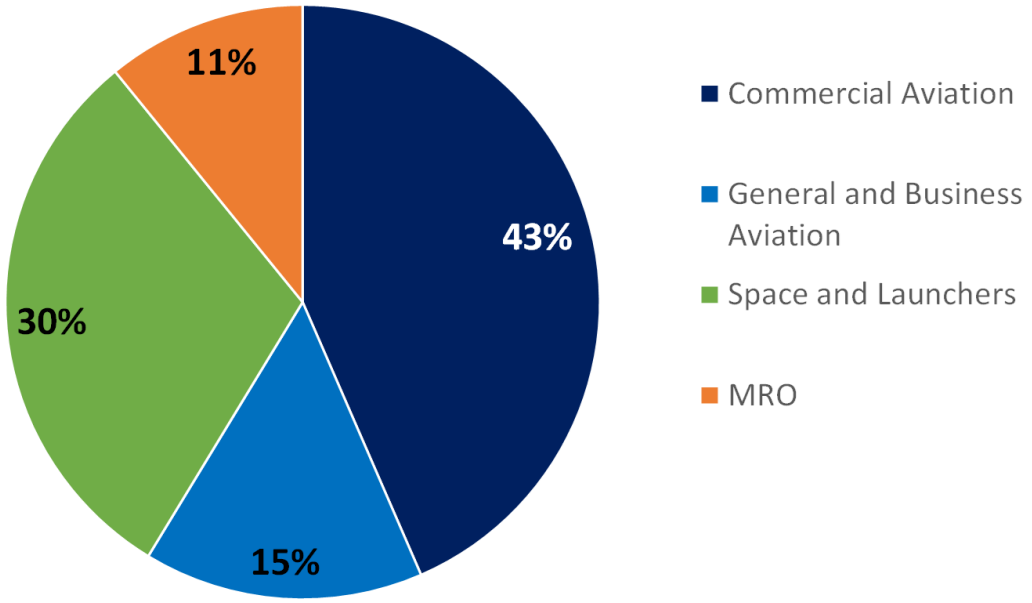
DAC: role and approach

DAC

The aerospace production chain is strategic for the Region with 12% investment in R&D. DAC is the second largest aerospace cluster in Italy, with a ruling industrial shareholdership

- *About 160 members, direct and indirect*
- *22 Large companies, 110 SMEs, 13 Research Centers, 5 Universities, other supporting entities*
- *13000 employees*
- *2.8 B€ revenue*

Enterprises for each DAC sector



Approach

"Industry first", i.e. short-to-mid term

"Best value for money"

Hypersonic Projects – National Initiatives

SPACEPLANE
Airbus

SKYLON
REL

SPACELINER
DLR

ZEHST
Airbus

flight

PHOENIX
Airbus

S3
Swiss Space

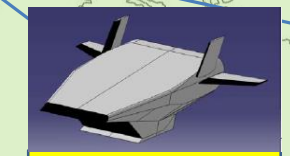
flight

SHEFEX I & II
DLR

flight

USV
CIRA

PHOEBUS
Univ Federico II



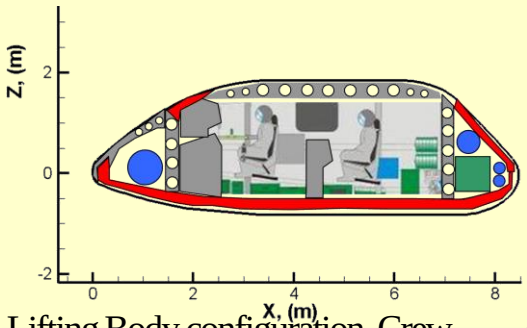
HYTAM
CIRA

HYPLANE
TRANS-TECH/
Univ Federico II

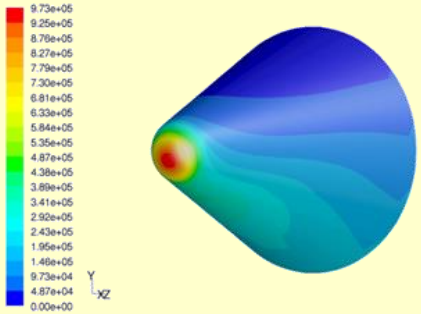
All born in Campania

Iceland
Sweden
Finland
Russia
Norway
Estonia
Latvia
Denmark
Lithuania
Ireland
United Kingdom
Russia
Belarus
Nether-lands
Poland
Germany
Belgium
Luxembourg
Czech Republic
Ukraine
Slovakia
Moldova
France
Switzerland
Austria
Hungary
Romania
Slove-nia
Croatia
Bosnia & Herz.
Serbia
Portugal
Italy
Montenegro
Kosovo
Bulgaria
Spain
Macedonia
Turkey
Albania
Greece

Hypersonic Projects – International Initiatives

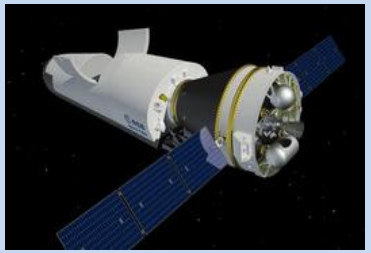
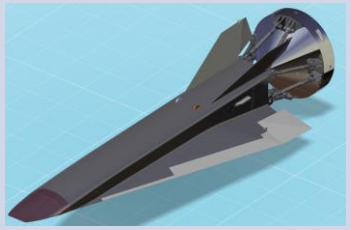


Lifting Body configuration. Crew Accommodation (*Univ Vanvitelli*)



Heat Flux on nose wall (W/m2)
USV nose cap – SIPROT (*Aerosoft*)

Campania participation

ACCESS TO SPACE	**EXPERT** 	**IXV** 	**SPACE RIDER** 
TRANSPOR-TATION	**LAPCAT 1 & 2** 	**HEXAFLY-INT** 	**STRATOFLY** 

Campania Research and Innovation Smart Specialization Strategy

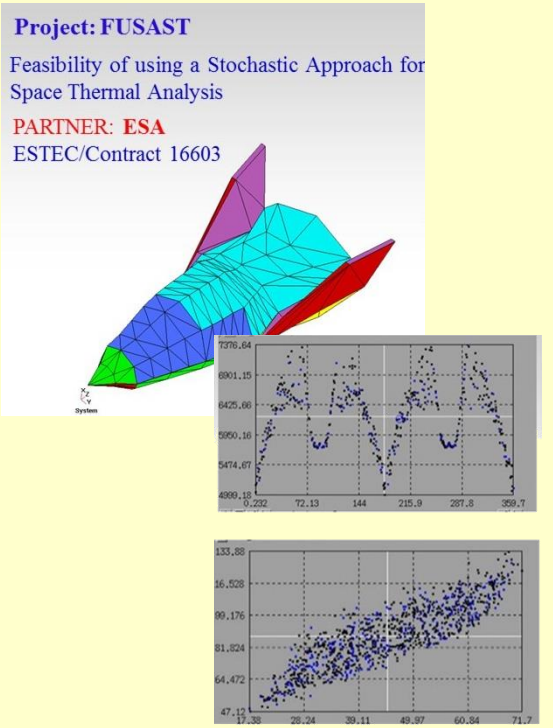
"… the premises exist for a characterization of Campania extending its traditional positioning in the field of Regional Transportation and General Aviation to that of the ***Business Aviation****, including innovation related to the implementation of* ***supersonic/hypersonic speeds*** *…"*

