EXOMARS 2016 – GNC APPROACH FOR ENTRY DESCENT AND LANDING DEMONSTRATOR

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ABSTRACT

This paper gives an overview of the most significant results, related to the Guidance Navigation and Control system design of the ExoMars Entry Descent and Landing Demonstrator Module (EDM) for the Exomars 2016 mission.
Although the technologies to descend on a planet with a capsule are well known and experienced, landing remains a critical point for whichever exploration mission. Several solutions for landing technologies have been used in past missions, from the active braking with throttleable or pulsed rocket engines and impact attenuations legs (Viking, Phoenix), pulsed raking and un-vented airbags (Pathfinder, MER) of pure impact attenuation with un-vented airbags (Beagle-2). The new JPL-NASA missions use active control with throttleable engines and direct delivery to surface of rovers with the sky-crane concept.
ExoMars Descent Module relies on the new technology of crushable structures for terminal impact attenuation that requires a precise control in the final instants, to be able to drop the lander at the specified altitude and with (nominally) null velocity and displacement versus the local vertical. Terminal braking is performed on Pulse Width Modulation of three clusters of three 400N engines, located directly on the Surface platform.
For the ExoMars mission success it will be necessary that every GNC task will be perfectly achieved: the Entry Point recognition, the parachutes deployment trigger, the engagement of relative terrain navigation with hybridization of the inertial navigation with direct measurements via Radar Doppler Altimeter (RDA), the engagement and control of the terminal descent phase, the terminal drop of the Surface Platform to the surface of Mars.
Looking in particular at the landing phase the ExoMars GNC has been designed trying to highlight some specific drivers: 1) Modular organization of the algorithm blocks based on functional roles (reference definition, state estimation and control action dispatching) and on affected axes (descent-vertical dynamics and attitude-horizontal ones), 2) Clear identification of the interconnections among the modules, 3) Definition of rules, simple as much as possible, to maintain continuously under control the evolution of each module dynamics and to force by construction adequate separation of the dynamics in the interconnected loops. For each of the three "G", "N" and "C" it is possible to identify a critical aspect.
The guidance must be able to compensate the engaging inaccuracy due mainly to radar Doppler scale factor errors and has to be designed in such manner to avoid jittering profile in the attitude reference generation, despite it is fed by noisy measurements.
The navigation has the complex role to guarantee sufficiently filtered state estimation but, in the same time, high promptness peculiarly in the initial instants of the controlled phase that require fast attitude control.
The control has to guarantee that the command is dispatched in the most effective way among the thrusters. The priority must be given to the attitude control in such a manner to achieve as soon as possible the alignment of the capsule to a direction opposite to the relative velocity (g-turn) also when starting from large attitude errors. Once the capsule has been aligned, accrued errors versus the descent profile can be recovered, ensuring, in the end, the fulfillment of both translational and rotational requirements. Last but not the least, a Backshel Avoidance Manoeuvre (BAM) has to be implemented in the cases where weak horizontal winds may induce the risk that the separated back-cover under parachutes may fall back onto the Surface Platform.
The key aspect for a project like the ExoMars EDM GNC is the verification of the robust performances. The control must work in presence of strongly variable initial conditions, radar Doppler and actuators generates high level of inaccuracies to be carefully managed Furthermore even in presence of a modular design there are several points in which the loops are interconnected. Thus a big effort has to be spent for this task to have an analytical assessment of the design reliability, to be later confirmed by the execution of a large number of Montecarlo analyses.