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DEVELOPMENT OF A TOOL FOR THE ANALYSIS AND OPTIMISATION OF ATMOSPHERIC RE-ENTRY TRAJECTORIES

Abstract

Atmospheric re-entry relies on different aspects of the space sector, such as the return of manned or unmanned payloads back to Earth, the exploration with landers and rovers of the outer planets with atmosphere, or additionally the demise of satellites at their End-Of-Life; all aspects nowadays of interest both for Space Agencies and private companies. The atmospheric re-entry from space is one of the most critical and complex engineering problems in the aerospace field. Stringent and specific mission requirements shall be satisfied to properly ensure a non-destructive and safe landing of the managed asset. The requirements' severity strongly depends on the type of the hosted payload by the spacecraft: manned or un-manned. Especially in the first case, the stringent mission requirements deeply affect the design of the spacecraft re-entry trajectory or 're-entry corridor', strongly impacting on the spacecraft overall design and mass budget. This paper deals with the preliminary analysis and design of re-entry corridors for manned and unmanned spacecraft. Physical and mathematical models have been developed to simulate the environment (i.e. atmosphere and gravity field) and the aerothermodynamics phenomena affecting the spacecraft along the re-entry phase. To verify the validity of the developed tool, different real missions have been firstly simulated, such as IXV by ESA and AS202 by NASA. The results have been then compared to the real mission data. An optimisation methodology has been developed and implemented into a flexible numerical program in Matlab® language. The program gives the opportunity to set initial conditions like the spacecraft's geometry and mass, and the so-called 'target conditions'. The outputs of the tool provide the users with the possibility to find the optimised re-entry corridors, identifying all the best-candidate Entry Interface Points that shall be achieved by the spacecraft to satisfy the imposed mission requirements. As additional output, structural, aerodynamic and thermal stresses acting on the vehicle are estimated in order to minimize their peak values. Furthermore, the re-entry windows from the parking orbit and the related de-orbit manoeuvres are also estimated, as well as the communication windows with the selected ground stations. Moreover, a sensitivity analysis has been implemented for completeness and to enhance the reliability of the produced solutions from statistical point of view. An applied study will be reported as example, together with the obtained results, highlighting their importance for planning and operating re-entry missions of present and future applications.