hypersonic
From 100.000 to 400.000 ft

Conceptual Design of a VTOL Hypersonic Transportation System Aimed at Performing Parabolic Flights

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Table of Contents

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Suborbital vehicle: a new era for civil transportation

Trans-atmospheric vehicles are becoming even more attractive for both aeronautics and space field for different reasons:

- *Precursors of hypersonic airplanes*
- *Test-bed for hypersonic enabling technologies, like thermal protection system, propulsion systems, etc.*
- *Precursors of reusable launchers*
- *Precursors of exploration vehicles*

Parabolic flights have become popular for touristic purposes offering short periods of micro-gravity experience and an amazing view of our planets. Moreover they can be the perfect environment to carry out scientific experiments that can be executed in short duration microgravity periods.

Considering the very promising market, it will also be extremely important to in-depth study safety and legal related issues.

Proper mission and system conceptual design methodology with rigorous trade off strategies can increase the mission success possibility.

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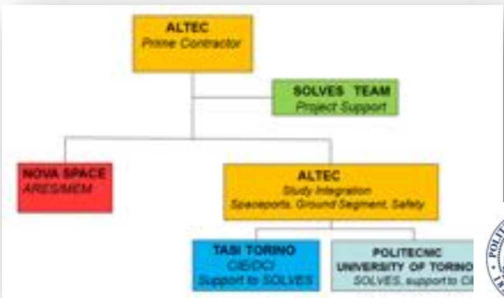
Research Program

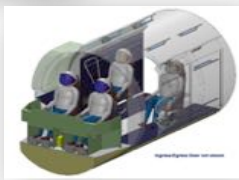
The Research Program: A private Malaysian Initiative

This presentation focuses on a Pre-Feasibility study granted to ***Altec S.p.A*** by a private Malaysian Stakeholder.

Politecnico di Torino together with ***Thales Alenia Space Italia – Torino*** actively contributes to the study for the mission analysis and systems design and to the design of the crew compartment.

Partners and Work Packages





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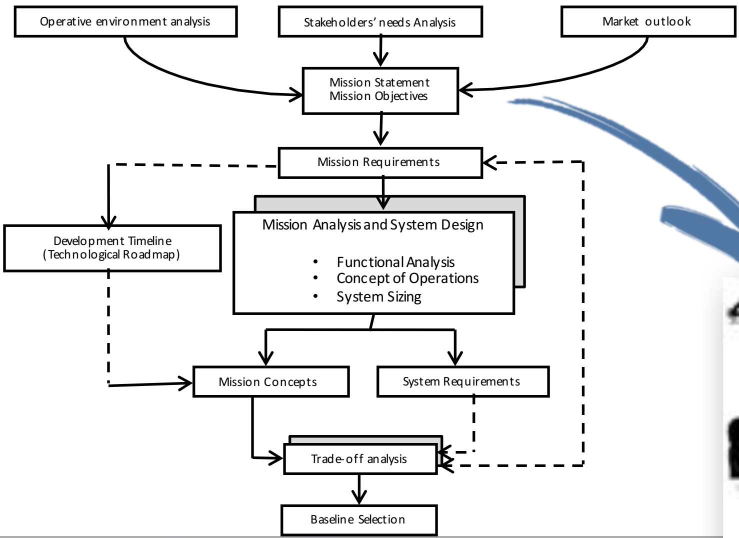
Methodology Overview



A good conceptual design methodology and the support tool chain shall guide the designers during the entire process that aims to create a product starting from stakeholder needs.

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Mission Statement and Mission Objectives Identification

Case Study Mission Statement

"The mission shall allow regular flight services to enable 4 flight participants at a time to reach 100 km to experience a period of microgravity and an amazing view of the Earth. The spacecraft shall perform a vertical take off from a sea-based or land-based platform and a vertical landing on the same site. Moreover, the additional capability to perform an un-crewed mission shall be considered.