General Aviation

Regional Transportation

Hypersonic Business Jet

DAC Hypersonic WG



Reentry system thermal analysis (*Blue Engineering*)

A dedicated Working Group has been set up by DAC formed by:

Large Enterprises	***SMEs***	***Research Centers***
AEROSOFT	*CALTEC*	*CIRA*
BLUE ENGINEERING	*EURO.SOFT*	*CNR-ISASI*
MBDA	*LEAD TECH*	
	PROTOM GROUP	***Academia***
	SÒPHIA HIGH TECH	*Univ. Campania "L. VANVITELLI"*
	TSD SPACE	*Univ. Naples "FEDERICO II"*
	TECNOSISTEM	

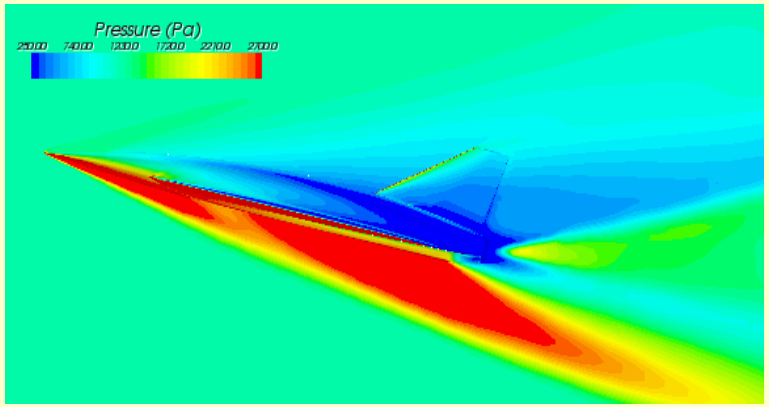
USV (*CIRA*)

DAC Hypersonic WG

Objectives

- Build-up a roadmap based on system study, on the basis of:
  - Regional scientific **tradition** and **background**
  - **Present activities** of its members
  - Specific "**reference target products**"
  - **Priority** technologies as much common as possible with respect to target products
  - Technologies that can reach **TRL 6 in some 5 years**
  - Target realization of a flight **demonstrator**
  - Consolidation of national and international **collaborations**

Supersonic air-to-air missile *(MBDA)*



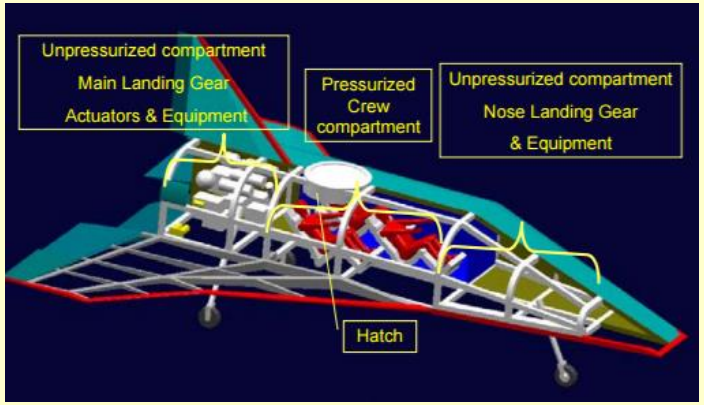
Hyplane pressure distribution at hypersonic speed (*Univ Napoli Federico II*)

DAC Hypersonic WG

Reference Target Products

1. Business jet for passenger/cargo transport

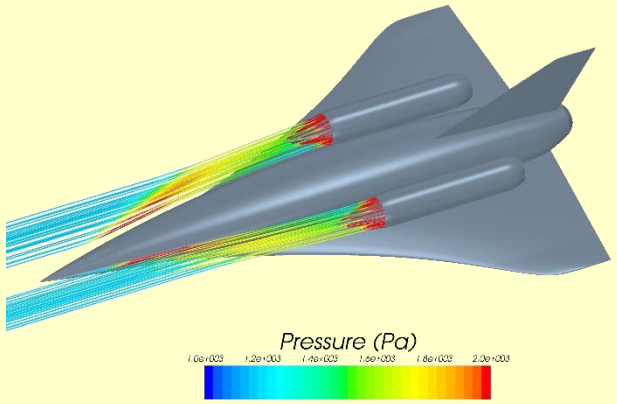
For P2P transportation. Single stage, air-breathing propulsion, low wing load, 6-10 pax, ≤Mach 4-5, low environmental impact propellant, CS25 certification and/or specific regulation



Phoebus, High-Lift-over-drag winged reentry spaceplane (*Univ Napoli Federico II*)

2. Suborbital spaceplane

For precursor microgravity experimentation and training, space tourism and access to space. Single HTHL stage, 6-10 pax or alternatively 600-1000 kg payload for small satellites launch to LEO, airbreathing-rocket combined propulsion, P2P flight capability (≈400 km downrange), not certified as a transport aircraft but in accordance with specific rules



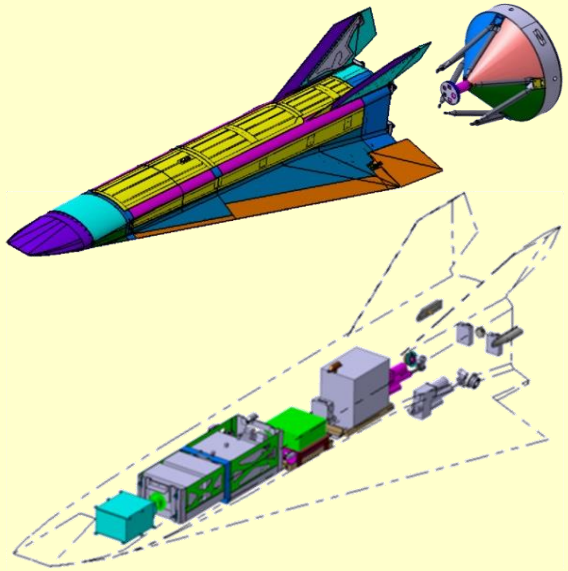
Hyplane, pressure along streamlines (*Blue Engineering*)

3. Manned or unmanned winged defense system

For defense/dual-use applications (surveillance, recognition, intelligence, transport), HTHL, ≤Mach 8

Perspectives

- **No doubt** about mid-to-long term perspectives of passenger-carrying hypersonic airplanes
- This **requires** ultra-fast, ultra-sleek winged vehicles, with low wing loading, streamlined fuselages, sharp nose and wing leading edges, able to maneuver along flight trajectories at small angles of attack
- Such kind of transportation requires accelerations and load factors of the **same order** as those characterizing the present civil aviation aircrafts (FAA/EASA standards)



