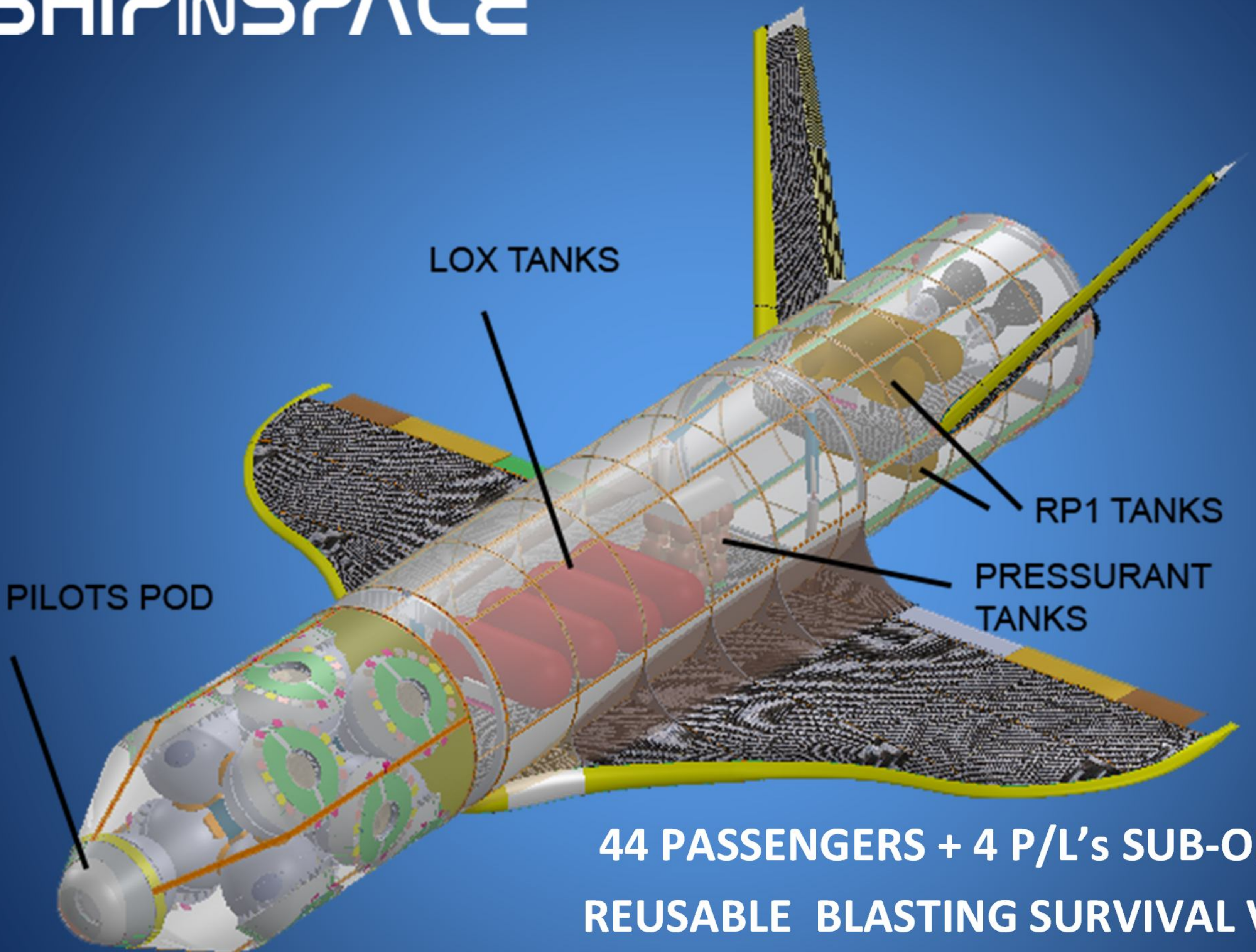
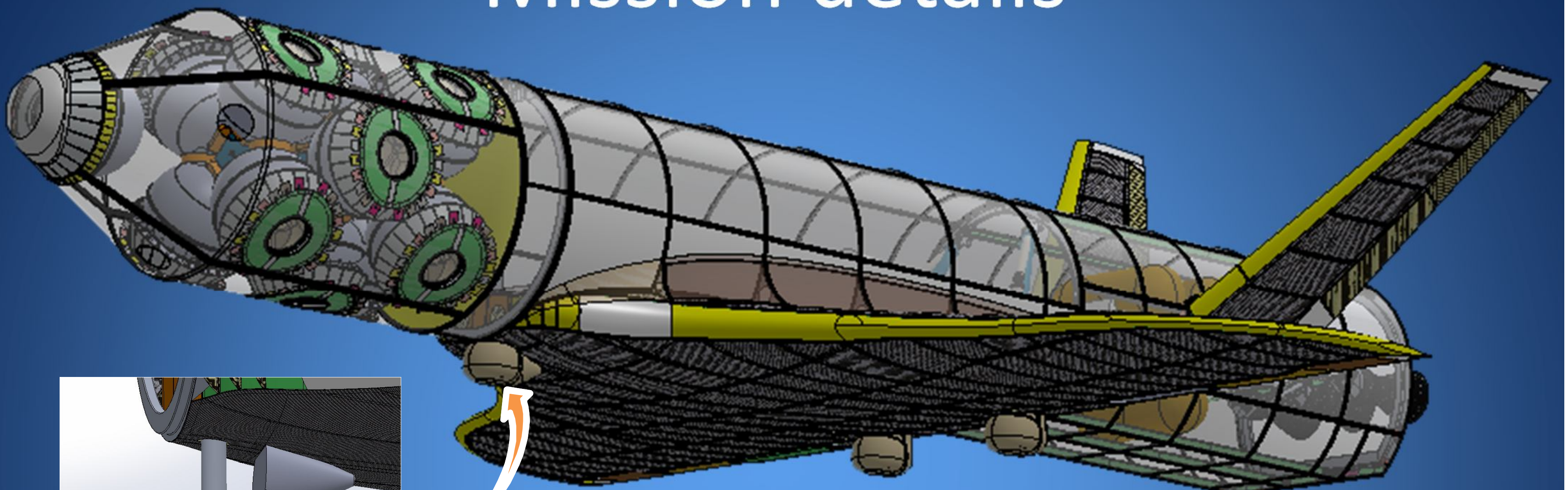
SHIPinSPACE

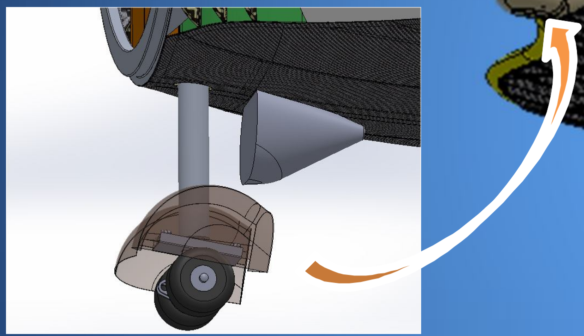


44 PASSENGERS + 4 P/L's SUB-ORBITAL REUSABLE BLASTING SURVIVAL VEHICLE

SHIPinSPACE

Mission details

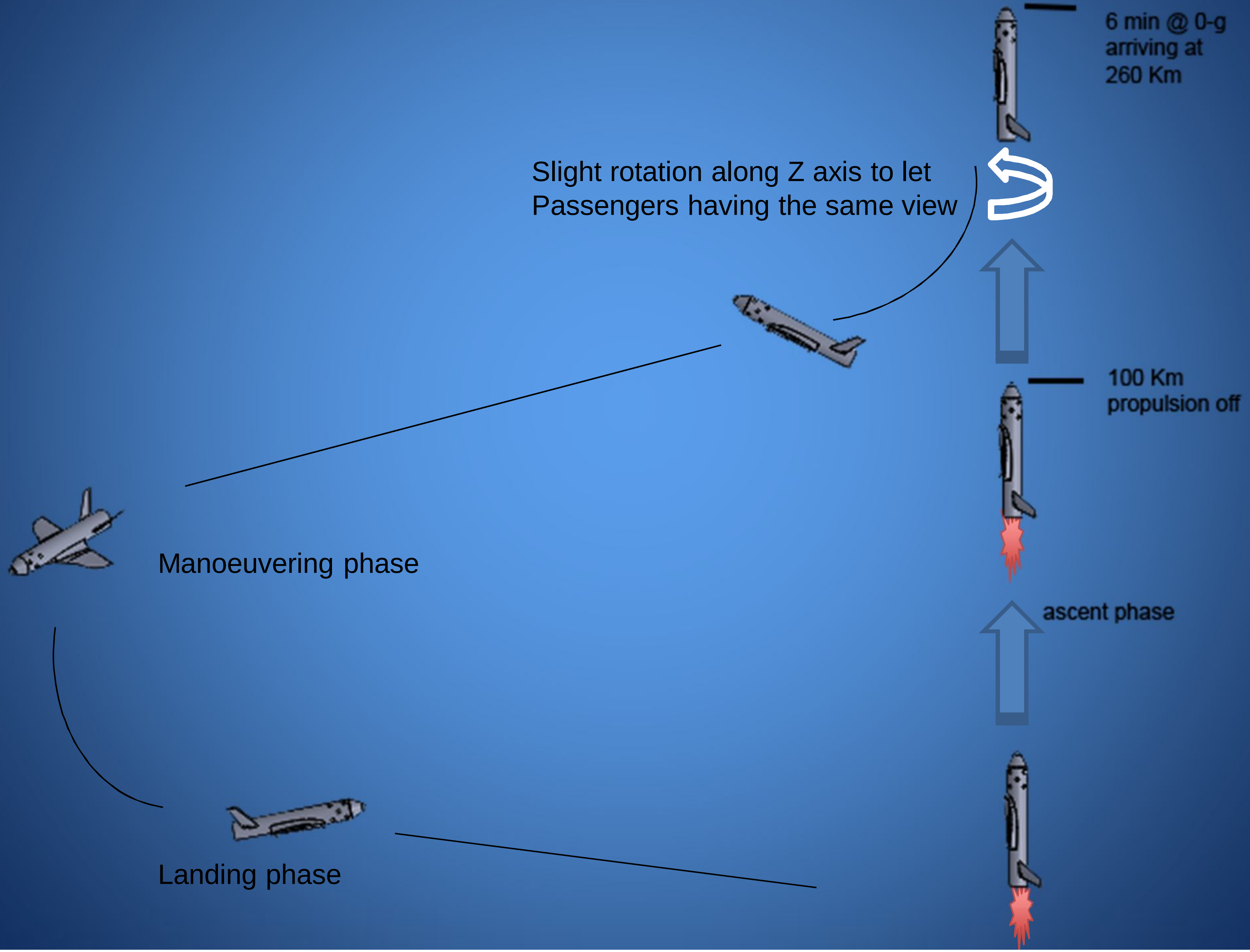




- Full reusability, automated with pilot override
- Vertical take-off and horizontal landing
- Low-cost and hi-rel. pressure-fed engines
- The Fairing, in case of a contingency, is capable to be pyrotechnically cut and let free the Passengers Pods that are not fastened to any structure for independent landing (parachutes), potentially surviving at a blasting event
- Target safety equal to a wide-body Aircraft (life risk at 10-6).
- Target launch cost $1M for $2.88M revenue per mission ($60k flight ticket)
- Mission frequency once a week for an annual EBIT of $85M

SHIPINSPACE

Mission details



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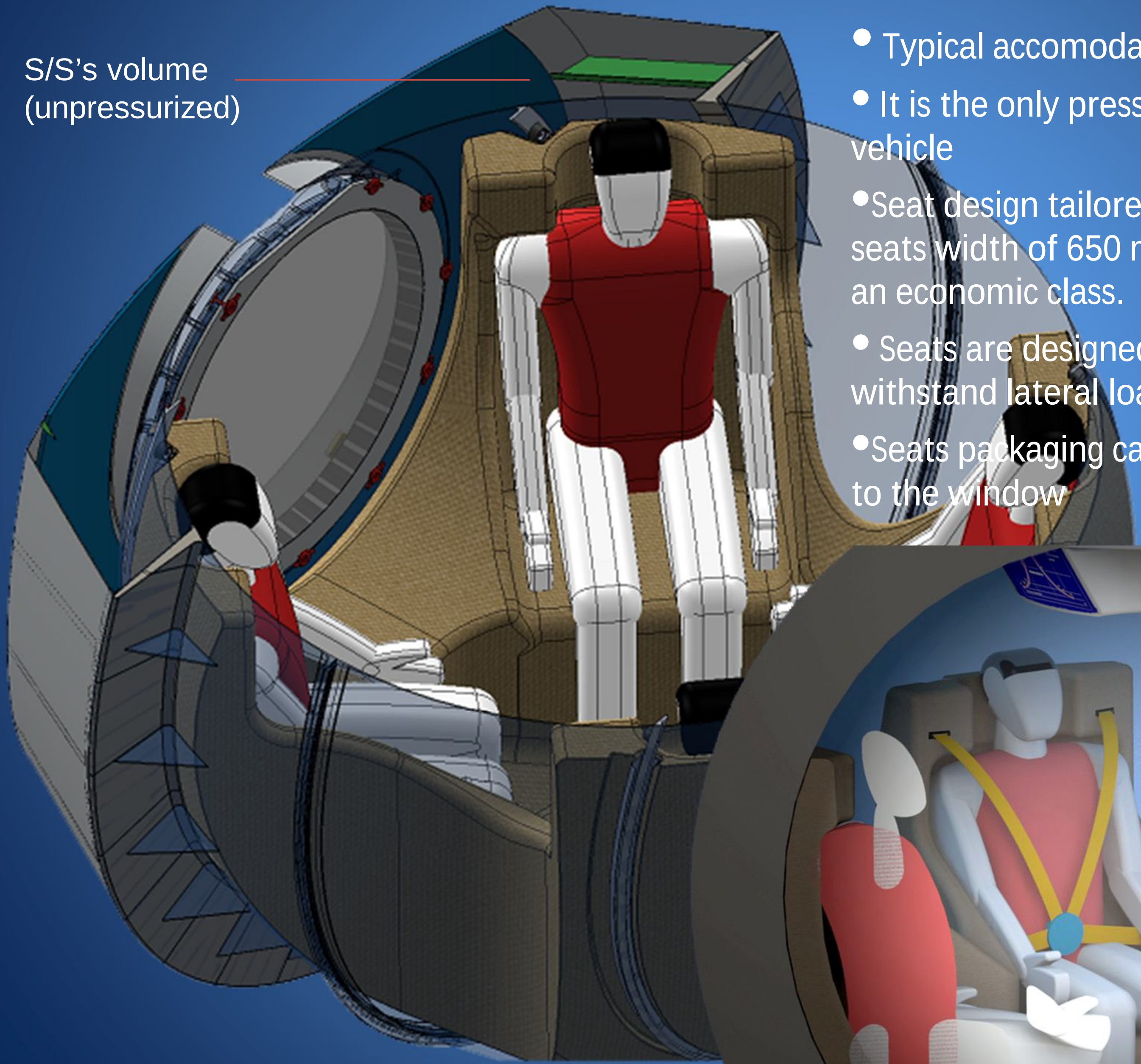
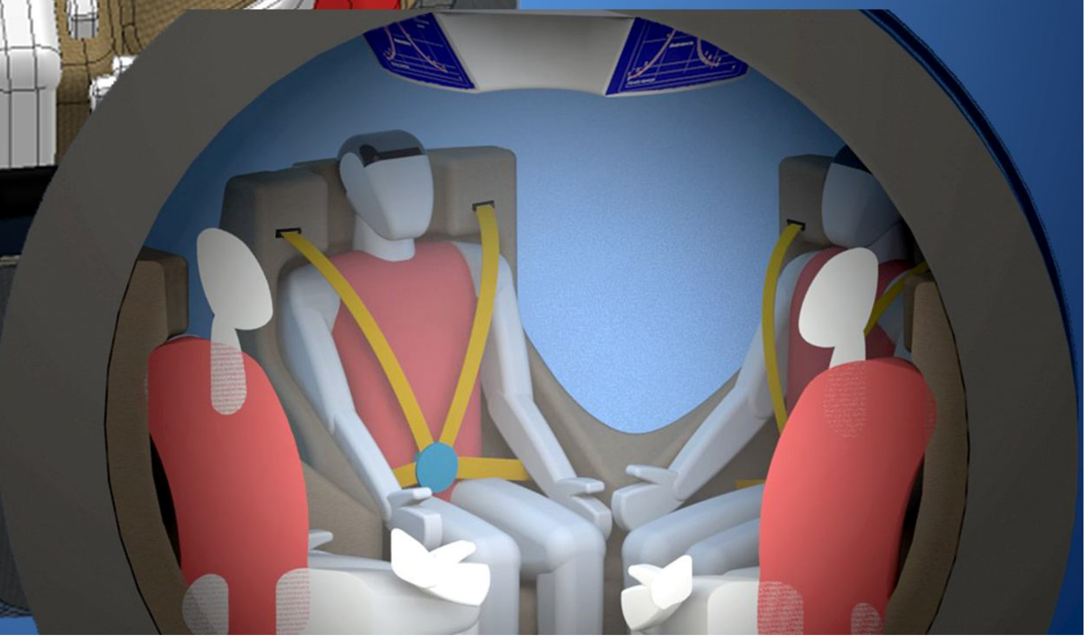
The Pod

S/S's volume
(unpressurized)



- Typical accomodation of 4 Passengers
- It is the only pressurized part of the SHIPINSPACE vehicle
- Seat design tailored to extra large people having seats width of 650 mm against the 450 typical of an economic class.
- Seats are designed in such a way Passengers can withstand lateral loads (0,5g)
- Seats packaging can rotate along the axis normal to the window



View of the Passengers close to the window

The 800 mm diameter window, 7 times larger than a wide-body Aircraft one, will permit an outstanding view of outside even for the 2 Passengers close to the window.

During the 6 min of 0-g the Passengers can move freely inside the Module getting their preferred outside picture

SHIPINSPACE

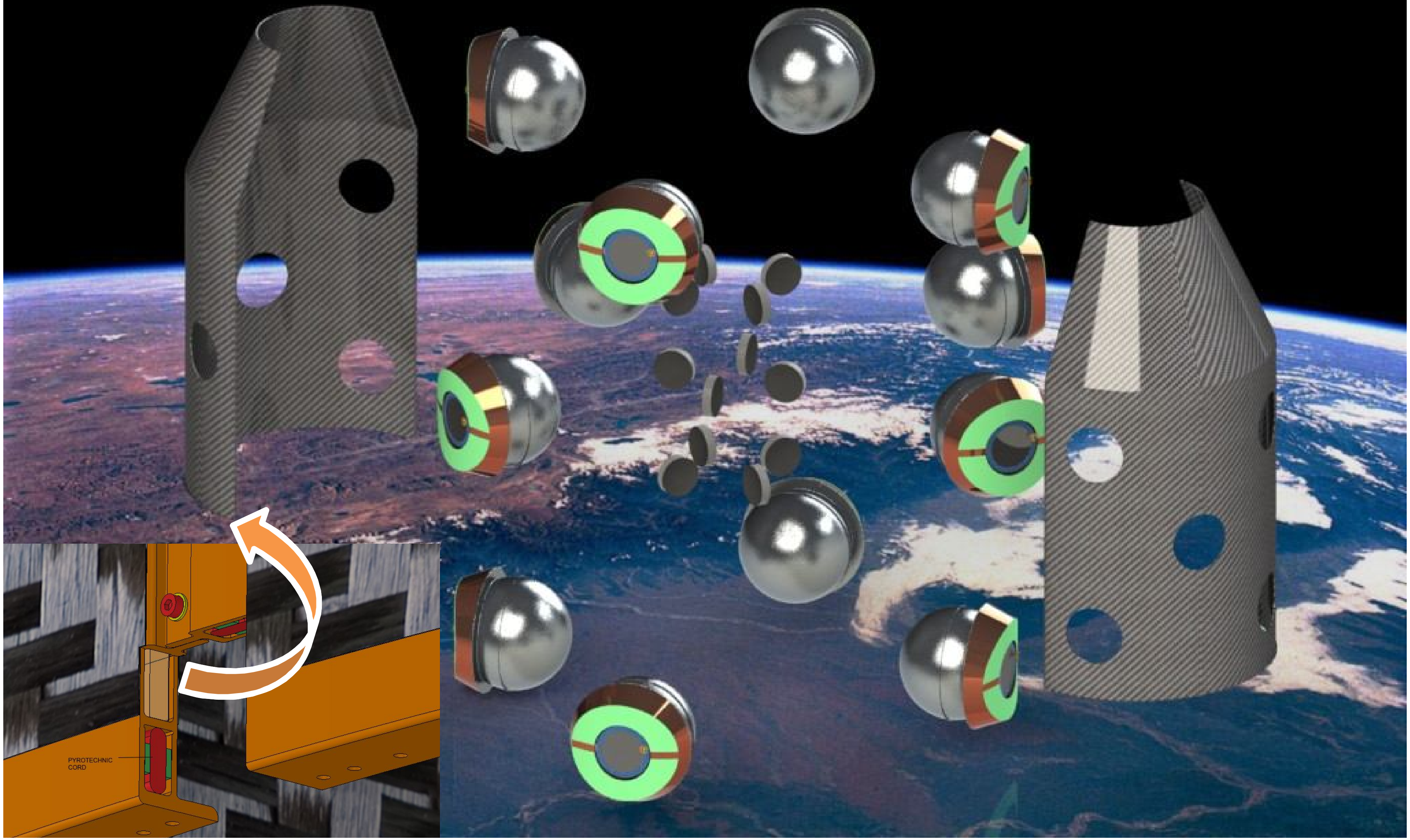
View of the Passengers located far from the hatch port

During the 6 min of 0-g at the top of the Parabolic flight Passengers experience weightlessness in free flying inside the Pod. An ergonomic study could verify that the space around the Passengers is higher than that of a business class of a wide-body aircraft

SHIPinSPACE

Emergency pyrotechnic cut

In case a life risk contingency is detected the Passengers Module can be pyrotechnically cut and the Pods free from descending independently one another, by means of embedded parachutes. This feature, unique to the SHIPinSPACE technology could have saved the life of both the Challenger and Columbia teams.



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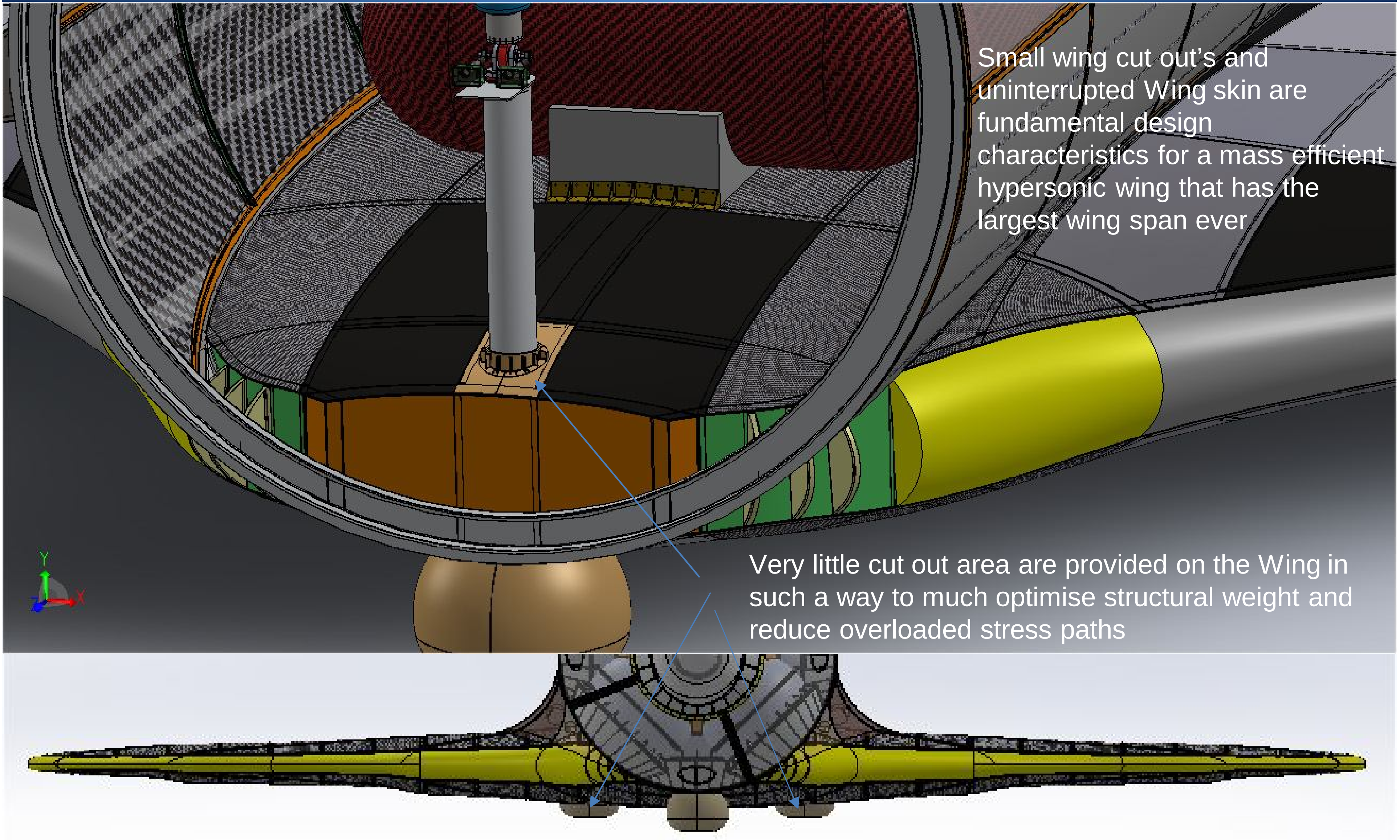
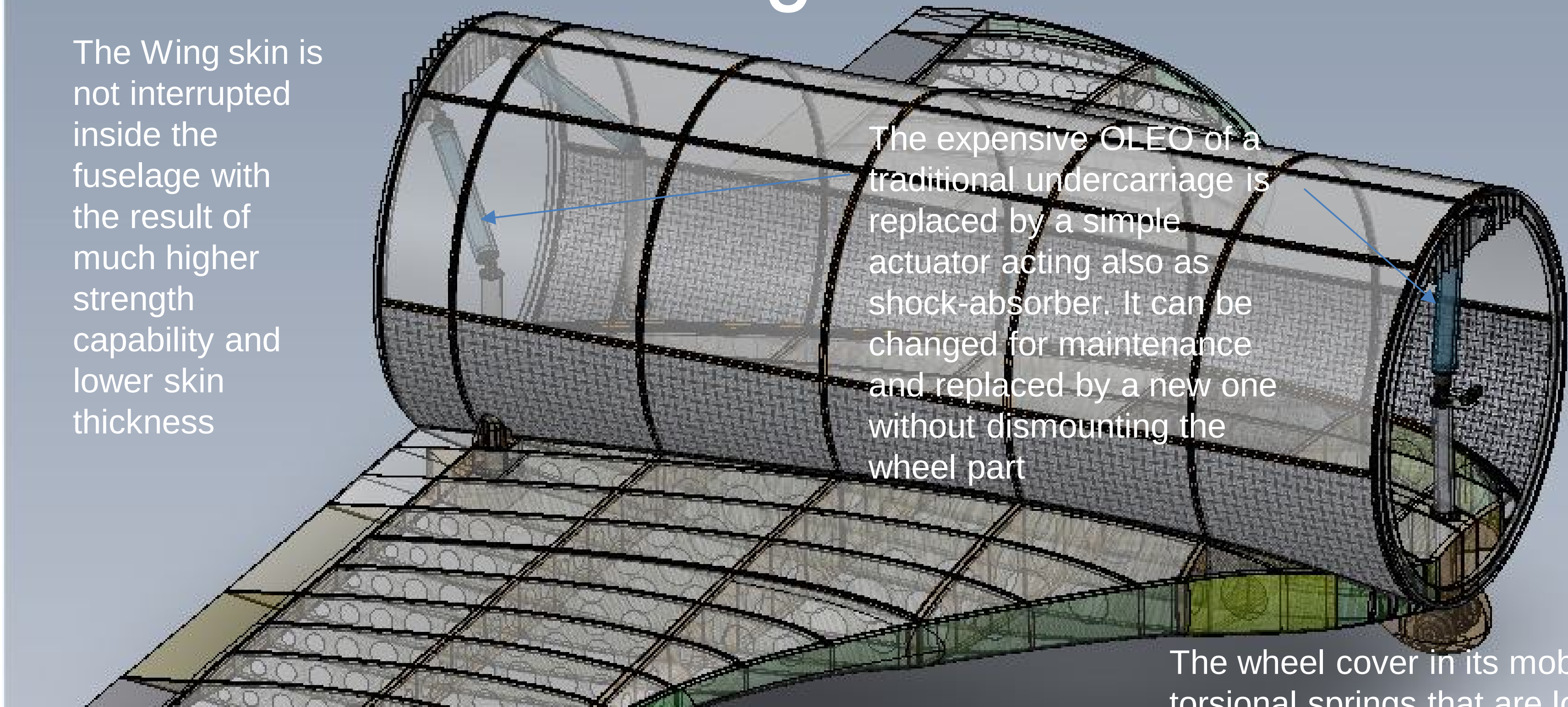
Undercarriage new concept