- **Stakeholder needs analysis**
- **Market forecasts and economical evaluations**
- **Geo-political considerations**

Primary Mission Objectives

- To ensure a regular flight service carrying 4 pax at a time
- To reach 100 km of altitude
- To experience at least 2 min of microgravity
- To perform vertical takeoff and landing
- To ensure an amazing view of the Earth

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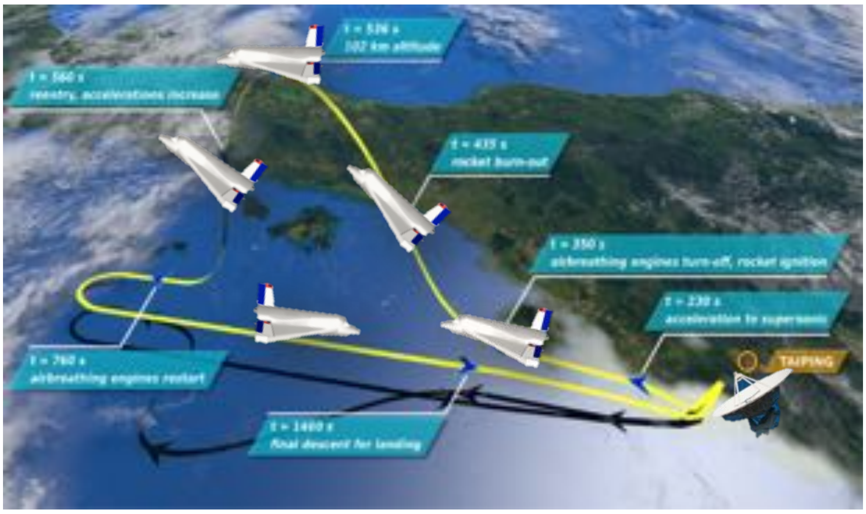
Mission Concept



This is the **nominal** simulated mission **trajectory** consisting of:

- *Vertical (Harrier- like) take off from a prepared pad closed to Taiping, Malaysia.*
- *Atmospheric Ascent with air-breathing propulsion*
- *Rocket powered ascent phase*
- *Microgravity period*
- *Unpowered Reentry*
- *Cruise back to Taiping*
- *Final descent and Landing on the same platform*

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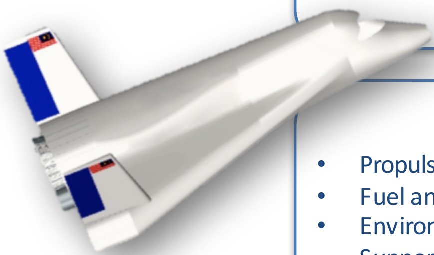
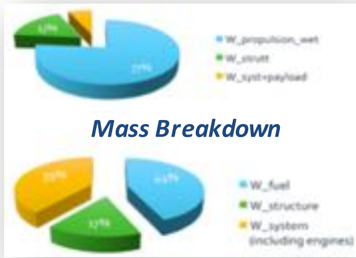
Mission Concept



Main Characteristics

- VTOL Capability (Max T = 300 kN)
- Maximum Take Off Mass 25000 kg
- Maximum Altitude 100 km
- 2 crew members + 2 (up to 4) flight participants



Subsystems

- Propulsion Subsystem
- Fuel and Propellant Subsystems
- Environmental Control and Life Support System (ECLSS)
- Landing gear and Landing Bags
- Emergency Parachute
- Guidance Navigation & Control (GNC)
- Reaction Control System (RCS)
- Flight Control
- Avionics

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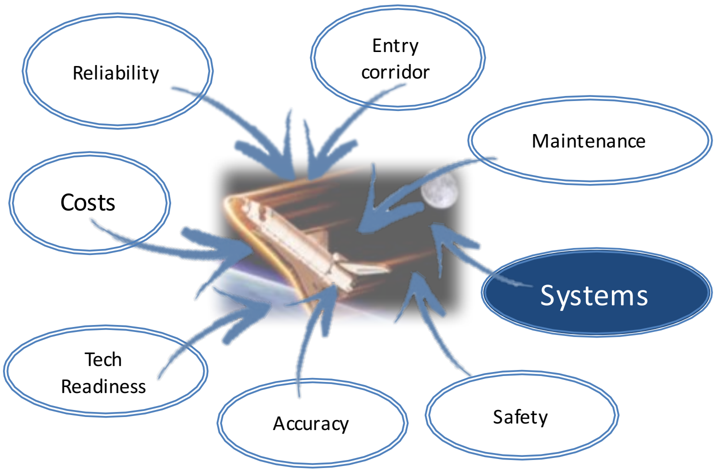
Architecture Design Definition



Once the required L/D value has been defined it is important to consider all the other requirements that could affect the external layout.

These requirements can directly arise from the mission analysis but also from different considerations, e.g. the way in which this spacecraft will be operated and produced.