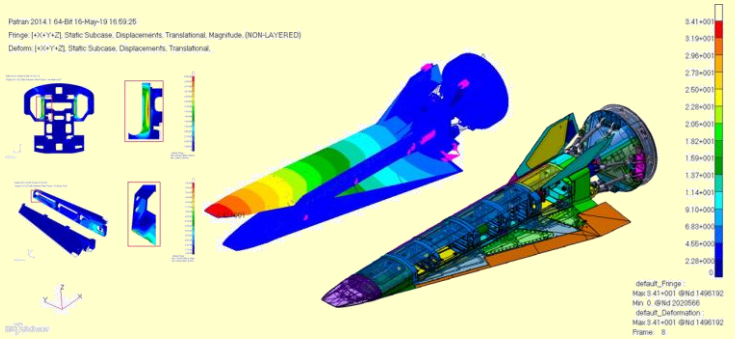
Hexafly-Int - *CIRA* is the project design authority

USV Avionic Subsystems (*TSD Space*)

Hypersonic P2P Transportation

- HTHL business-sized airplane for not too high speeds (≤ Mach 5) is **more affordable** than larger & faster hypersonic airplanes, in terms of both technology and market maturation
- Market analysis speculations **support** such a development, taking into account both military, commercial and institutional purposes
- It shall and can be based on **state-of-art almost available technologies**, e.g. titanium for structures and turbo-ramjet engines (instead of less proven scramjets required for faster aircrafts)

Hyplane concept development (*Trans-Tech*)



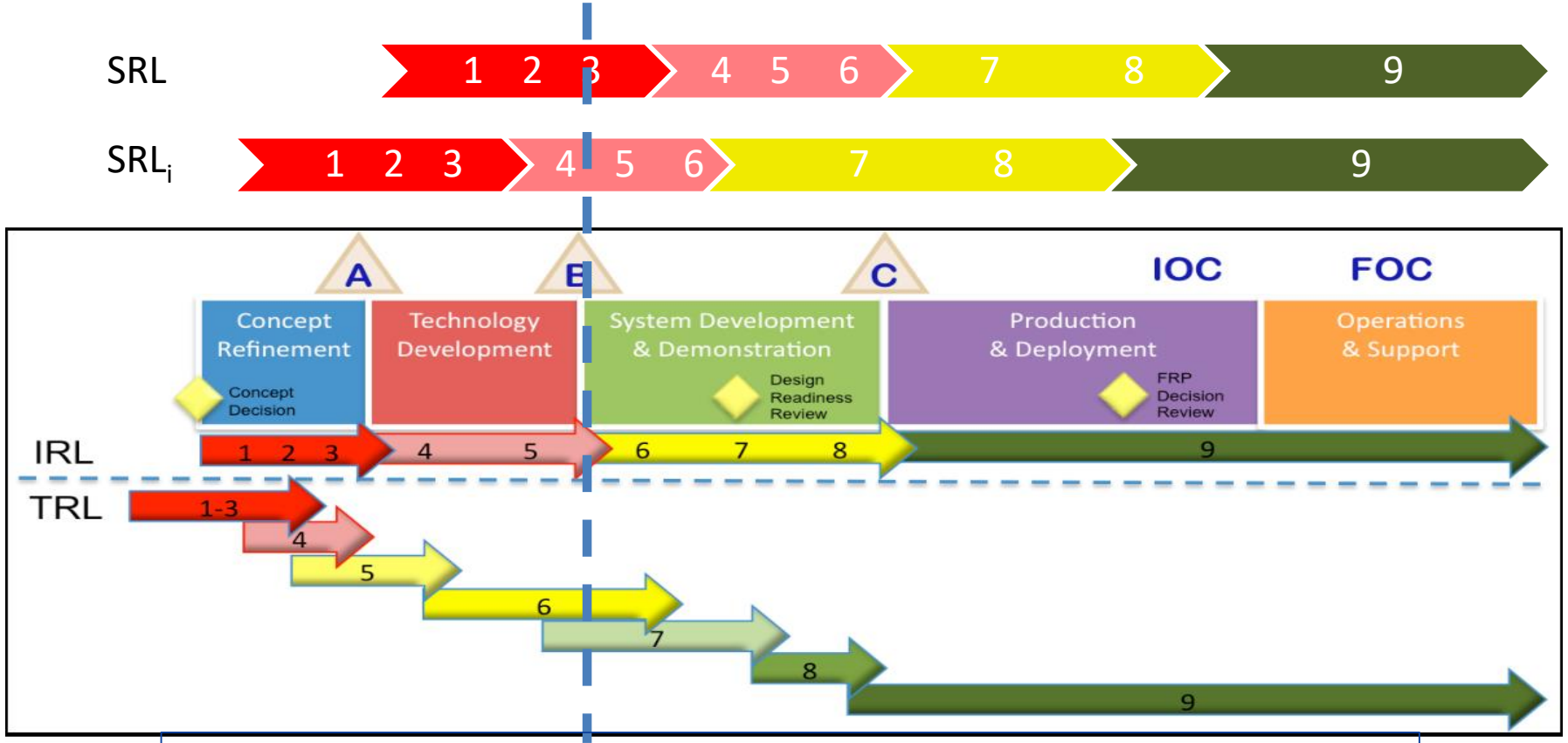
Design and analysis of structures of Hexafly-Int (*Tecnosistem*)

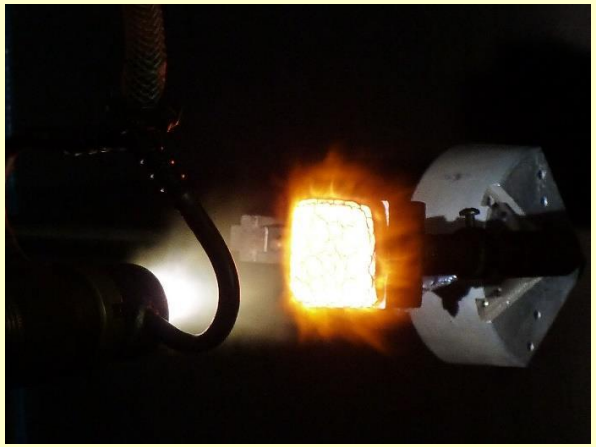
Technology Assessment alone is not sufficient to determine the maturity of a system

$IRL_{ij} = f(TRL_i, TRL_j)$

$SRL_i = f(TRL_j, IRL_{ij})$

$SRL = f(SRL_1, SRL_2, \ldots SRL_n)$





IXV tiles testing in SPES PWT (*Univ Napoli Federico II*)

IRL_{ij}	*Integration Readiness Level of technologies "i" and "j"*
SRL_i	*Sub-system "i" Readiness Level impacted by technologies "i" and "j"*
SRL	*System Readiness Level*

DAC Campania Aerospace District

Hyplane *(Trans-Tech, Univ Napoli Federico II)*

A possible concept

- 6-seats, Mach 4.5 spaceplane
- HTHL from 80% of available airports (L<1000 m) within the present set of governing rules
- Market:
  - Urgent Business Travel & Perishable Commodity Air Cargo
  - Micro-g Research, Space Tourism, Training, High-altitude Air-launch
  - Other

- may fly up to three sub-orbital parabolas to 70 km altitude or one to the Karman line
- or 7000 km point-to-point trajectories in less than 2 hours at a cruise altitude of about 30 km