SHIPINSPACE

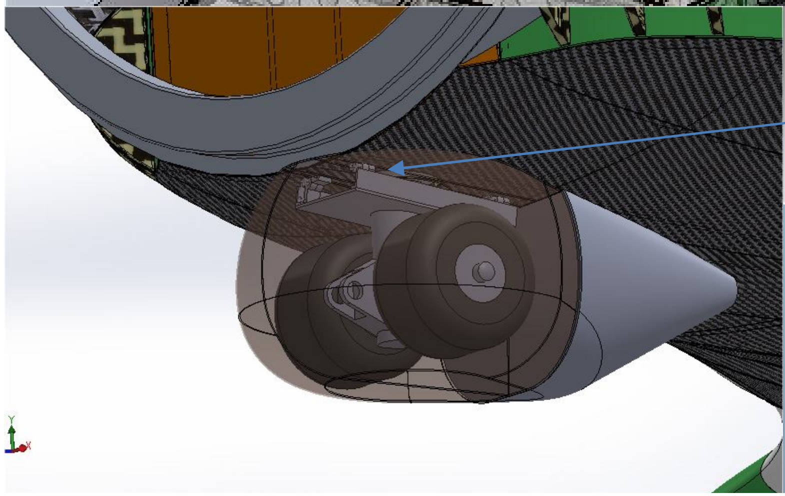
Wing Module

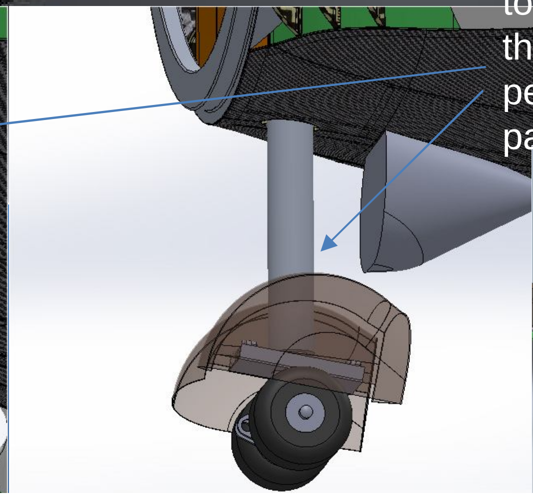
The Wing skin is not interrupted inside the fuselage with the result of much higher strength capability and lower skin thickness

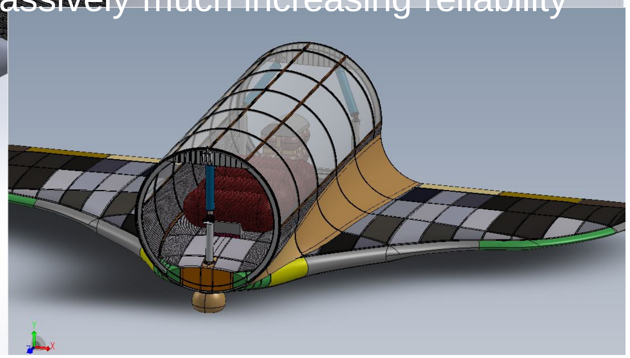


The expensive OLEO of a traditional undercarriage is replaced by a simple actuator acting also as shock-absorber. It can be changed for maintenance and replaced by a new one without dismounting the wheel part

The wheel cover in its mobile part has torsional springs that are loaded when the undercarriage is closed up. This permits the cover halves are opened passively much increasing reliability







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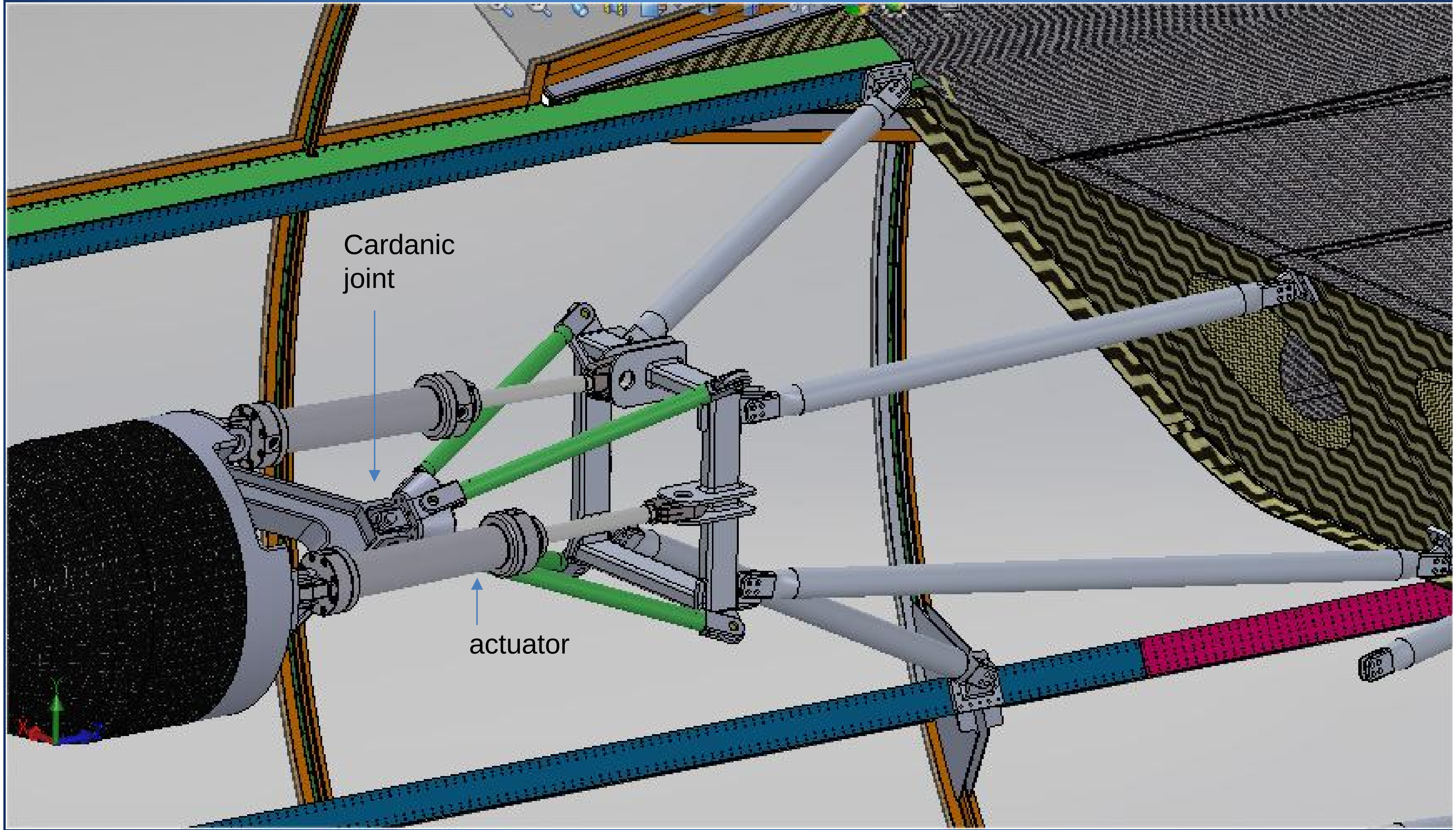
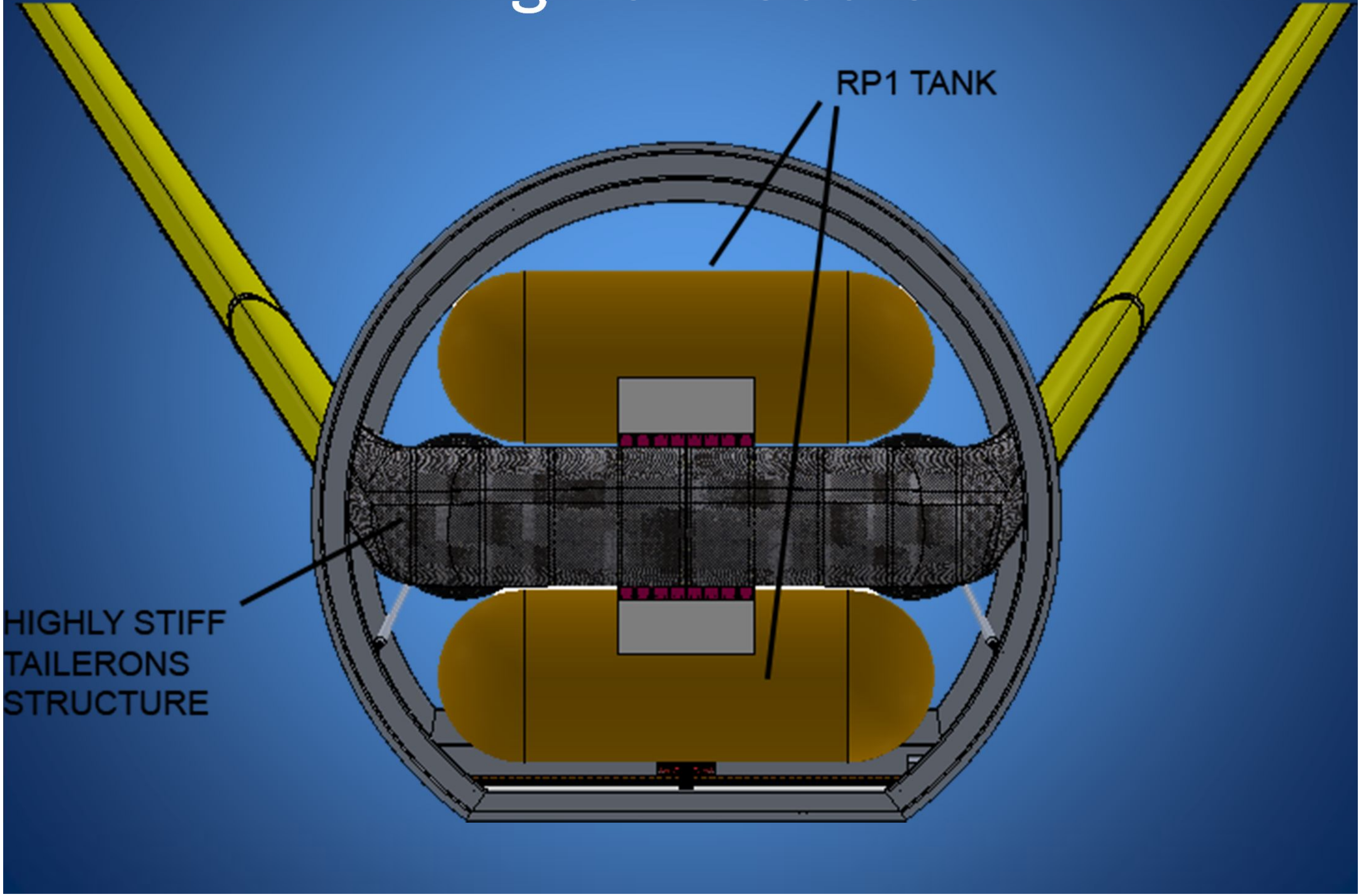
Engine Module



Engine Module



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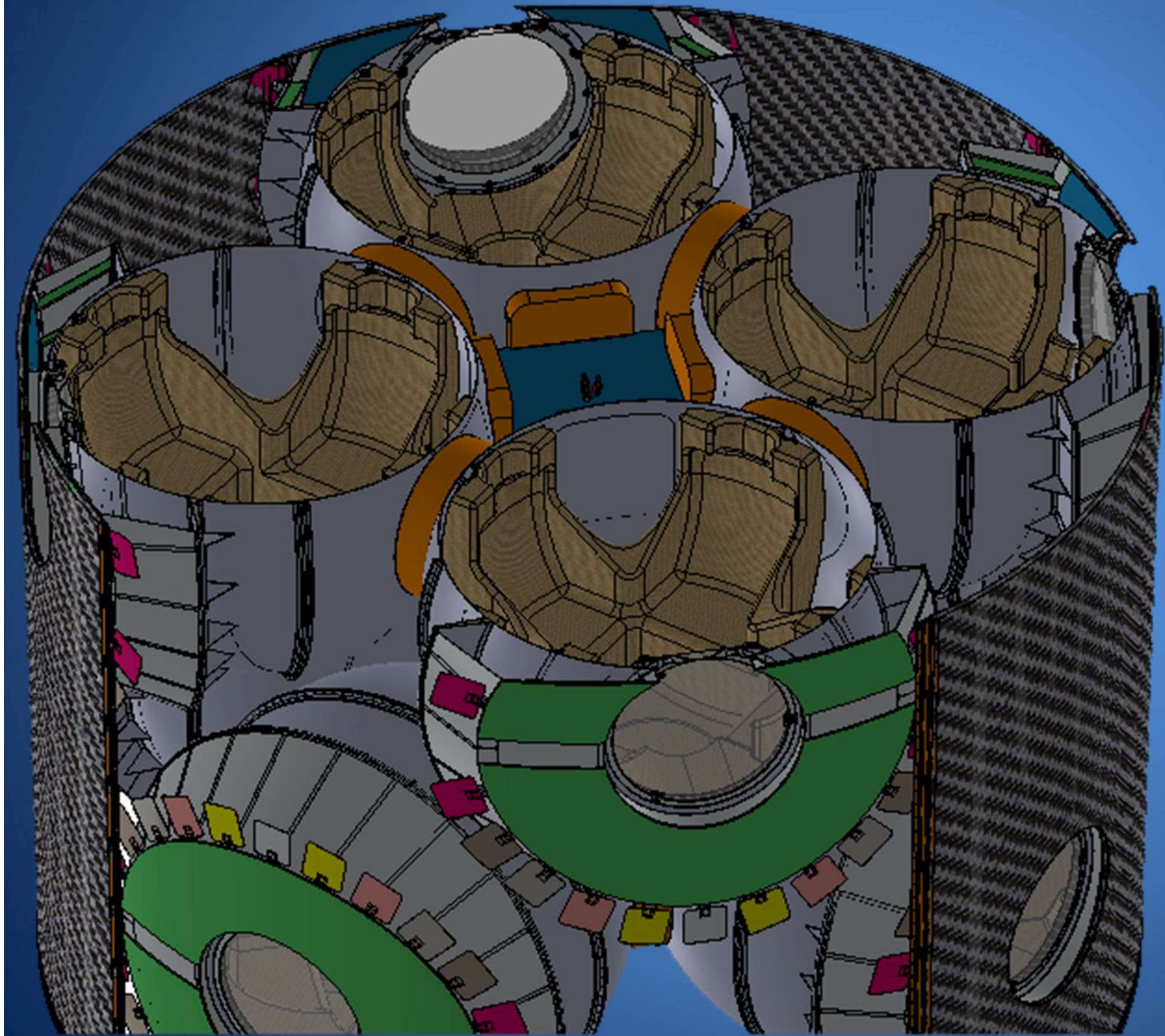
Passenger Module



Being the Pods the only pressurized volumes with an ideal shape to challenge pressure differential, the remaining part of the vehicle is totally unpressurized. This much simplifies design.

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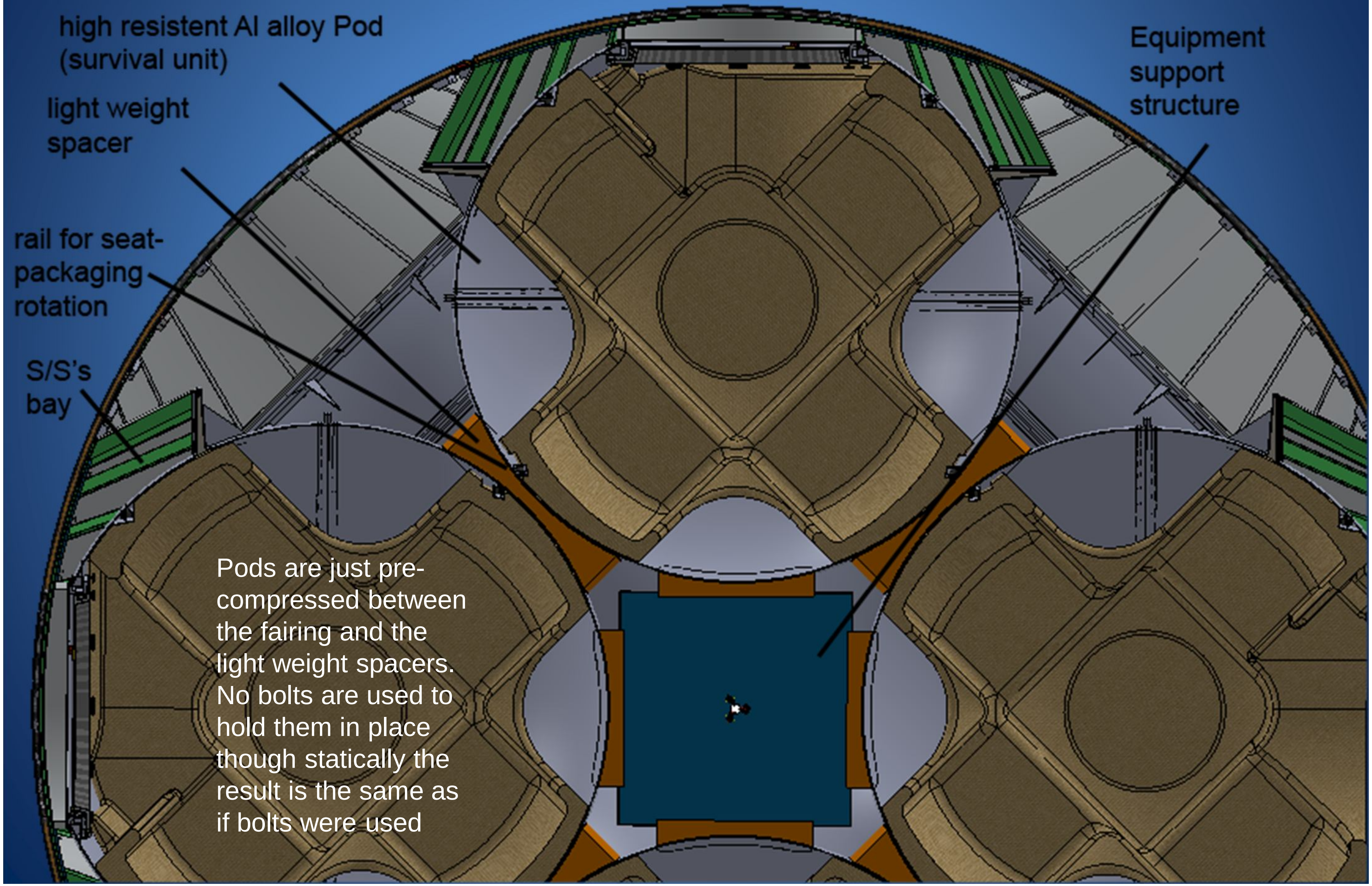
Passenger Module



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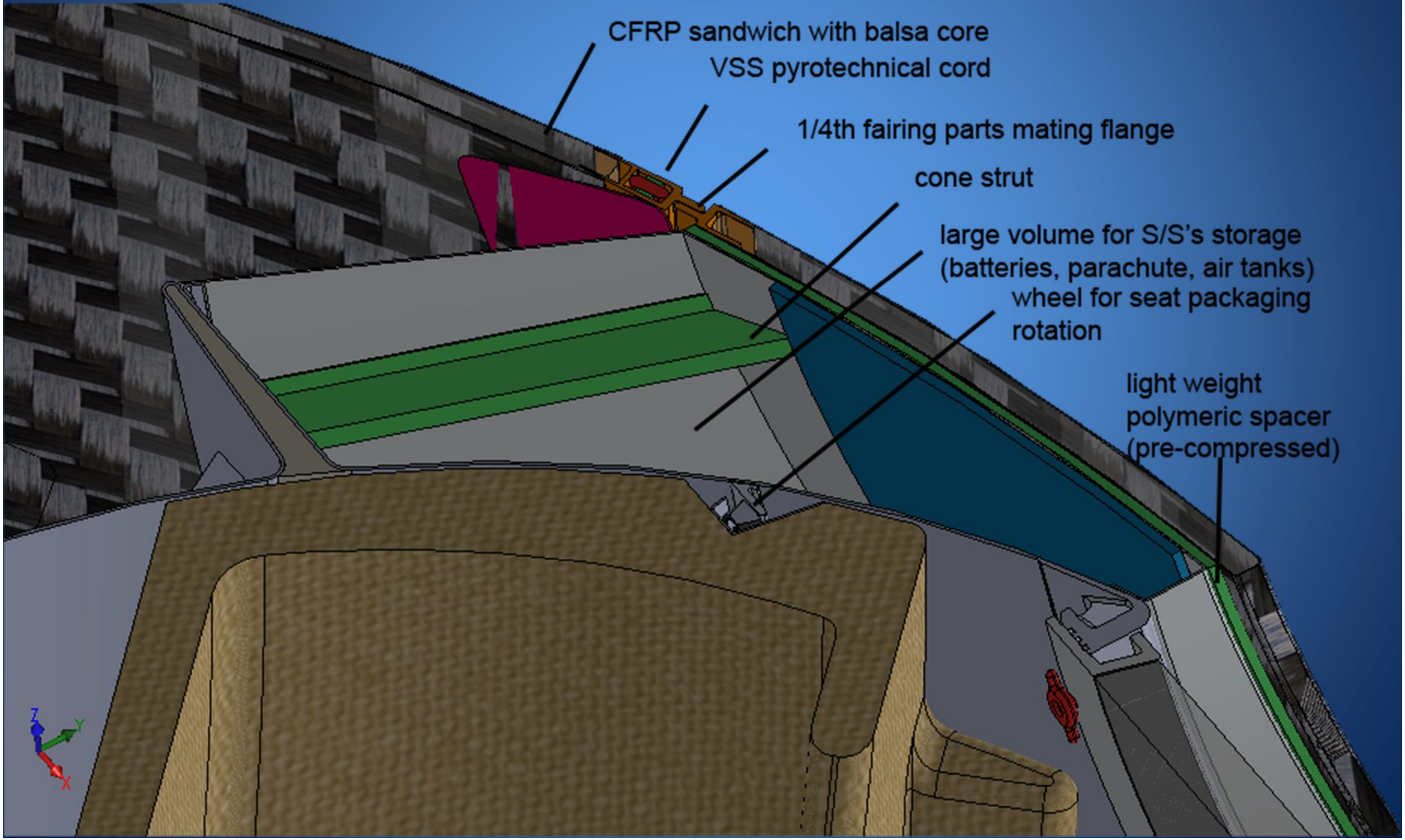
Passenger Module



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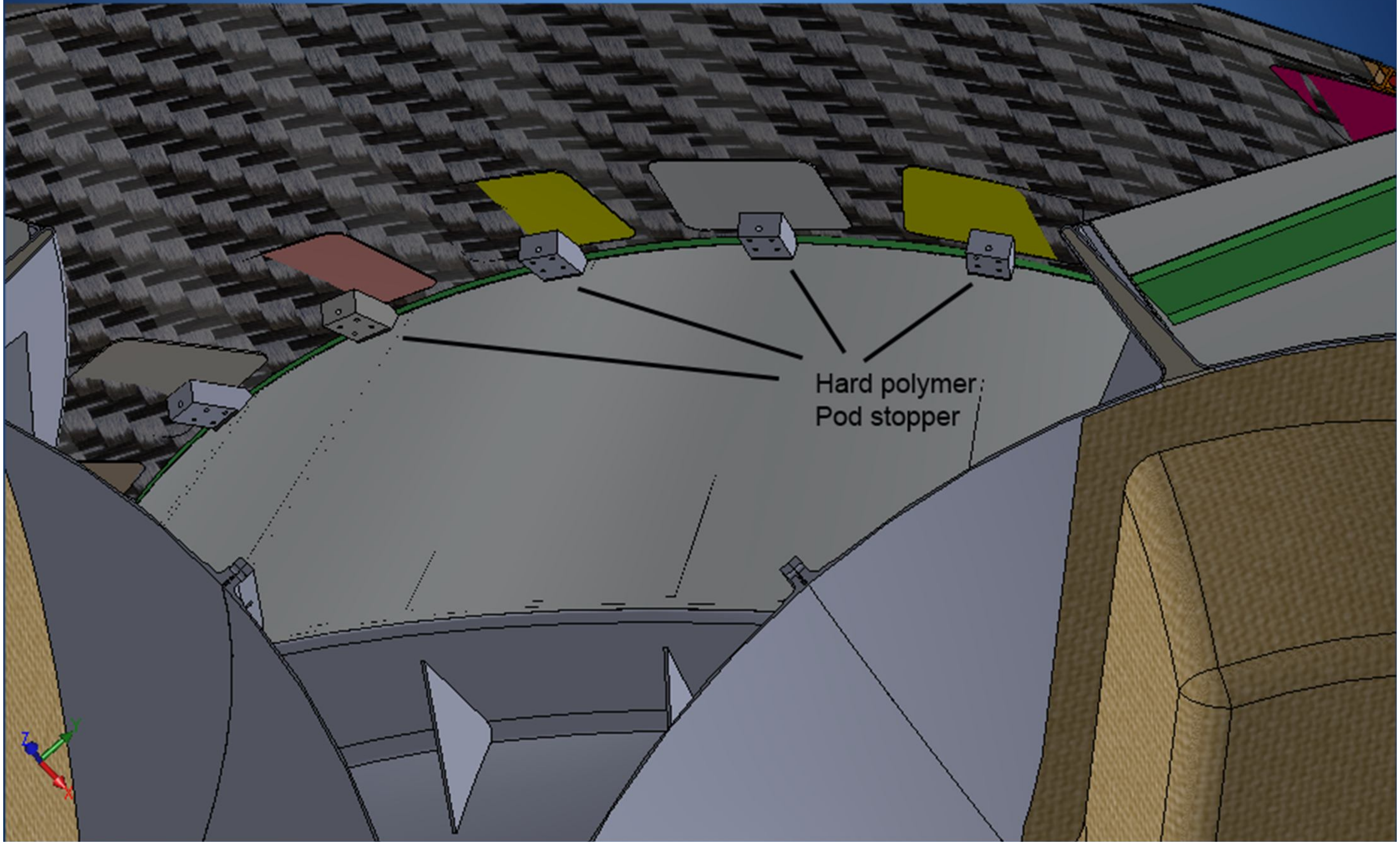
Passenger Module



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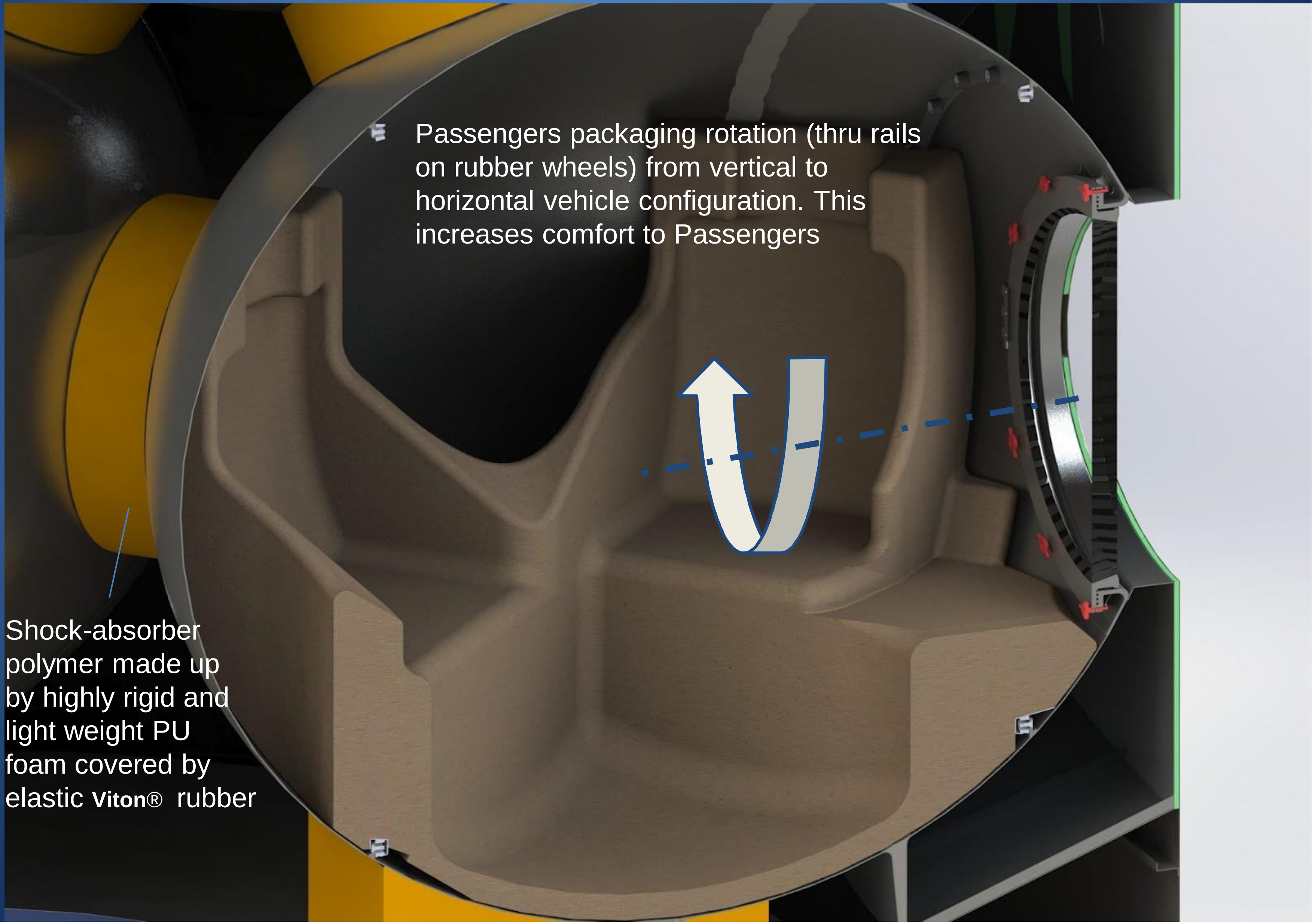
Passenger Module