Special attention should be devoted to the analysis of ***systems*** *and subsystems and their on-board* ***integration****, especially if they are based on pretty new and disrupting technologies.*

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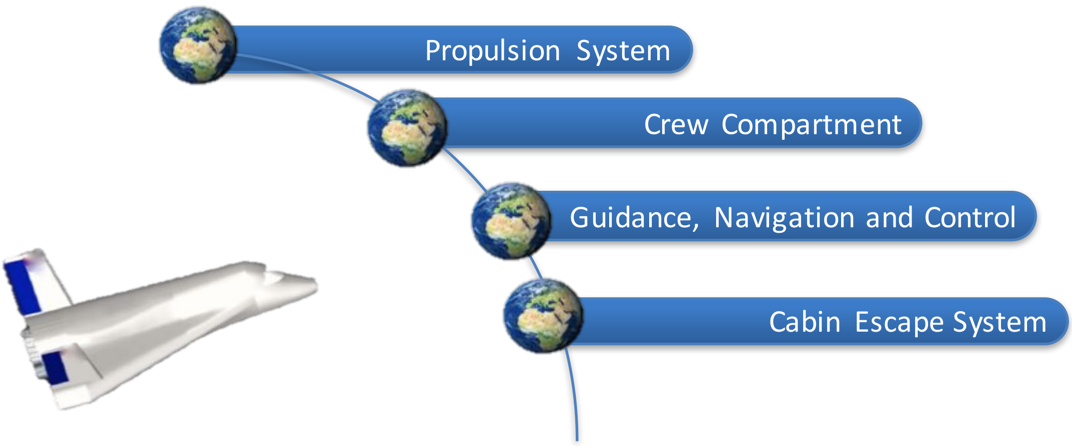
Pushing systems



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Pushing systems

- Propulsion System
- Crew Compartment
- Guidance, Navigation and Control
- Cabin Escape System

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Propulsion System

Hypotheses

Stakeholders' needs

- Vertical Take-off and Landing vehicle
- Precision and soft landing capabilities

Local Regulations

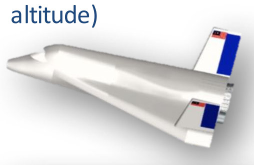
- No Rocket ignition up to a certain altitude
- State-of-the-art components

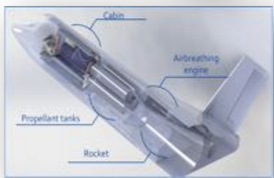
Mission Requirements

- To take-off&land in the same place
- To Reach 100 km

Results

SSTO with dual propulsion System:
- ***Air-breathing*** (for take off and landing maneuvers)
- **Rocket** (to reach the target altitude)





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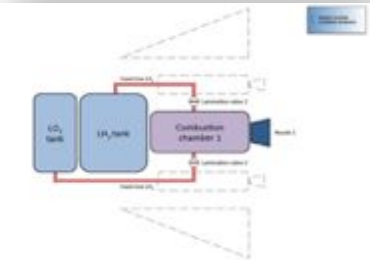
Propulsion System: air-breathing engines

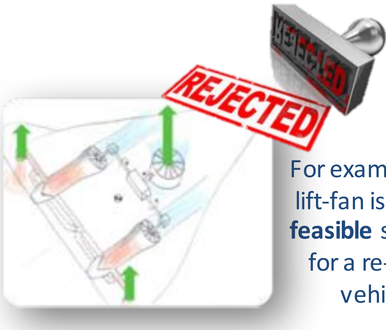


Two air-breathing engines able to:

- Guarantee VTOL by means of steerable nozzles placed in the bottom.
- Sustain the vehicle during the atmospheric climb up to the ceiling altitude

Rocket motor able to:

- Guarantee the spaceplane to be able to reach target altitude



For example, the lift-fan is a **non-feasible** solution for a re-entry vehicle

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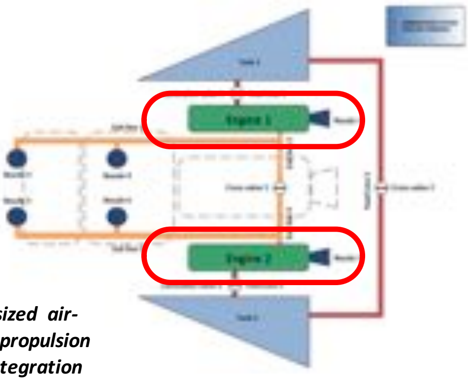
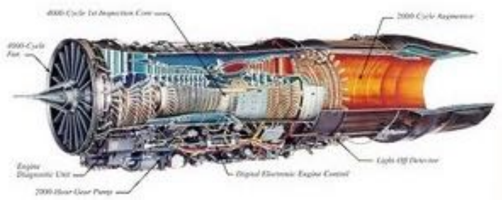
Propulsion System: air-breathing engines

The second proposed solution has been selected for the development of short/middle term demonstrator. The other solution, more complex and with high-related costs, will be be taken into account for further evaluations.