TRANS-TECH
TECHNOLOGY TRANSFER and ENGINEERING SERVICES

Department of Industrial Engineering,
University of Naples "Federico II"

hyplane+

SEZIONE ROMA DUE LUIGI BROGLIO ASSOCIAZIONE ARMA AERONAUTICA

P2P Stratospheric Flight Scenario

20 km, Mach=2.5
Switch to Ramjet mode

Acceleration along a constant dynamic pressure trajectory

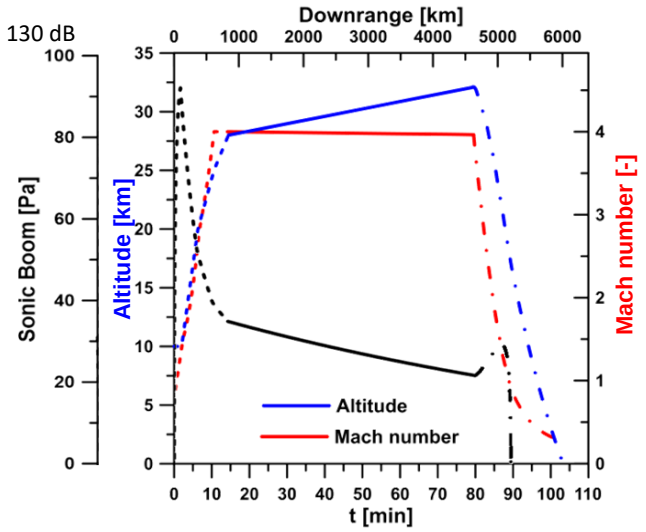
10 km, Mach=0.8

Horizontal take off

Cruise phase,
30 km, Mach=4.5
(Range >7000 km)

Descent and approach to terminal area

Horizontal landing

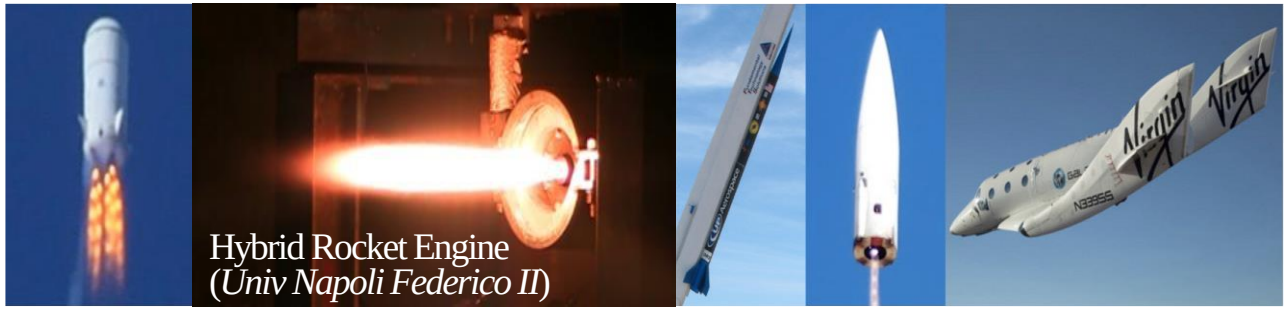


$$\Delta p = \frac{K W^{\frac{1}{2}} (M_0^2 - 1)^{\frac{3}{8}}}{M_0 H^{\frac{3}{4}}}$$

K	*from Concorde and Space Shuttle data*
W	*instantaneous weight*
Mo	*instantaneous Mach*
H	*instantaneous altitude*

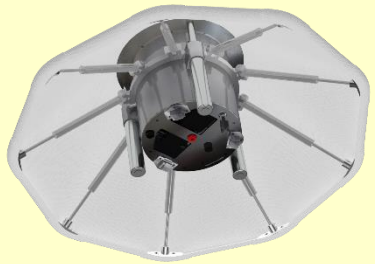
Suborbital Flight

- The increased interest for commercial space access is creating conditions for a **new spaceflight industry** to produce Suborbital Reusable Vehicles (SRV's)



- Suborbital space activities (e.g. micro-gravity research, technological demonstrators, space tourism) will be accomplished at **highly reduced costs**
- From another point of view, the cost associated with suborbital space access flight is strongly conditioned by the **still small dimension of its market** and accessibility to critical technologies
- Therefore, hypersonic technologies suitable for this market as well as for point-to-point fast transportation **can facilitate** the endeavor

Comparison of Space Tourism Vehicles



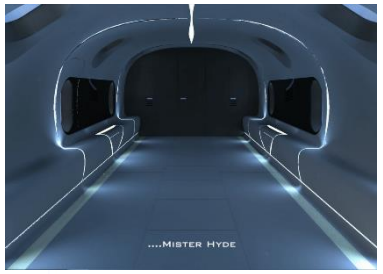
Mini Irene Demonstrator – Mechanical Design (*Lead Tech*)

Additive Manufacturing design and production of space systems components *(Sophia High Tech)*

IXV reentry vehicle - engineering participation (*CIRA*)

Comparison with Similar projects	HyPlane [IT]	SpaceShipTwo [USA]	Lynx [USA]	Spaceplane [FR]
				
Speed [Mach]	**Mach 4.5**	Mach 4	Mach 3.5	Mach 3.5
Max altitude [km]	100	**110**	70	100
Pax number	**6**	6	1	4
Downrange [km]	**1.500** (7.000 stratospheric flight)	56	n.a.	n.a.
Max acceleration [g]	**4.2** (better comfort)	6	4.5	4.5
Propulsion type	**Turbo-Ramjet** (green propellants)	"Hybrid " rocket (Mather aircraft support)	"Cryogenic" rocket	Turbojet + "Cryogenic" rocket
Take-off and landing site	**Any Civil Airport** (runway < 1000m)	Spaceports	Spaceports	Spaceports

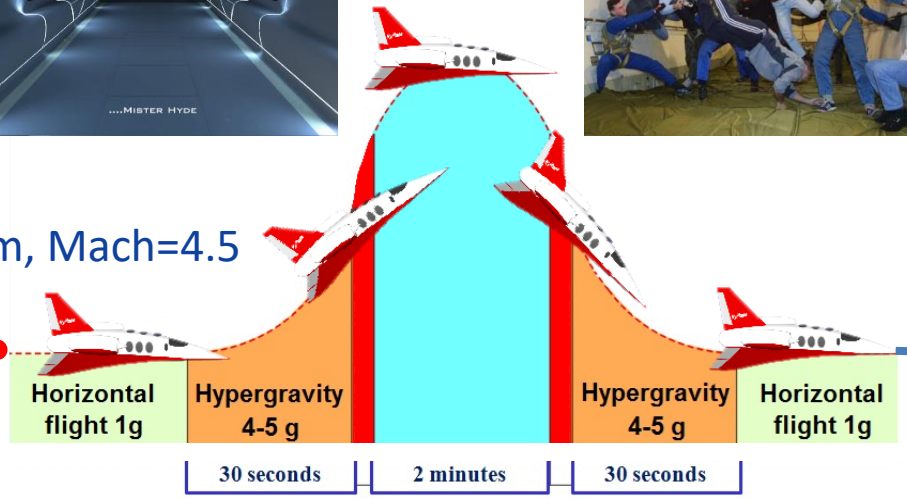
Suborbital Flight Scenario



Either 1 parabola at >100 km or up to 3 parabolas at ~70 km

30 km, Mach=4.5

20 km, Mach=2.5
Switch to Ramjet mode



Descent and approach to terminal area

10 km, Mach=0.8

>2.5 min Weightlessness per jump

Horizontal take off

Horizontal landing

Potential Market Size

The correct potential marketplace for Hyplane is the combination of two markets:

- **Supersonic/Hypersonic transportation**
- **Suborbital space flight**

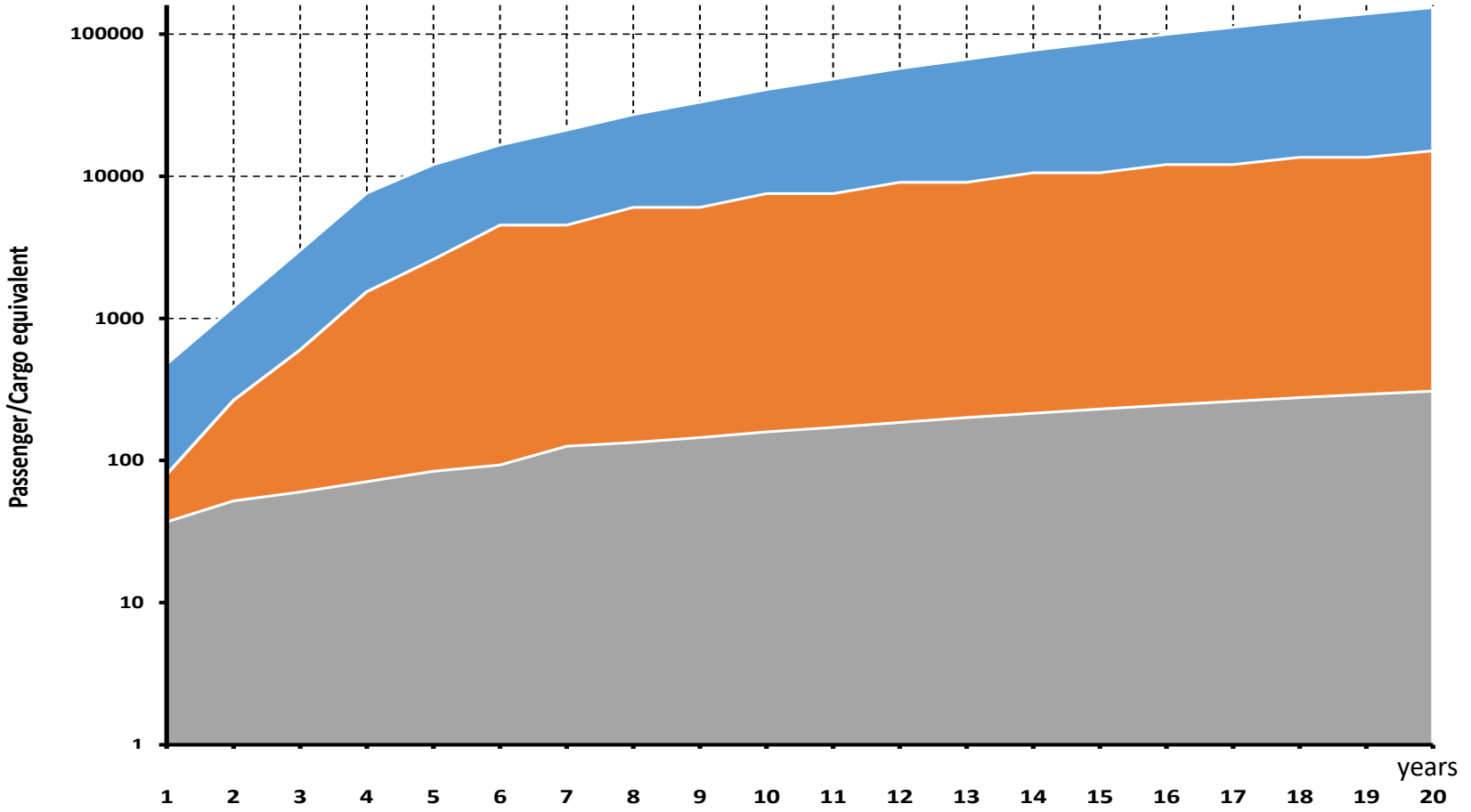
The first one addresses mainly the segment of urgent business travel for passengers as well as fast cargo transportation for special goods/products such as mail and express, pharms, valuables live, perishable, transcontinental organ transport

The second one refers mainly to space tourism, research, training & services.

Mini-Irene Flight Experiment, Mechanical parts (*Lead Tech*)

Digitalization processes and Virtual Reality (*Protom Group*)

Potential Market Estimate



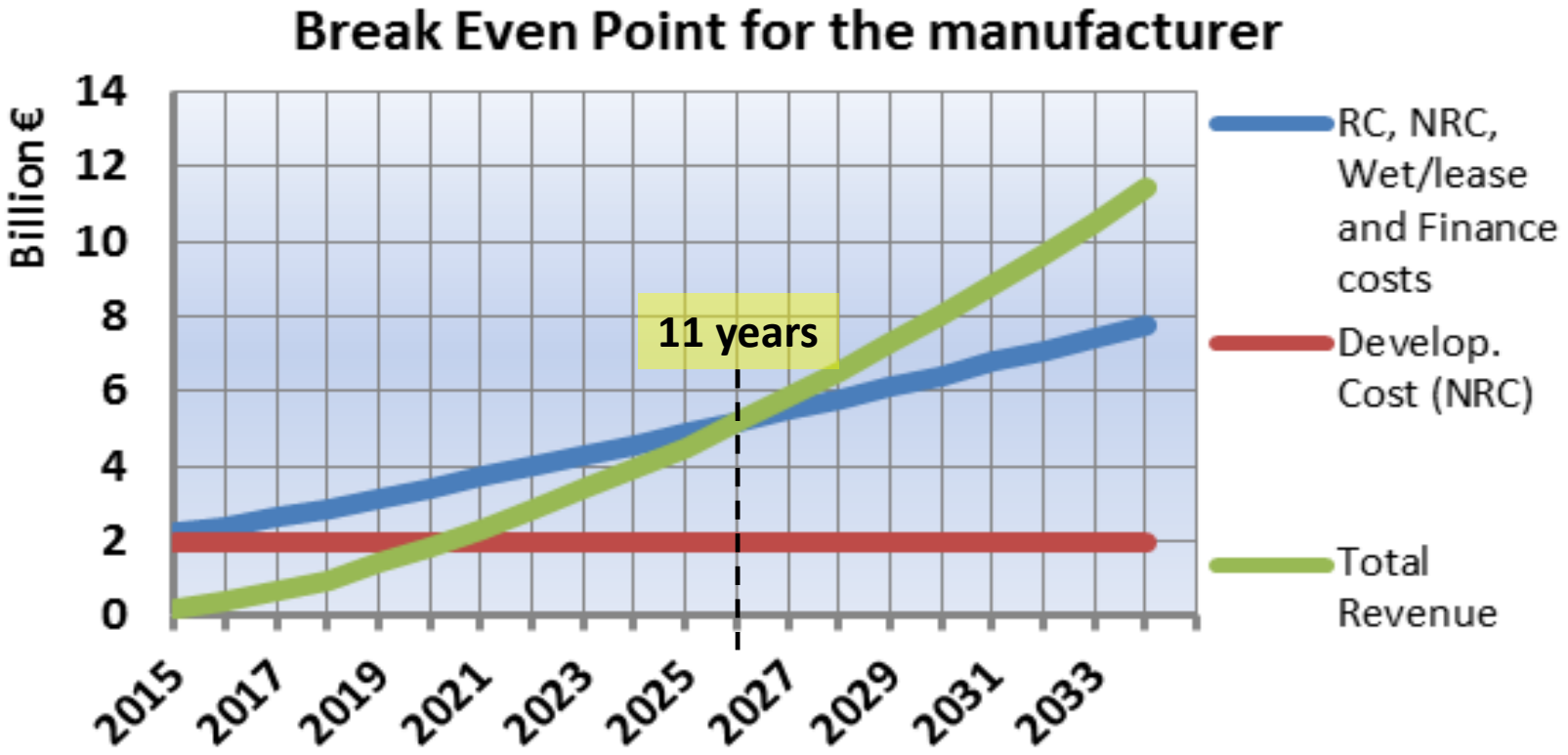
Source: FAA, Airbus, Boeing, GAMA, Bombardier et al. Analysis by Trans-Tech

