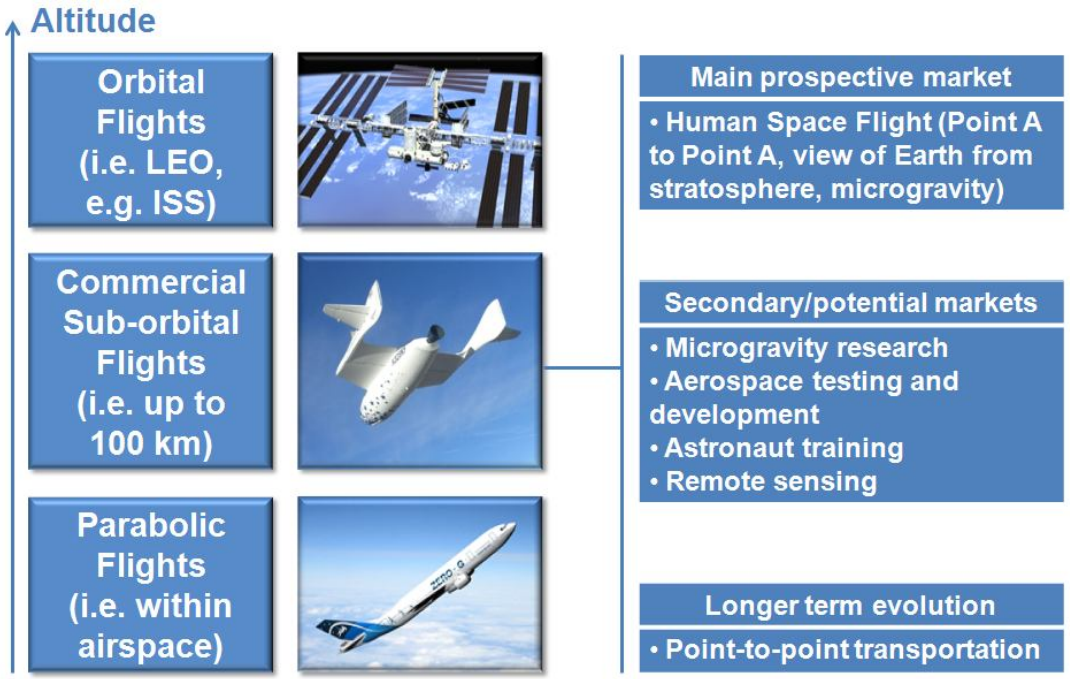
HYPLANE - Small HYpersonic airPLANE for Space Tourism and Point-to-PointTransportation

RAFFAELE SAVINO, SR ITALIA

From sub-orbital to orbital commercial transportation

Examples of small reusable airplane-like vehicles (Scaled Composite SS1, SS2, BSP Ascender, EADS spaceplane, XCOR Lynx) are being developed to perform sub-orbital missions, which could represent a first step towards a safer, more comfortable and less expensive access to Space in the near future



SPACE ACCESS and AIR TRANSPORT SYSTEMS of the FUTURE

- **Hypersonic speed**
- **High altitude**

- **Re-usability**
- **Airline-like operational paradigm**

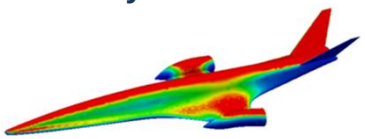
- **Impressive gains in airline productivity**
- **Order of magnitude reductions in cost of access to space**

Long-term vision for future access-to-space and hypersonic transportation

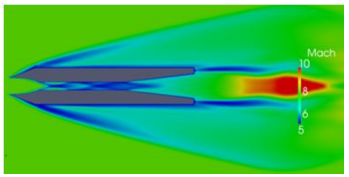
Many problems still to be solved:

Trajectory selection
Periodic cruise
Multi-staging
Off-design optimization
Transonic drag
Landing/takeoff
Guidance and Control

Engine/airframe integration
High efficiency inlet
Starting/unstarting
Unsteady flows



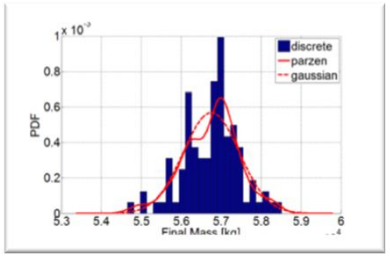
Finite-rate chemistry
Fuel selection and handling
Piloting and enhancers
Nozzle reactions
Engine/attitude coupling



Engines, combined cycles
Internal flows
Fuel injection and mixing
Multimode operation
Plasmadynamics/MHD

Leading edge physics
Shock location
Off-design aerodynamics
Aeroelasticity
Sharp leading edge heating/cooling
Advanced materials/TPS
Plasma and telemetry
Sensing and communication
Navigation and guidance
Boundary layers – transition, etc.
Surface interactions (roughness)

Coupled Optimization
Operability
Health monitoring
Testing and Evaluation



The University of Naples "Federico II", under the eagis of the Space Renaissance (SR) Italia Space Tourism Program and with the support of other Universities and small and medium enterprises, is investigating a new vehicle concept for long-duration space tourism missions and hypersonic point-to-point transportation

Bristol Spaceplanes Limited

DAC Distretto Aerospaziale della Campania

Centre for Future Air-Space Transportation Technology

TRANS-TECH TECHNOLOGY TRANSFER and ENGINEERING SERVICES

PIAGGIO AERO

blue Group Engineering & Design

Geven

DESA engineering

Bauhaus Luftfahrt Neue Wege.

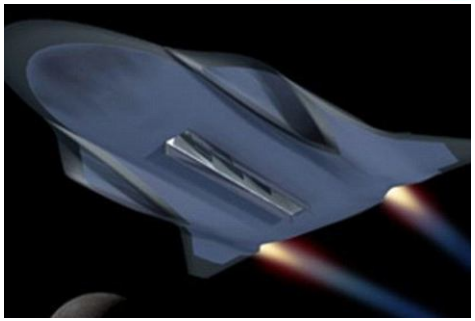
Slot Consulting

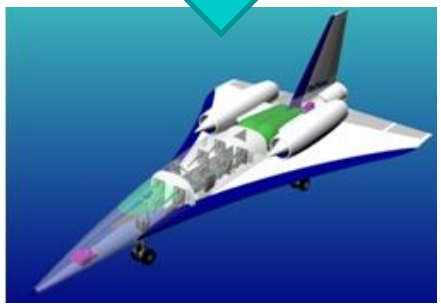
DLR

SAPIENZA UNIVERSITÀ DI ROMA

HyPlane Programme

- Previous supersonic or hypersonic commercial designs tended toward large aircrafts, characterized by hundreds of tons of mass and hundreds of passengers





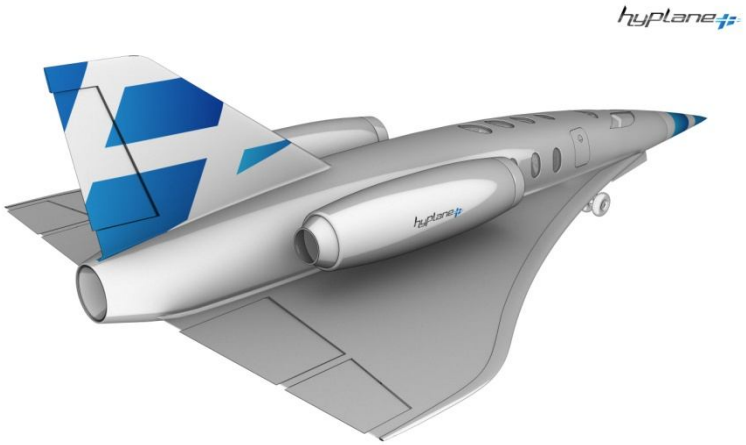
- A small passenger hypersonic plane (six seats, 5000-6000 Km range in less than 2 hours, horizontal takeoff and landing on small airports) may offer access to stratospheric and space flights as safe, convenient and commonplace as today's commercial air transportation, **by integrating state-of-art aeronautic and space technologies** and represent a first step towards the development of larger and more complex systems, but at the same time may open new markets and applications

A personal HYpersonic airPLANE

Space Tourism 2.0

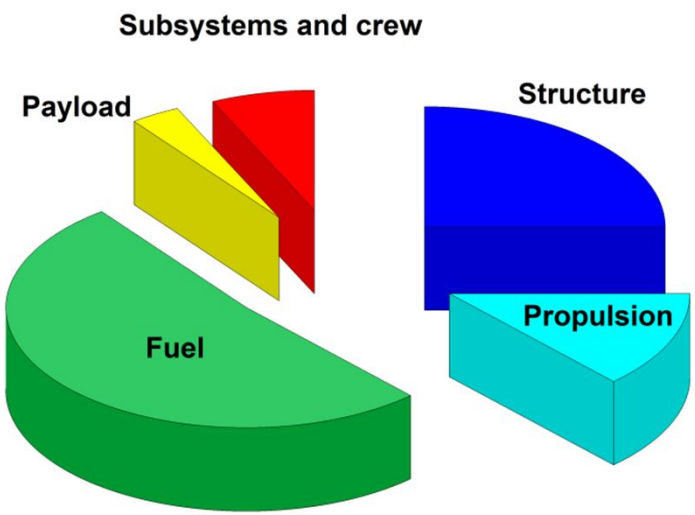
- can fly a series of Space Tourism parabolas at max altitude above 70 km
- 6000 km distances in less than 2 hours with cruise altitude at about 30 km
- **integrates state-of-art aeronautic and space technologies**

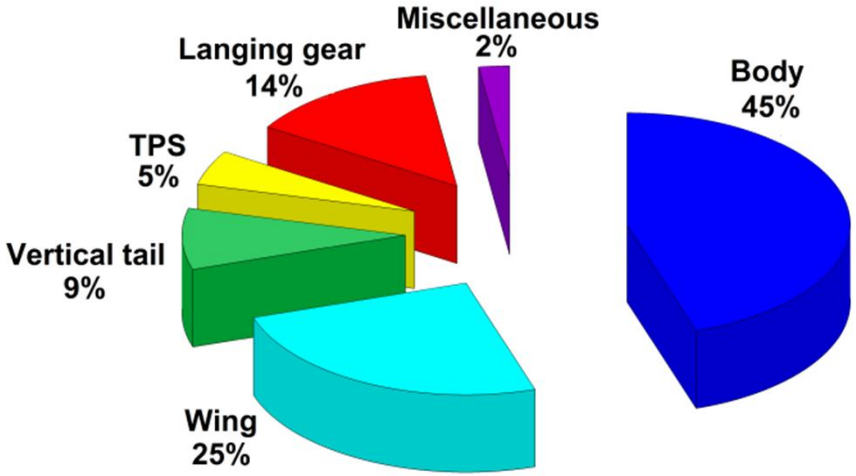
- 6-seats small Mach 4-4.5 spaceplane
- HTHL within the present rules governing common airports
- Urgent Travel market segment
- Space tourism
- Future reusable first stages of air-breathing space-access vehicles



System configuration

- Conceptual design defined by complex interplay of aerodynamics, atmospheric heating, materials and structures, propulsion, fuel selection, cabin configuration, tank and subsystems sizing
- Powered by combined cycle engines, turbo-ramjet plus rocket
- Horizontal Takeoff and Horizontal Landing (HTHL) from some 80% of worldwide available runways (L>1000 m)
- 25 t Gross Take Off Weight