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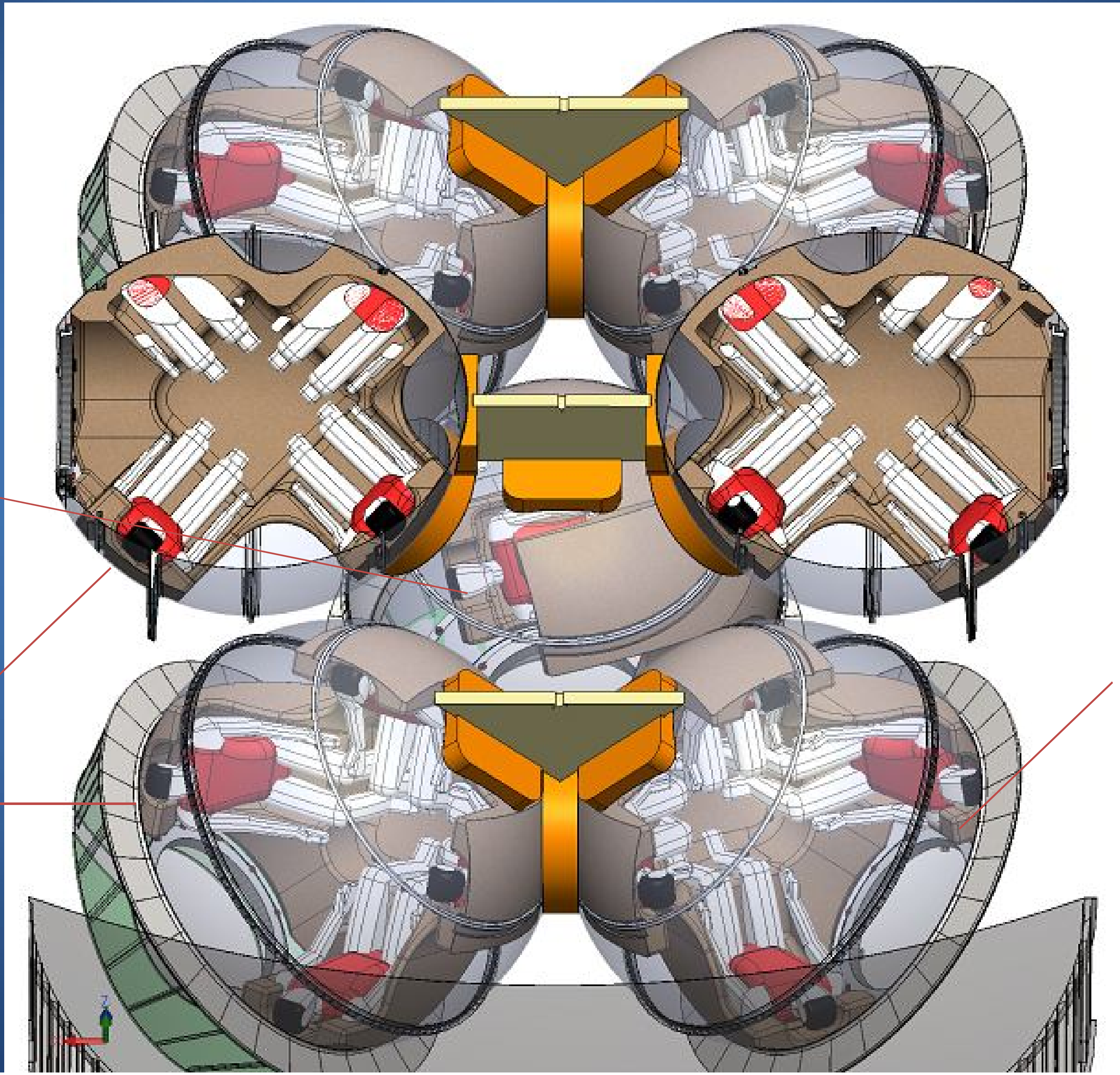
Passengers configuration during descent and landing

The loads during the descent are normal to this figure plane.
The Pods in the 2° floor and in the middle have only 2 passengers who experience loads with the back normal to loads (most optimized configuration).
The Pods in the 2° floor on the right and left side have loads perfectly in line with the back.
All others Pods have loads with about 80% of the load in line with the back and 20% lateral.



Anti-g suits and lateral head stopper on the seats will be enough to counteract an about 0.5g lateral load.

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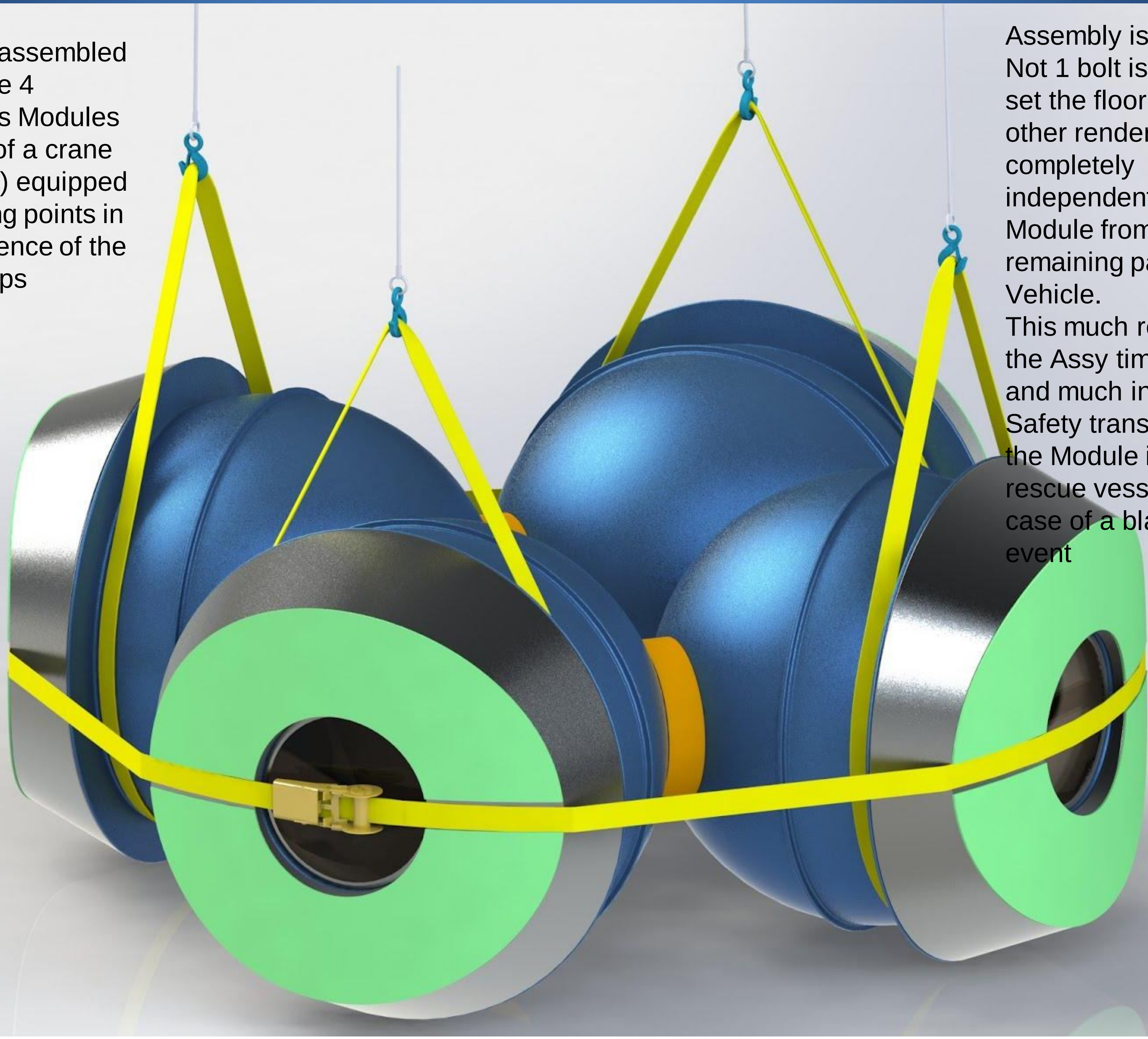
Floor Assembly

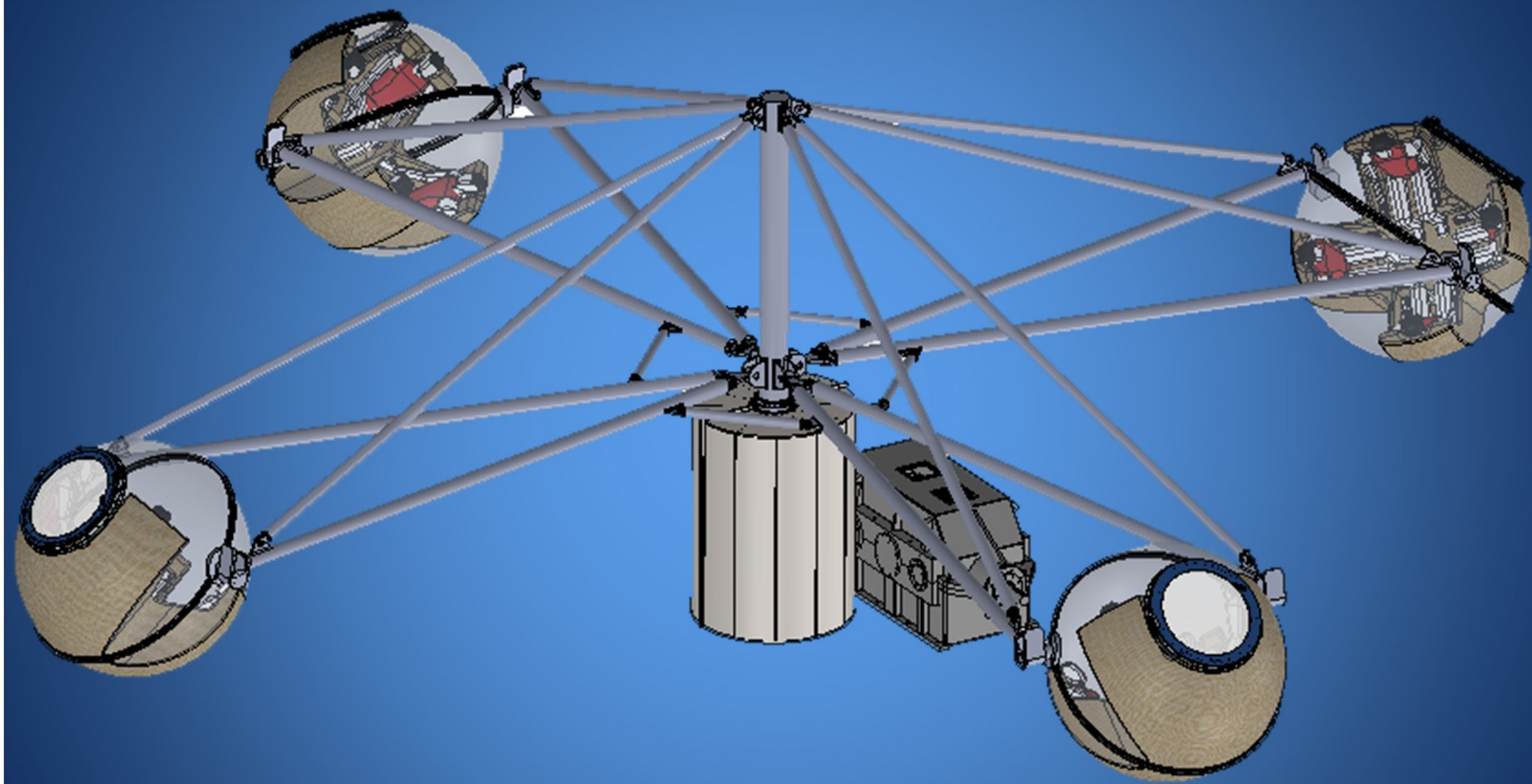
Floors are assembled by lifting the 4 Passengers Modules by means of a crane (not shown) equipped with hoisting points in corrispondence of the towing straps



Assembly is easy. Not 1 bolt is used to set the floor over the other rendering completely independent any Module from the remaining part of the Vehicle.
This much reduce the Assy time, BoM and much increase Safety transforming the Module in a rescue vessel in case of a blasting event

SHIPinSPACE

Mission preparation



Passengers get trained during a 5 sessions trial spread over a period of 2 years on machines like this centrifuge to accomodate people the same way as they will be in the SHIPinSPACE Vehicle.

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Mission preparation

Passengers experience the same level of loads that will encounter during the flight.
Maximum acceleration will be 2.0g during ascent phase at the end of the propulsion phase and 2.5g during maximum drag along the descent.

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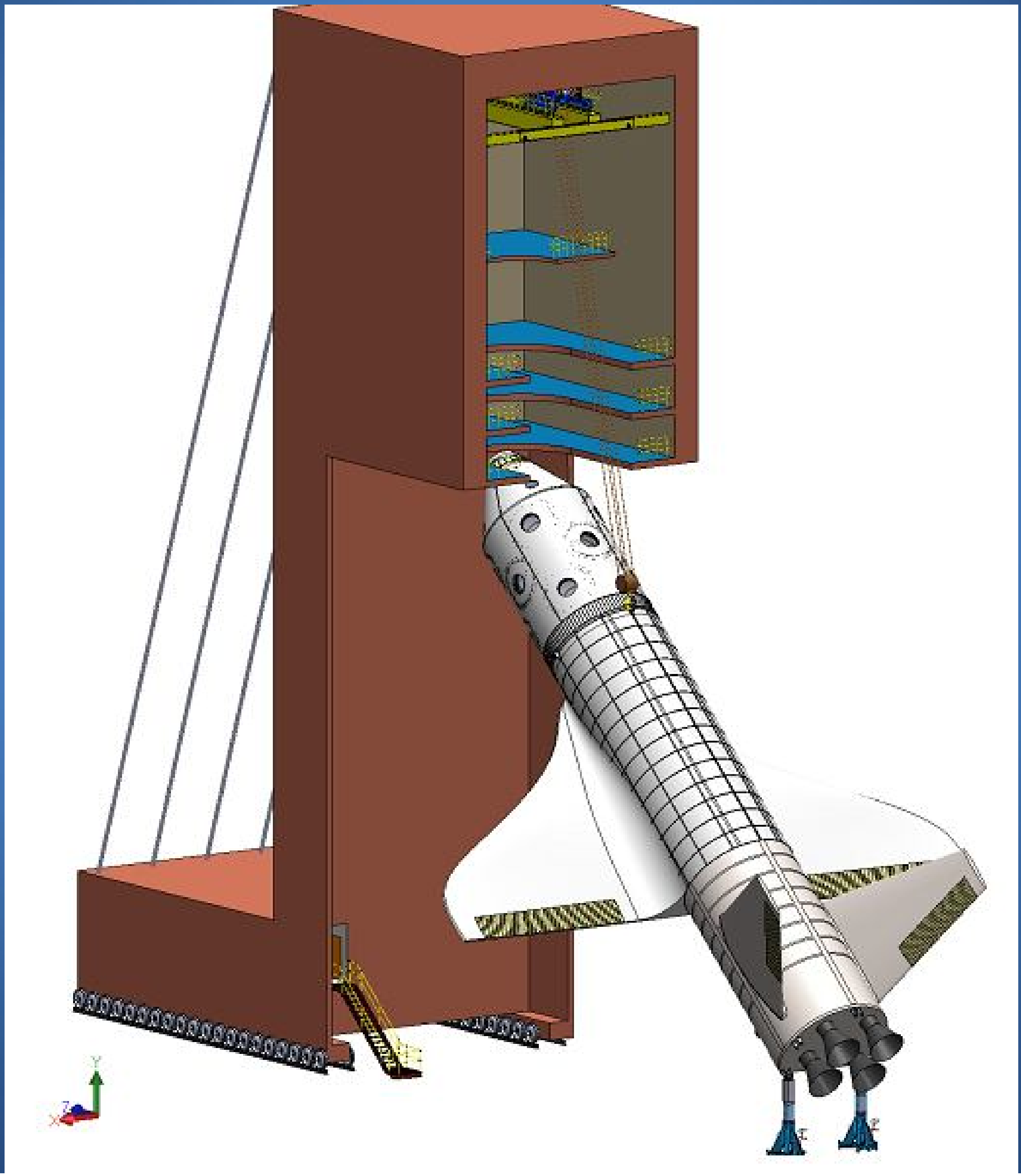
Operations after landing

After landing the Vehicle is tilted from horizontal to a vertical configuration by means of a crane mounted on a mobile gantry. 2 pivot points are fixed on ground on the Vehicle in correspndence of 2 trunnions.



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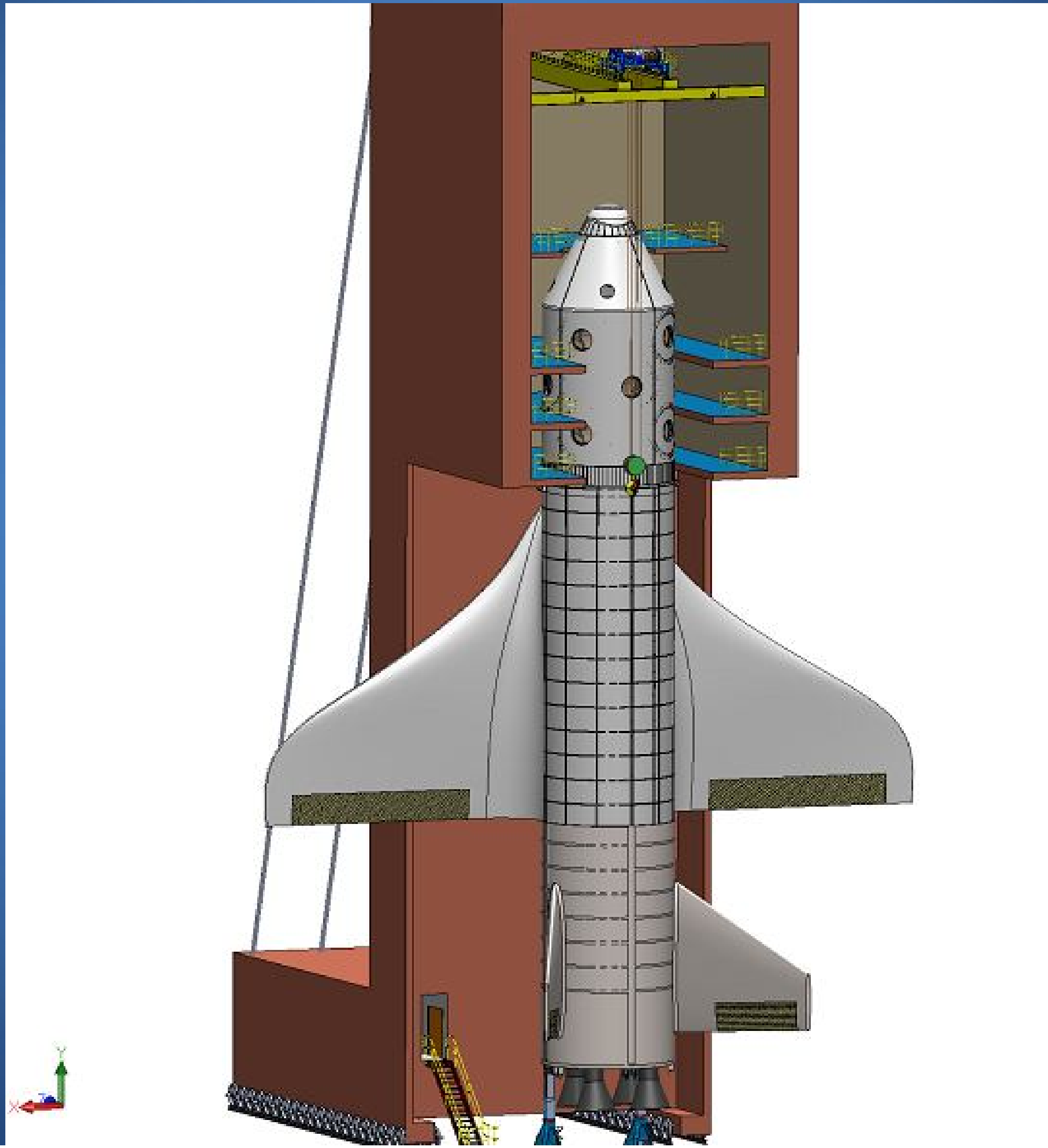
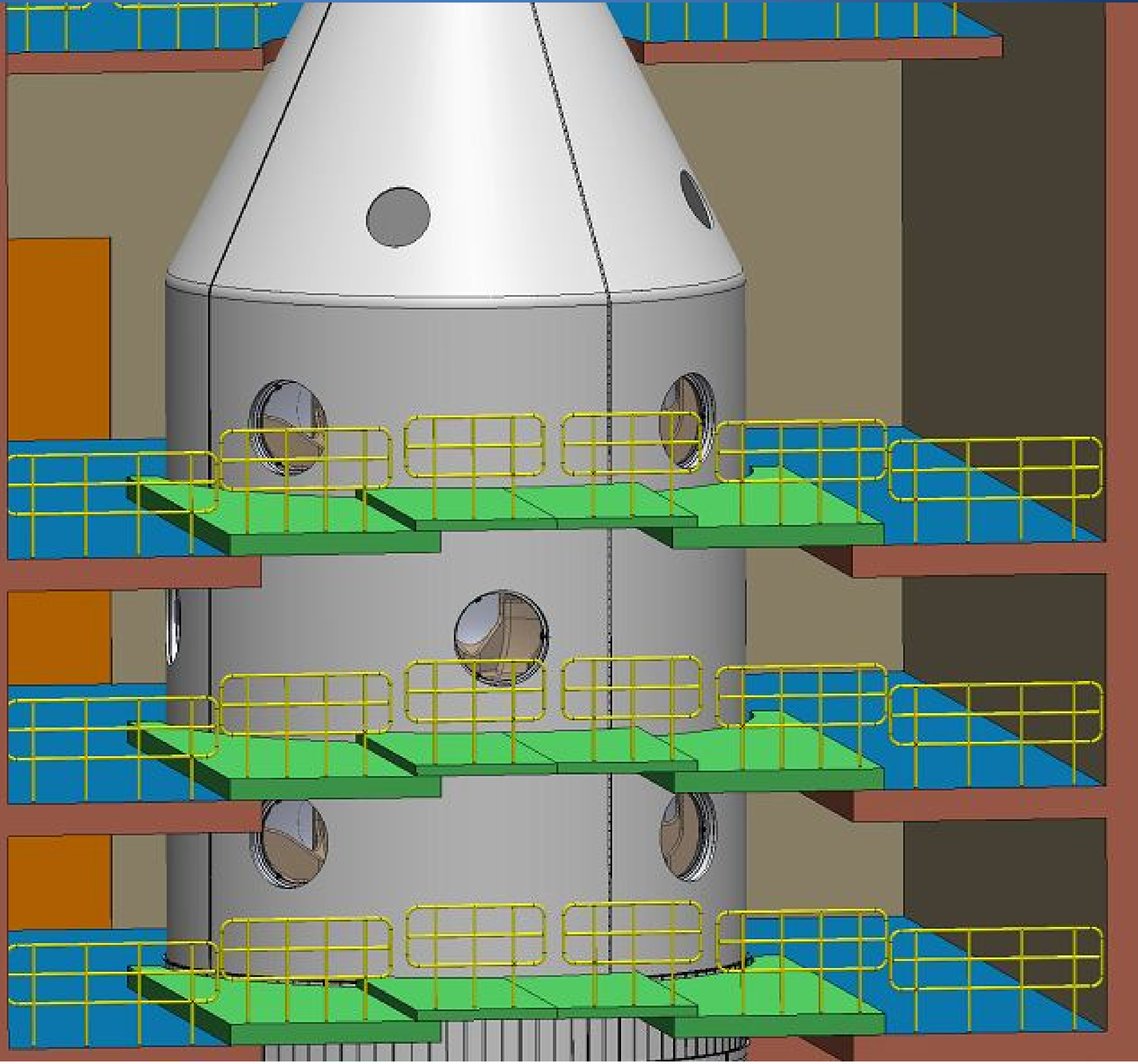
Operations after landing

The vertical configuration is the most appropriate to get in/out of the Passengers and to spend comfortably the time needed for the flight equipment checks, Passengers fastening, Pod hatch closure and Pod pressurization.