P2P passenger/cargo transportation

Suborbital flight for experimentation, training and tourism

Others

Results of the Business Plan

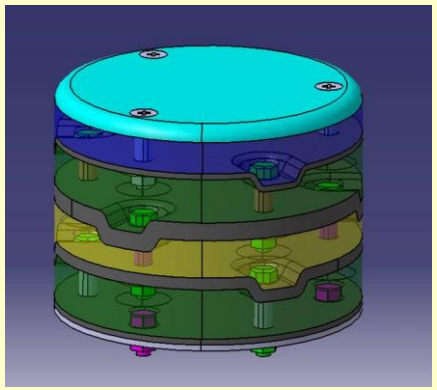


2 B€ development investment

10 B€ total life cycle cost

13.7 B€ total life cycle revenue

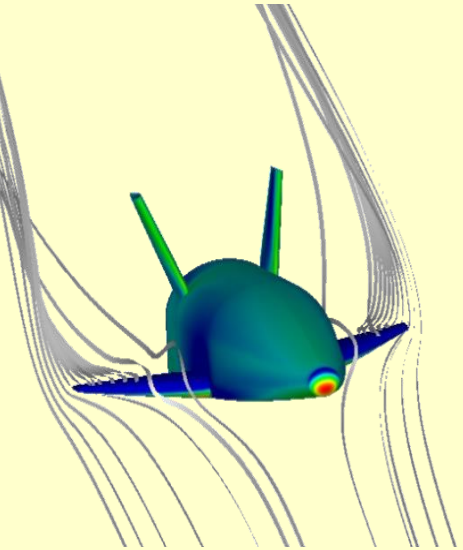
3.7 B€ total life cycle First Operating Margin (EBITDA)



Multi-layer_multimaterial SIPROT TPS (*Aerosoft*)

Defence and Dual-Use

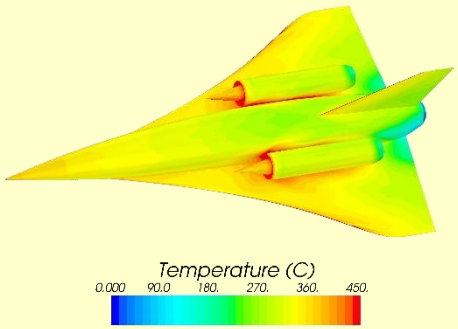
Supersonic/hypersonic radomes (*MBDA*)



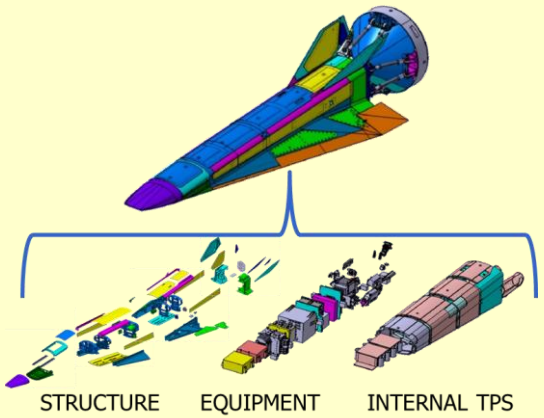
Hypersonic winged body configuration (*Univ Vanvitelli*)

- The need to protect an area from possible threats **coming from very high altitudes or even space** is acquiring stronger and stronger relevance:
  - Global deployability
  - Prompt global strike
  - Enemy defense suppression
  - Operational responsive space access

Defence and Dual-Use



Hyplane surface temperature (*Blue Engineering*)



Structural Design and equipment accommodation of Hexafly-Int (*Tecnosistem*)

- **Rapid reach** of a military theater or interception of very fast intruders in the air space are acquiring higher priority for air forces:
  - Surveillance
  - Recognition
  - Intelligence
  - Transport

Hyplane military configuration *(Trans-Tech)*

Technologies

- Large windshields
- Eventual substitution/ integration of windows with artificial vision

Primary hot structures:
- Titanium: thermal expansion issues, joints and couplings with other materials
- Composites: high temperatures

Inlet:
- Optimal dimensioning
- Materials
- Center body optimal movement and control

Stability and control:
- Center of pressure displacement management
- Flight qualities

- Radar transparent materials
- More performant radar

- Large and more numerous windows
- Eventual substitution/ integration of windows with artificial vision

Vehicle configuration:
- Multidisciplinary Optimization
- Sonic boom reduction

- Wing thermo-structural design

- Aerodynamics in a wide range of speed and altitude
- Wing profile optimization
- Wing optimization (plant shape, area, dihedral angle, …)

- Local Aerothermodynamics

Air Turbo-Ramjet or SERJ:
- Thermodynamic cycles
- Preliminary design
- Materials
- Low emission or green propellants

Endoreactor (booster):
- Hybrid propulsion
- Low emission or green propellants

Build up the Roadmap

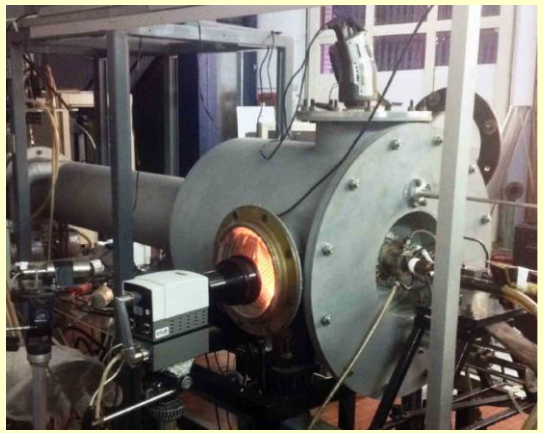
Step 1
- Freeze top requirements from reference target projects

