Advanced GN&C Technologies for TAEM: Flight Test Results of the Italian Unmanned Space Vehicle

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This paper describes the guidance, navigation and control challenges posed by the Unmanned Space Vehicles Program. Within the framework of this program the Italian Aerospace Research Center has conceived several advanced GN&C technologies useful in the Terminal Area Energy Management phase of a re-entry flight pattern. These technologies were flight tested during the first two dropped transonic flight tests (DTFT1 and DTFT2) of the program. More specifically, this paper will present the design of the adaptive guidance algorithms developed to accomplish the mission objectives of the DTFT2 flight test. Flight results will be shown in order to state the performance of the guidance strategy putting in evidence, where possible, its most promising aspects for future TAEM applications.

I. Introduction

THE Italian Aerospace Research Center is conducting an aerospace national research program named Unmanned Space Vehicles (USV). The main objective of this program is to design and manufacture unmanned Flying Test Beds (FTB), conceived as multi-mission flying laboratories, in order to develop and demonstrate innovative technologies for materials, structures, aerodynamics, guidance, navigation and control and critical operational aspects peculiar of the future Reusable Launch Vehicles (RLV) and aerospaceplanes[1,2,3].

Based on the velocity range under investigation, the whole USV program has been divided into several parts, the first of which, named *USV_1 project*, relates to the subsonic, transonic and low supersonic regimes of flight. Specifically, the USV_1 project aims at improving knowledge in different technological areas, from transonic aerodynamic and aerostructural behavior to advanced autonomous guidance, navigation and control.

Two identical autonomous and unpowered Flying Test Beds (called FTB_1 but nicknamed *Castore* and *Polluce*) have been designed and produced to support the execution of the USV_1 program. Two transonic flight missions (Dropped Transonic Flight Test 1 and 2) have already been carried out, on a total number of three. All missions have similar flight profiles in which the FTB_1 vehicle is carried up to an altitude between 20 km and 30 km using a stratospheric balloon and it is then released to carry out a gliding flight until the deployment of a recovery parachute that allows the vehicle to splashdown safely.

From the perspective of the Guidance, Navigation and Control (GN&C) systems, the three missions will allow CIRA to investigate and flight test critical technology aspects related to the autonomous execution of a typical Terminal Area Energy Management (TAEM) phase of a re-entry flight from a velocity of about Mach 2 down to the typical Approach/Landing Interface (ALI) speed of Mach 0.5 and below.

How technology advancements in the GN&C domain can contribute to a more autonomous, more safe and less costly future generation of RLVs is well stated in open literature[4,5,6]. The most relevant technology advancements appear to be related to *adaptive guidance techniques with on-line trajectory re-planning capabilities* and to *robust and fault tolerant control techniques*. Obviously, such innovative GN&C systems need improvements in the fields of robust analysis and design/verification techniques for highly non-linear time-varying plants with uncertain parameters.

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