Air-breathing engines data	
Overall Thrust [kN]	300
Diameter [m]	1.18
Length [m]	4,85
Fuel [kg]	2265



Hypothesized air-breathing propulsion system integration



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Propulsion System: rocket motors

The exploitation of simulations since the beginning of the conceptual design of this special kind of spacecraft, allows to select a proper rocket motor guaranteeing the right amount of thrust.

Rocket Motor data	
Overall Thrust [kN]	300
Diameter [m]	3
Length [m]	4
Fuel [kg]	5200

RL-10 rocket motor and related propellant tanks on-board installation

RL-10 rocket motor

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Pushing systems

- Propulsion System
- **Crew Compartment**
- Guidance, Navigation and Control
- Cabin Escape System

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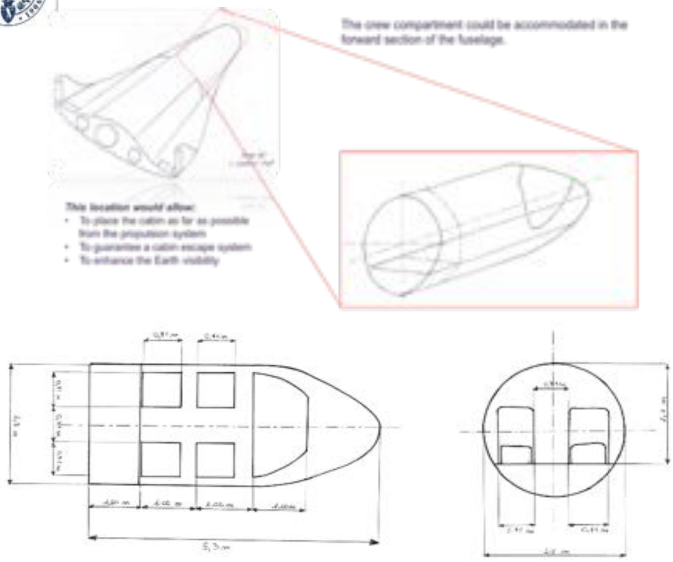
Crew Compartment



➢ ***Crew compartment location:***

The crew compartment has been located in the aft – fuselage, considering:

- *Visibility*
- *Distance with respect to the propulsion system*

➢ **Crew compartment external envelope**

Its main envelope has been derived from the following evaluations:

- *Number of passengers*
- *Number of flight participants*
- *Comfort level*
- *Pilot visibility*

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Crew Compartment

➢ ***Sliding seats:***

The proposed configuration allows passengers to float during the micro-g period, at the top of the parabolic trajectory. In order to enhance the free room available, sliding seats have been designed.

➢ ***Windows or O-LED panel?***

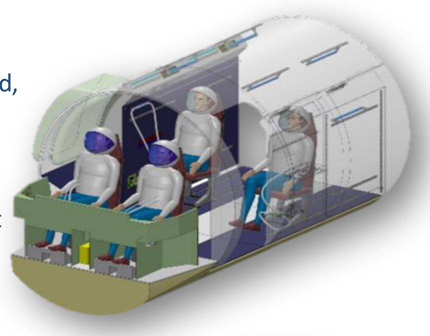
Innovative technologies can allow avoiding structural holes (and related weight increments), guaranteeing a complete virtual immersion in the external environment.

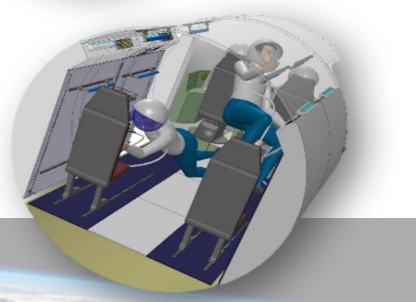
➢ ***Payload location***

Depending on the experiments to carry out, different locations of the payload could be hypothesized, taking into account the possible need of human interfaces, CG proximity, operations, etc…

➢ ***ECLSS***

Cabin interface of the main subsystems have been taken into account in order to precisely evaluate the effective available room.