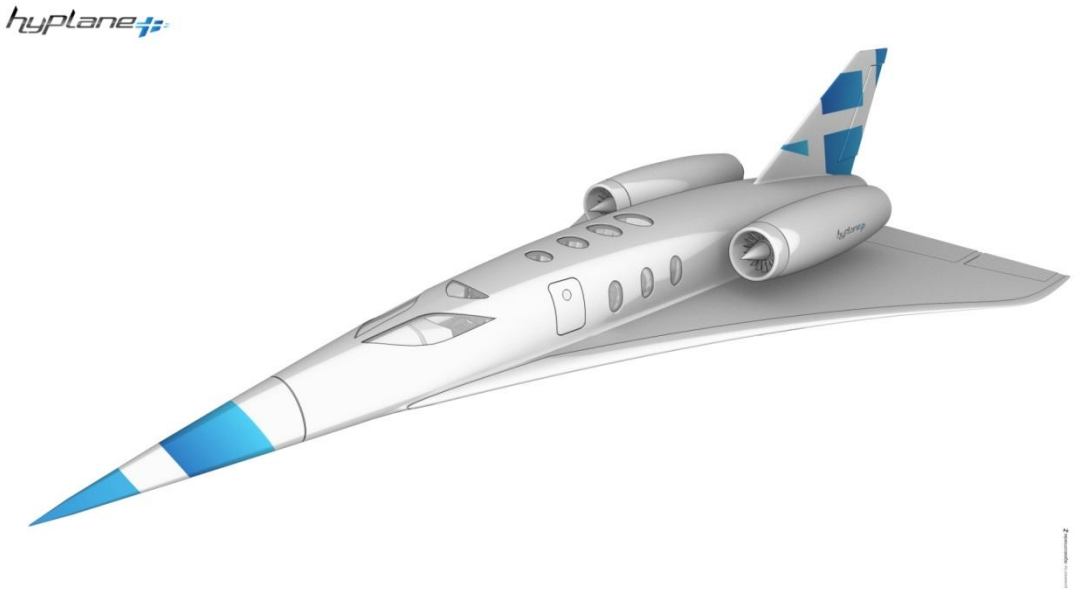


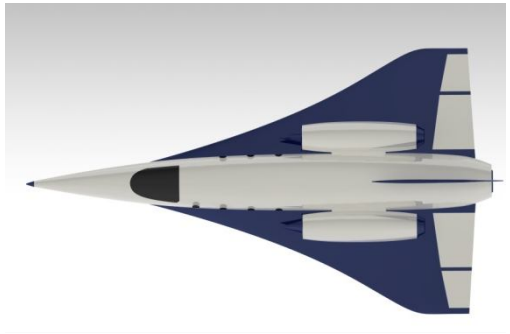


Structural mass breakdown

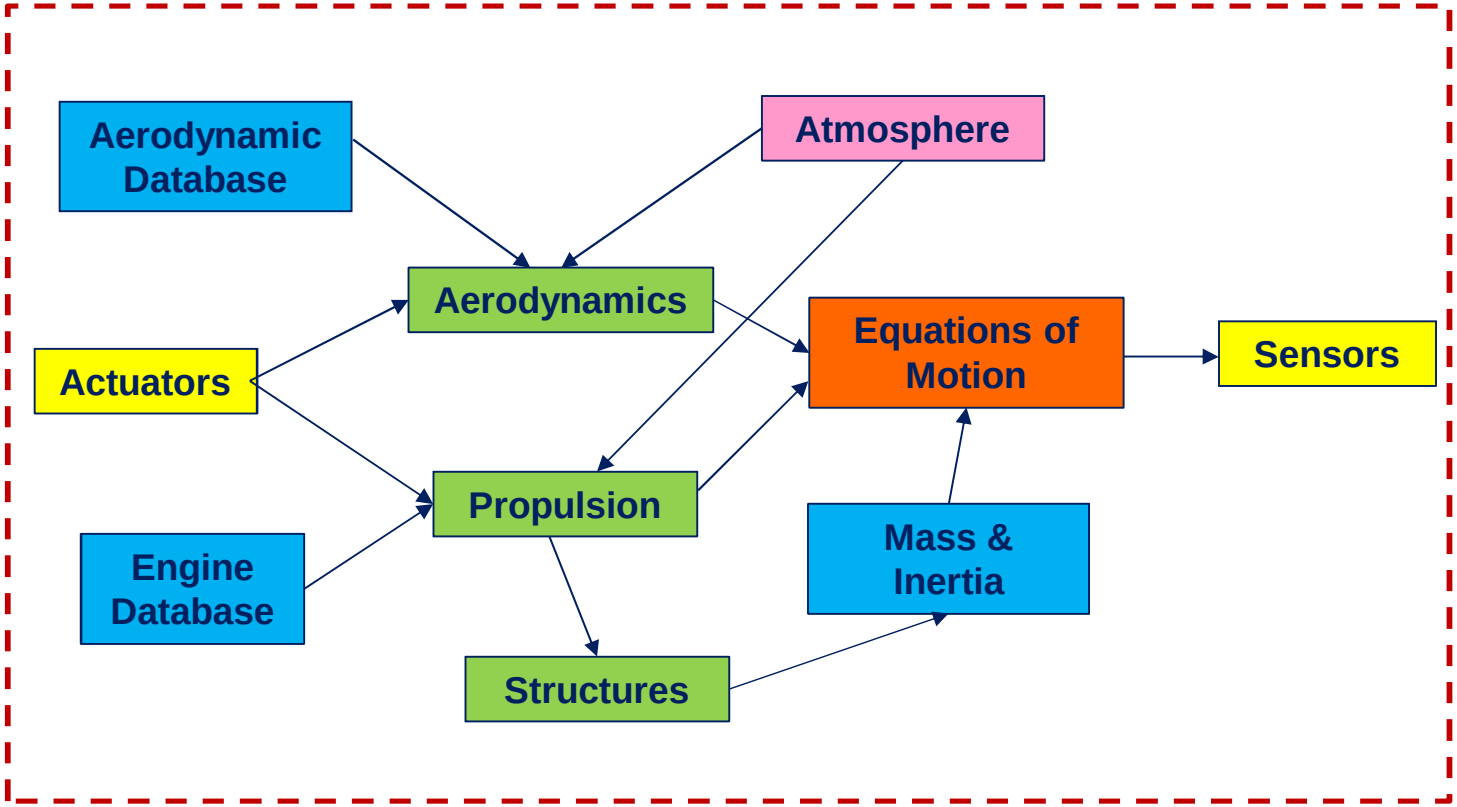
System configuration

- Variable-delta planform of wing + fuselage shape to provide aerodynamic stability and manoeuvrability over a broad speed range
- 30 km altitude flight, due to the low wing loading, offers also a better Earth view and may open to new applications
- Max speed as high as Mach 4-4.5





Multipurpose Aircraft Simulation Laboratory



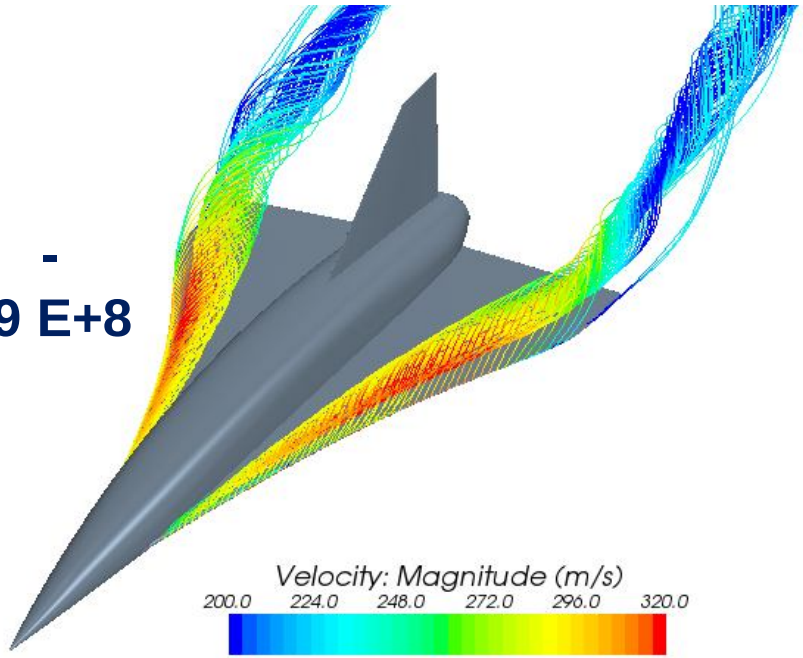
Necessary Inputs : Mass & Inertia, Aerodynamic Model, Propulsion Model