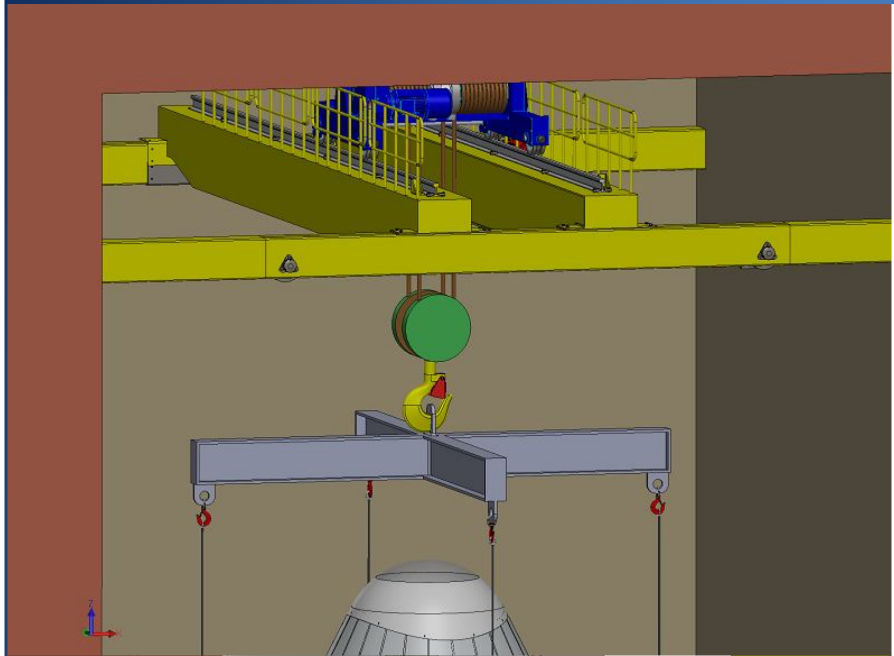


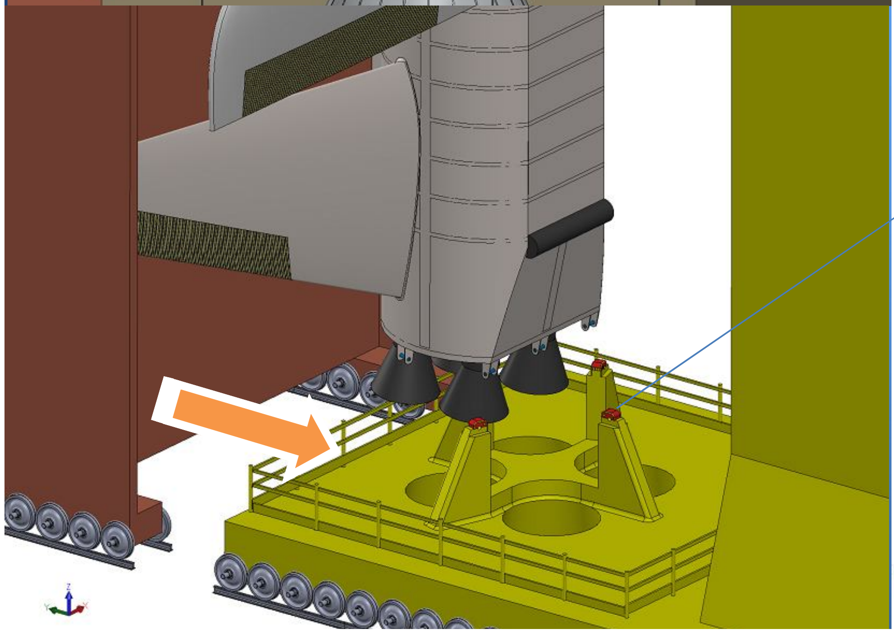
Operations after landing

Operations during the on/out board rely on a gantry having 3 independent floors with a fixed part and some mobile plateforms that once closed permit accessibility operations to be made in parallel, then much optimising the time needed to get in/out of the Passengers

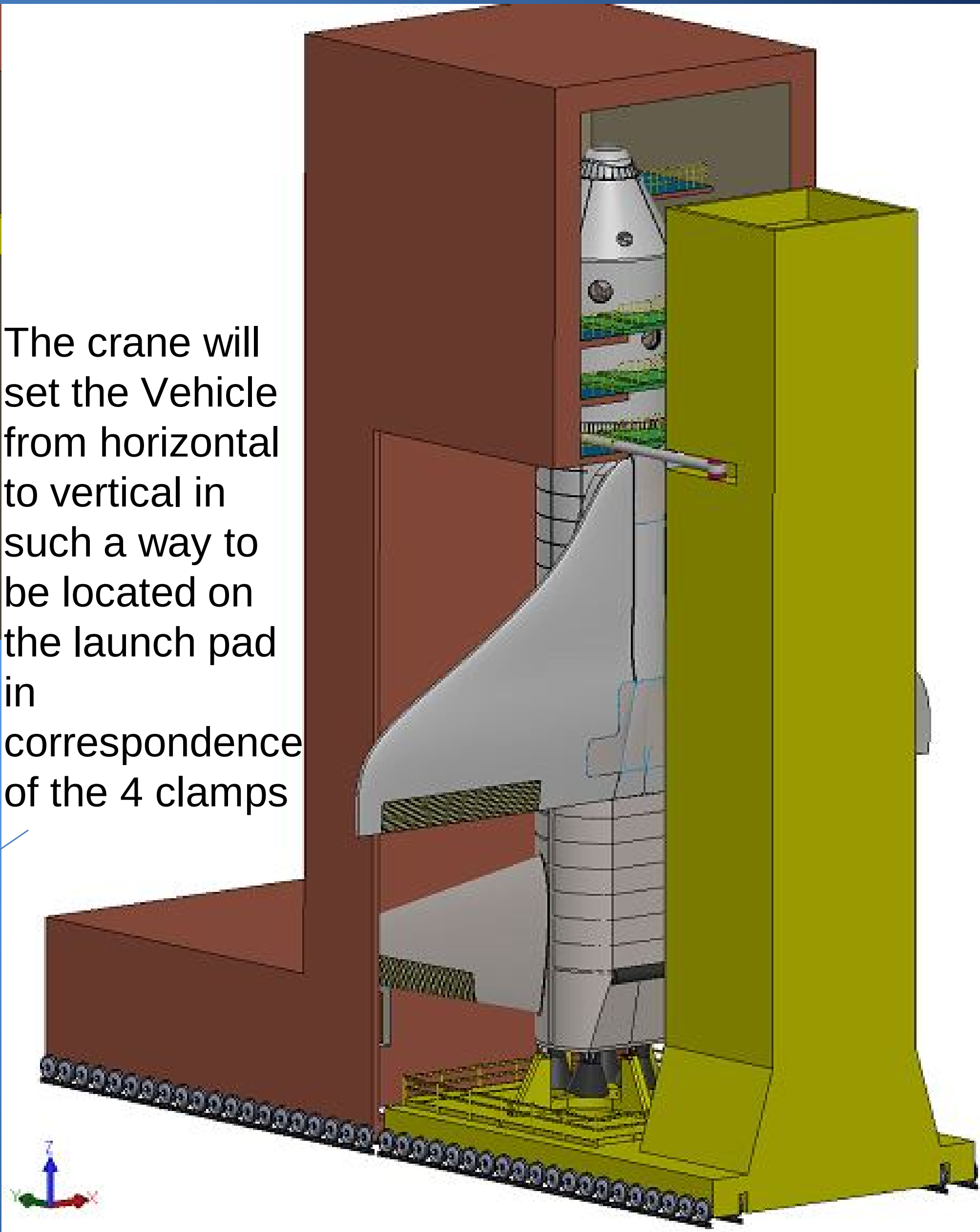


Operations before take-off





The crane will set the Vehicle from horizontal to vertical in such a way to be located on the launch pad in correspondence of the 4 clamps



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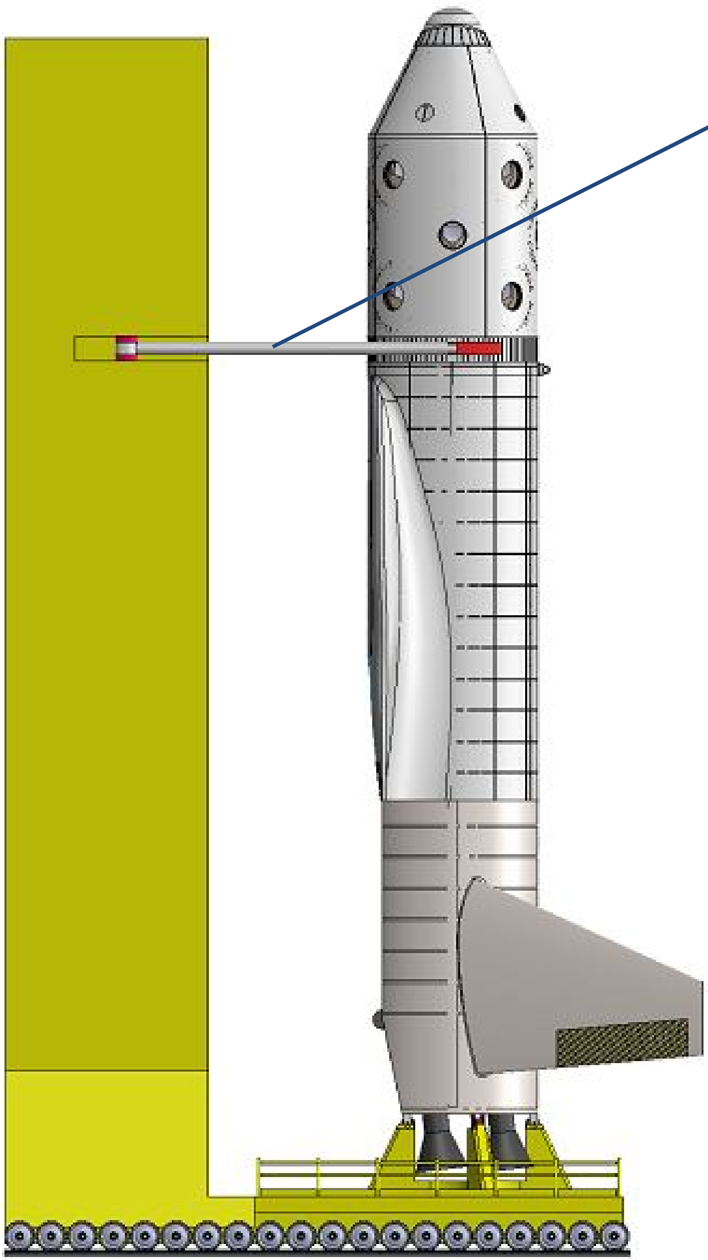
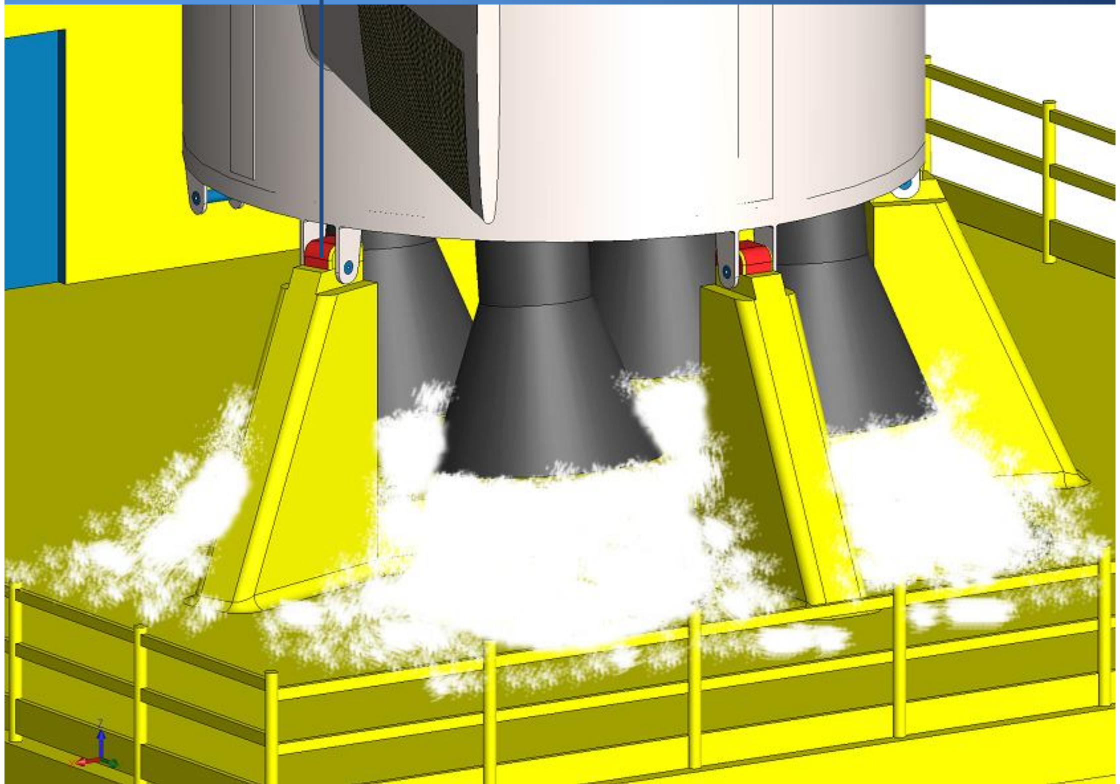
Take-off



Arms open 5 sec before take-off

On-ground clamps open only after main chamber pressure is checked for each engine



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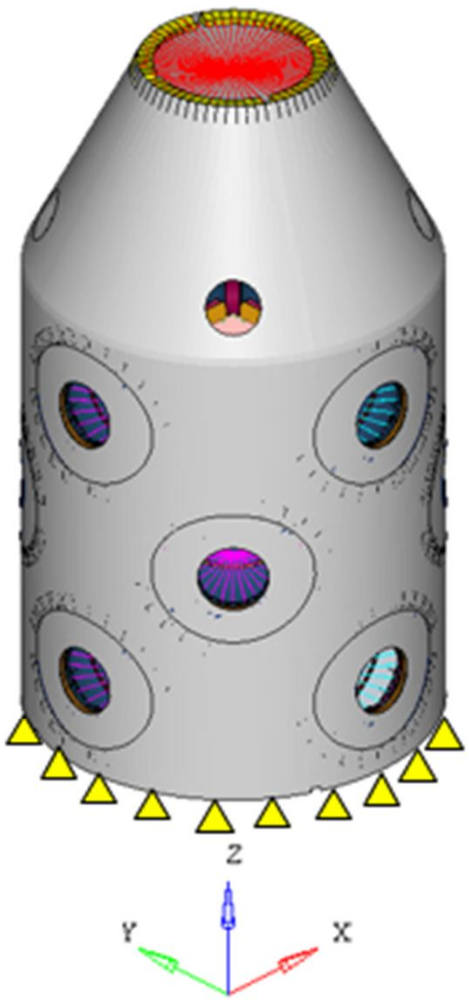
FEM static analysis on Passenger Module



Ascent loads cases

The CAD model has axis references in which the x-axis is rotated by 45° with respect to the vehicle Z axis.
The inertial loads specified in the Vehicle axis reference (X, Y and Z) are:

Ax=2.5g
Ay=0.5g
Az=3g

By transforming the vectors to the local CAD model the loads become:

Ax=1.414g
Ay=2.121g
Az=3g

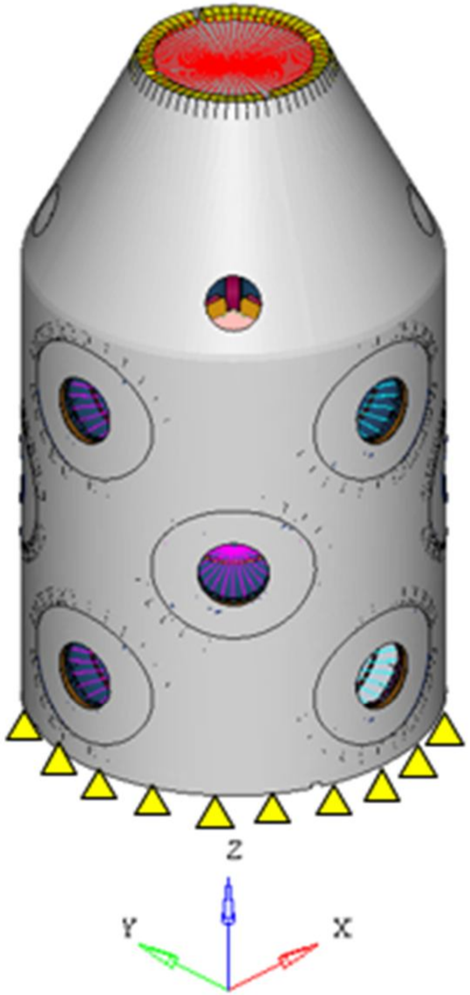
2 load cases are analysed:

1° CASE: only inertial loads

2° CASE: inertial loads+ internal Pod pressurization of 1bar

The system is fixed on the base of the fairing

FEM static analysis on Passenger Module



Descent loads cases

The CAD model has axis references in which the x-axis is rotated by 45° with respect to the vehicle Z axis.
The inertial loads specified in the Vehicle axis reference (X, Y and Z) are:

The inertial loads specified in the Vehicle axis reference (X, Y and Z) are:

Ax=3.75g
Ay=0.5g
Az=2g

By transforming the vectors to the local CAD model the loads become:

Ax=2.30g
Ay=3.01g
Az=2g

2 load cases are analysed:

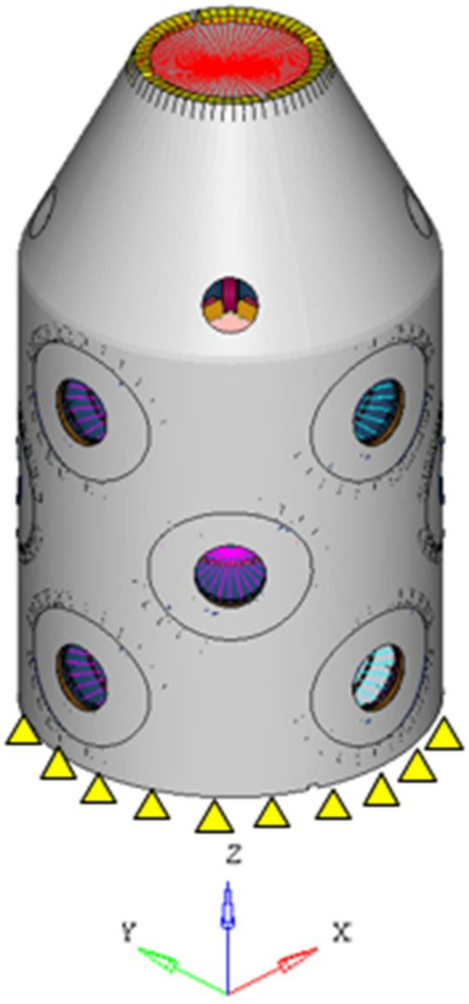
1° CASE: only inertial loads

2° CASE: inertial loads+ internal Pod pressurization of 1bar

The system is fixed on the base of the fairing.

SHIPINSPACE

FEM static analysis on Passenger Module



Crash landing case

The CAD model has axis references in which the x-axis is rotated by 45° with respect to the vehicle Z axis.
The inertial loads specified in the Vehicle axis reference (X, Y and Z) are:

Ax=1g
Ay=0
Az=10g

By transforming the vectors to the local CAD model the loads become:

Ax=0.707g
Ay=0.707g
Az=10g

One load case is analysed:

Only inertial loads

The system is fixed on the base of the fairing.

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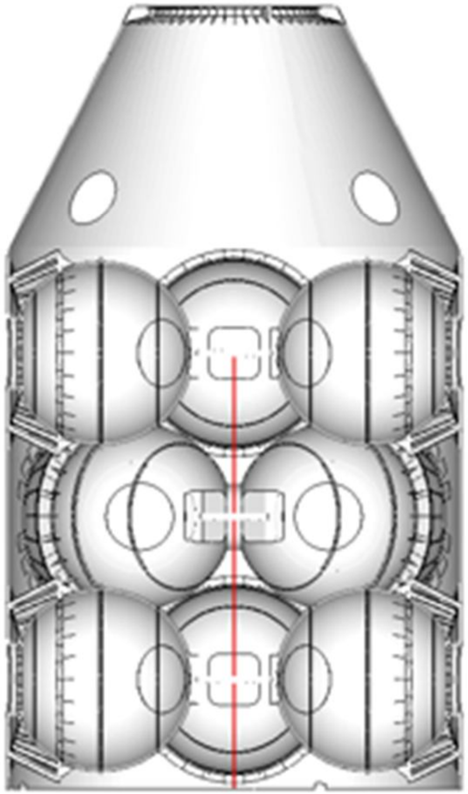
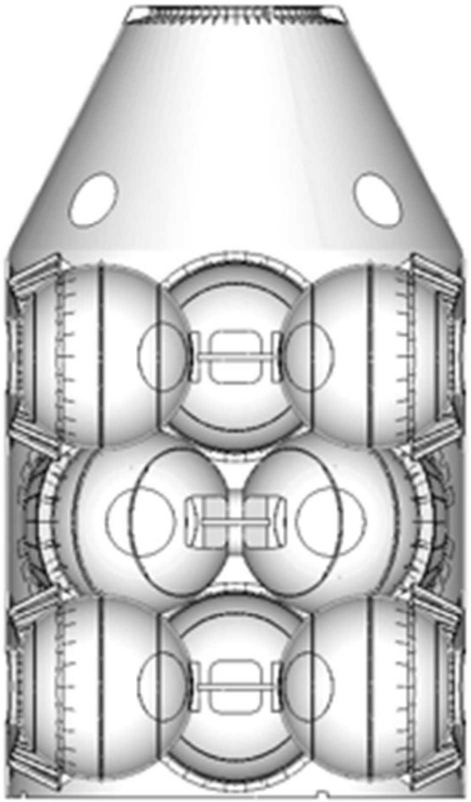
FEM static analysis on Passenger Module

Two different model are analyzed:

- With rods (red) of circular hollow section 80x2 that link Passenger floors
- Without rods



Total mass of model
16.010 Kg



Total mass of model
15.988 Kg

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FEM static analysis on Passenger Module

Maximum Von Mises stress calculated

Load case		Model with rods		Model w/o rods	
		Fairing [MPa]	Pods [MPa]	Fairing [MPa]	Pods [MPa]
Ascent	w/o Pod pressurization	61.2	122.4	68.3	136.6
	with Pod pressurization	52.3	182.0	58.6	186.7
Descent	w/o Pod pressurization	74.5	125.8	78.6	135.3
	with Pod pressurization	66.6	179.0	69.9	182.6
Crash landing	w/o Pod pressurization	73.6	221.7	89.5	254.8
		-	-	-	-

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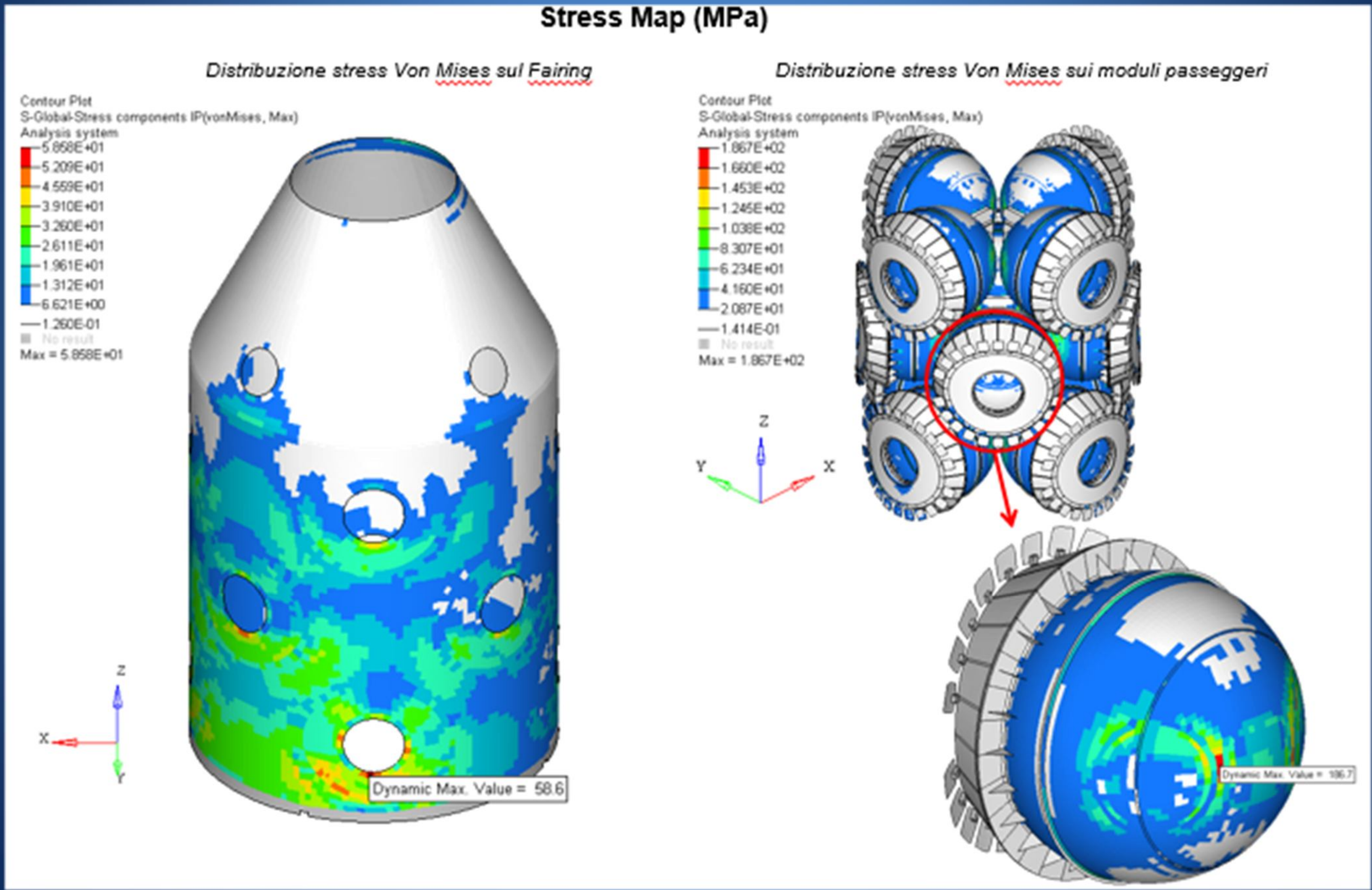
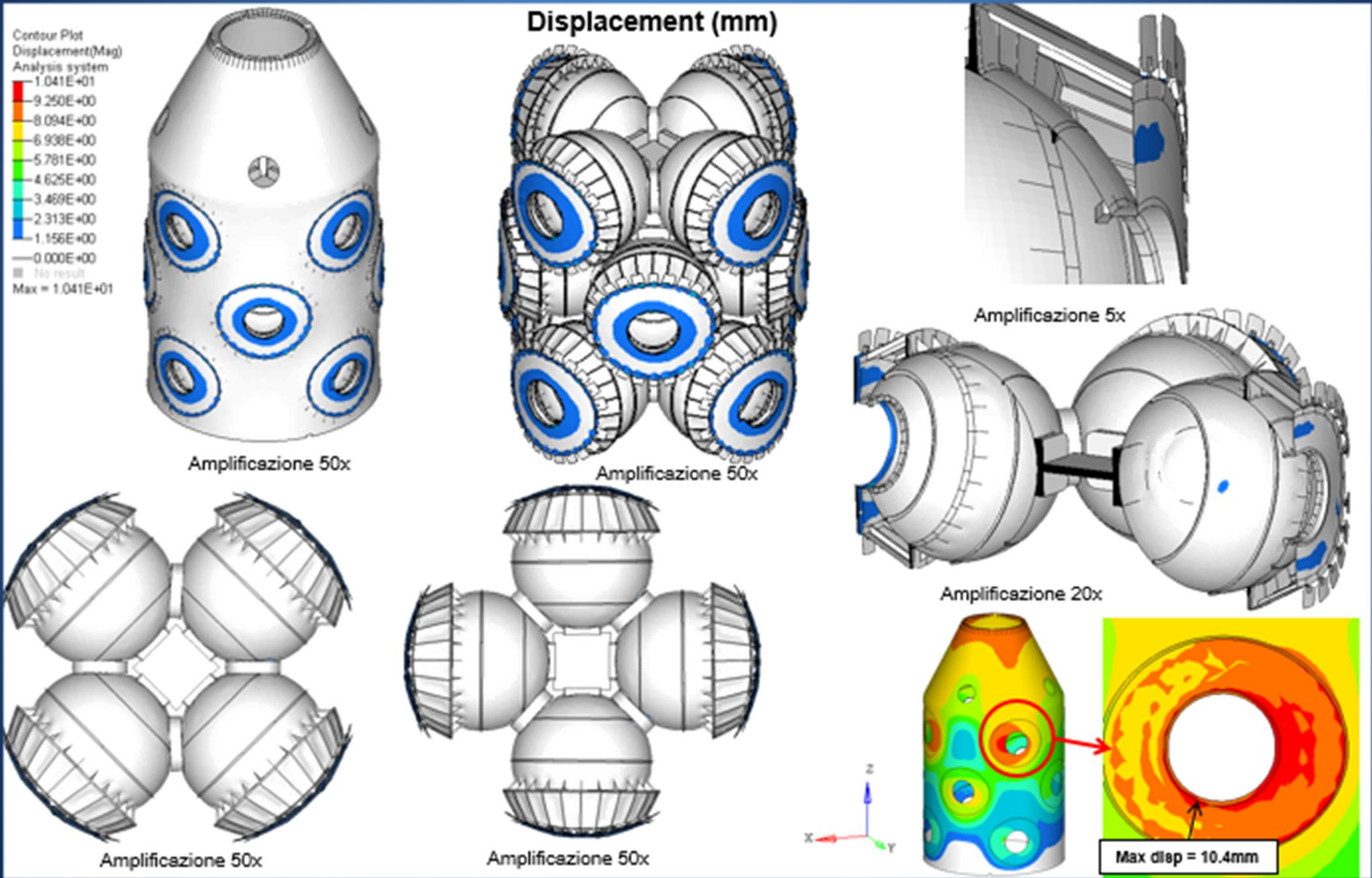
FEM static analysis on Passenger Module



FEM static analysis on Passenger Module



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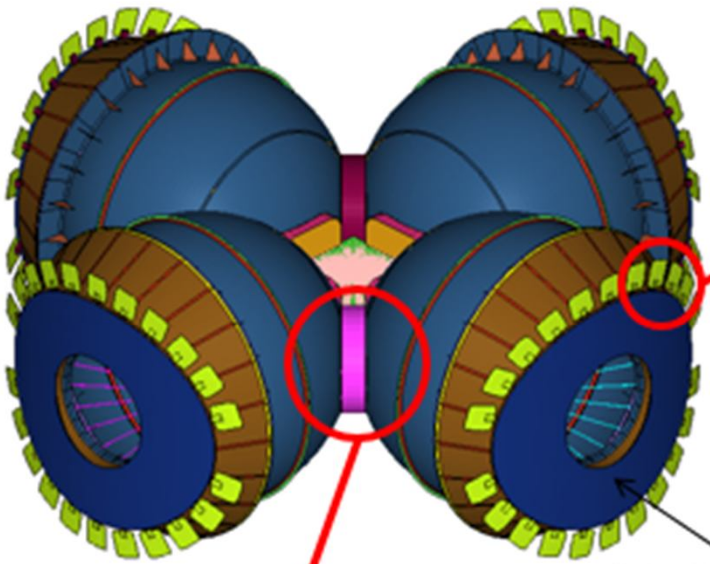
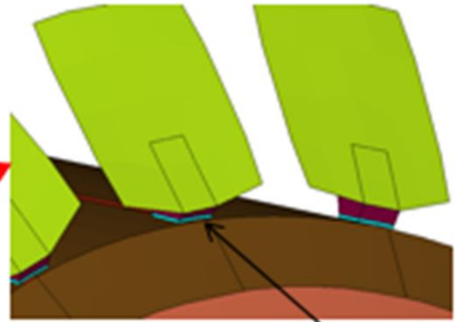
FEM dynamic analysis on Passenger Module

Summary of predominant modes for model with rods

Mode number	Natural frequencies [Hz]	Effective mass [Kg]		
		X	Y	Z
1	12.85	11.345	0.405	0.000
2	12.85	0.404	11.345	0.000
5	23.60	0.000	0.000	9.016
6	25.37	2.881	0.063	0.000
7	25.38	0.063	2.881	0.000
14	33.89	0.000	0.000	0.417
17	37.35	0.000	0.000	0.254
18	42.62	0.000	0.000	2.793
21	51.53	0.000	0.000	0.320
46	66.72	0.000	0.000	1.593
	Total	14.693	14.694	14.393

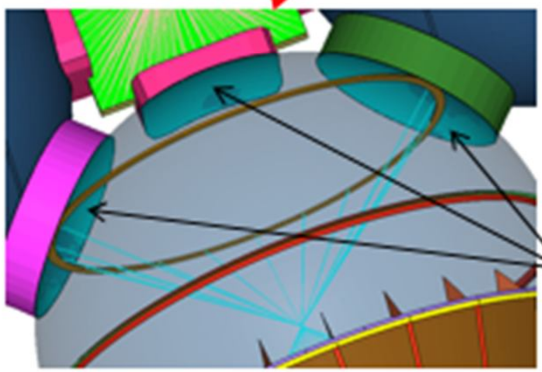
FEM elements properties





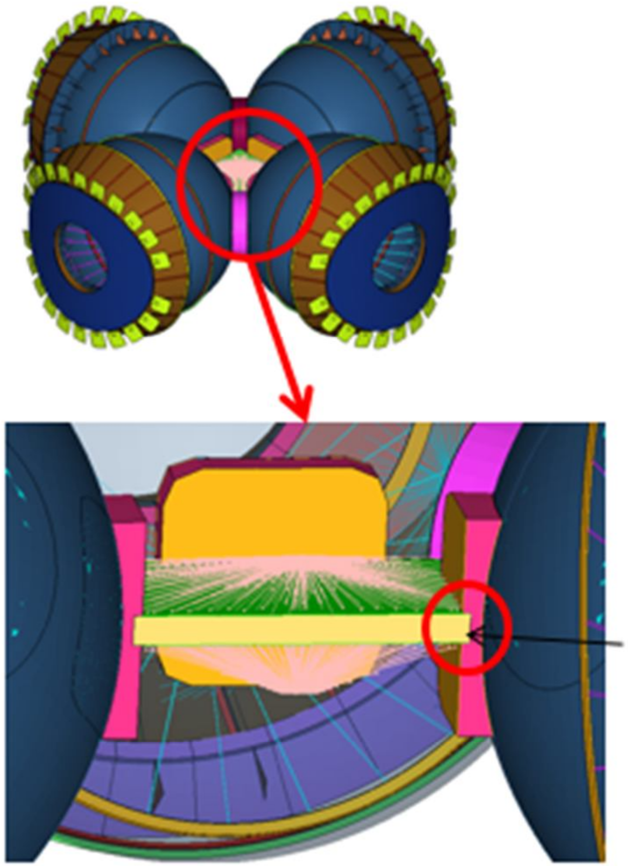
The pad fins (green) are glued on fairing and on plastic supports (purple). Between plastic supports and the coverage of Pod Passenger (brown) is interposed a hard rubber (E = 100Mpa - blue) that is compressed on the Pod. Rubber has a structural damping factor of 0.4.

