MISSION ANALYSIS AND FLIGHT MECHANICS OF EARTH EXPERIMENTAL MISSIONS

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In the European context, several experimental missions have been planned to improve the knowledge of hypersonic systems. The general aim is to increase the safety of the future re-entry or planetary probe missions and optimize designs by reducing margins.

There are several needs for hypersonic experimentation. On one side, from the point of view of subsystems it is of interest to increase the TRL of critical EDL technologies, like TPS or GNC by demonstration with scaled vehicles in representative environments. On the other, there is also need to validate the tools used for design in several disciplines, in particular aerodynamics and aerothermodynamics, where scarce experimental data are available. Finally, the design of the experimental vehicle is also a demonstration of system design and operations.

From the 3 levels of experimentation, in flight research, experimental demonstrators or full scale vehicle, the ones of interest in view of planetary probe missions are the first two. In flight research vehicles are test bed for basic research. The Expert and RadFlight capsules fall within this type, while IXV and BLAST belong to the area of experimental demonstration with subscale vehicles.

The objective of the "RadFlight" Re-Entry Flight Experiment is to reduce the large margins considered today in the design of TPS for high speed science exploration sample return missions by improving our knowledge on radiation process, radiation / ablation coupling and occurrence of transition from laminar to turbulent boundary layer. It is a re-edition of the Fire II experiments. The RadFlight capsule is ballistic and falls within the 50 kg class.

The Intermediate eXperimental Vehicle (IXV) is a re-entry demonstrator whose objective is to tackle the basic European needs for re-entry from LEO. The vehicle is a 2 Tons class lifting body with ceramic and ablative TPS materials performing a controlled re-entry.

The Beyond LEO Advanced Subscale Test (BLAST) is a System Design Experience aimed to enhance the European system design capability and provide in-flight data. BLAST is a high-speed demonstrator whose main objectives are the in-flight experimentation of TPS systems, the design and successful operation of a GNC system for a lifting re-entry configuration in skip entry and the collection of detailed information related to the flowfield during the superorbital entry phase.

This paper focuses on the RadFlight, IXV and BLAST Mission Analysis and Flight Mechanics. The mission analysis and Flight Mechanics of an experimental mission plays a key role to assess the feasibility of the mission and to advance the expected benefits before entering in detailed definition phases. Experimental mission are usually very constrained by low cost and hence optimization, scaling and other simplifications cannot prevent the user from getting the intended knowledge. It is them important to understand the bounds and limitations and to analyze the compatibility between the required experimentation and the available resources. Advanced methods and tools are applied with the general aim of incorporating as much requirements as possible with increasing level of fidelity in order to reduce the design iteration loops.

The Mission Analysis of such experimental vehicles has a double challenge: first, to identify a feasible design space where all of subsystems of the demonstrator can be designed. Ex: the vehicle must flight within an entry corridor with adequate stability and control characteristics. On the other, to ensure the representativeness of the flight envelope with respect to the research or demonstration. Ex: a stable flight within the entry corridor out of the region of interest for the intended experimentation is safe but useless.

This paper presents the mission design for each of the 3 experimental vehicles with special emphasis on the coupling between the mission, system and the experimentation objectives. All the 3 missions are suborbital: the vehicle is injected in a suborbital arc and in the case of RadFlight and Blast there is a booster element that provides the additional energy needed to reach beyond LEO velocities. At the end of the suborbital arc the vehicle re-enters into the atmosphere. IXV and BLAST perform a controlled entry, while in the case of Radflight the entry is ballistic. As a result, in the 3 cases an end to end Mission design approach is required in order to properly couple the entry phase restrictions with the ascent capabilities.

The main characteristic of the RadFlight Mission is the strong coupling between all of the phases: ascent, acceleration with the booster and re-entry. The feasibility requires an end to end approach from lift-off to parachute deployment in order to identify the entry corridor in which the capsule on one side respects all of the mission and System constraints, including compatibility with the Volna launcher and on the other fulfils the experimentation objectives in terms of aerothermodynamics environment to be measured (minimum level of radiation heat flux and coupling between convective and radiative flow).

The IXV vehicle is the concept in more advance state (facing CDR actually). The large design margins required by the aerothermodynamics induce a narrow corridor which is challenging for both Mission and GNC. The Mission Design process considers visibility, Flying Qualities, safety and trajectory constraints during the mission design leading to a robust trajectory design. The end-to-end trajectory optimization process from lift-off to splashdown and performance evaluation (Monte Carl) is presented as one of the key mission design elements, as well as the integration of high fidelity models for the vehicle aerothermodynamics and GNC.

Finally, the BLAST Mission Analysis combines the complexity of the IXV vehicle in terms of representativeness of an operational mission with restrictive safety requirements with the peculiarities of the high speed re-entry, which tightly couples ascent and re-entry phases.

Within the paper, the different Mission Design approaches will be presented and the main results and status discussed which includes trajectory optimization, Flying Qualities, GNC, end-to-end Monte Carlo assessments, visibility, safety aspects and technological aspects.

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