Aerodynamic analysis

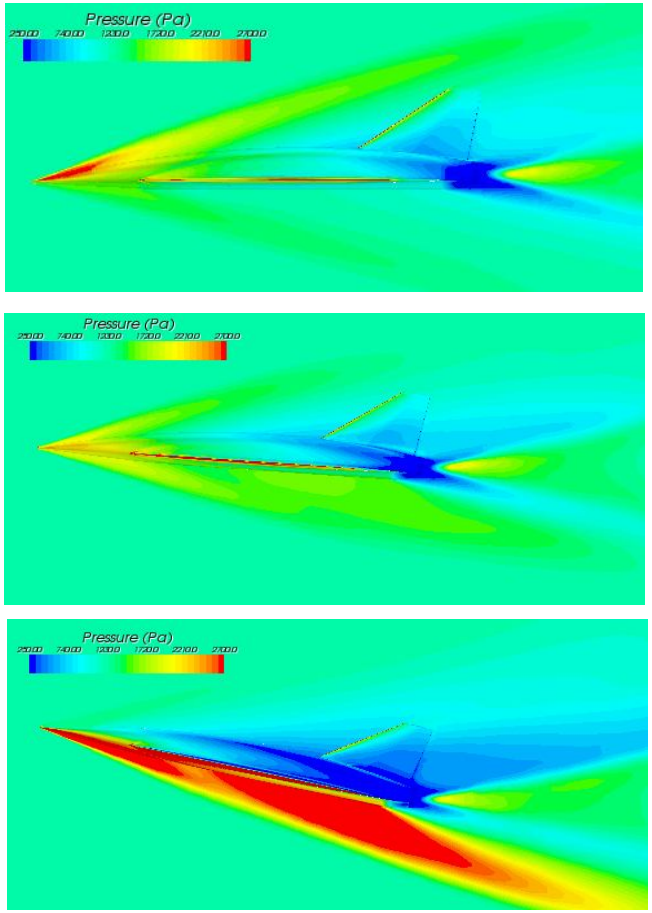
CFD analysis

- 8M cells computational grid
- RANS Equations
- K-Ω Turbulence Model

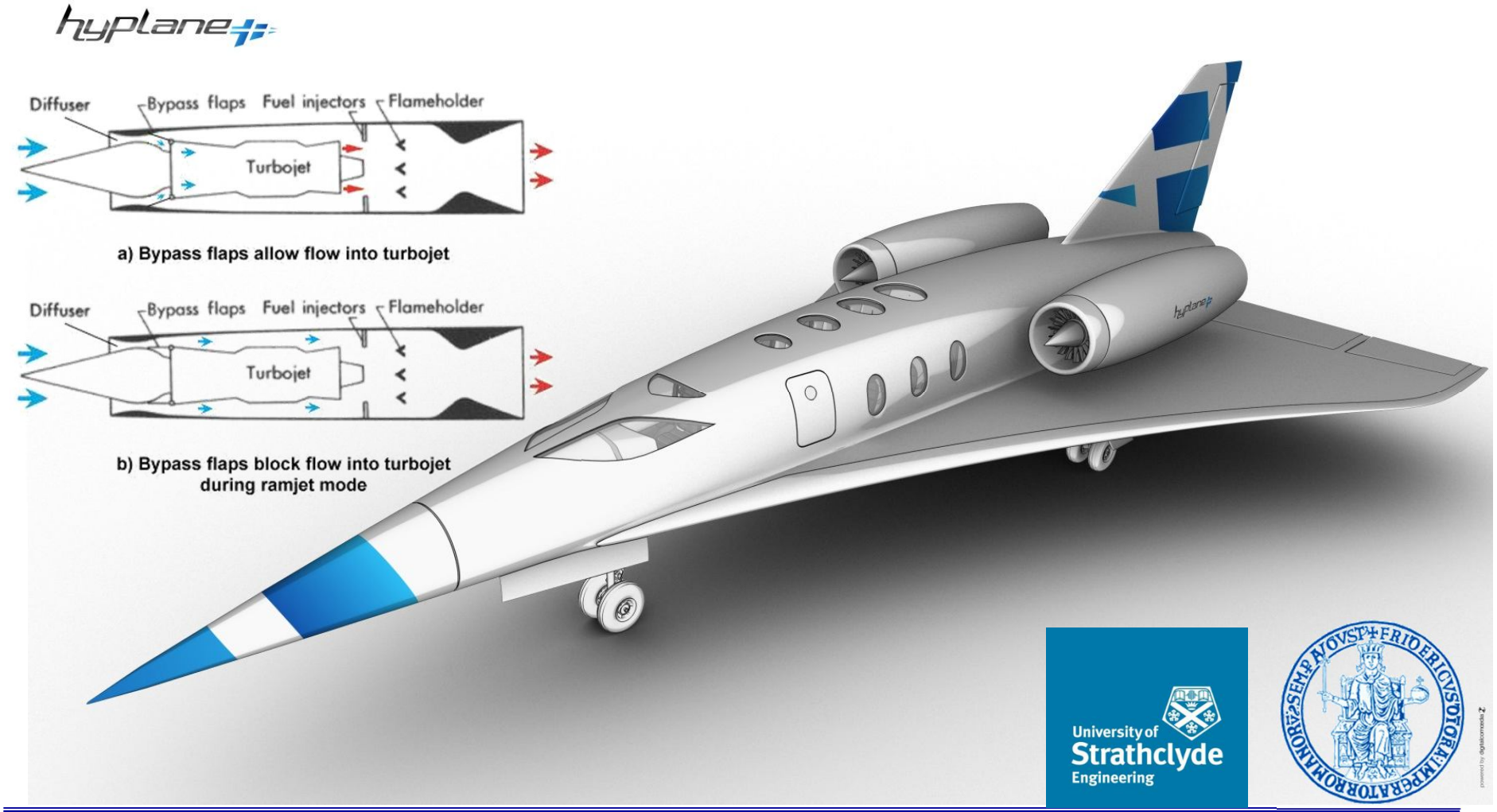
M = 0.7 -
Re = 1,9 E+8



M = 4 - Re = 1.7E+7

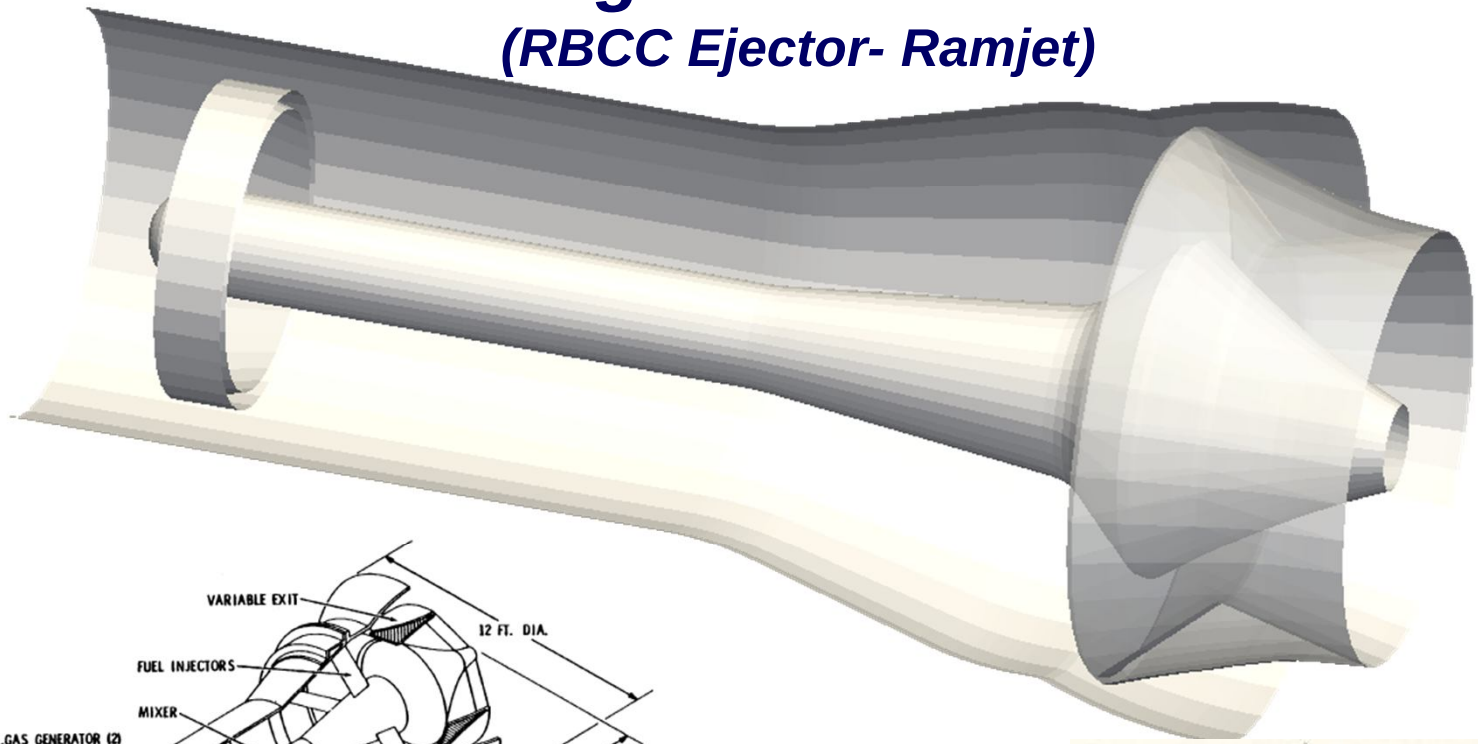


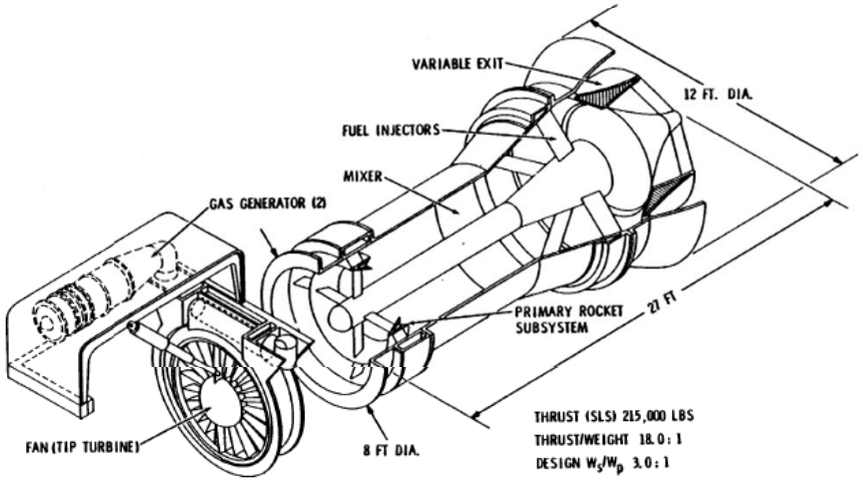
Turbine-Based Combined Cycle (TBCC) Model



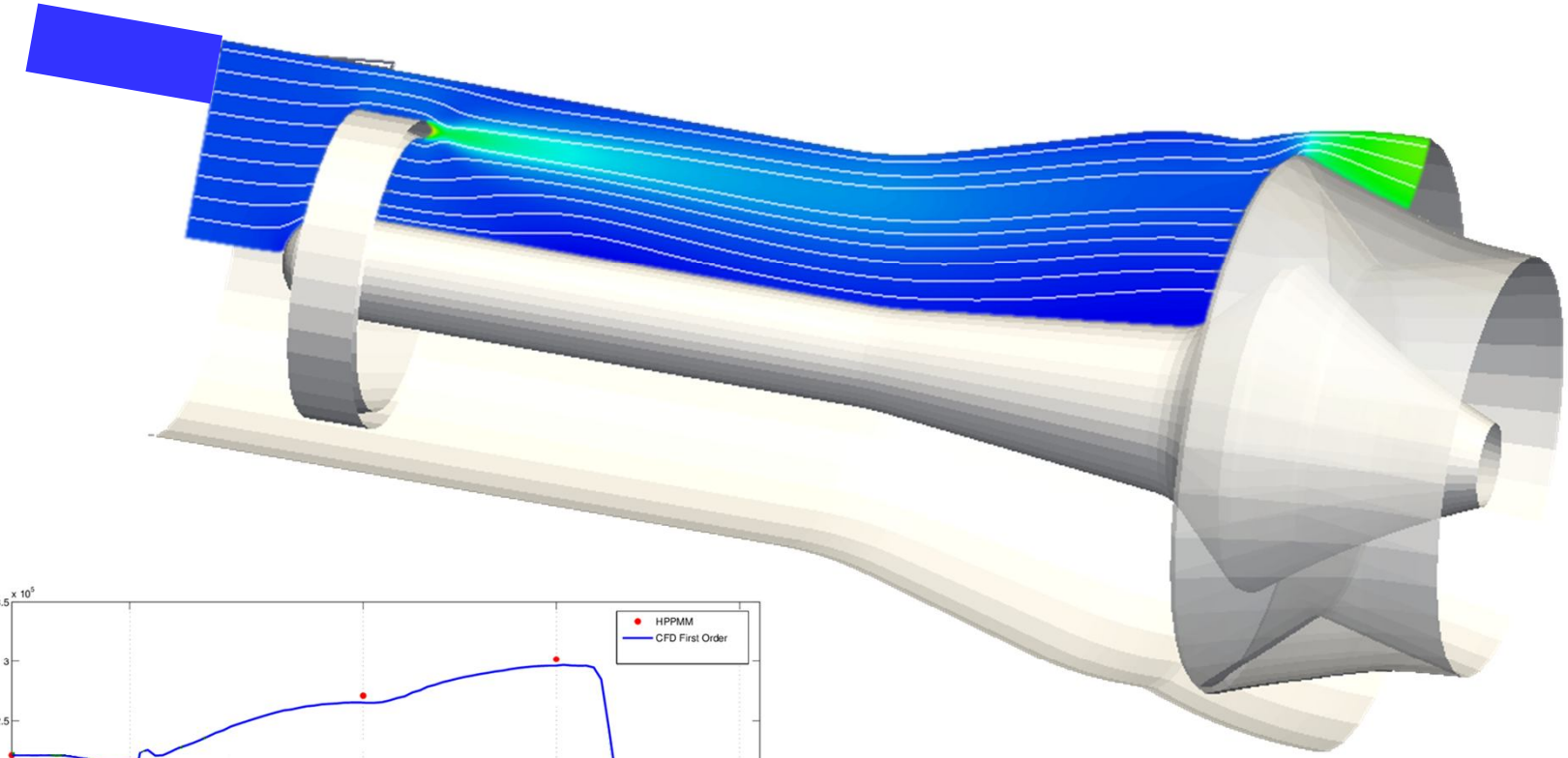
Engine Performance Model:

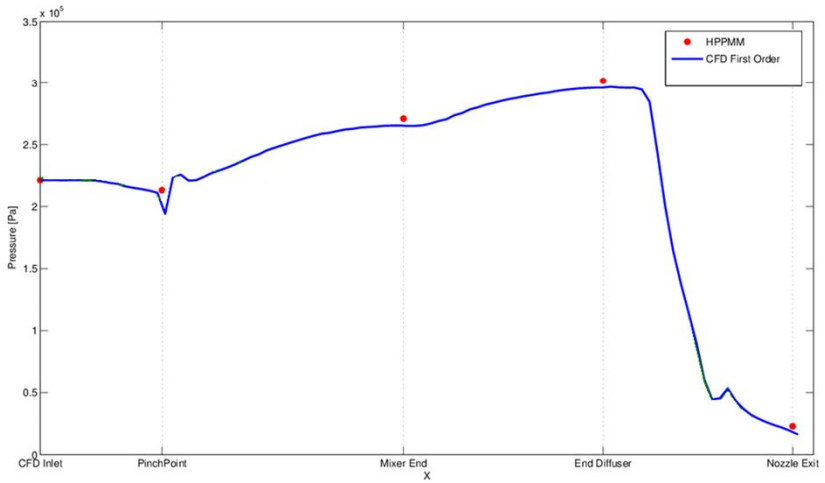
(RBCC Ejector- Ramjet)





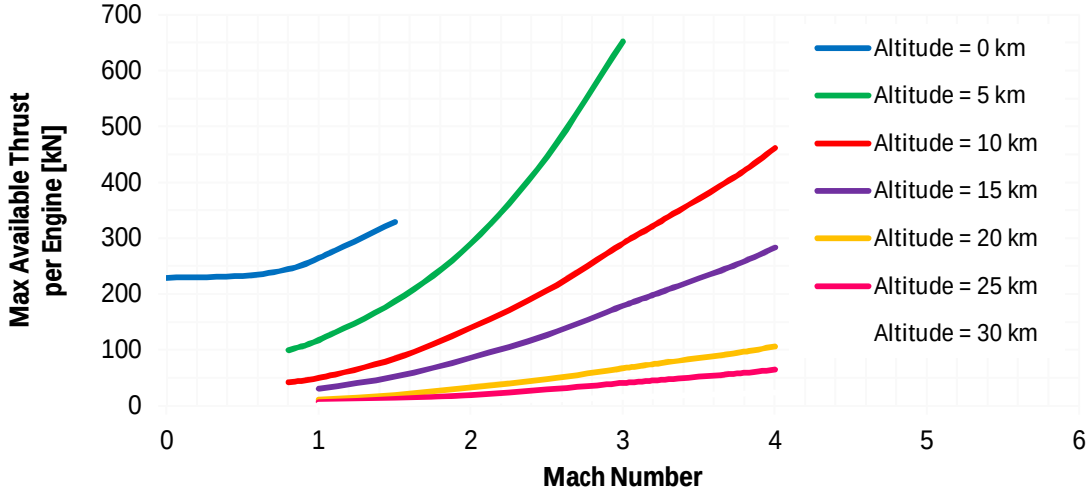
ASTRO DIVISION
THE Marquardt CORPORATION
CORPORATE OFFICES, VAN NUYS, CALIFORNIA



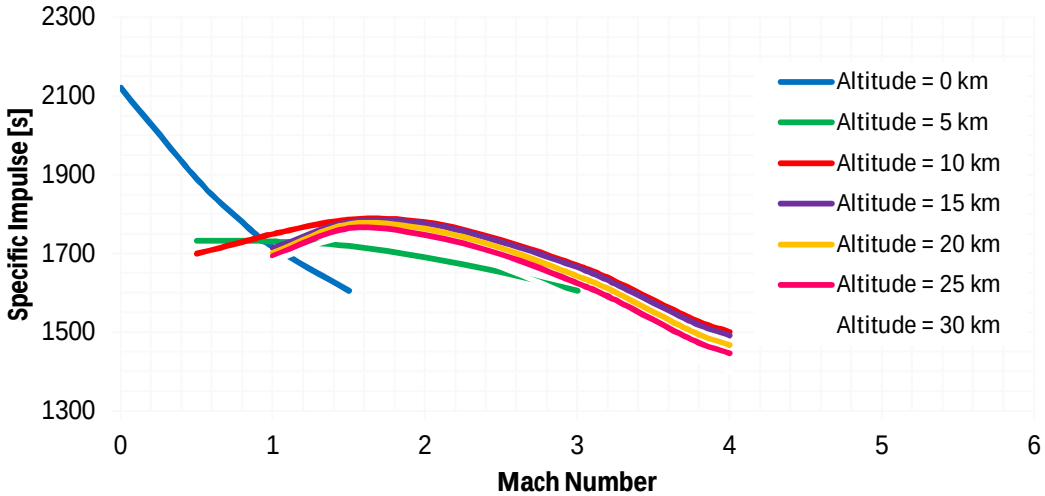

x 10^5
3.5
3
2.5
2
1.5
1
0.5
0
Pressure [Pa]
HPPMM
CFD First Order
CFD Inlet
PinchPoint
Mixer End
End Diffuser
Nozzle Exit
X

Turbine-Based Combined Cycle (TBCC) Model

Maximum Available Thrust (per Engine)



Specific Impulse

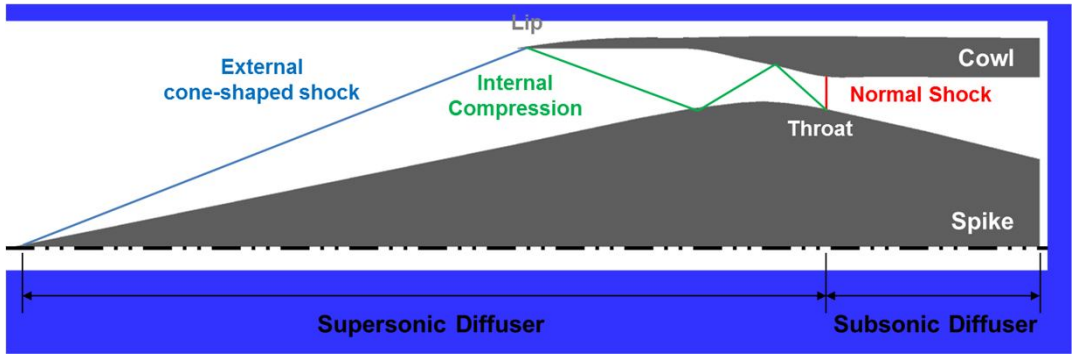


Air Intake of TBCC Design

- Axysimmetric mixed internal/external compression supersonic inlet
- Design conditions (M=4, H=30km) : the spike produces a cone-shaped shock merging at the cow lip of the engine followed by an internal compression which terms with a normal shock in the throat, ensuring subsonic conditions at the entrance of the combustion chamber