Step 2
- Identify (common) high-TRL available technologies

Step 3
- Set up collaborations and work sharing

Step 4
- Bring selected technologies at adequate TRL

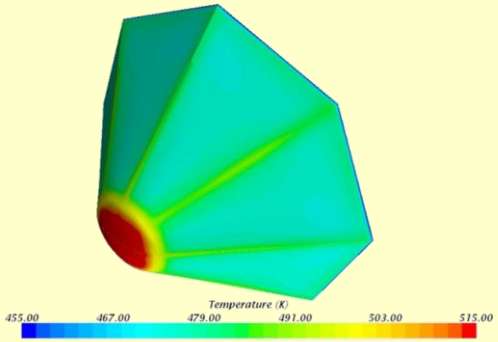
Step 5
- Develop the demonstrator



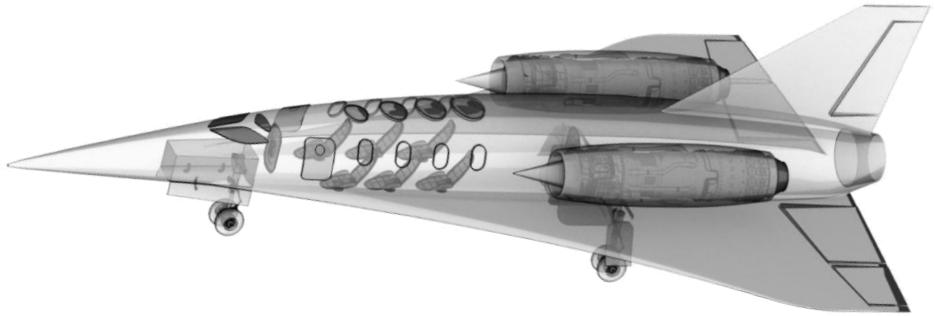
SPES PWT
(*Univ Napoli Federico II*)

Proposed Demonstrator

- Aerostructure: titanium baseline
- Propulsion system: twin EJ200 turbofan (from Eurofighter) + rocket booster
- People on board: one experimental pilot
- Target missions: A) 1 suborbital jump up to 100 km with 300 km downrange
  B) < 1.000 km stratospheric flight
- Development cost: ~1/10 of full development costs, i.e. ~200 M€
- Development time: ~4 years
- Operations: from Grottaglie or from the Suborbital Experimental Polygon



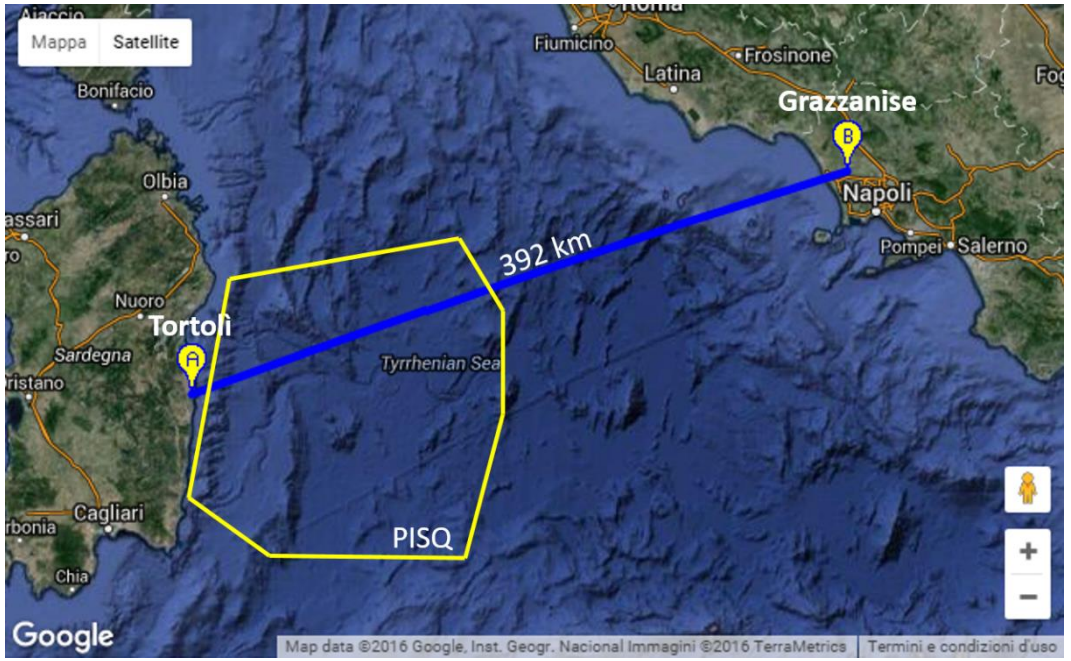
Deployable Structure Technology
(Univ Napoli Federico II)



Suborbital Experimental Polygon

DAC is supporting the development of ***Grazzanise military airport*** *to become an experimental safe spaceport. Furthermore, DAC is promoting the development of the* ***Suborbital Experimental Polygon*** *combining Grazzanise with PISQ (inter-forces polygon of Salto di Quirra) and Tortolì or Decimomannu airport in Sardinia.*

This Suborbital Experimental Polygon will make available the perfect operational scenario where to test and make use of the hypersonic demonstrator.