Soft rubber (E = 1MPa) is glued to the fairing and compressed to the Passenger Pod. The rubber has a structural damping factor of 0.4.

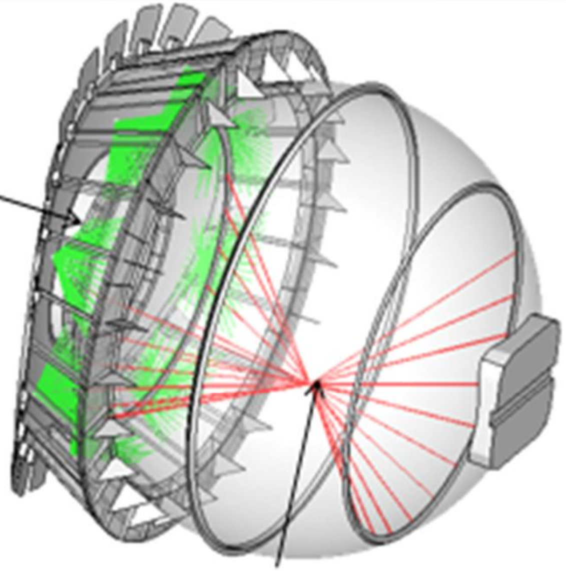


Each Passenger Pod is in contact with three disks through an hard rubber (E = 100Mpa-blue) that is tied with it. Rubber has a structural damping factor of 0.4.

FEM elements properties



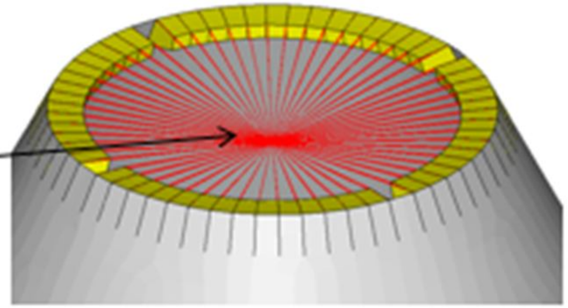
8 equipement mass of 10kg are distributed on area connected by green elements.



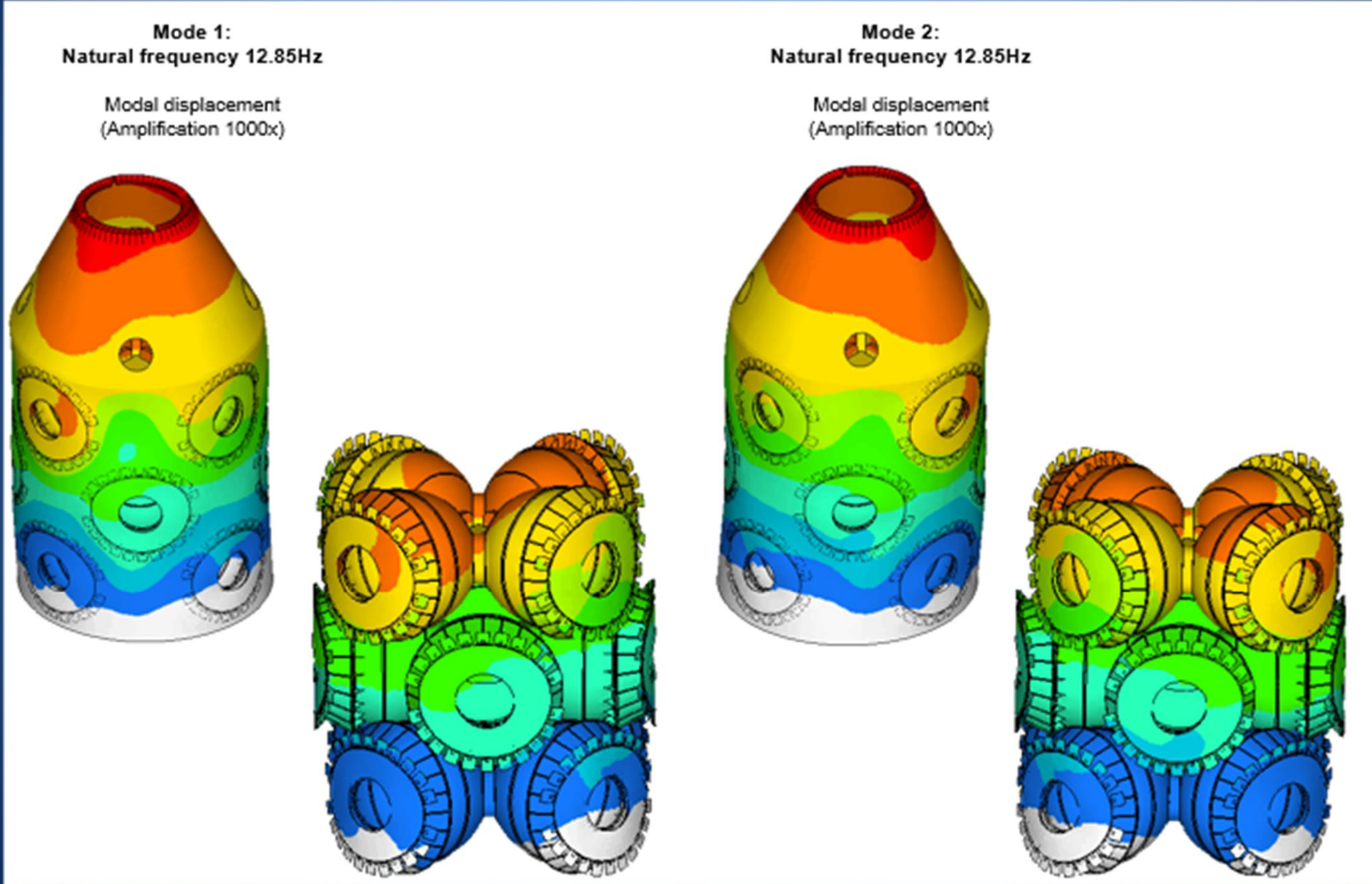
Area of contact between the bracket and central disc of Passenger Pod . The two components shown are compressed.

The seats +4 Passengers (each of 85kg)+45 kg of equipment are modeled with a concentrated mass of 536 kg placed in the center of gravity of this system and distributed on the rails by the red element.

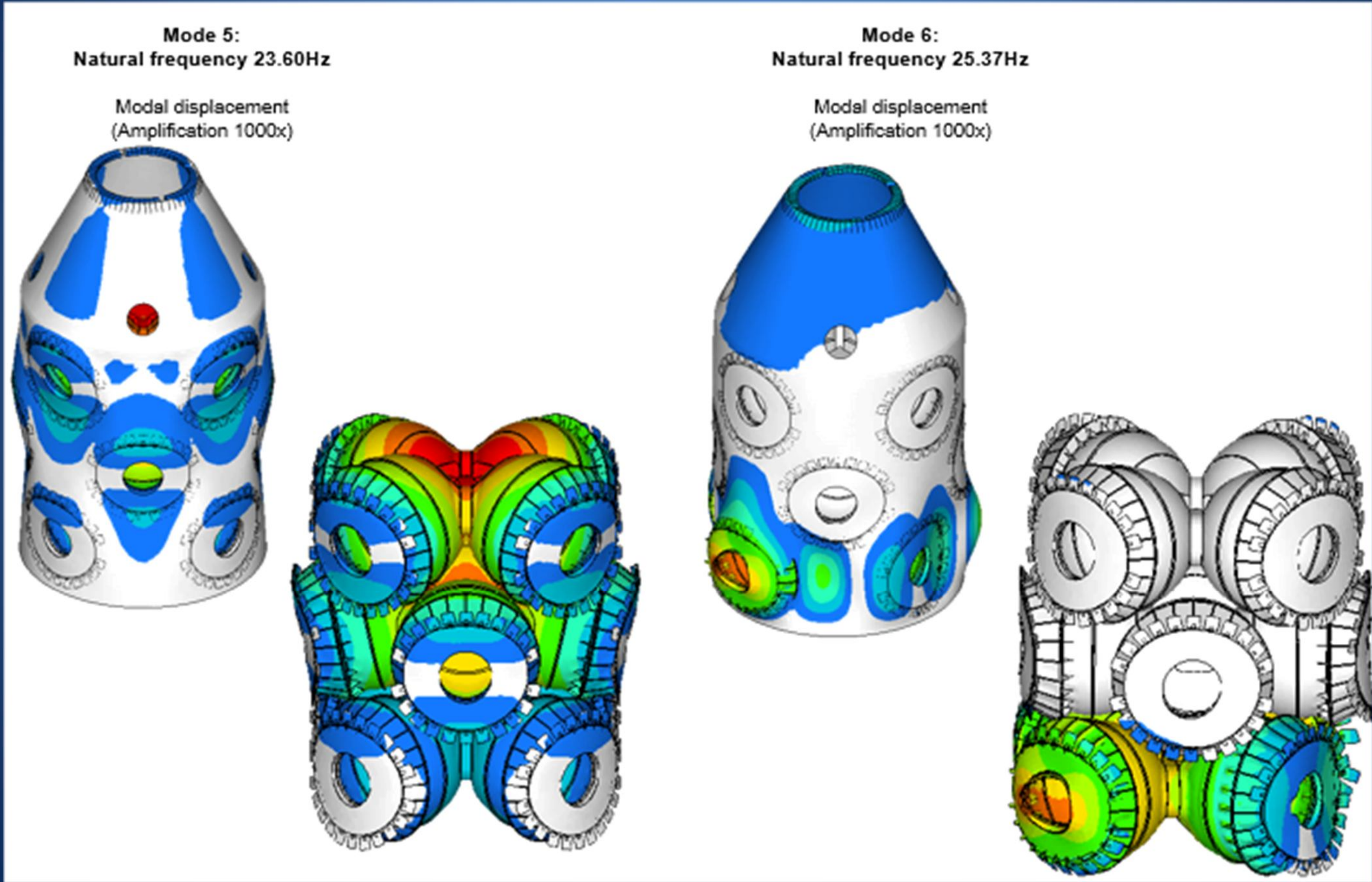
Pilot Pod is modeled with a concentrated mass of 947 kg distributed on the upper face of the aluminum reinforcement.



Modal analysis on Passenger Module



Modal analysis on Passenger Module



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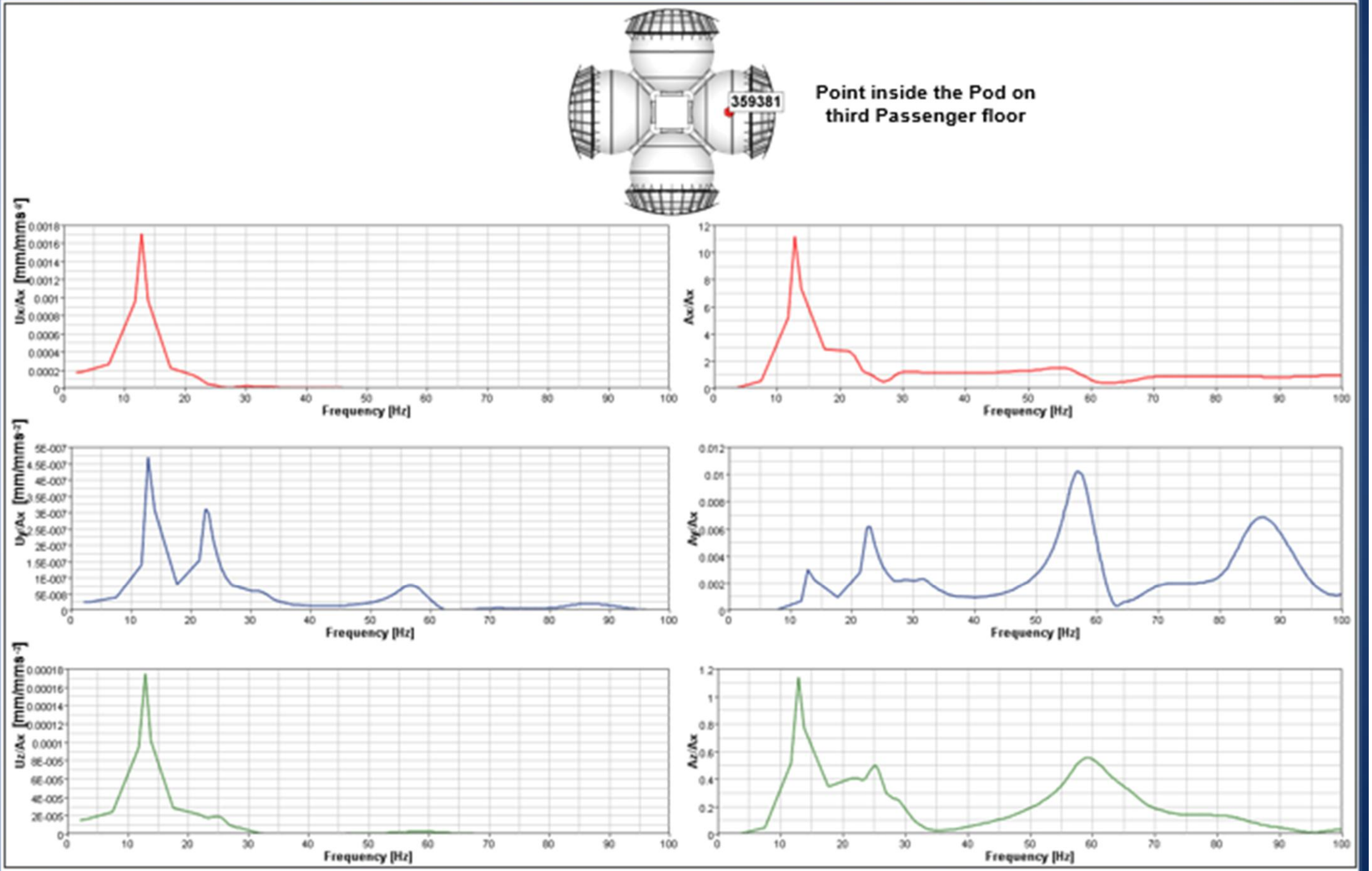
Transfer functions for load at X direction



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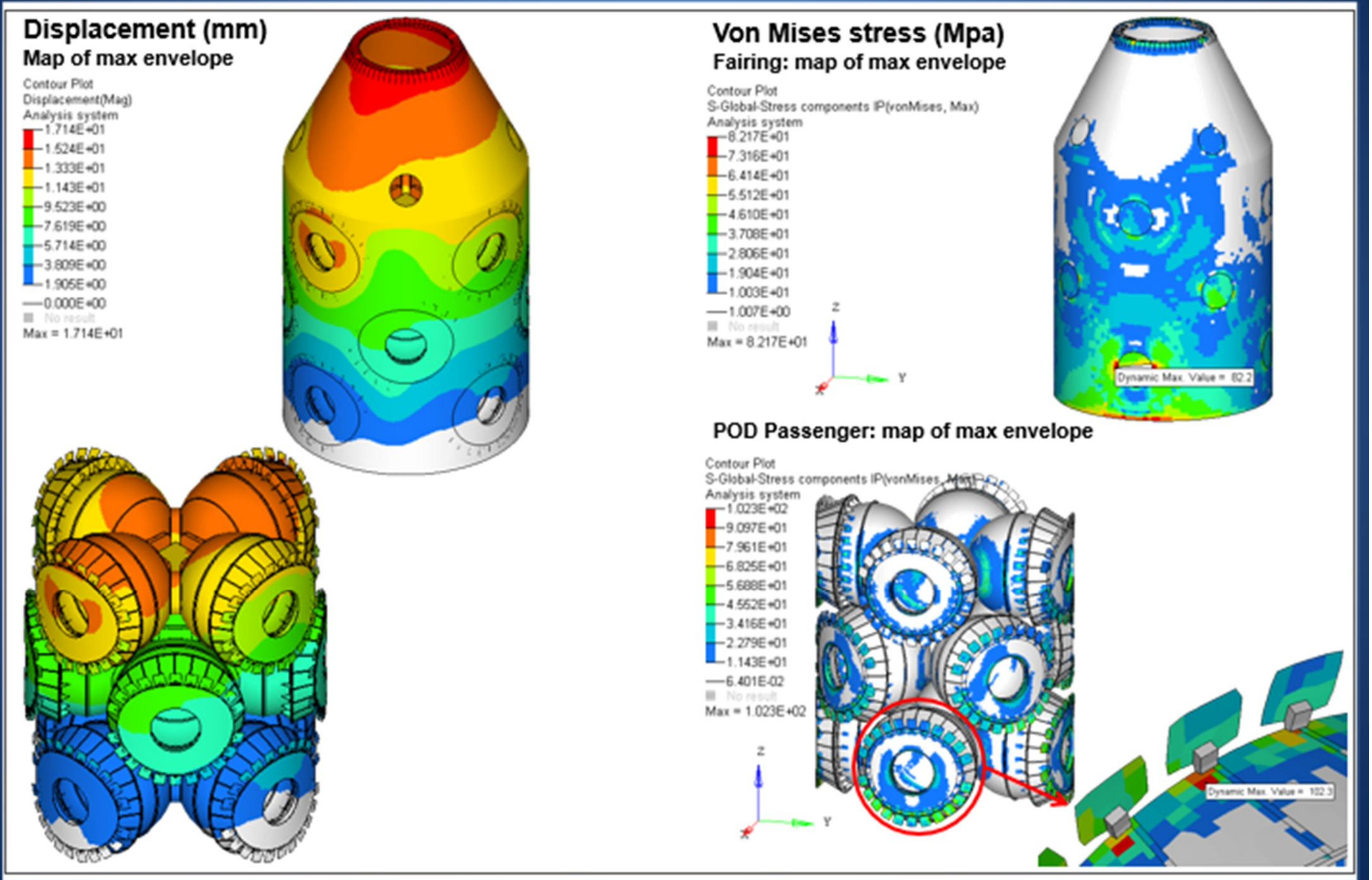
Steady state dynamic analysis load at X direction



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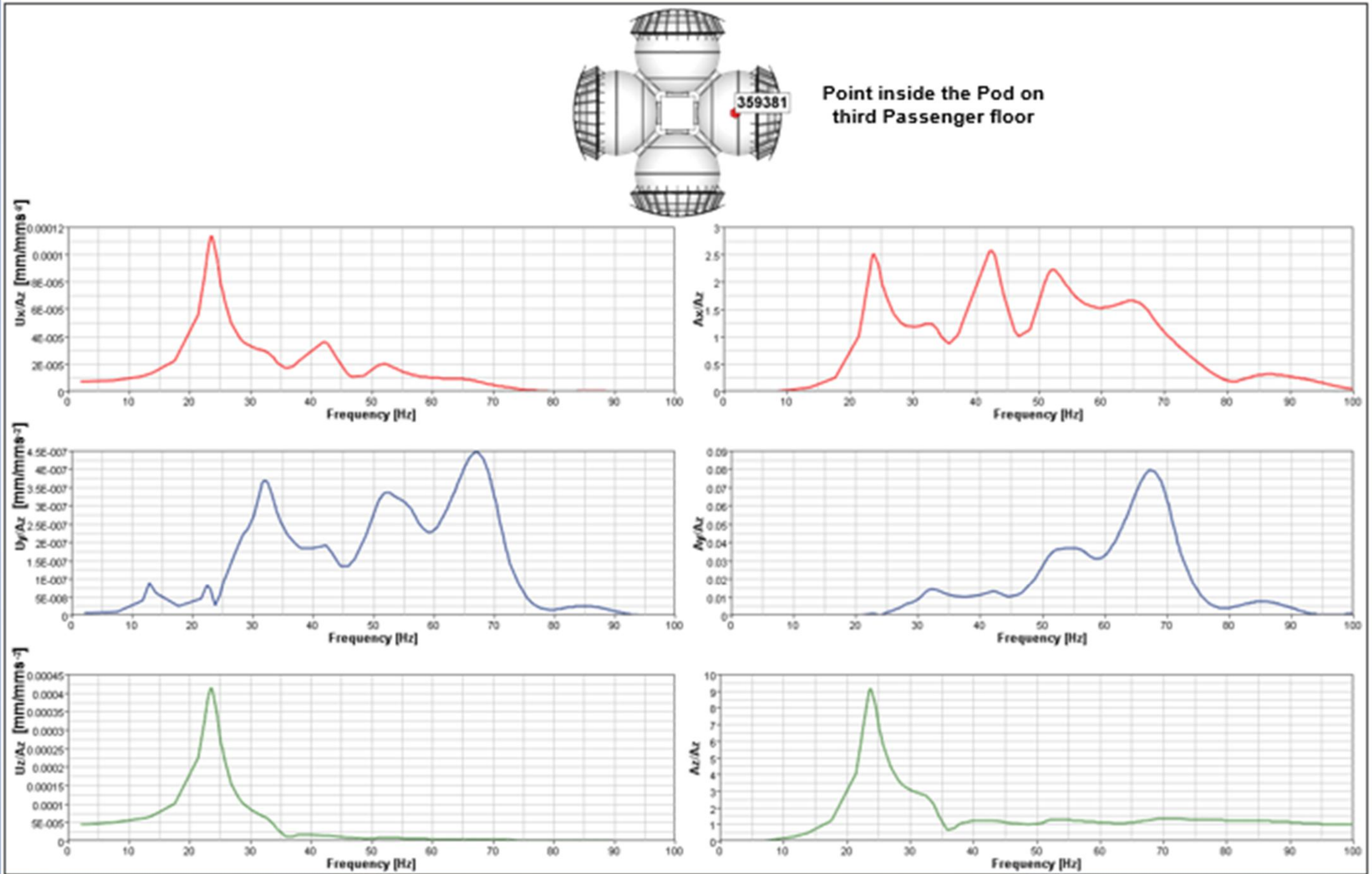
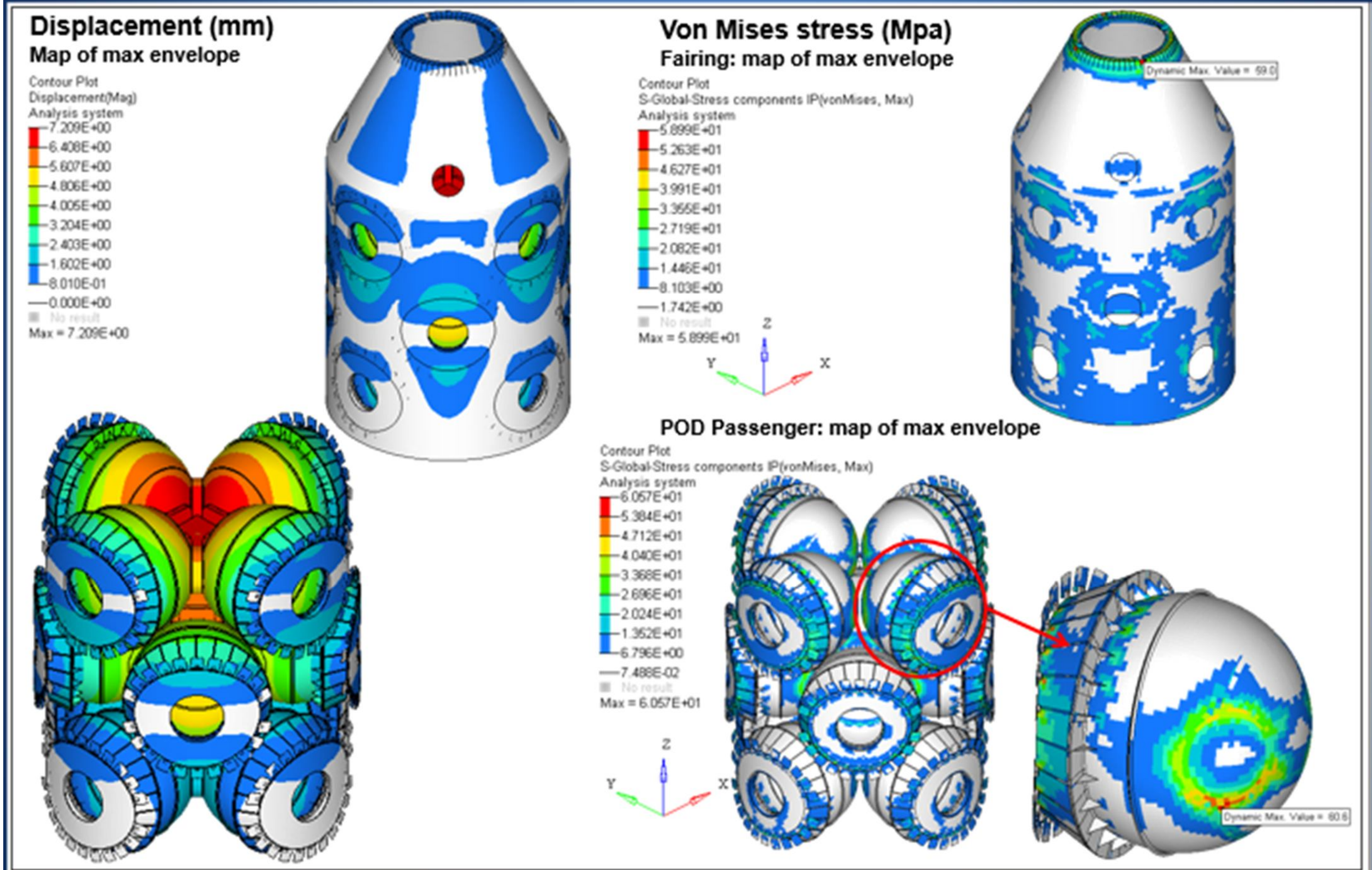
Transfer functions for load at Z direction



Transfer functions for load at Z direction



Margin of Safety for principal components

Margin of Safety for a safety coefficient of 1.5

Component	Model with rods			
	Static analysis [MPa]	Dynamic analysis [MPa]	Yield stress [MPa]	Margin of Safety (minimum)
Fairing	74.5	82.2	-	-
POD Passenger	179.0	102.3	393.0	0.46

Component	Model without rods			
	Static analysis [MPa]	Dynamic analysis [MPa]	Yield stress [MPa]	Margin of Safety (minimum)
Fairing	89.5	82.1	-	-
POD Passenger	182.6	102.2	393.0	0.43

Note: Margin of Safety is defined as:

$$\frac{\sigma_{adm}}{\sigma_{work}} - 1 \geq 0$$

Where σ_{adm} is the ratio between yield stress and safety coefficient.

-To evaluate margin of safety factor for fairing component realized in sandwich composite itis required more detailed analysis.