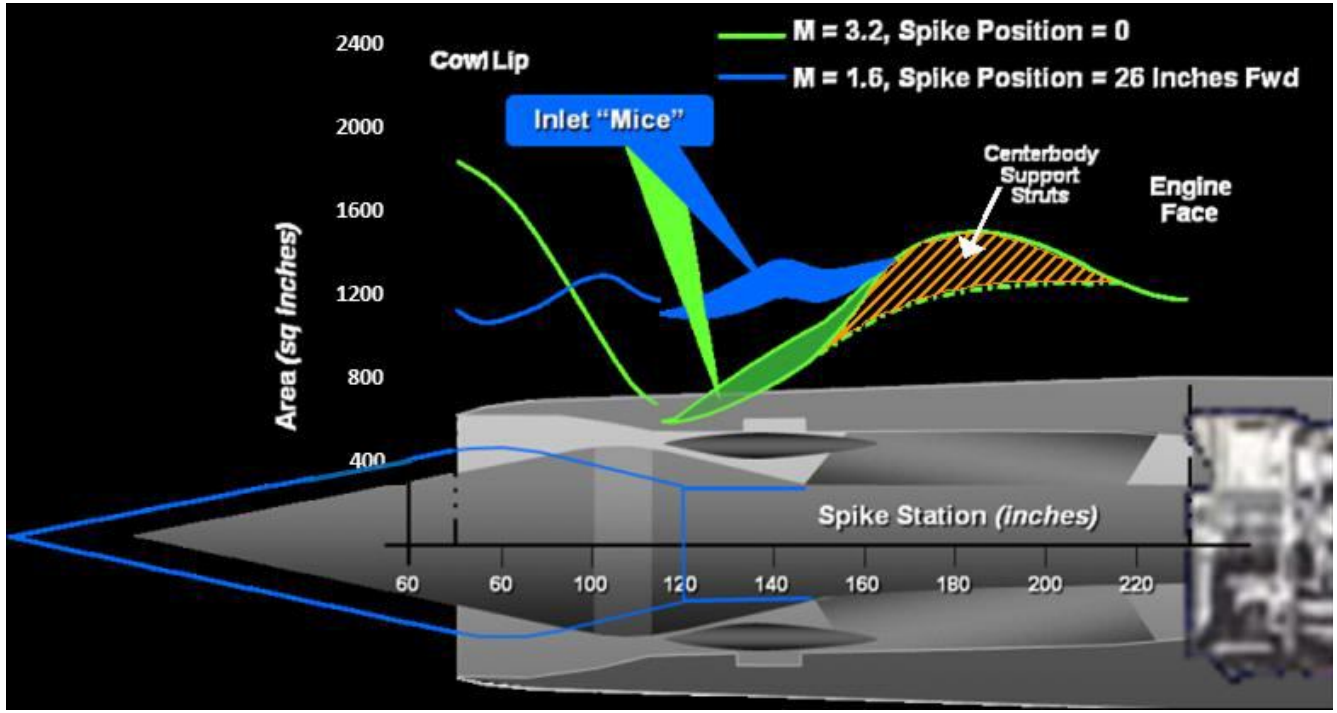
Lockheed SR-71 Blackbird

Design Conditions



Air Intake of TBCC Design

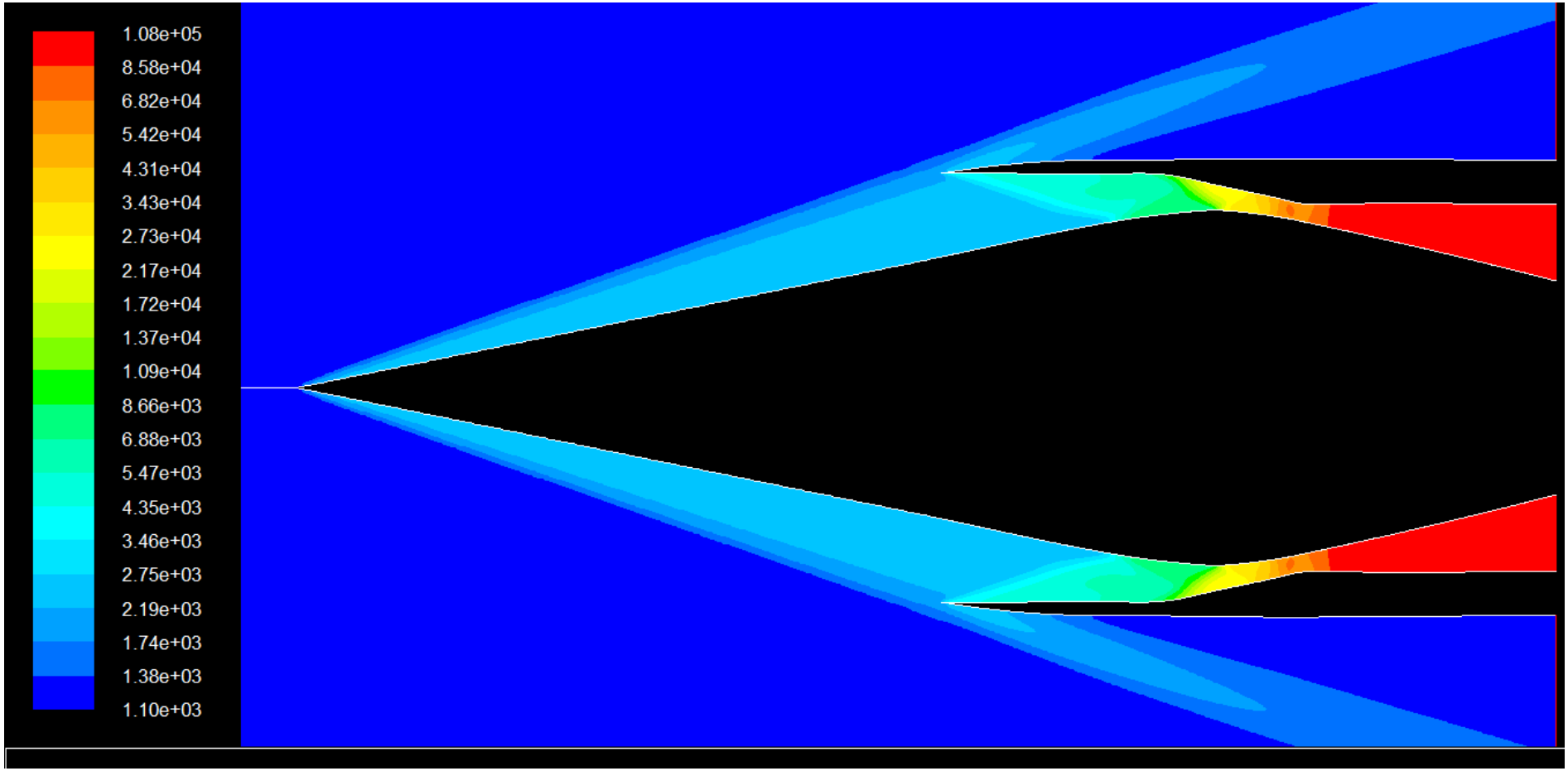
- Translating spike to ensure the chocked condition in the throat and subsonic conditions at the entrance of the combustion chamber, for an extended range of conditions of the HyPlane flight envelope