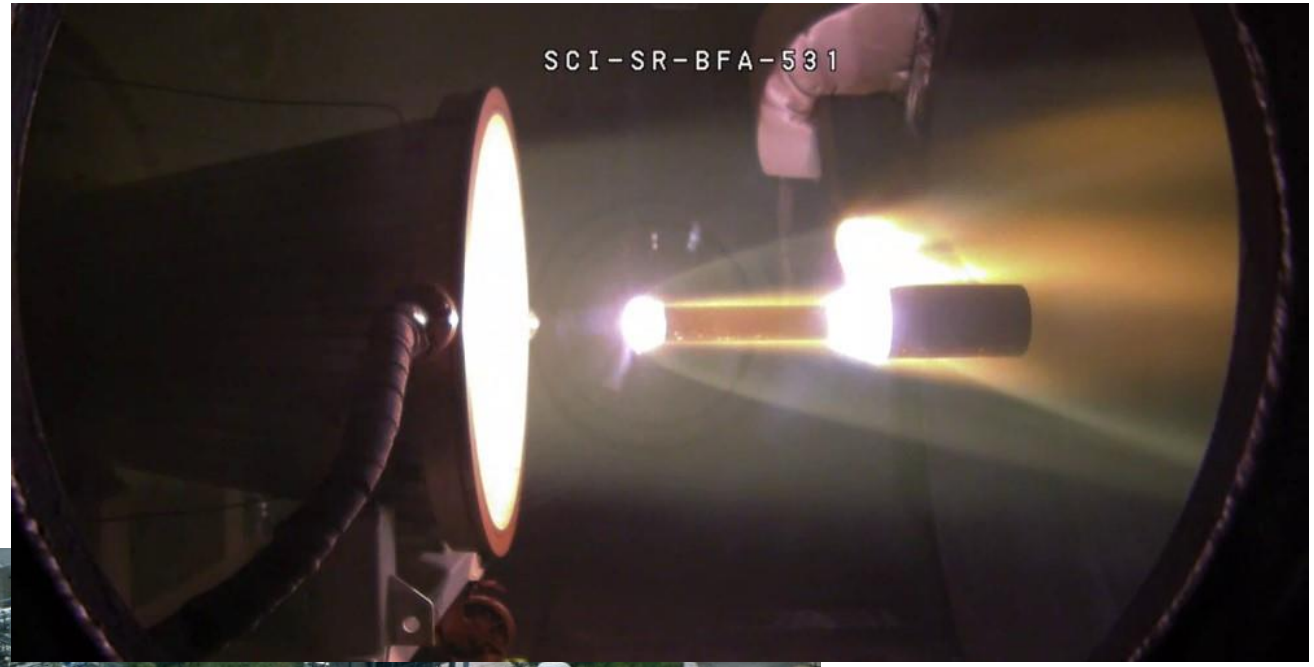
Grazzanise Safe Spaceport

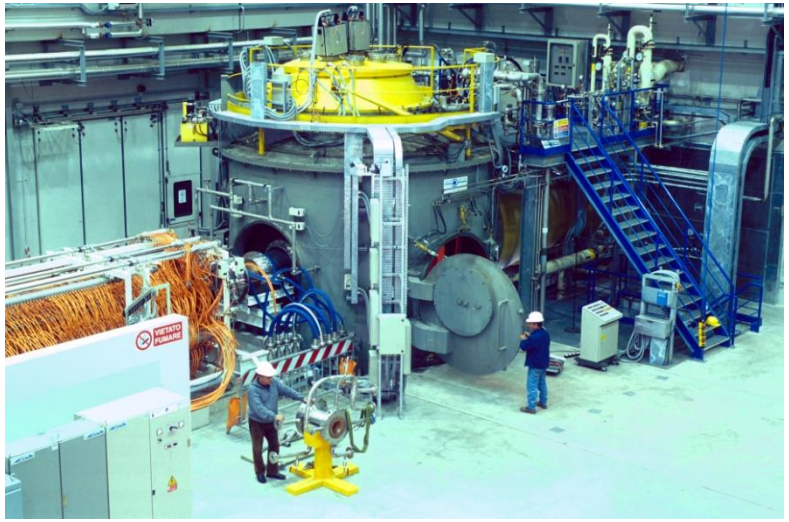
ICAO Indicator: LIRM
2990 x 30 m airway
ATS Authority: Italian Air Force
Special Rules for VFR Traffic: see ENR 6.3-9
Less than 10 km away from the sea
Few and scattered habitations

Ground Facilities

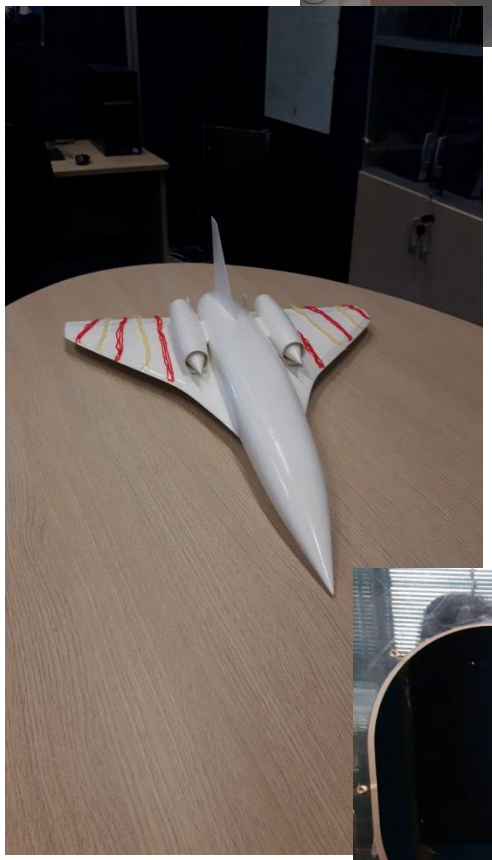
70 MW PWT Scirocco of CIRA

- Modification to test hypersonic propulsion systems





Thank you for the attention!



A special thank to the students and young engineers groups

RESERVE

Market Estimate for a Hypersonic Civil Airplane (HCA)

First class - decreasing since years:

1980: 5%; 1990: 2% *Today <0.2% ➔ 3 million pax/yr.*

Business class – Most of the old first class passengers are today business class customers, representing *20% ➔ 330 million pax/yr.*

Concorde (up to 2003) - *0.01% ➔ 150.000 pax/yr.; 80% business + 20% High Net Worth Individuals*

Assuming the HCA will be chosen by 10% of first class travelers + all Concorde wealthy passengers + 10% Concorde business passengers ➔ 342000 pax/yr. (i.e. 0,16% of Premium class) ➔

some 950 pax/day

The HCA market is too low for an aircraft of the class of hundreds tons MTOW and/or hundred passengers!

Ticket price would have to rise by at least 5X Concorde ➔ >100000€!

Market Estimate for a Hypersonic Business Jet (HBJ)

First class - decreasing since years:

1980: 5%; 1990: 2% *Today <0.2%* ➔ *3 million pax/yr.*

Business class – Most of the old first class passengers are today business class customers, representing *20%* ➔ *330 million pax/yr.*

Concorde (up to 2003) - *0.01%* ➔ *150.000 pax/yr.; 80% business + 20% High Net Worth Individuals*

5% of Concorde passengers are willing to pay up to € 80,000 a ticket for a hypersonic point-to-point journey (Webber, 2012)

Assuming conservatively the HBJ will be chosen by 10% Concorde business passengers + all Concorde wealthy passengers ➔ *42.000 pax/yr.* ➔

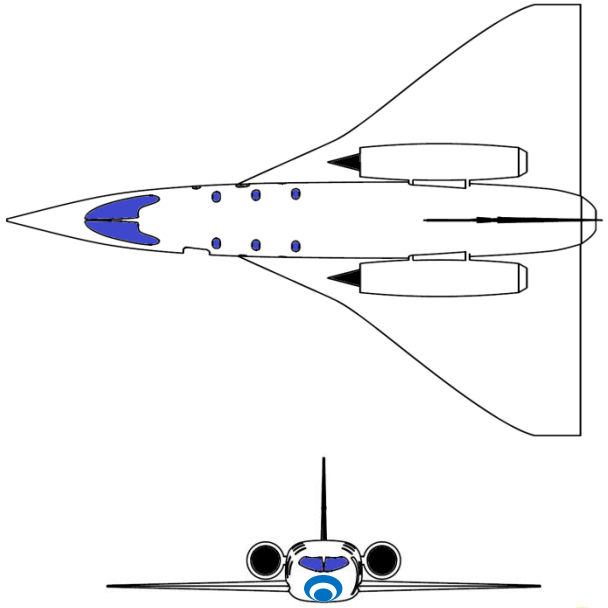
100-150 pax/day

Potential buyers could be:

- *Fractional owner companies*
- *Private individuals*
- *International/multinational companies*
- *Governments*

Business Plan Summary

- Reference frame: time 20 years and 1/5 market share
- Number of units per Market typology:
  - ✓ **102 units** from SBJ/HBJ
  - ✓ **10 units** from suborbital space tourism, research, training & services
- Development cost (NRC) = **2 B€**
- Production cost of one vehicle (RC) = **40 M€**
- HYPLANE selling price = **80 M€**
- Operating cost: **28 k€/ P2P flight** **155 k€/STflight**
- Ticket price : **10 k€** (P2P) **50 k€** (ST)



DAC – Campania Aerospace District

THE PRESENT FOR THOSE DESIGNING THE FUTURE