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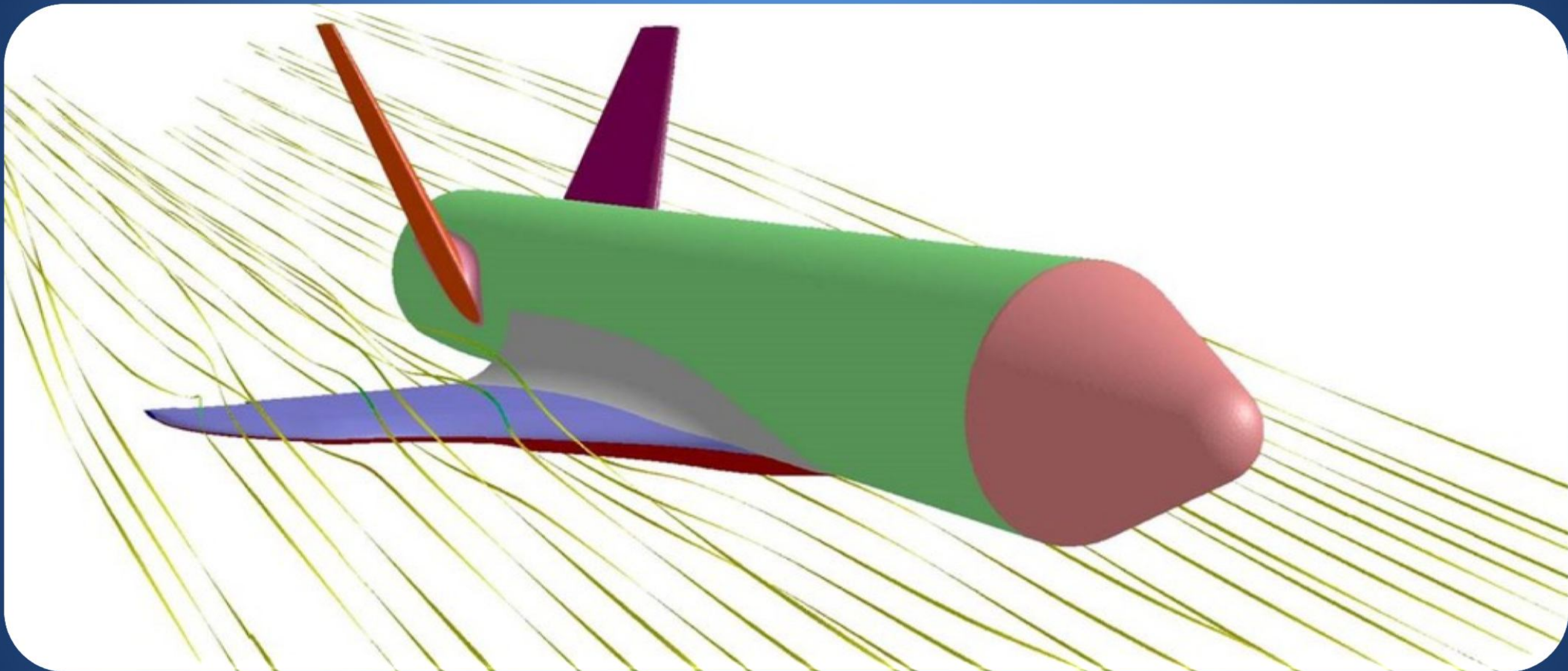
The role of CFD in the development of a new concept of space transportation system



Author: Massimiliano Tarrini

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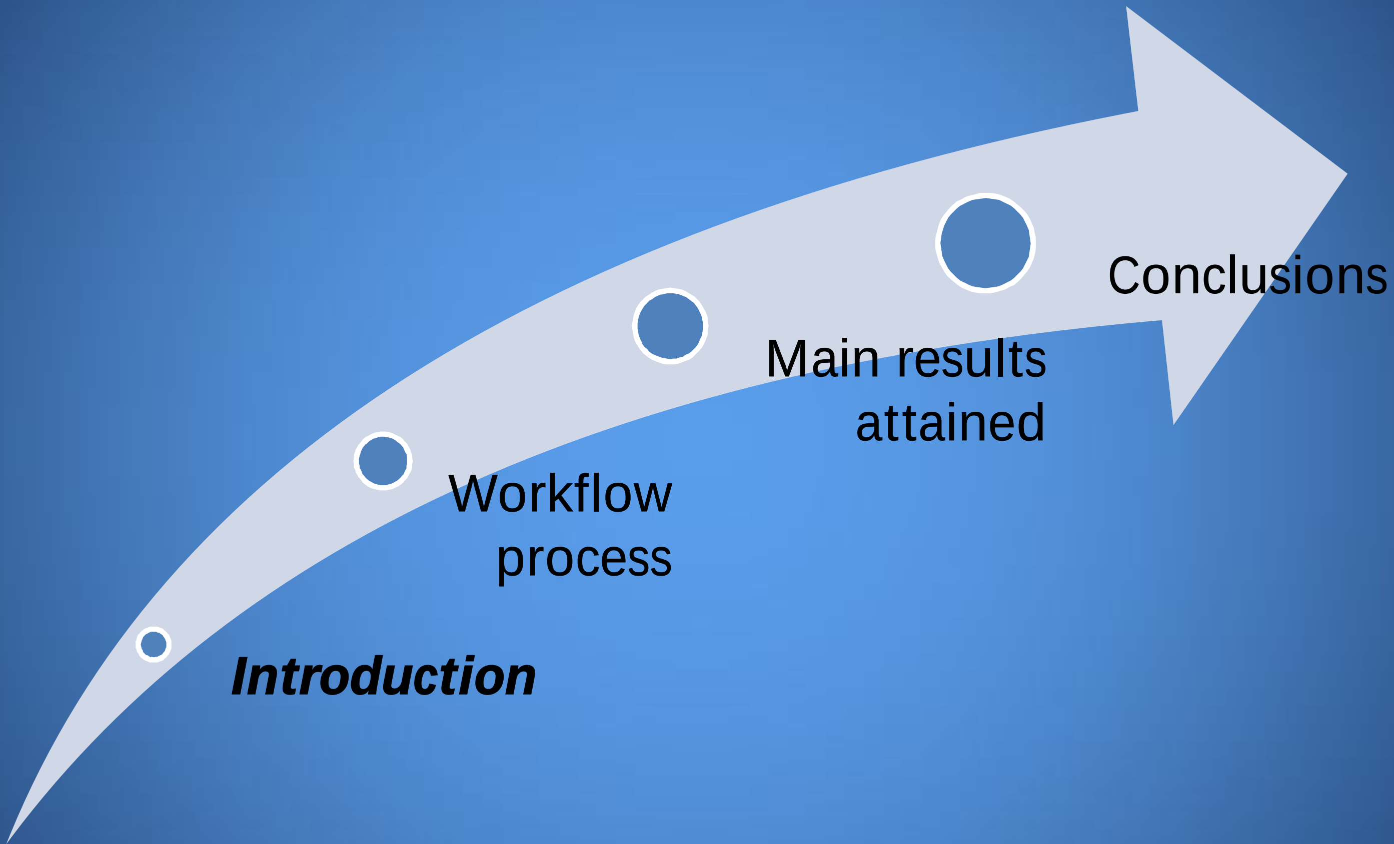

Introduction:

Design process of a brand new vehicle for space transportation can be considered as big Challenge in terms of capabilities involved and different skills required.
Concurrent engineering process can indeed compress time and cost giving design team required information on loads and flight conditions behavior avoiding test at least in the early phase of Design.
Indeed CFD, Computational Fluid Dynamics, is the mandatory option to avoid wind tunnel and flight test.
Here will be presented some of the main results gained using concurrently the skills of the Structural Team and the Aerodynamic Team.

As second item of this presentation will be detailed the result of the proficient use of CFD in order to get insight on the flight mechanics of the proposed configuration.

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Introduction: Sizing Mission Requirements

While keeping sizing mission as previously defined, some figures were carried out in order to properly design wing, tail and their layout.
Requirements indeed were identified as:

1. *Capability of generating an excess 5% in terms of lift for payload and W_{eo} at 130knots for the wing*
2. *Capability of withstanding different regimes of Mach, from high mach, to transonic to low speed*
3. *Keeping W/S less than 1300N/m^2.*
4. *Being neutral at 0° angle of attack with tail*
5. *Being statically stable in fixed control.*
6. *Low AR configuration in order to get lift at high AOA and good flight performance at High Mach*

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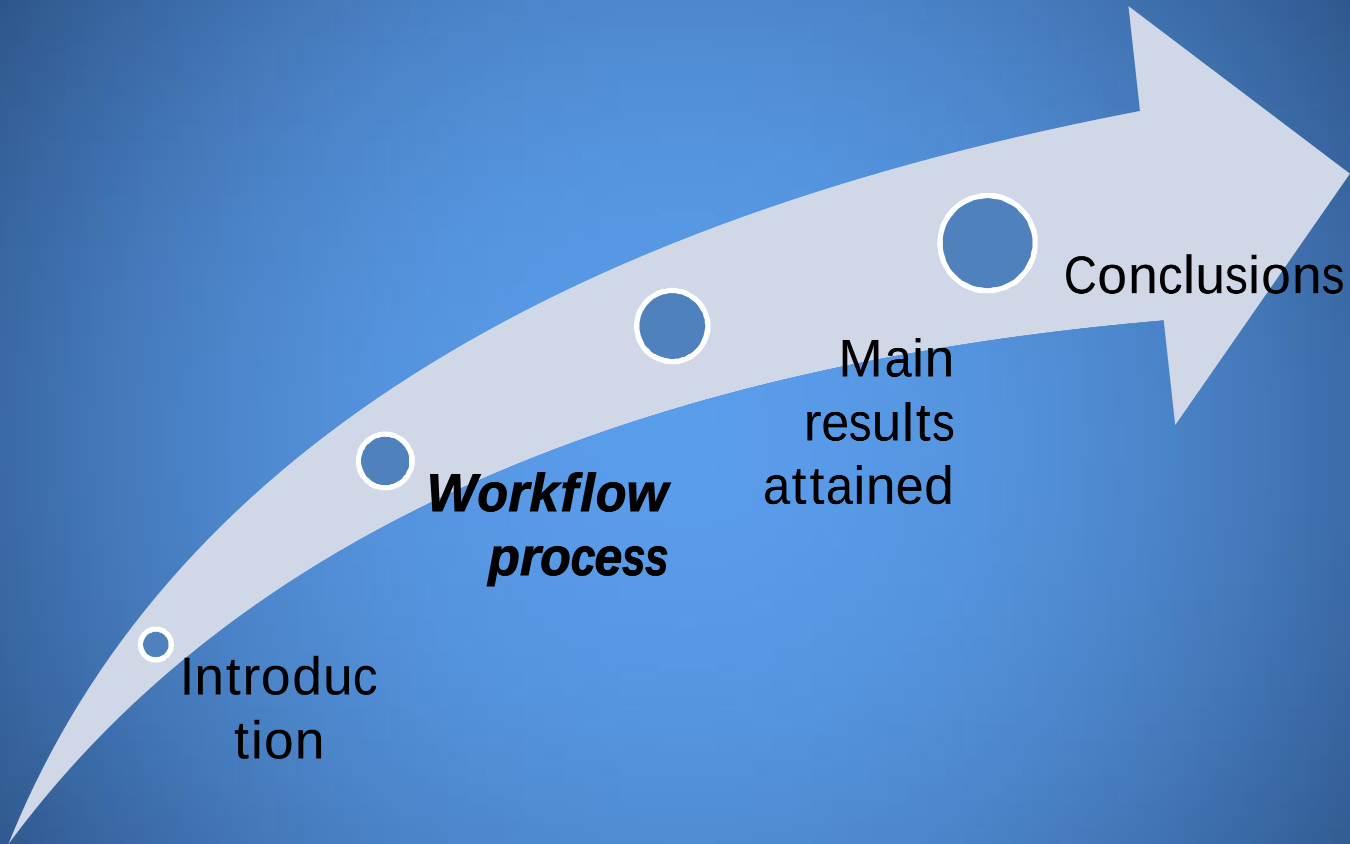

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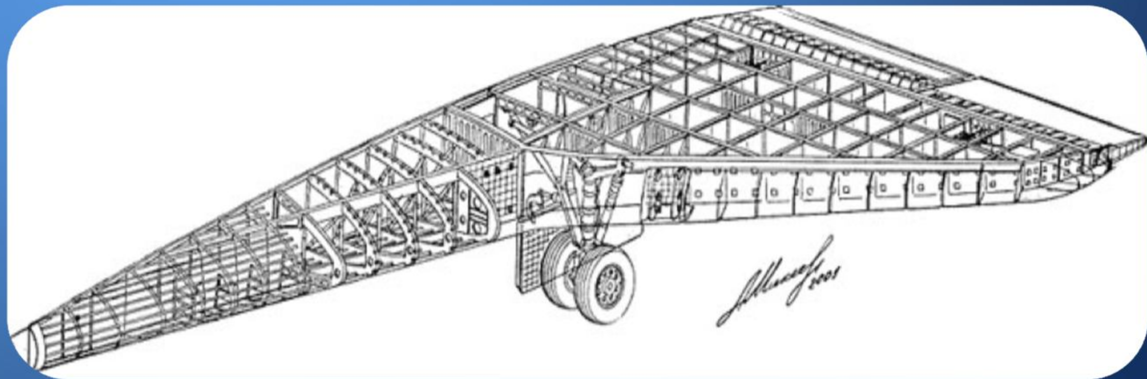
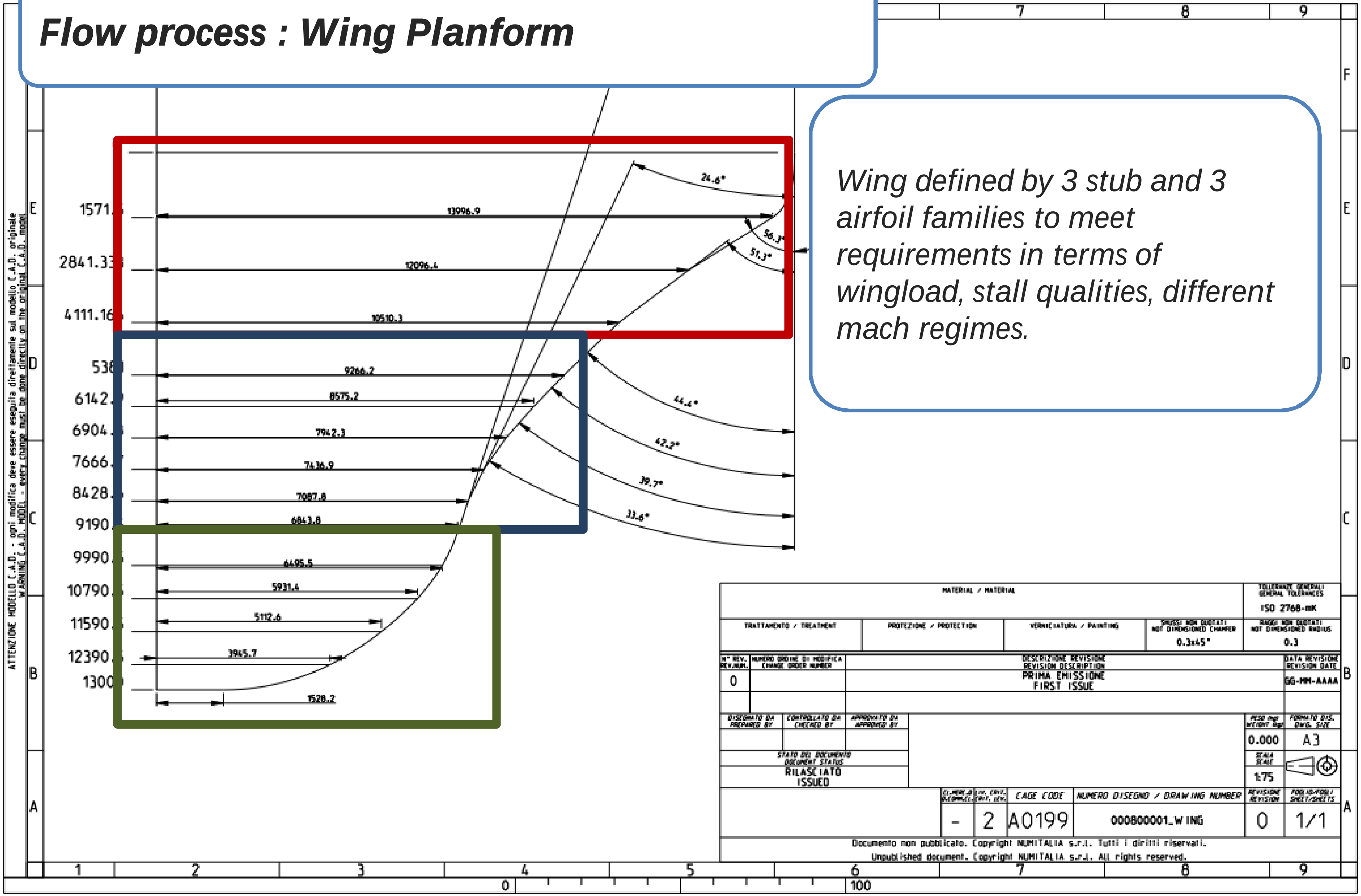
Flow process: Sizing Mission Requirements

Starting from "similar" configuration the process of definition of wing tail lead to the Isolated wing defined as inspired by Concorde Design, Avro Vulcain Design, Space Shuttle design and so on... Their planform with sigmoid leading edge was a starting point for the design



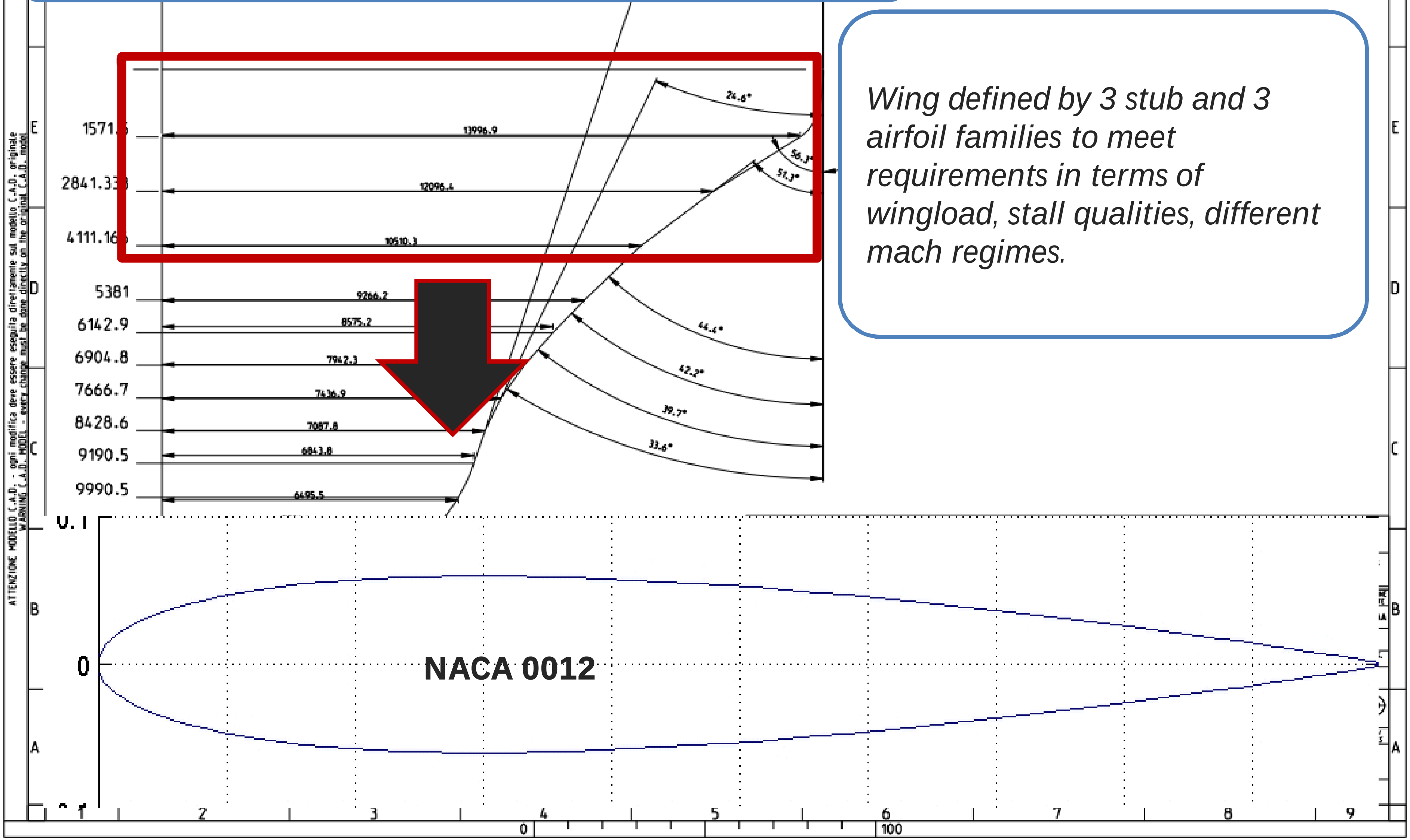
Flow process : Wing Planform



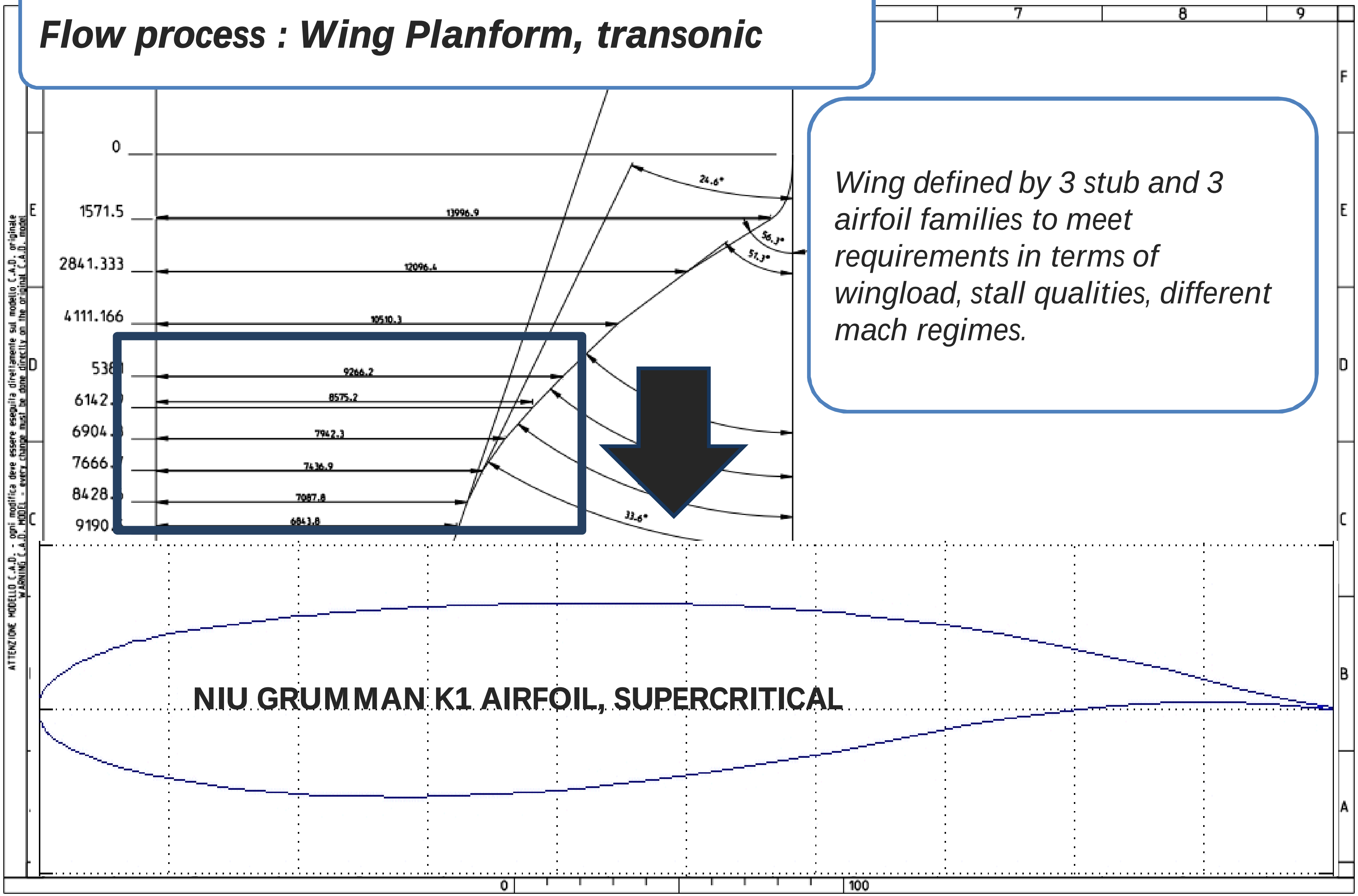
Wing defined by 3 stub and 3 airfoil families to meet requirements in terms of wingload, stall qualities, different mach regimes.

Flow process : Wing Planform, supersonic

Wing defined by 3 stub and 3 airfoil families to meet requirements in terms of wingload, stall qualities, different mach regimes.



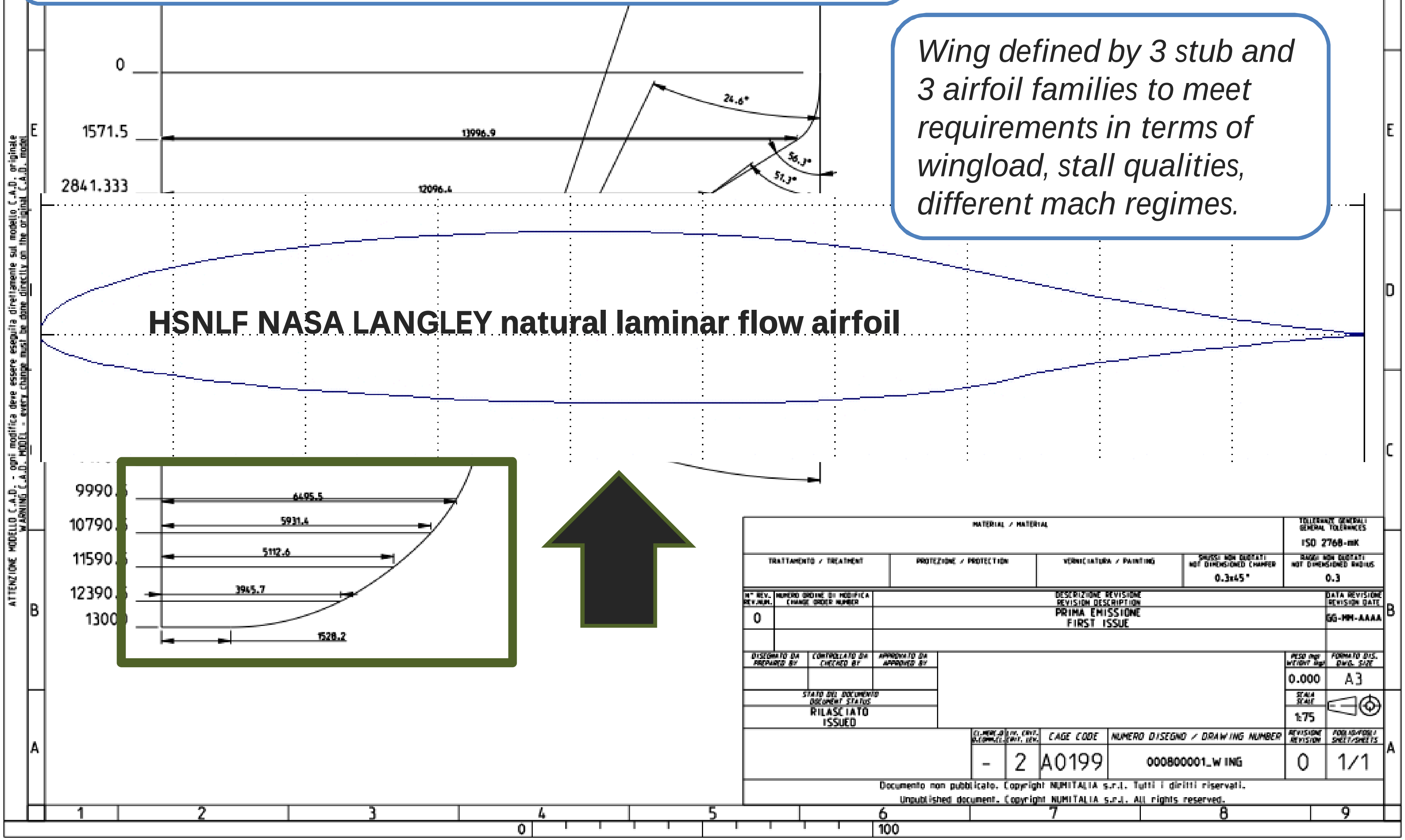
Flow process : Wing Planform, transonic



Wing defined by 3 stub and 3 airfoil families to meet requirements in terms of wingload, stall qualities, different mach regimes.

Flow process : Wing Planform, subsonic

Wing defined by 3 stub and 3 airfoil families to meet requirements in terms of wingload, stall qualities, different mach regimes.