Air Intake of TBCC Design

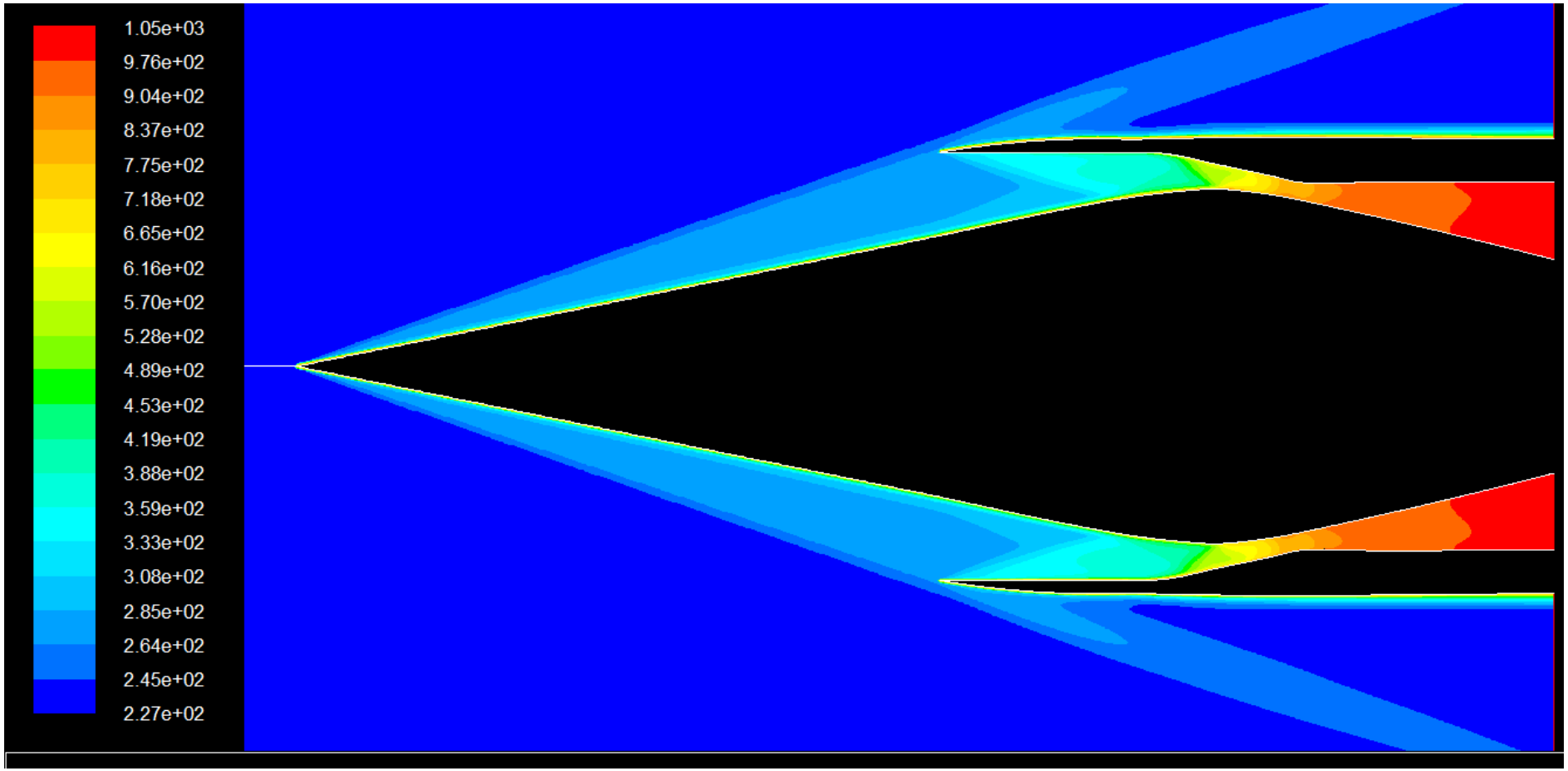
Mach number

Air Intake of TBCC Design



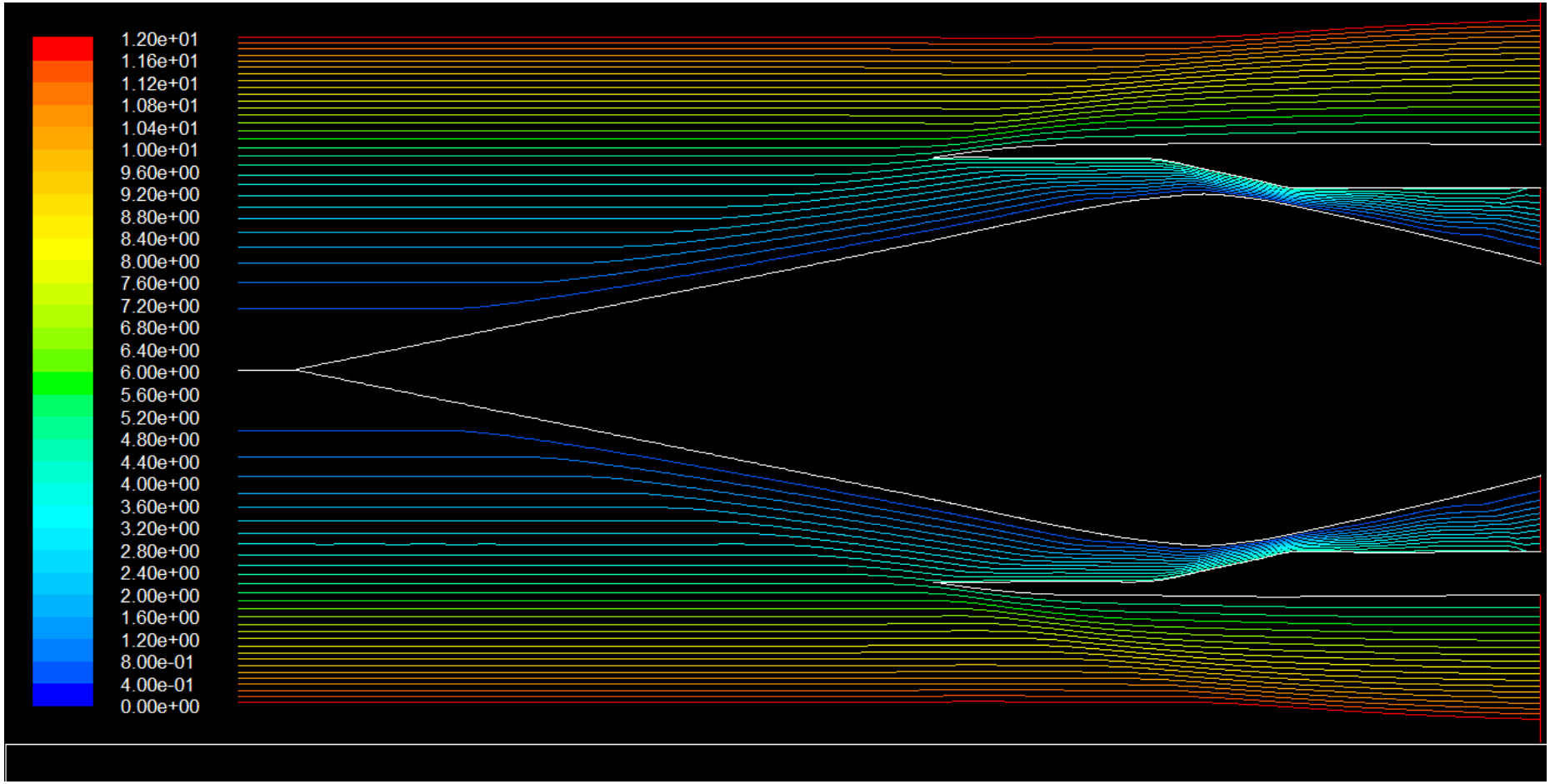
Pressure

Air Intake of TBCC Design



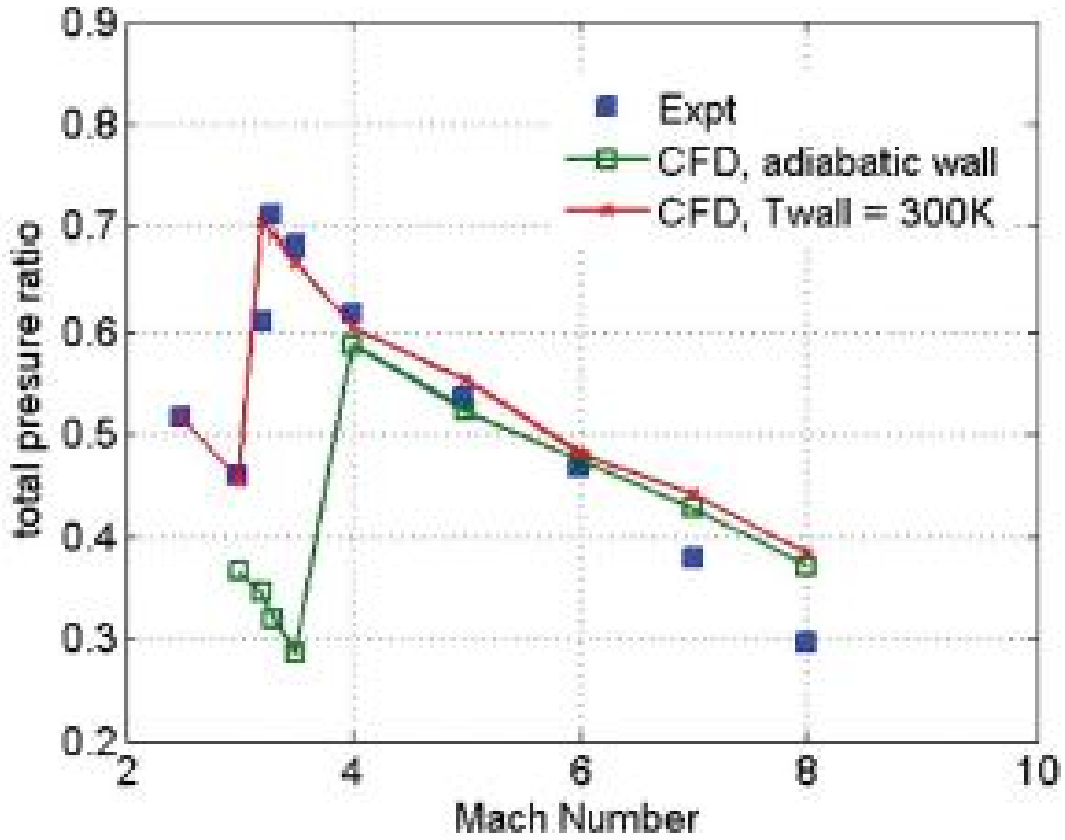
Temperature

Air Intake of TBCC Design



CFD Results

Efficiency - Pressure Recovery $\eta = p_{02}/p_{01}$ as a function of M_∞



HyPlane Mission Profile - Hypersonic cruise

20 km , Mach=2.5
Switch to Ramjet mode

Acceleration along a constant dynamic pressure trajectory

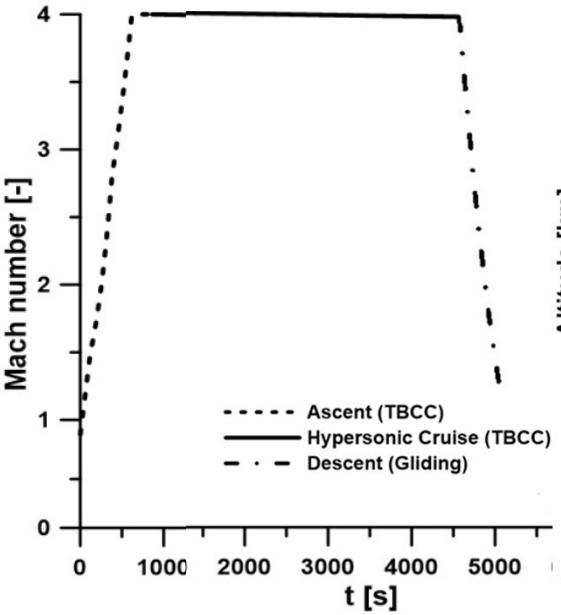
Cruise phase,
30 km, Mach=4-5
(Range≈5000-6000 km)

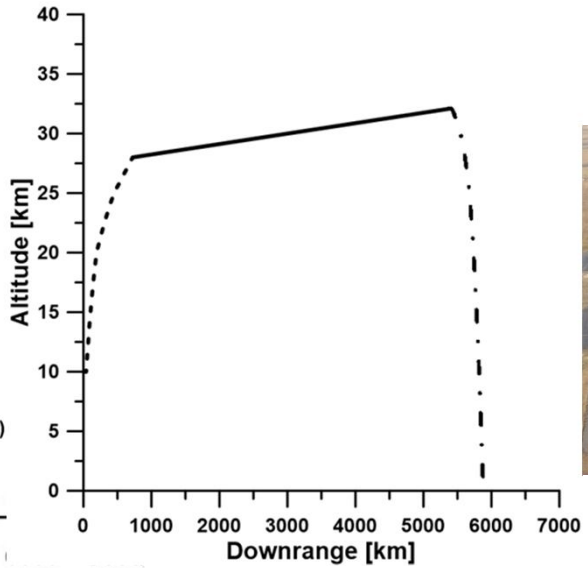
Descent and approach to terminal area

10 km, Mach≈0.7

Horizontal take off

Horizontal landing



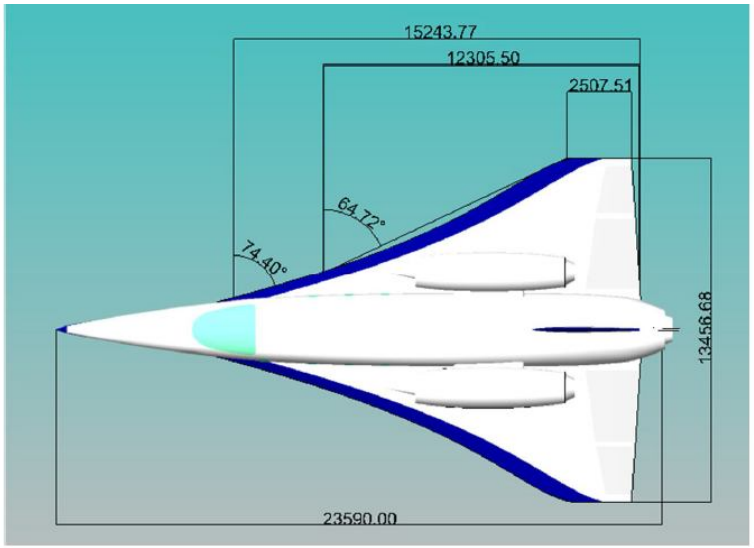


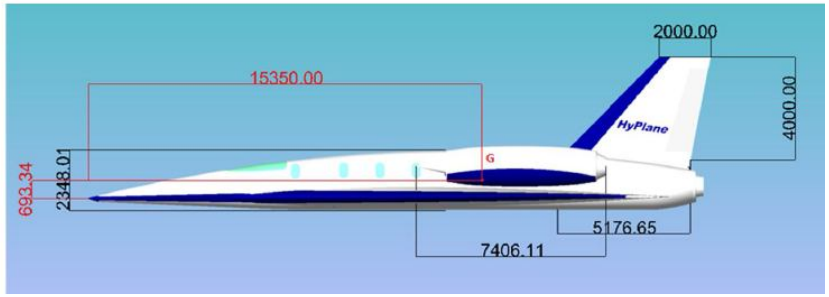
Range Map

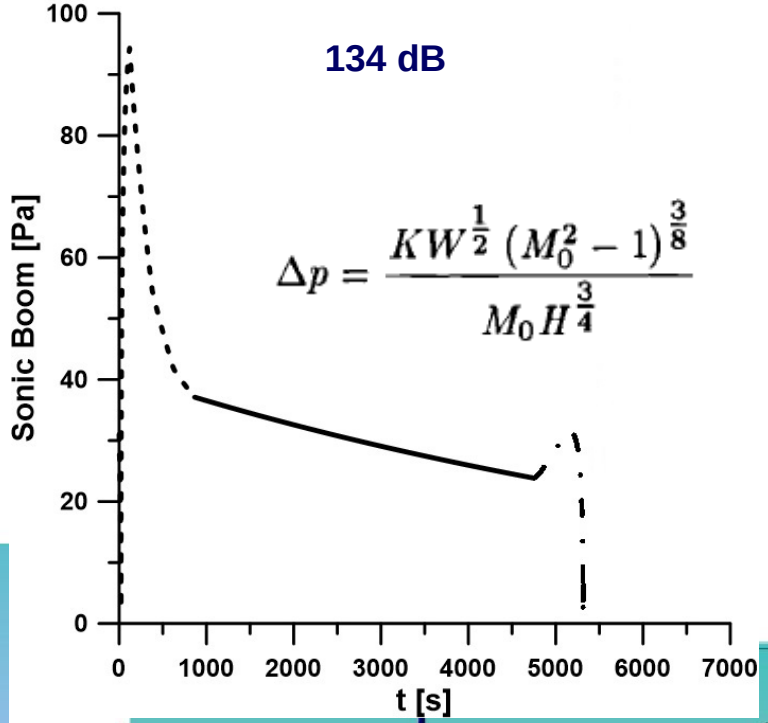
Range Map

Range Map

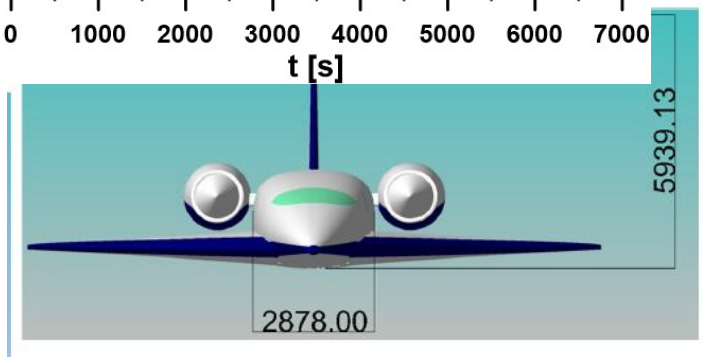
HyPlane– Sonic boom







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



$$K = 28 \text{ lbf/ft}^2 \ (\text{ft}^{\frac{3}{4}}/\text{lbf}^{\frac{1}{2}})$$

$$\left[260 \text{ N/m}^2 \ \ (\text{m}^{3/4}/\text{N}^{\frac{1}{2}})\right]$$

and W is the instantaneous weight of the vehicle. The constant K was deduced from data from the Concorde and the Space Shuttle,[9.11]

