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A CONCEPTUAL DESIGN TOOL FOR PRELIMINARY SIZING OF SUBORBITAL TRANSATMOSPHERIC VEHICLES

Abstract

Until recent times, the boundary between atmospheric and space flight domains was clear and the separation between the two domains was quite large: most aircraft fly below 20km of altitude, whereas spacecraft orbit the Earth above 250km from Earth surface. Vehicles crossing this boundary are launch vehicles, going up, which exit the atmosphere to put a spacecraft into orbit, and, going the other way round, entry vehicles, which take astronauts back to Earth after their period in orbit. Access to space by means of suborbital vehicles for space tourism is changing this scenario and, in the future, transatmospheric and hypersonic vehicles will further blur the boundary between atmospheric and space flight domains. The possibility of covering distances comparable to half of the circumference of the Earth in flight times in the order of one hour would radically change intercontinental commercial and emergency transport, hence suborbital transportation of goods and people is attracting increasing attention and investments. However, commercial applications of this concept require the solution of several technological, economic, and regulatory challenges, before it becomes available for deployment at scale. The focus of the paper is on suborbital vehicles, with a mission profile divided into four phases: (i) an acceleration that brings the vehicle out of the atmosphere; (ii) a ballistic transfer covering most of the travel distance; (iii) an atmospheric reentry close to destination; (iv) a glide to the landing site. The paper is based on the initial outcomes of the research program iConDes (Integrated Conceptual Design Tools for Suborbital Vehicles), funded by the European Union through Next Generation EU (Project Identification Number P202272HBN). Several challenges are encountered in the preliminary design of this class of vehicles, such as the definition of a trajectory that minimizes the fuel required during the ascent and the estimate of thermal and mechanical stresses experienced during the descent. The latter is far from trivial, for the

very complex aerodynamic phenomena that characterize the boundary layers developing on the fuselage (e.g. laminar-to-turbulence transition, chemical dissociation, interaction with shock waves, etc.). Hence, preliminary sizing and weight estimation of a vehicle capable of executing the required trajectory while withstanding these stresses requires a complex multidisciplinary approach featuring the integration of diverse analysis tools, including, among many others, trajectory optimization, conceptual design, and computational fluid dynamics techniques. The development of an integrated conceptual design platform encompassing all these aspects will be described in some detail.