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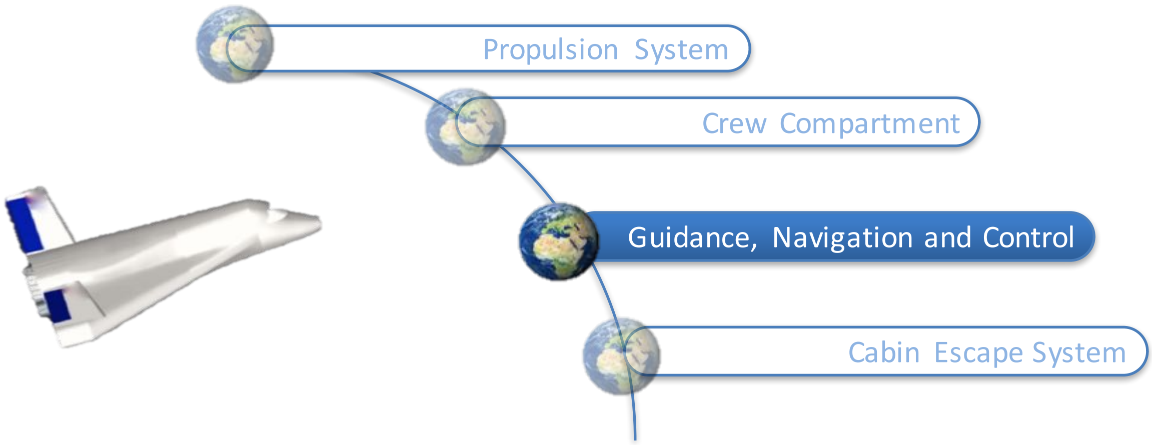
Pushing systems



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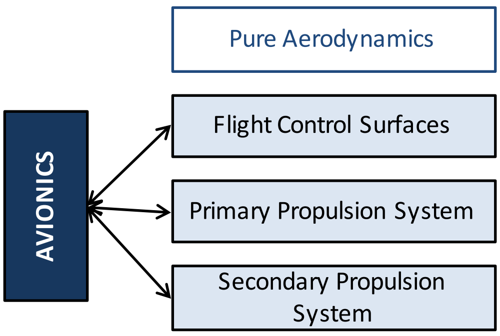
Guidance, Navigation and Control

Depending on the mission phase, the GNC functions could be exploited by different systems or sub-systems.



Guidance, Navigation and Control Strategies

- ***VTOL:***
  The proposed configuration allows to perform an Harrier-like Vertical Take Off, exploiting the hot exhaust gases from the 4 steering nozzles. The selected system architecture (with proper redundancy levels) and ad-hoc control laws will ensure stability also in out-of-nominal conditions.
- ***Ascent:***
  During the ascent phase, both he primary propulsion system and flight control surfaces could be exploited to control the spacecraft.
- ***Re-entry***
  During the re-entry phase, secondary propulsion system (together with ad-hoc deceleration systems) should be exploited until flight control surfaces are effective again.

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Cabin Escape System

- Propulsion System
- Crew Compartment
- Guidance, Navigation and Control
- **Cabin Escape System**

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Cabin Escape System

In order to guarantee a high level of safety to the overall system, considering the presence of a rocket motor and propellant forces the designers considered solutions for a flight participant escape system.
Different solutions have been considered to solve this problem:

- ***Single-Seat Escape System***

Each seat is ejected and shall survive until the Earth surface is reached. Please notice that this configuration is not convenient in case of a vehicle carrying more than 2 people. Indeed, each "survival-shell" shall contain a backup-version of all the vital subsystems.

- ***Cabin Escape System***

This solution shows a detachable aft-fuselage in case of serious contingency scenario. All the vital subsystems (or a backup version of them) shall be installed in this part of the fuselage. This solution is more suitable in case of 2+ passengers. It is also suitable for **non-trained** passengers!

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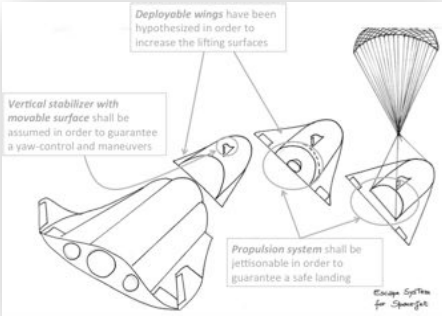
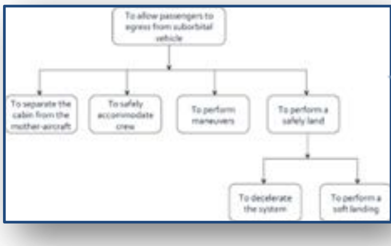
Cabin Escape System



The proposed solution consists of a detachable front part of the fuselage equipped with all the subsystems necessary for guaranteeing flight participants survivability.