MAXIMUM Take off weight: 25 Tons

CHARACTERIZATION	dBA	EXAMPLE NOISE CONDITION OR EVENT
	145	---
	140	---
	135	---
Threshold of pain	130	Surface detonation, 30 pounds of TNT at 1,000 feet
	125	F/A-18 aircraft takeoff with afterburner at 470 feet
Possible building damage	120	Mach 1.1 sonic boom under aircraft at 12,000 feet
Threshold for immediate NIPTS	115	F/A-18 aircraft takeoff with afterburner at 1,600 feet
	110	Peak crowd noise, pro football game, open stadium
	105	Emergency vehicle siren at 50 feet
	100	F/A-18 aircraft departure climbout at 2,400 feet
Extremely noisy	95	Locomotive horn at 100 feet; 2-mile range fog horn at 100 ft
Quiet	45	Typical rural area daytime background conditions
	40	Quiet suburban area at night
	35	---
Very quiet	30	Quiet rural area, winter night, no wind
	25	---
	20	Empty recording studio
	15	---
Barely audible	10	Audiometric testing booth
	5	---
Threshold of Hearing	0	---

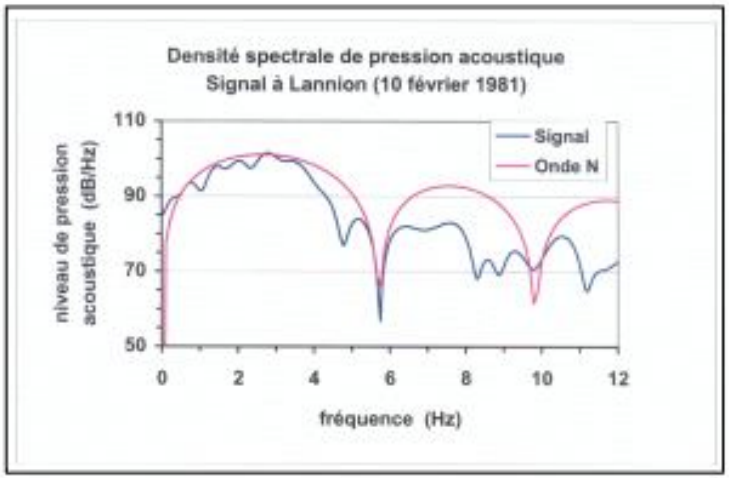
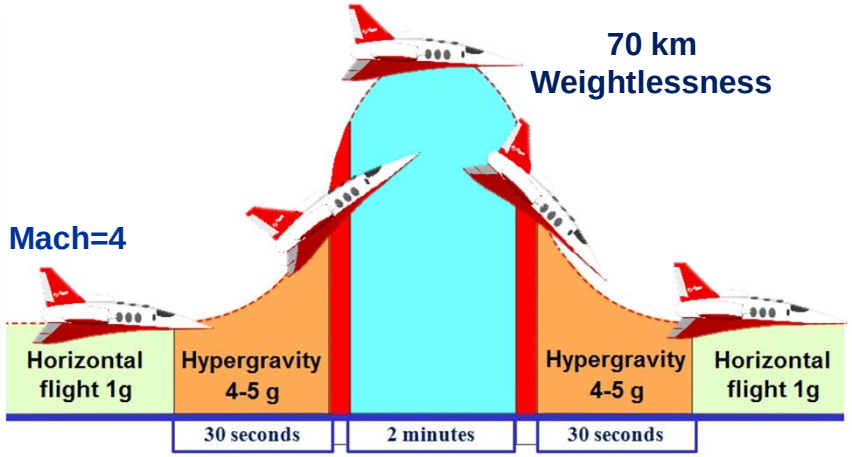
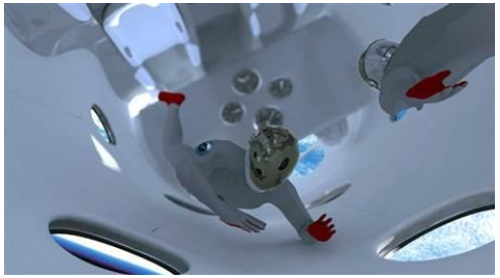