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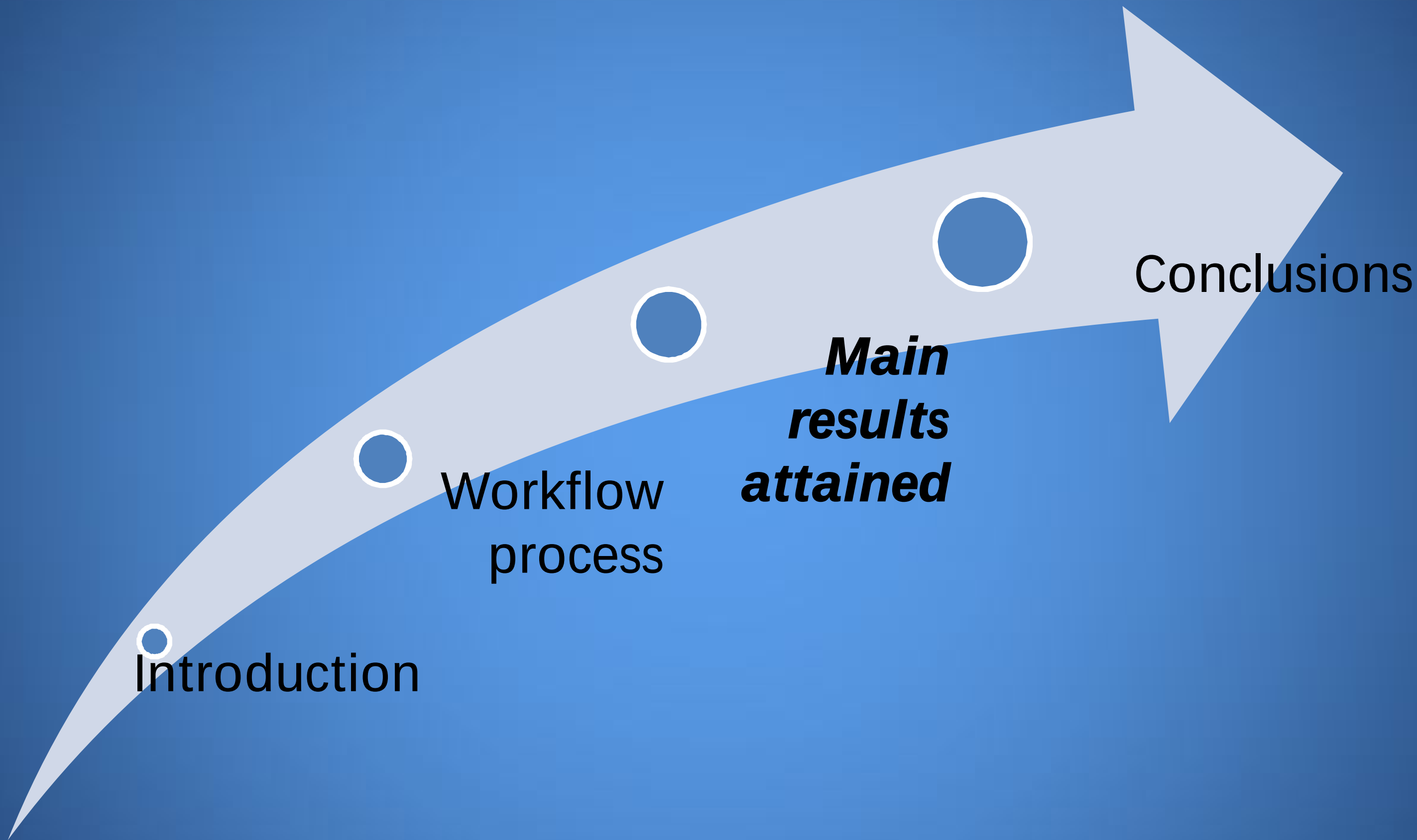

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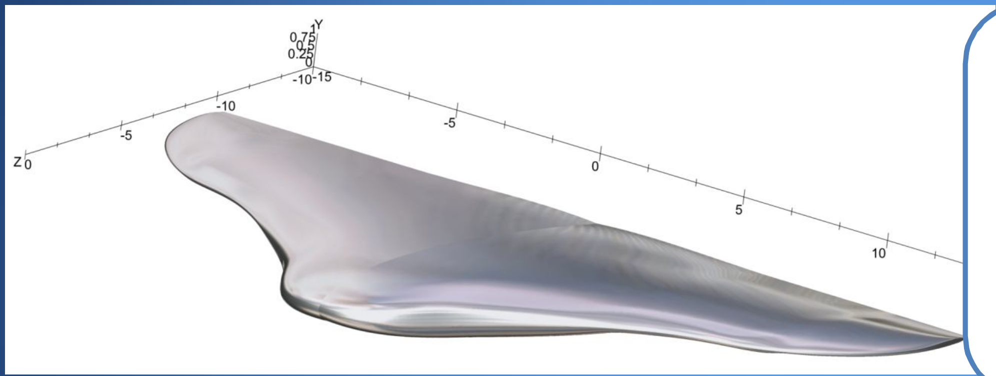
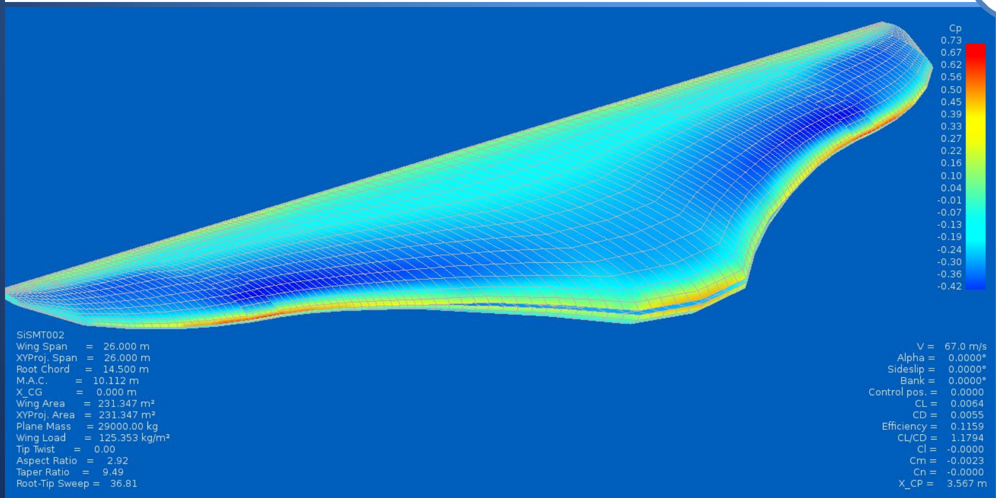
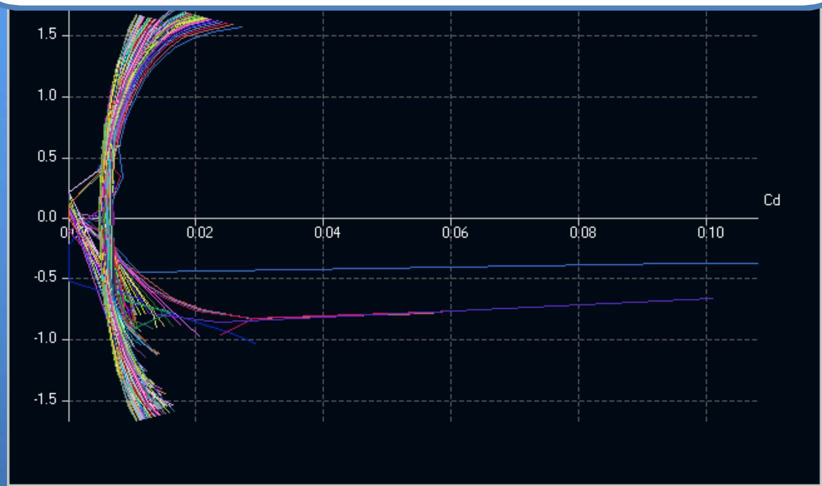
Main results: Isolated wing

Lofting the wing then proofing at approach speed flight condition variing A0A, polar plot of the configuration was drawn up



C_p and polar plots for different angle of attack from -15° to +15° were quickly obtained for the isolated wing capable of reaching trim condition at around 5.5°. Wing sizes 26m in span with a lifting surface of 232m². AR is around 3. Wing load is 1177.2N/m²





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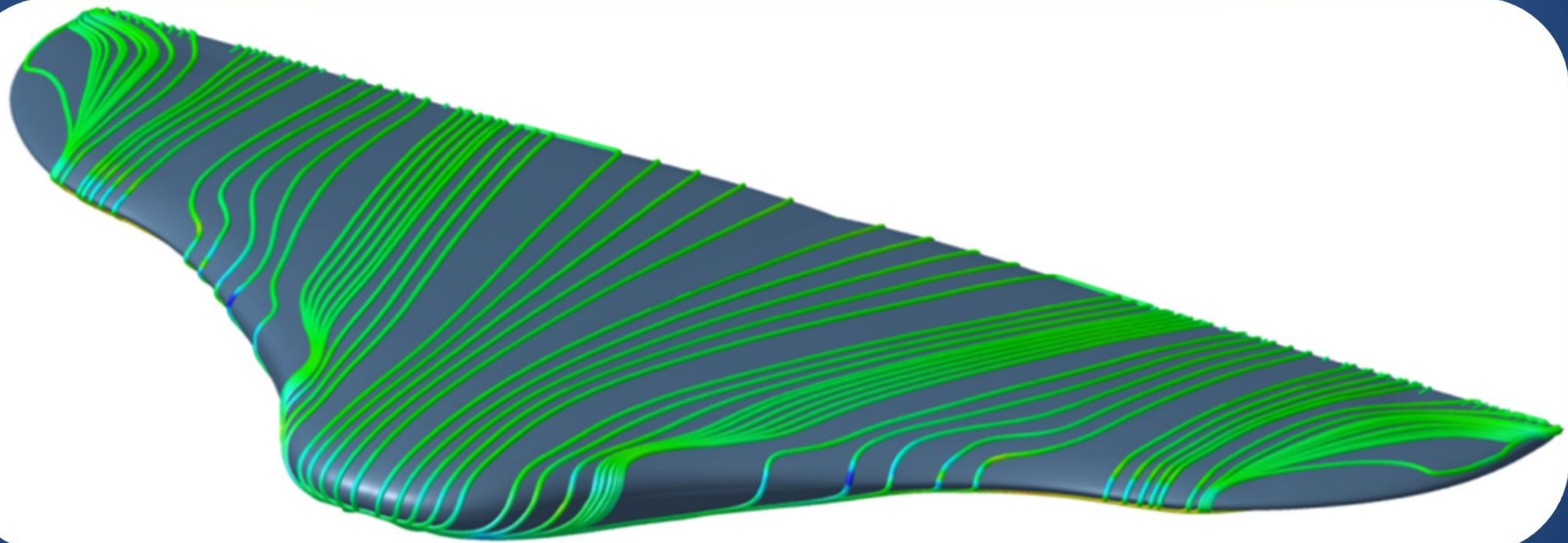
Main Results: Isolated wing, CFD verification

CFD overcomes main limitation of VLM taking into account viscosity related phiysics so giving information about real stall qualities of the wing for example.... And real total Drag.



At 15° stall occurs, near tip, at leading edge... this wasn't observed using solely VLM

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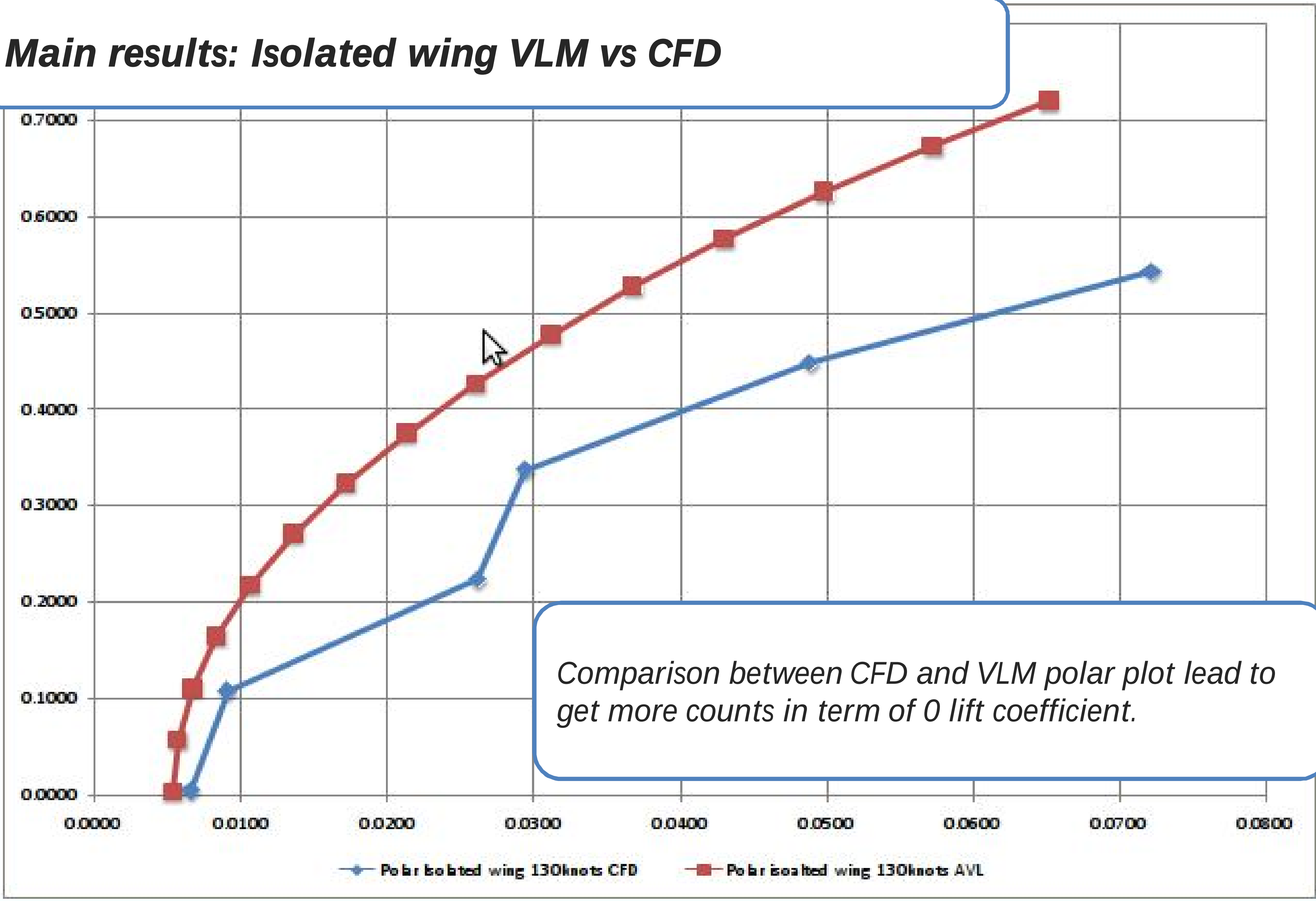
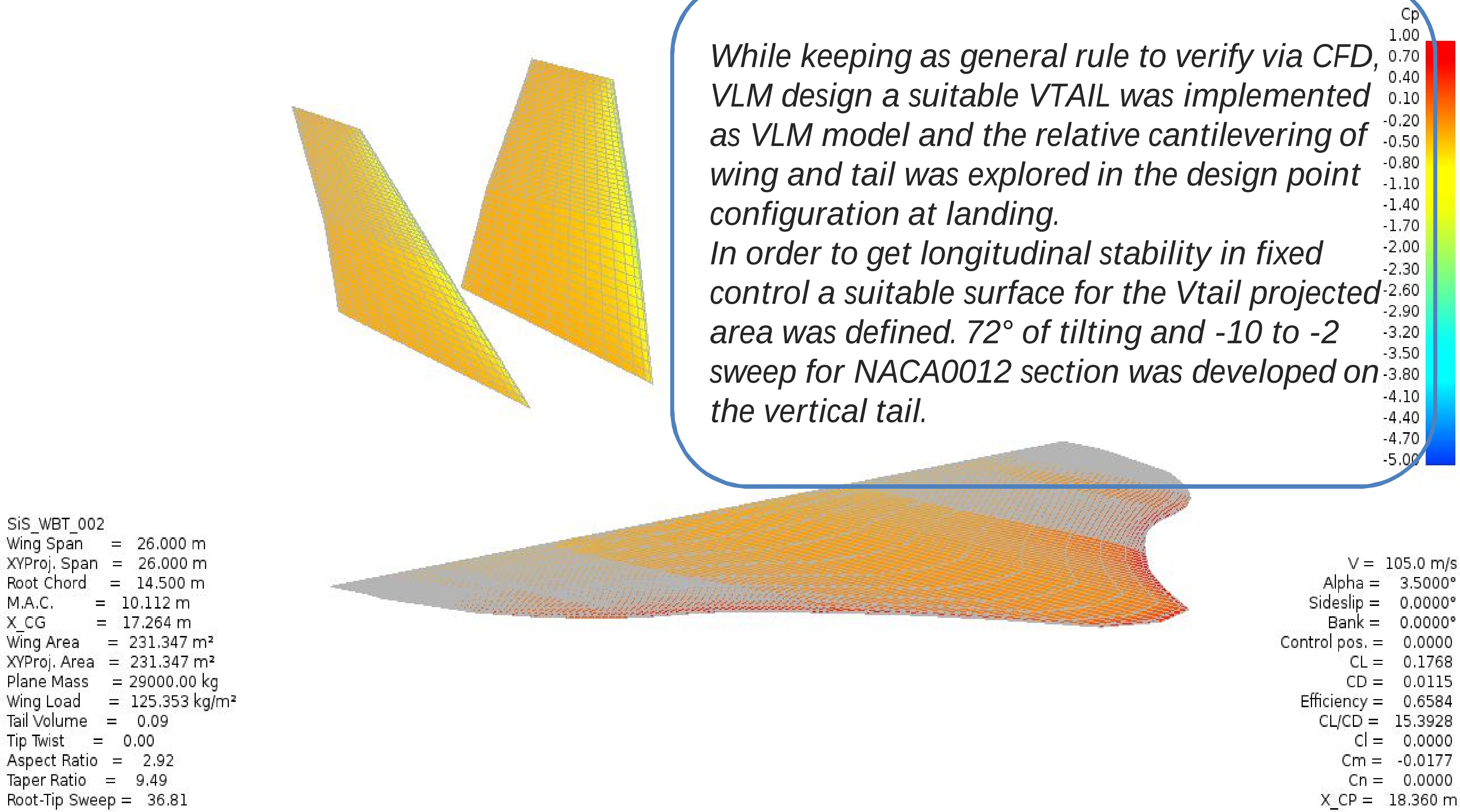
Main results: Isolated wing VLM vs CFD



Comparison between CFD and VLM polar plot lead to get more counts in term of 0 lift coefficient.

Main results: Wing tail to Wing tail body configuration

While keeping as general rule to verify via CFD, VLM design a suitable VTAIL was implemented as VLM model and the relative cantilevering of wing and tail was explored in the design point configuration at landing.
In order to get longitudinal stability in fixed control a suitable surface for the Vtail projected area was defined. 72° of tilting and -10 to -2 sweep for NACA0012 section was developed on the vertical tail.



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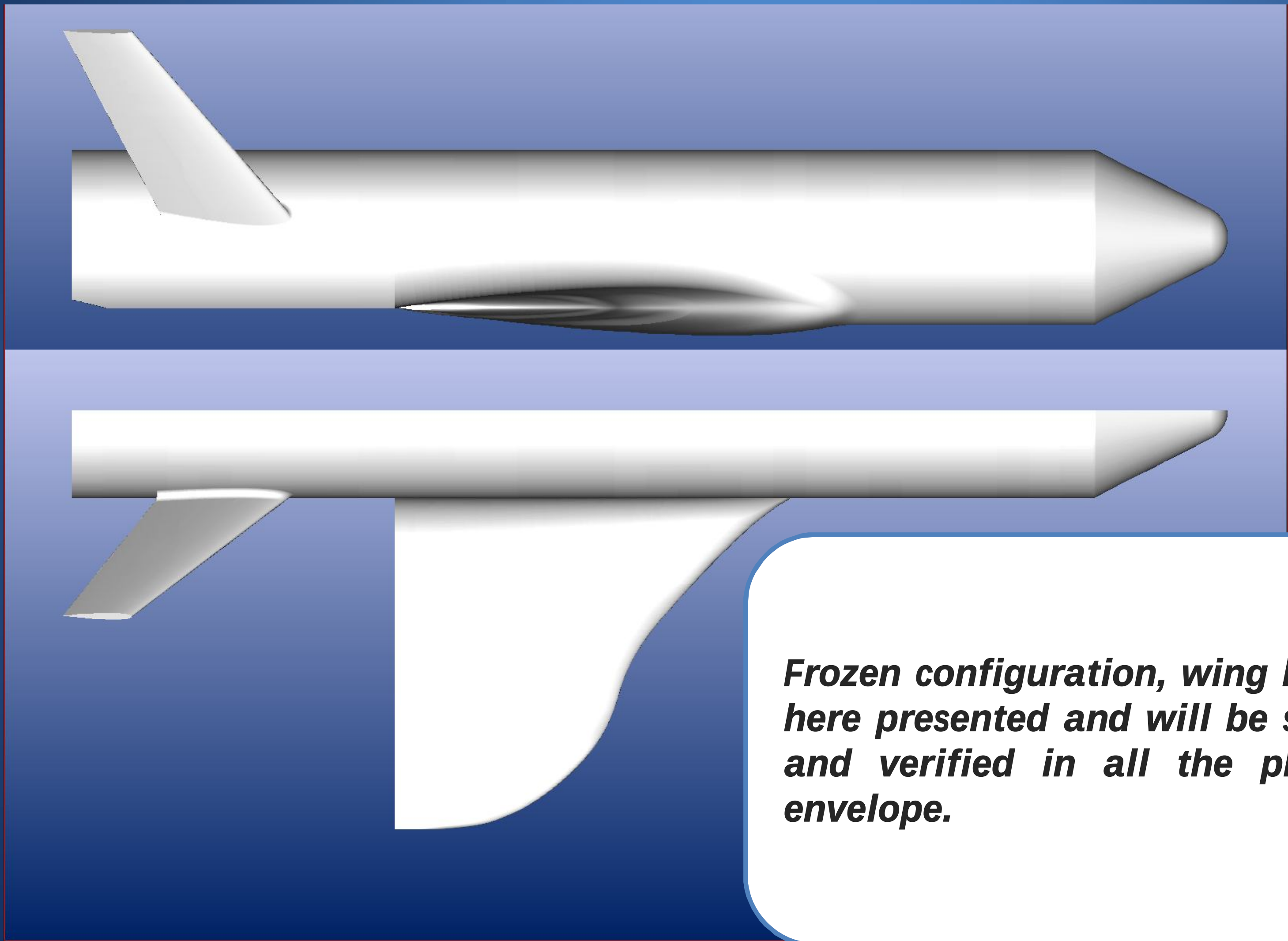
Main Results: Wing Body VTAIL configuration



Frozen configuration, wing body and tail is here presented and will be studied via CFD and verified in all the phases of flight envelope.

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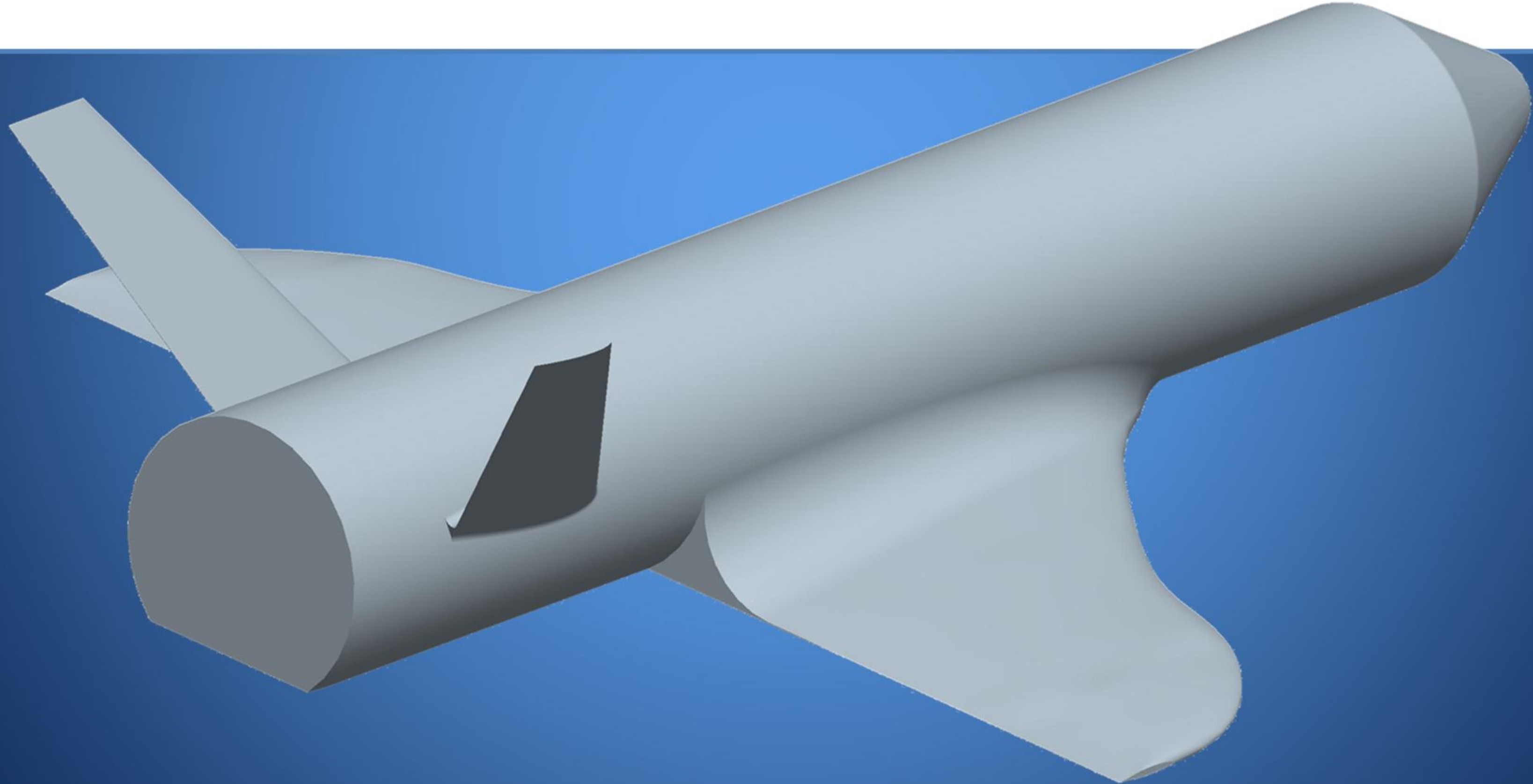
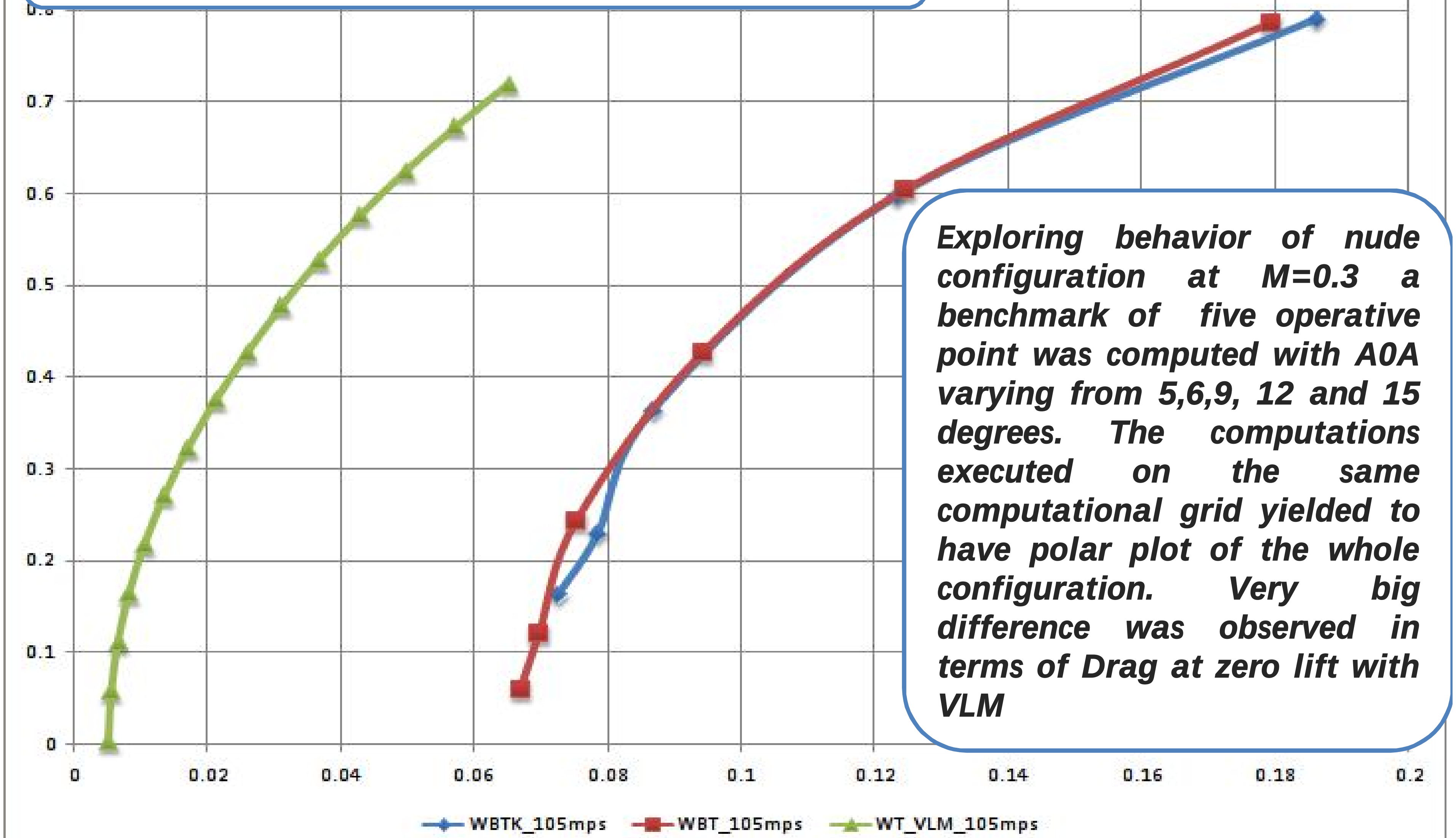
Main results: Sizing Mission Requirements

