Multi-Disciplinary design 4 future reusable space transportation systems

Keywords: Reusable Ascender & Re-entry vehicle, System Design, Multi-Disciplinary Design

Objective of activity:

Future Space Transportation system need to operate like aircraft in order to be cost efficient in providing rapid access to space (SpaceX/Darpa/Masten/Starship/Relativity-Space Terran R).

Develop a **radical new concept of suborbital reusable space transportation system** combining and integrating the latest technological means available to provide in a state of the art evolvable transportation system. The vehicle shall be able to orbit shortly, de-orbit, and perform aero-assisted re-entry and vertical precision landing.

The vehicle shall be designed to operate in an aircraft like fashion with **autonomous and adaptable**

1) mission planning,
2) end to end flight execution,
3) and short turn around time with limited refurbishment/inspection up to only refueling.
4) towards full reusability

What are the development**, design, material and production (steel-3D print etc..)**, impacts to meet embedded autonomy in responding to mission, system, design and operations objectives?

In order to address these needs, it is necessary **to radically re-think** current reusable rocket design (not a copy of SpaceX F9, but an evolution of Starship), development and production concepts by developing the vehicle and systems from a multi-disciplinary design perspective

accounting for all stakeholders in order to derive the latest state of the art efficient technologies that meet the specifications in terms of cost, production, performance and operations.

Tasks-What/How

Mission, system, design, production and operations requirements shall be elaborated.

Requirements shall be developed to capture the design using latest digital tools for the development of digital twins. Model Based Engineering processes shall be used and integrated among all involved disciplines.

Development plan shall be elaborated:

- **Logistic design** shall be elaborated using advanced System Engineering computational tools.
- Architectural design for the vehicle system and subsystems shall be established.
- This research shall develop an infrastructure that allows optimizing vehicle shape, structure & materials from an efficient production perspective in terms computational design and automated production means.
- Further, subsystem activities addressing loads, aerodynamics, propulsion, flying qualities and GNC against the efficient production and operation shall be elaborated in separate activities.
- Vehicle shape design via mission profile optimization, flying qualities assessment for precision flight. Combined aero and retro-propulsive landing technologies and GNC system requirements (including sensors and actuators), GNC design, development and validation shall be developed.
- Integrated engine control development plan shall be developed.
- Design to Produce plan addressing digital twin and model based engineering
- Development & Implementation plan

Outcomes:

A series of Multi-disciplinary PhD's Topics can be associated to the objective of this System level activity. These can be gradually developed according the master development plan

Launcher Multi-physics Mission Design

Keywords: Multi-Physics Mission Design Framework: Integrated Trajectory, Multi-Physics Optimization, Design and Deployment for Reusable Space Transportation Systems mission analysis, flexible dynamics – Model Base Engineering – Digital Twin

Objective of activity:

Bring up a team Multi-Disciplinary Research and Engineering Team for the Co-design and integration of:

- Generic Reusable Space Transportation Advanced Modeling & Simulation and Analysis System
- The system shall be built up on a new physics based numerical computational platform using advanced modelling and simulation infrastructures – Julia – Mathworks Simscape – etc..
- Develop a Large Scale Mathematical Optimisation Infrastructure.
- Rapid Heterogenous Multi-Physics Simulation Engine in advanced multi-physics packages as Simscape, Modia or other are to be investigated – solving stiff DAE problems / forwards and backwards simulation
- Deploy Integrated Fluid Dynamics, Structures Modelling and Simulation / Modelling Physics governed via Partial Differential Equations
- Develop multi-physics propulsion modelling, simulation and control design framework (Evolution of Eco-sim-pro etc..)
- Deploy coupled Wind Gust, Loads, Aero-Thermal Elastic modes, via the Partial Differential Equation Modelling (sloshing and distributed aerodynamics)
- Develop tools for Uncertainty Management and Quantification and Sensitivity analysis via Auto-Differentiation / Convex Optimisation
- Development of a High Fidelity Multi-Physics Simulator for E2E Mission Analysis Ascent to Landing, GNC Analysis, Loads Analysis, Fault & Degradation Analysis, Safety Analysis
- Deployment of massive rapid simulation
- Develop complex data visualization and analysis tools.

Tasks-What/How

Mission & multi-disciplinary system design shall be elaborated:

- Review of existing multi-physics modelling technologies
    - Requirements shall be developed to capture integration of disciplines using advanced digital engineering modelling, simulation and design tools. Requirements shall be formalized in high level languages as System Composer and embedded into model advisor. The entire process shall be developed to achieve digital continuity.
    - Architectural design of the Framework infrastructure shall be developed in order to couple multi-physics disciplines
- Development plan of the modelling and simulation framework shall be elaborated resulting in collaborative co-design activities.
    - Architectural vehicle system and subsystems design shall be established.
    - Co-engineering activities using integrated tools shall lead to demonstrate how to optimised vehicle shape, structure, propulsion, aero and GNC functions with emphasis on autonomous flight and operations.
    - Develop and assess advanced real time guidance, control and FDIR technologies for the demonstration of novel safe mission profiles. Flying qualities for precision flight will be studied.
    - Optimal aero and retro-propulsive maneuver and precision landing strategies will be studied.
    - Framework will be developed incrementally through integration of various interface disciplines.
    - Rapid prototyping shall be validated through experiments, subscale articles as well as benches from where real data can be fed back into the digital design. System Identification and Model Validation techniques will be developed. Design of experiment.
    - Synthesis

Deliverables

A series of PhD thesis topics can be allocated to this topic.