Figure 8 : Real and theoretical spectra of sonic boom

HyPlane Mission Profile - Space Tourism





30 km , Mach=4

20 km , Mach=2.5
Switch to Ramjet mode

Descent and approach to terminal area

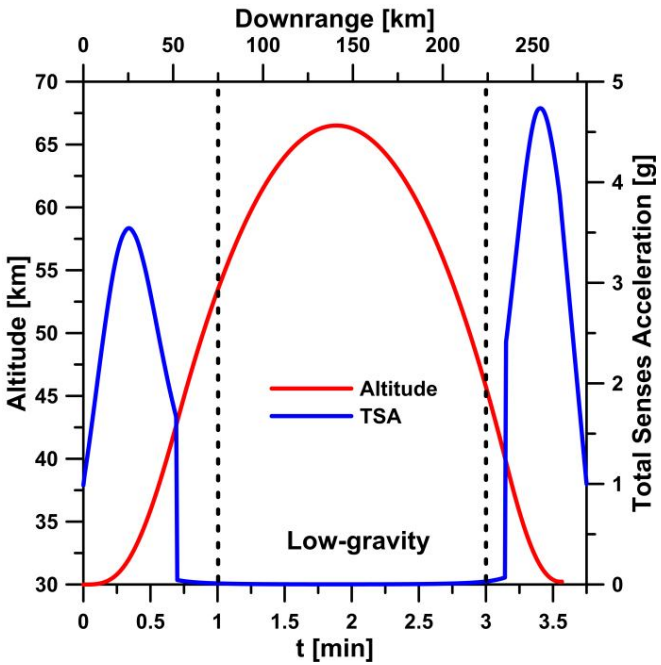
Sequence of sub-orbital jumps

10 km, Mach=0.6

Horizontal take off

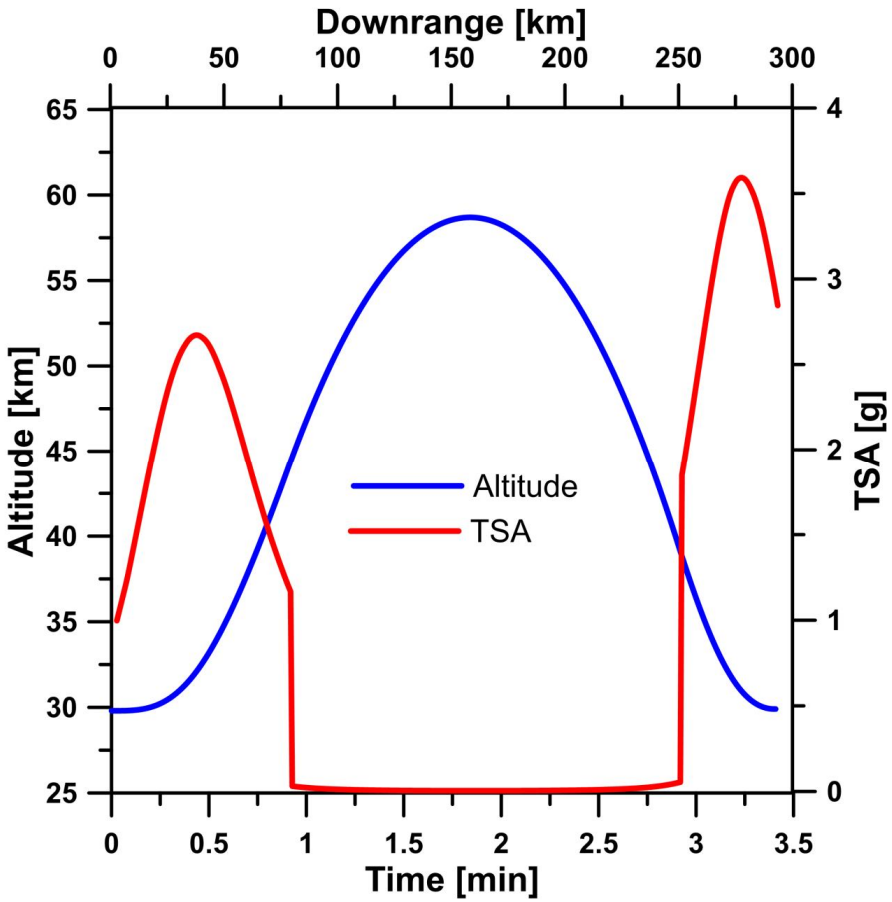
Horizontal landing

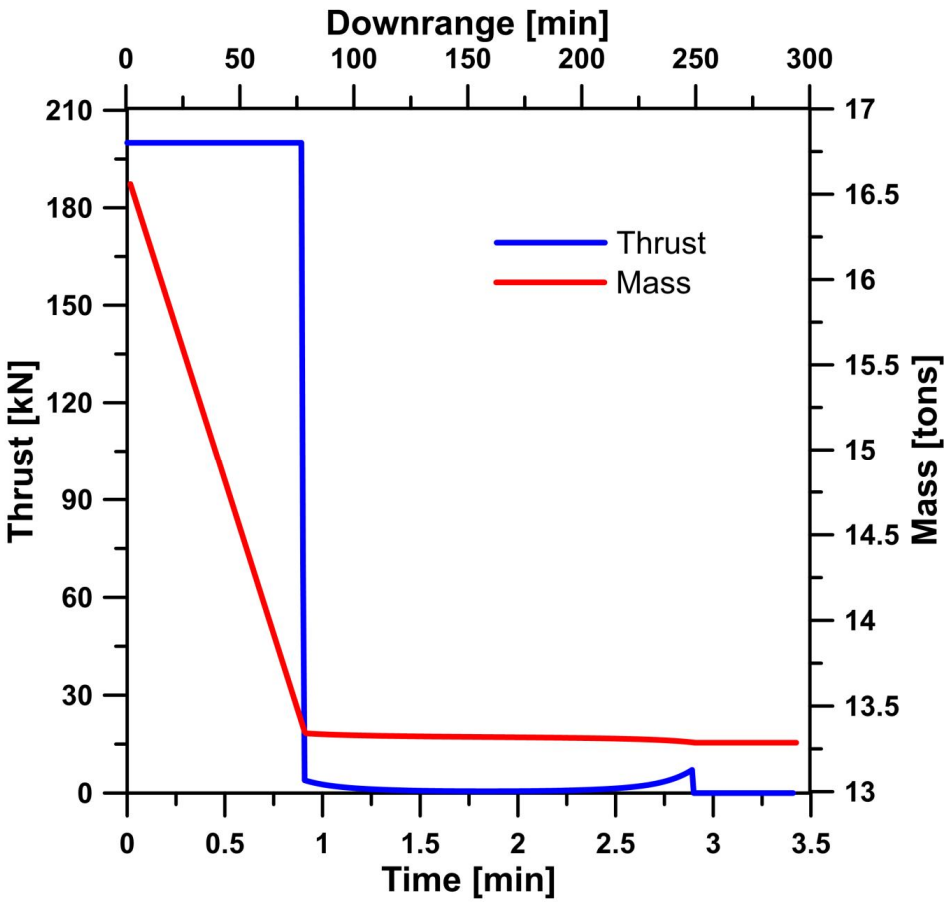
Flight Performances – Space Tourism



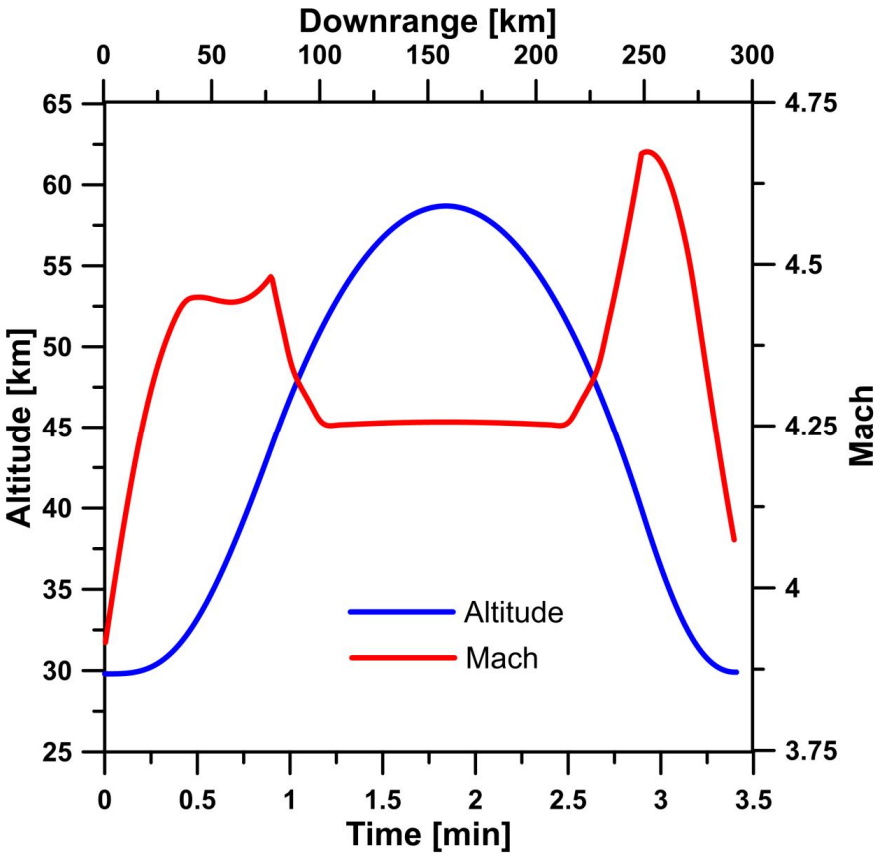
- HyPlane is able to execute some parabolas during one single flight. Max downrange for each sub-orbital jump is 300 km
- Relatively low max acceleration ~4.5-5 g immediately prior to two minutes of weightlessness (≅70 km altitude)
- Opportunity to execute microgravity research under repeated, relatively long duration weightlessness, offering ideal conditions in preparation of long-duration missions onboard orbital space laboratories
- Unique possibility to follow a more flexible research approach (using typical laboratory-type instrumentation, participation of the research team on their experiments during flight, reusability)

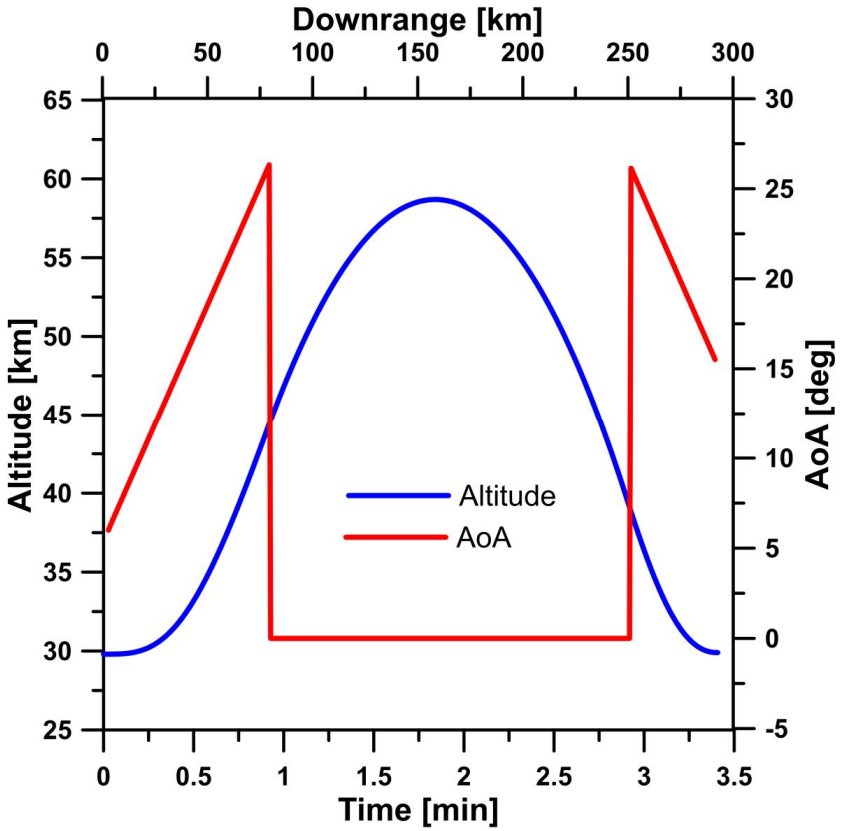
Flight Performances – Space Tourism (cont'd)



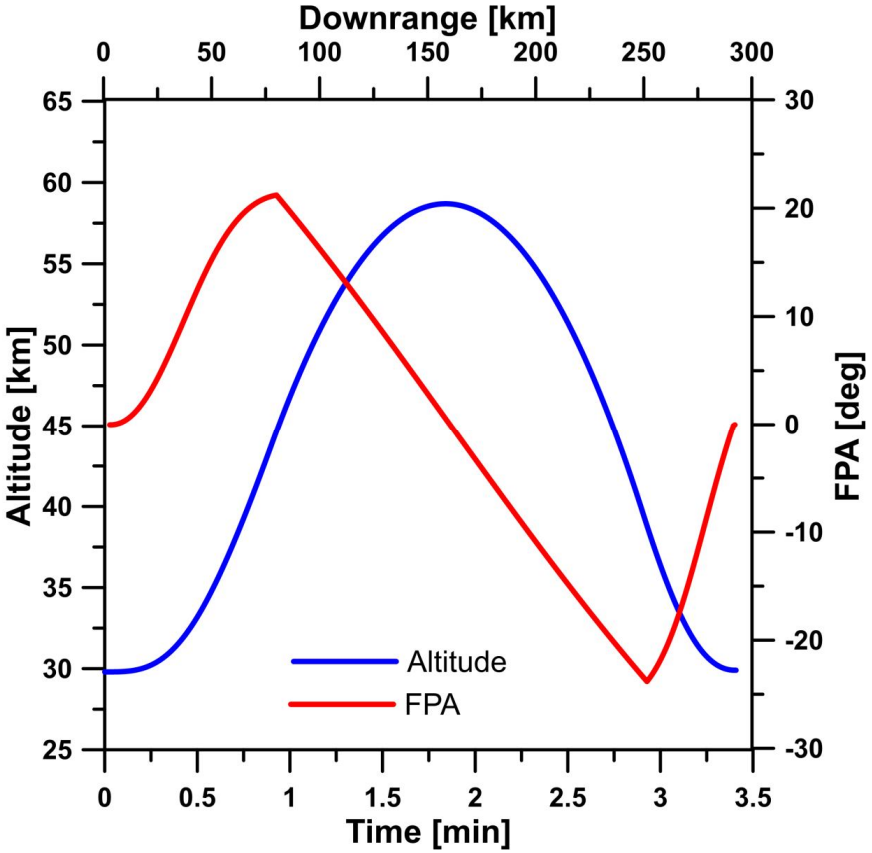


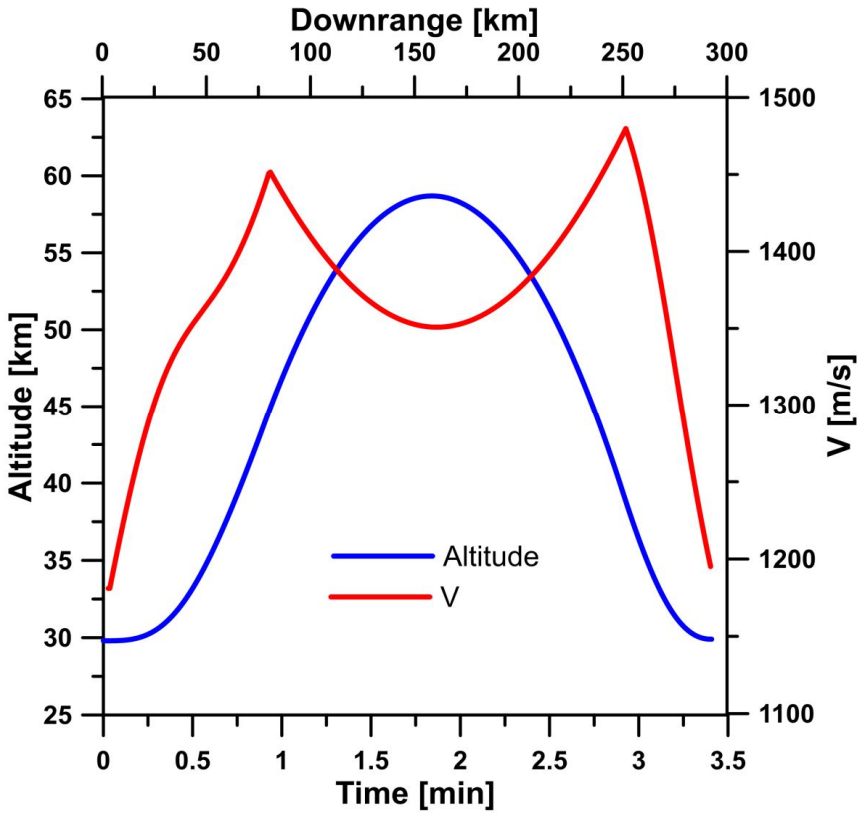
Flight Performances – Space Tourism (cont'd)





Flight Performances – Space Tourism (cont'd)





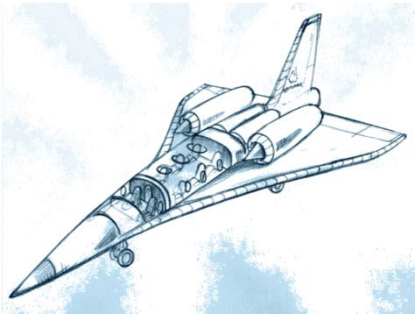
Comparison with vehicles for space tourism

	Cabin Volume [m³]	Maximum Altitude [km]	Downrange [km]	Maximum Acceleration [g]	Passengers [#]
HyPlane	17-20	65-70	>1000	4.5	6 (+2)
Space Ship 2	15	110	56	6	6 (+2)
Lynx	-	70	-	4.5	1 (+1)
EADS Spaceplane	3	100	-	4.5	4 (+1)

Prospective Markets

1. Extended duration space tourism

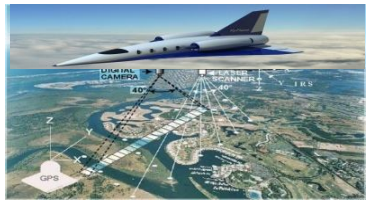
2. Hypersonic intercontinental transportation)



3. Urgent business travel

4. Fast cargo transportation

5. Low gravity Research



6. Aerospace testing and development

7. Remote sensing