Nude configuration studied at approach speed of 130knots, at Mach 0.3 and at High Mach.
For subsonic leg here will be presented main results for Mach 0.3



Main Results: CRUISE GLIDING at MACH 0.3



Exploring behavior of nude configuration at M=0.3 a benchmark of five operative point was computed with A0A varying from 5,6,9, 12 and 15 degrees. The computations executed on the same computational grid yielded to have polar plot of the whole configuration. Very big difference was observed in terms of Drag at zero lift with VLM

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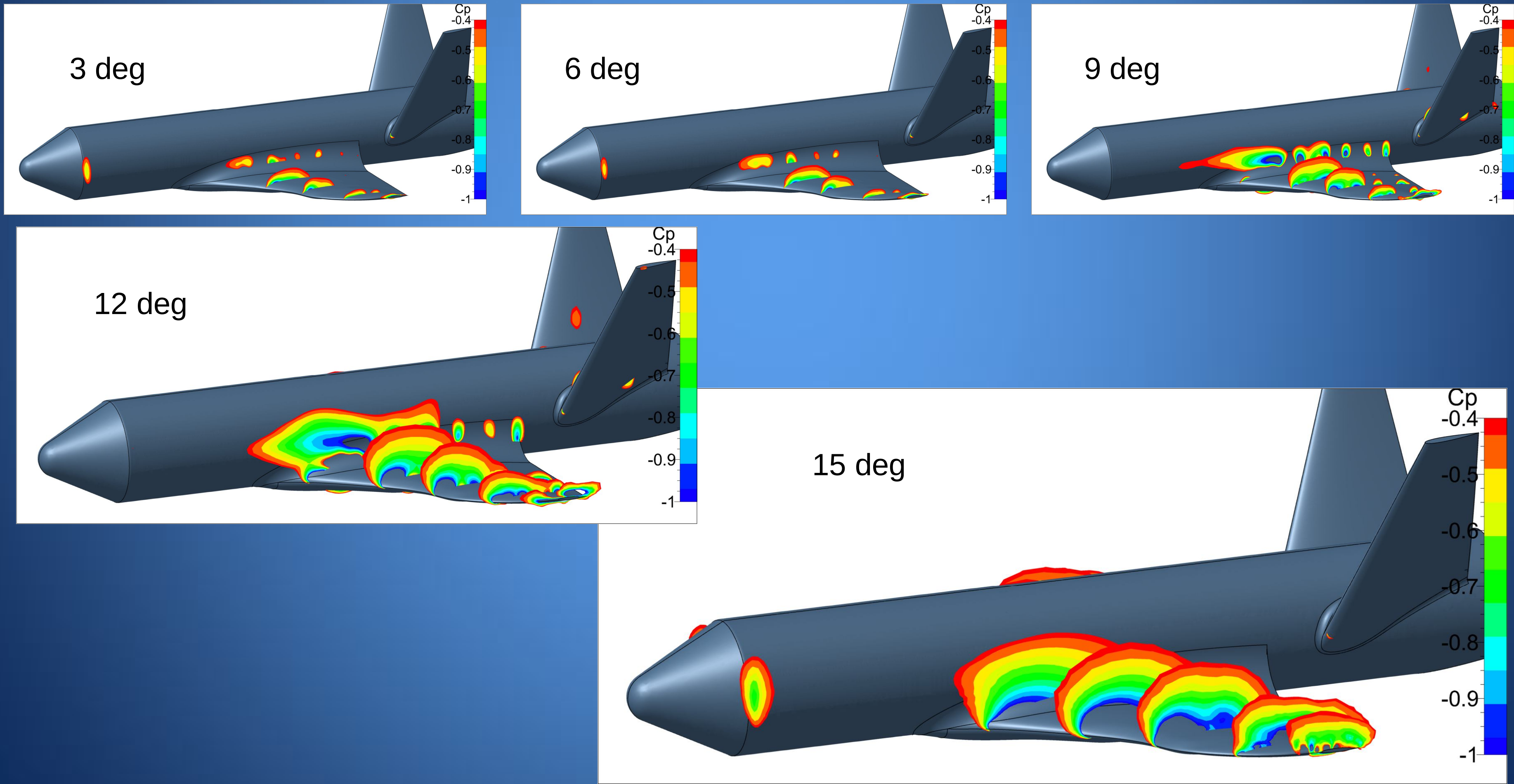
Main Results: CRUISE GLIDING at MACH 0.3

Results in term of Coefficient of pressure was obtained



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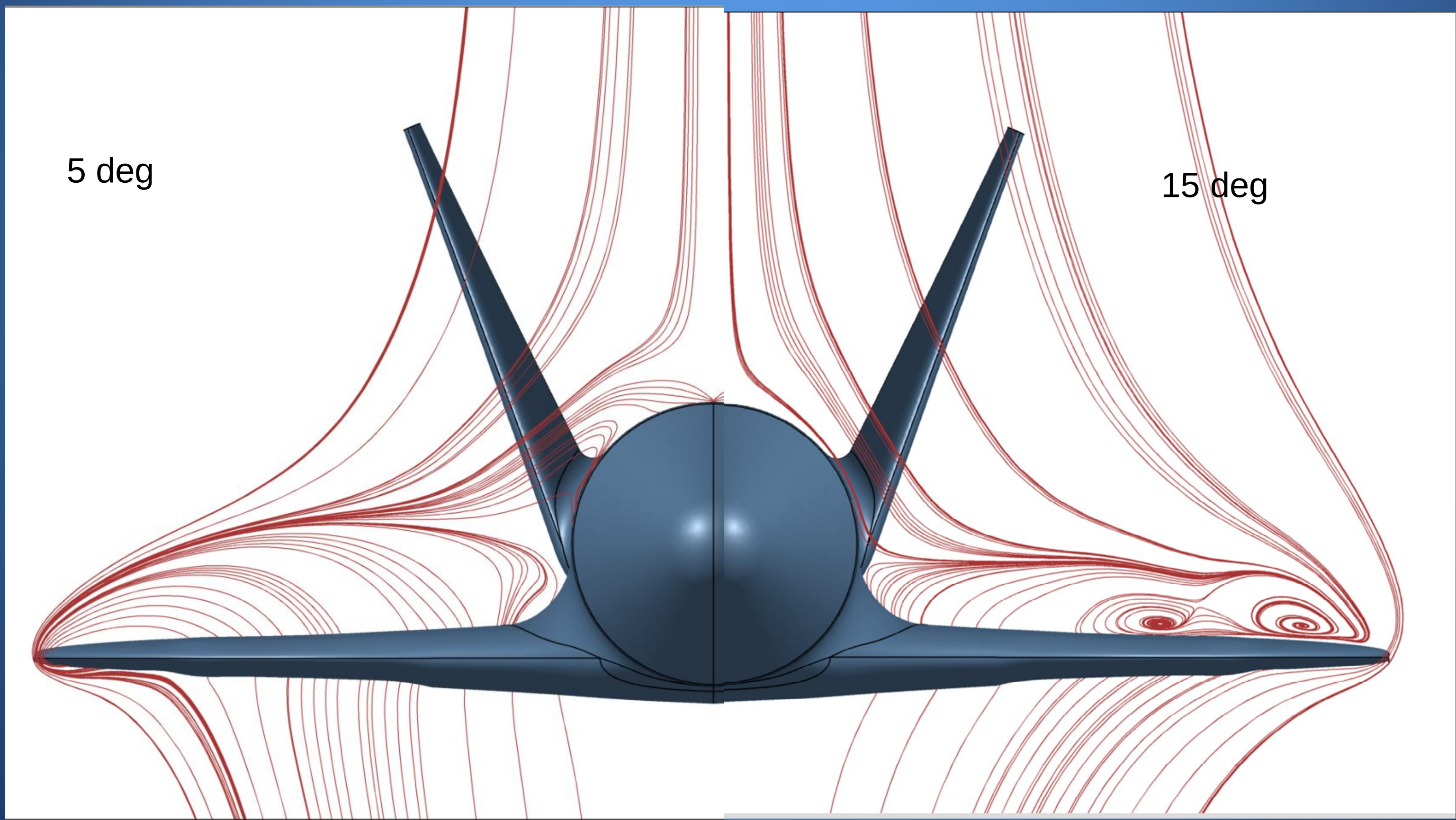
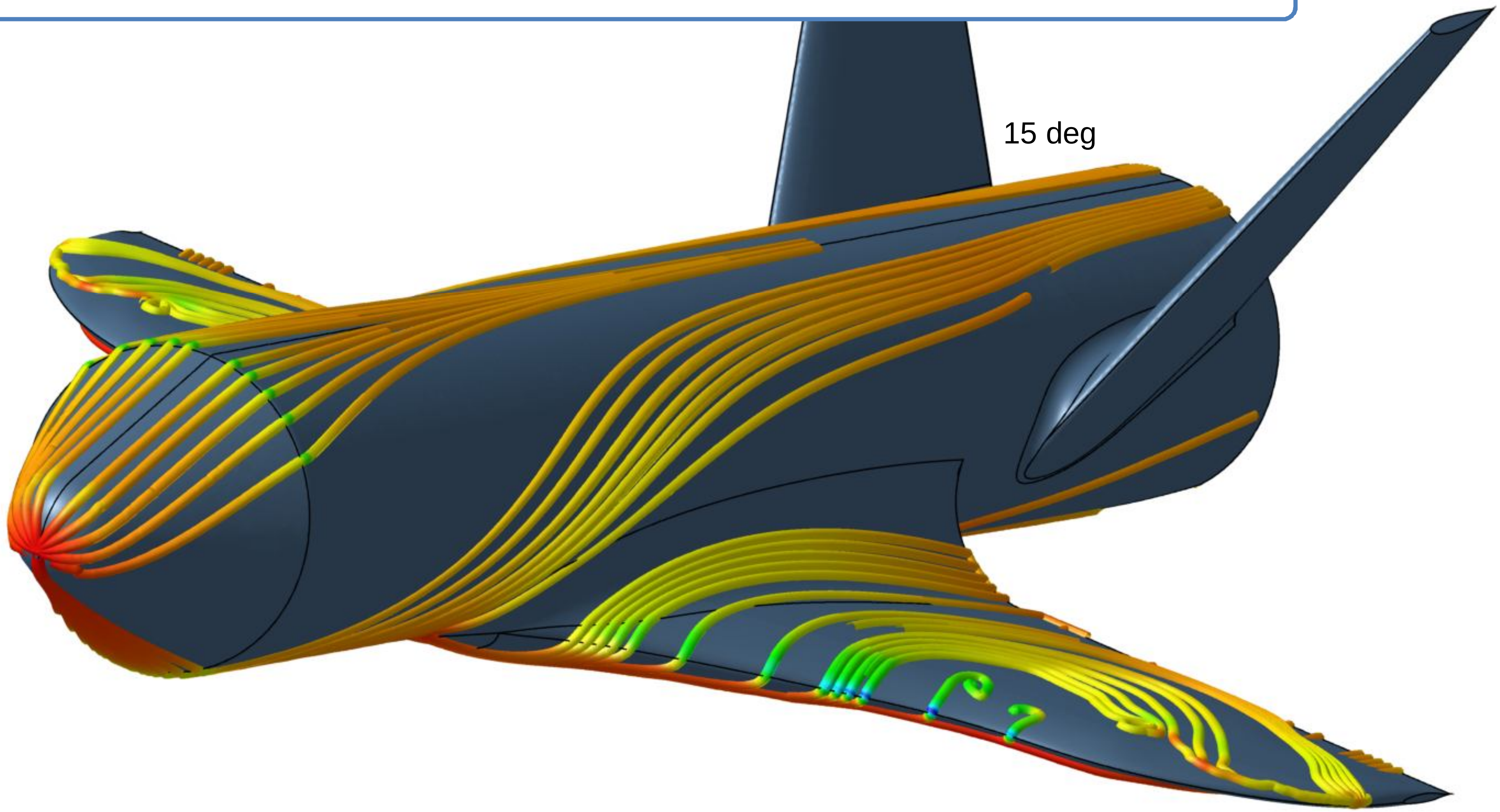
Main Results: CRUISE GLIDING at MACH 0.3

Results in term or in term of transverse streamlines underlining stall occurrence at 15°



Main Results: CRUISE GLIDING at MACH 0.3

Friction velocity path shows the evident stall at tip at 15°. This stall doesn't involve control surface.



Main Results: Insight on Flyght Mechanics

CFD indeed is the best tool aimed even to study flight mechanics. Neither wind tunnel testing, nor flight test on full scale can indeed reproduce the real condition in which Stability Derivatives are evaluated. No DIGITAL DATCOM database is useful due to the peculiarity of the configuration at hand.

As counterpart then CAMPAIGN to sample Stability derivatives has been done with interesting results.

Roll Axis Moment and Lift increase due to the presence of aileron has been studied variing AoA, varing $\delta_{alieron}$ for 3 angle of control surface.

Then a plot of the moment has been drawn up.

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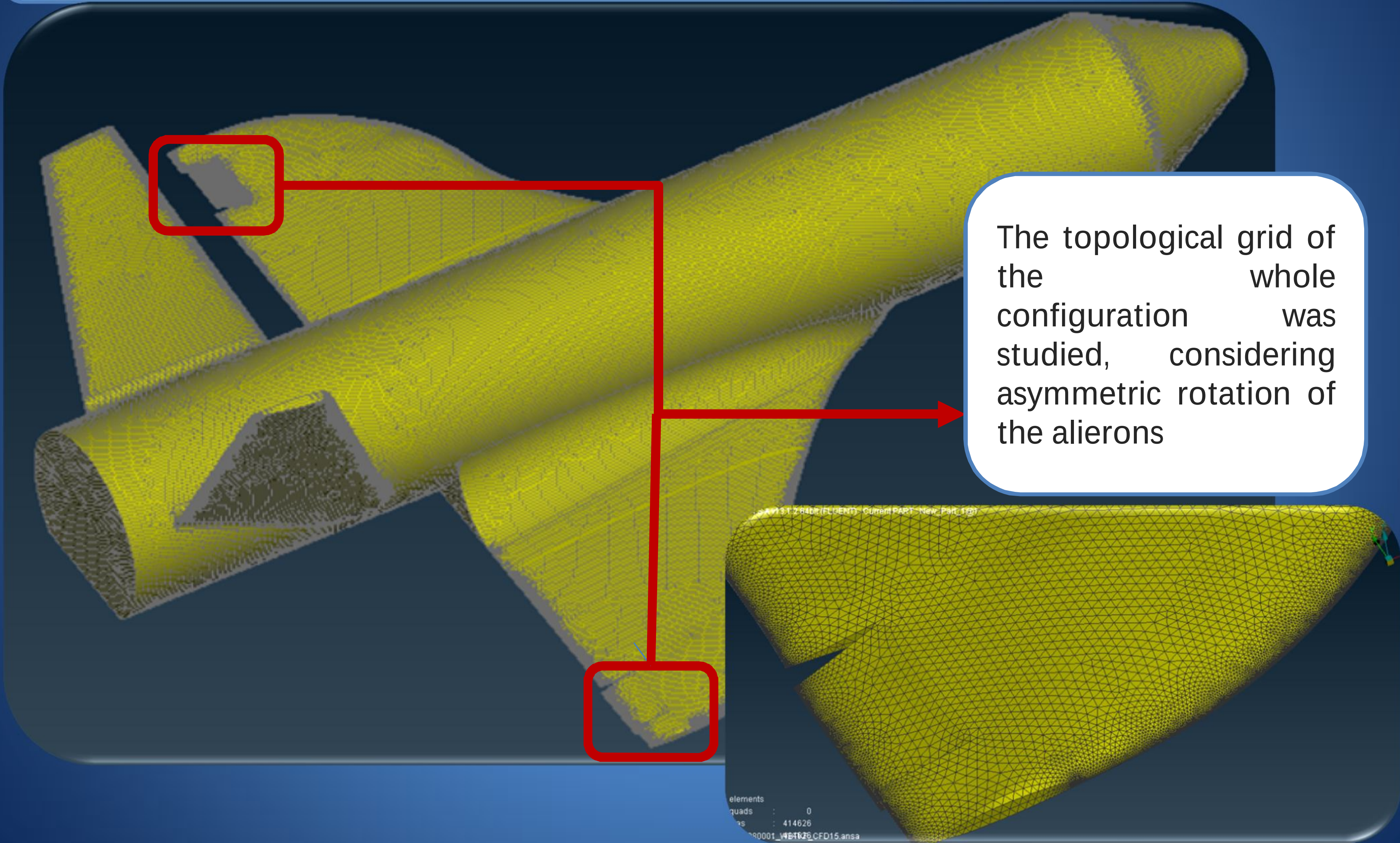
Main Results: Insight on Flight Mechanics



The topological grid of the whole configuration was studied, considering asymmetric rotation of the alierons

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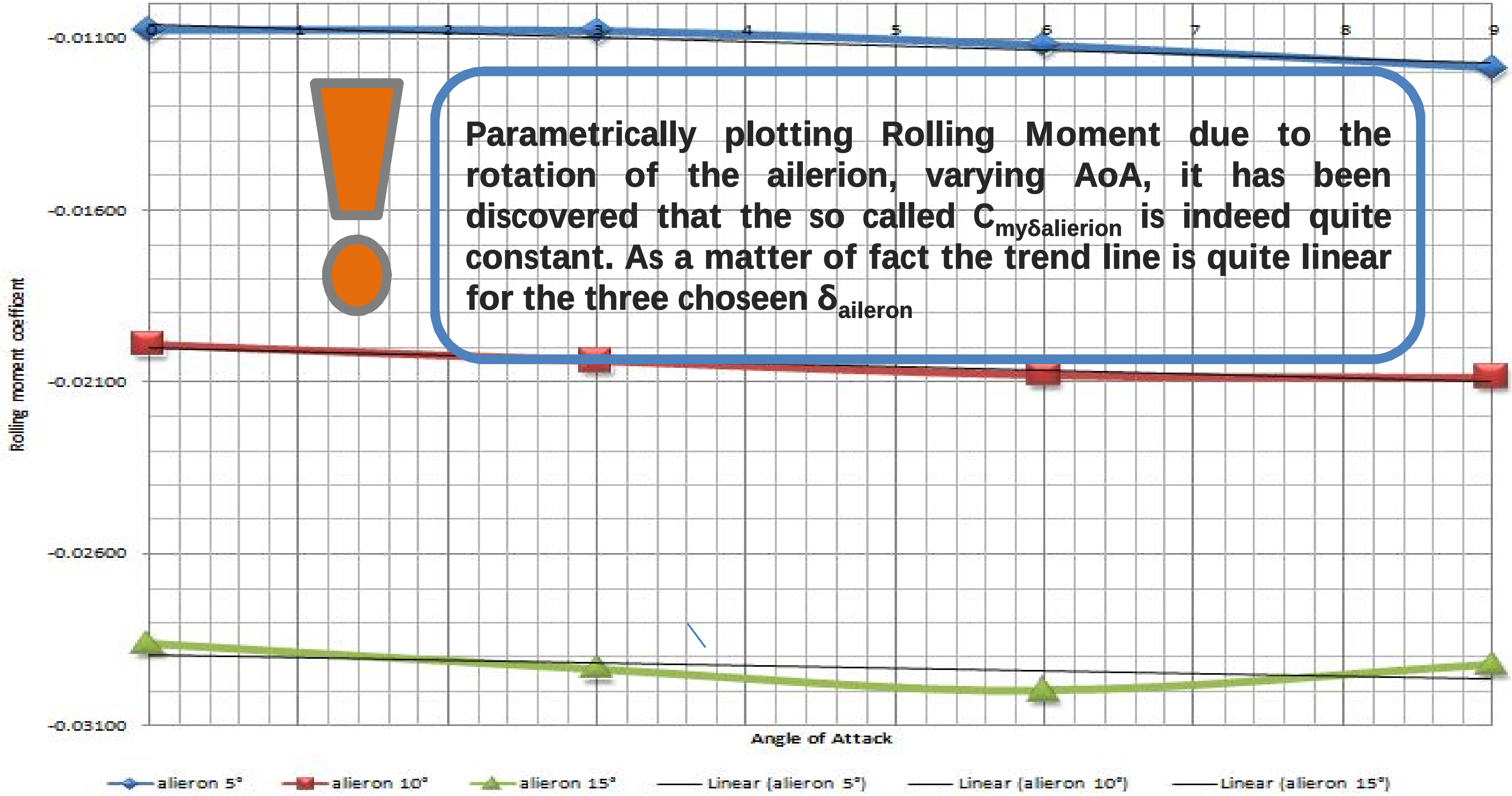
Main Results: Insight on Flight Mechanics



Parametrically plotting Rolling Moment due to the rotation of the ailerion, varying AoA, it has been discovered that the so called $C_{my\delta alierion}$ is indeed quite constant. As a matter of fact the trend line is quite linear for the three choseen $\delta_{aileron}$

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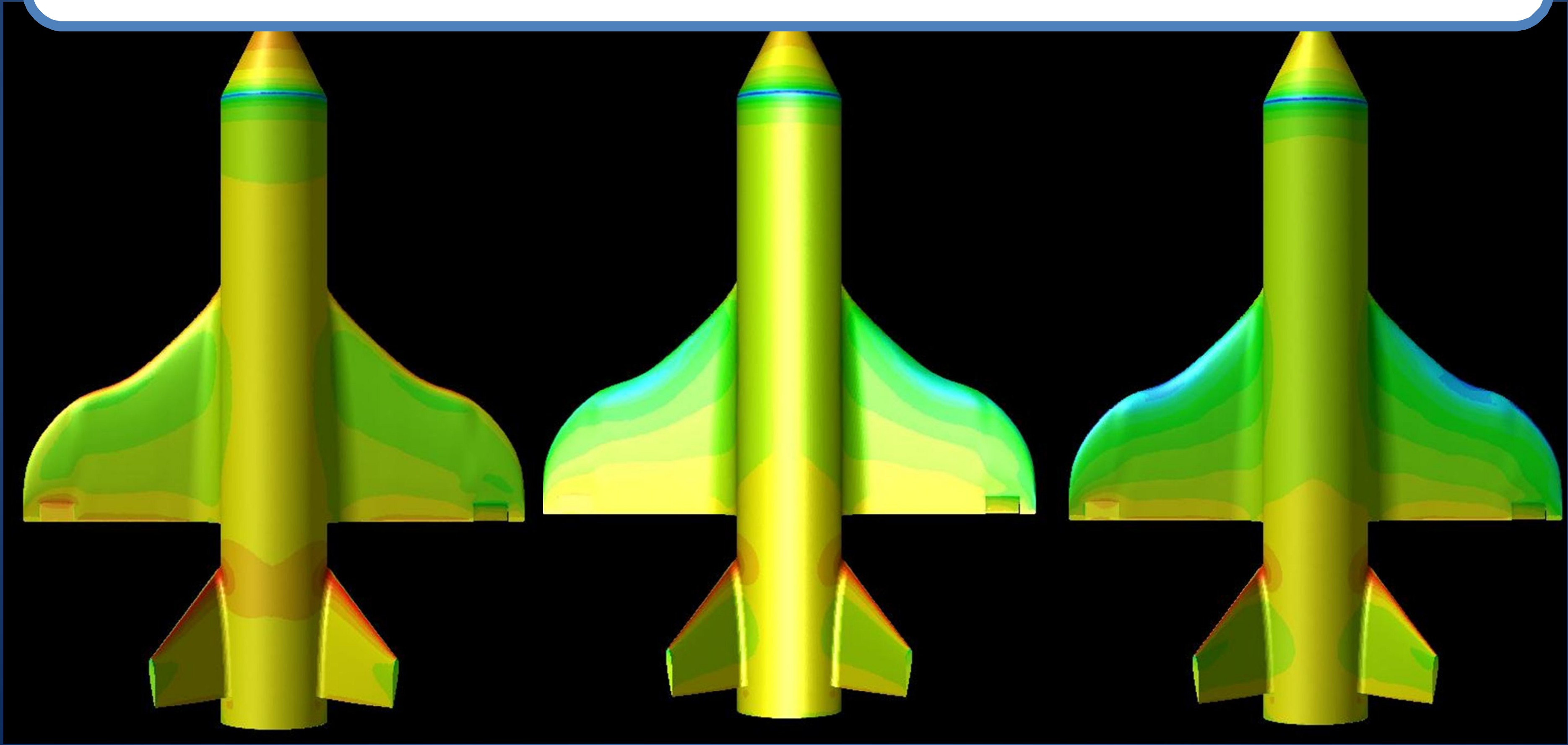
Main Results: Insight on Flight Mechanics

This three contour plots of CoP withness the increase of suction on the right wing due to the deflection at δ_a=15deg @ AoA=3,6,9 deg. These three ones have same scale.



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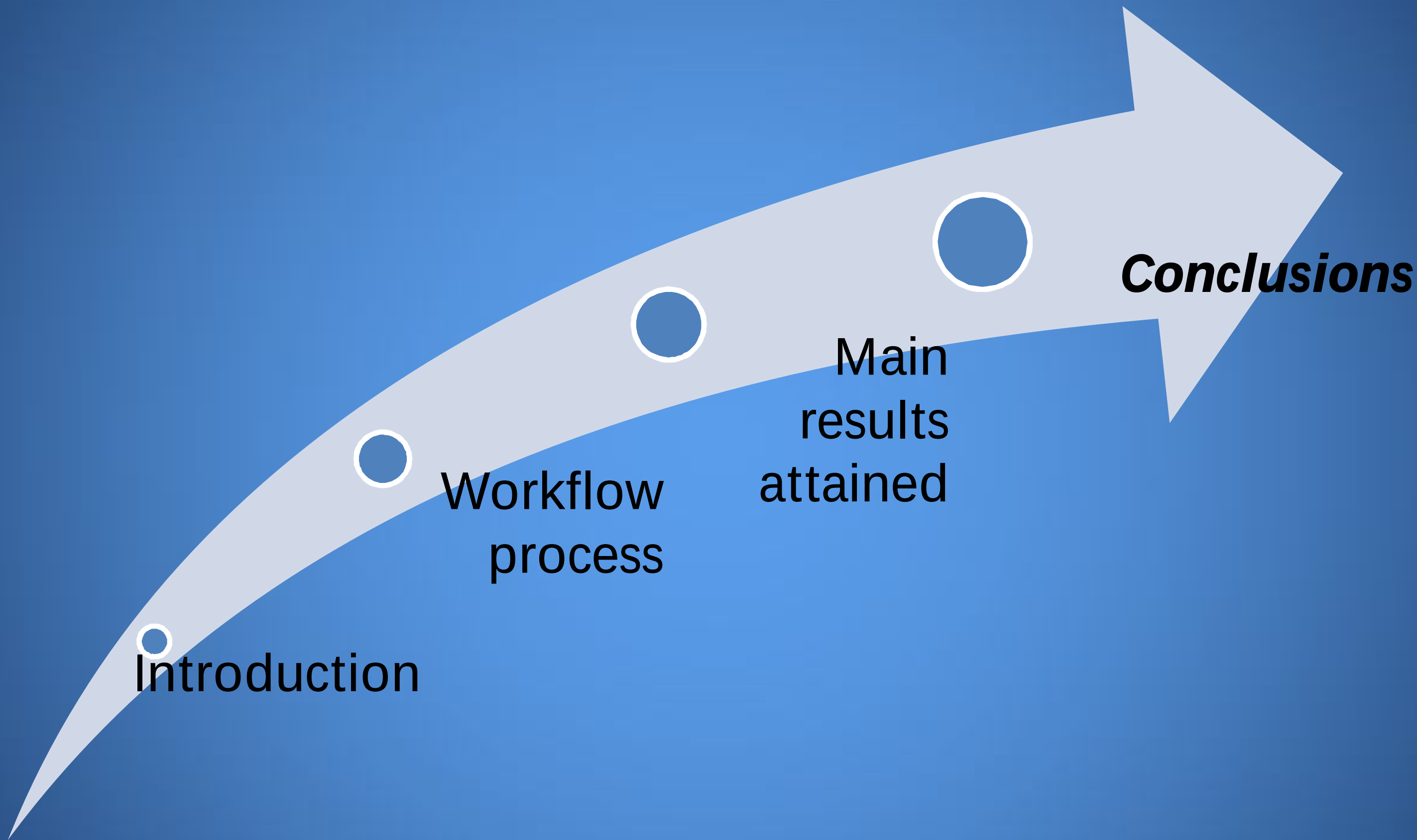

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Conclusions and future developments... more has to come!

Challenging to design a brand new concept of STS, CFD has been considered a mandatory tool for the Design Team in order to define preliminary configuration of the vehicle.

Moreover the parallel use of VLM technique as a complementary tool for CFD shows its handiness but even its main limitations.

Once layout was defined and frozen, studies on main aerodynamics and flight mechanics were explored easily throught CFD getting insight on loads and stability derivatives.

The use of CFD is and will be progressively integrated in the design process, expecially on the second phase where details will be added. For sure immediately on going step will be the analisys of the aerothermodynamics during the Re-Entry phase.... But this is on going....

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Thank you for the attention!

...got any Question?