GN&C Re-Entry Technologies Needs and Challenges in CIRA-USV Program

L. Verde - CIRA

The CIRA Unmanned Space Vehicle (USV) program focuses on the development of flying laboratories (Flying Test Beds, FTB) and in-flight demonstration of selected technologies related to some key aspects of future space vehicles, namely atmospheric re-entry, sustained hypersonic flights and reusability. Advanced materials, Aerothermodynamics and Guidance Navigation and Control are the areas on which the USV program technological improvements will be specifically expected.

With reference to the conventional NASA Shuttle flight phases definition of Entry, Terminal Area Energy Management (TAEM) and Approach & Landing, the USV program foresees in-flight demonstration of advanced GN&C technologies for the TAEM and Entry phases.

For what concern the TAEM demonstrations, in February 2007 a first transonic drop test (DTFT1) from 20Km was executed reaching Mach number of about 1.1 in a fully autonomous controlled flight. Two other missions are scheduled in years 2008-2009 to reach Mach numbers up to 2.0, for a complete simulation of the TAEM phase of Re-Entry flight.

The aim of DTFT1 mission was to validate the Stability & Control Augmentation system for TAEM phase of flight and to demonstrate effectiveness of the following technologies:

- Application of Unscented Kalman Filter for aerodynamic coefficients and disturbances identification using an estimation before modelling technique;
- Uncertainty modelling and analysis techniques for estimating allowable aerodynamic uncertainty ranges which still lead to predefined vehicle manoeuvrability and stability properties;
- Probabilistic and deterministic methods for control law clearance along an unsteady trajectory
- Application of MATLAB/Simulink Automatic Coding environment in a state-of-the-art real time OS for both GN&C implementation and on-ground validation.

The presentation introduces the above identified technological needs and lesson learned from execution of the DTFT1 mission in terms of further developments to be performed for future re-entry vehicles, at least for the TAEM phase.

Also included in the presentation an overview of the two technologies planned for demonstration in the subsequent two missions for TAEM phase of flight. One relates to application of the most effective control system techniques between a fuzzy scheduled μ-controller and an adaptive model following controller for overcoming the low performance robustness of the DTFT1 controller. The second one relates to an on-line trajectory planning algorithm for TAEM phase capable to better handle emergency and off-nominal conditions when compared to the space shuttle guidance strategy.