Paper ID: 66968
oral
student

IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Upper Stages, Space Transfer, Entry & Landing Systems (3)

Author: Mr. Stefano Farì
German Aerospace Center (DLR), Germany

Mr. Davide Grande
University College London (UCL), United Kingdom

VECTOR FIELD-BASED GUIDANCE DEVELOPMENT FOR LAUNCH VEHICLE RE-ENTRY VIA ACTUATED PARAFOIL

Abstract

The increased availability of affordable and reliable off-shelf components, together with the growth of compact embedded systems, has led industries and research institutions to start developing proprietary launch systems. These platforms can, for instance, deliver small payloads into orbit or allow experiments at specific atmospheric conditions for scientific studies. Given the requirement for low operational costs, reusability proves to be crucial. Since these vehicles may terminate their ascent several kilometers away from the launch site, they need to be equipped with an onboard autonomous recovery system. To reach this goal and to enhance safety of nearby areas, re-entry can be performed by means of a controlled parafoil. As practically shown by Rocket Lab recent developments, the solution offers a lightweight and space-efficient control mechanism for autonomous placement of the falling rocket to specific ground coordinates. Therefore, more efficient and implementable guidance strategies must be investigated.

This paper aims at presenting a Vector Field (VF) path-following guidance for a parafoil-rocket system re-entry. VF methods have already shown remarkable results for fixed-wing unmanned vehicles due to the lower steady-state errors as compared to other approaches, while retaining the potential for real-time implementation. With this work, the method is for the first time extended to the application of a launcher recovery. The formal stability proof of the guidance law is guaranteed using the Lyapunov approach. Performance is established by means a dynamic simulator: the overall architecture is structured using two nested closed loops, where the outer one represents the VF guidance law, whereas the low-level inner one is in charge of controlling the yaw angle by applying differential steering signals to the canopy strings. To design the yaw controller, an optimal control approach is employed. The parafoil-rocket vehicle is modeled using the multi-physics object-oriented language Modelica, that allows the implementation of a 9DOF dynamic model, proven to be sufficiently accurate for the considered system dynamics. The latter is then compiled and embedded within the Simulink environment to allow the integration with the designed guidance and control algorithms.

Lastly, the proposed solution is validated with the realistic case study of an existing low-altitude sounding rocket re-entry. The results of the end-to-end simulations are shown, highlighting overall satisfactory performance even in presence of severe wind disturbances.