From Functions….
….to the subsystems

- Mechanically Initiated Pyrotechnic Mechanisms
- Rear Flaps
- Deployable wings
- GNC & RCS
- Inflatable landing bags
- Parachute
- Emergency ECLSS
- Suits
- …

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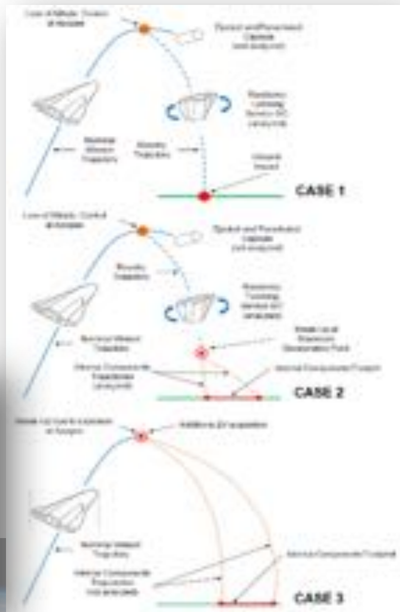
Cabin Escape System

At the same time, in order to ensure adequate safety levels also in case of contingency, different failure scenarios have been analyzed. Moreover, a detailed analysis of **impact points** have been carried out.
In particular, 3 contingency scenarios were evaluated:

- **Case 1:** loss of attitude control at the trajectory apogee: escape system is ejected and the rest of the spacecraft randomly tumbles until the impact on ground.
- **Case 2:** loss of attitude control at the trajectory apogee escape system is ejected and the rest of the spacecraft randomly tumbles until reaching the maximum admitted deceleration rate. Overcoming this limit causes the fragmentation of the vehicle and the internal components are released and reach the ground.
- **Case 3**: Catastrophic explosion at the trajectory apogee without any possibility of detaching the escape system. This catastrophic scenario has been evaluated in a qualitative way but deeper analyses will be performed in more advanced design stages.



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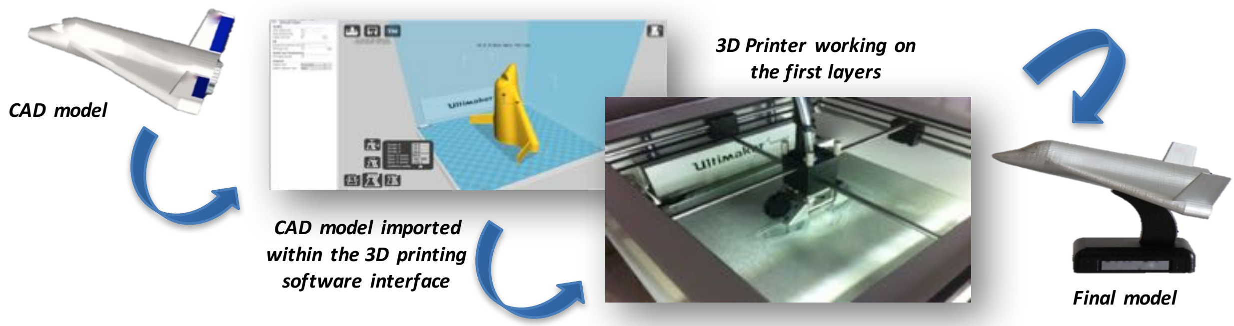
From sketch to 3D printed model

The exploitation of Rapid Prototyping techniques such as the 3D Printing technology is envisaged in order to create low-cost model useful for further advanced evaluations for which scaled model could be admitted.



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Final Remarks and ideas for the future

- The heterogeneous team allowed a continuous and ***fruitful sharing of knowledge*** and soft and hard skill improvements.
- In future, further investigations will be carried out considering different aspects of this complex system. In particular, specific efforts will continue to be devoted to the definition of the ***on-ground infrastructures*** required in order to support the relevant operations and make this spacecraft able to safely carry out the required missions.
- Special attention will be devoted to the study of the ***Re-Entry phase***.


Thank you for
your attention
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