DESCENT GUIDANCE AND NAVIGATION AT MARCOPOLO-R ASTEROID 2008EV5

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ABSTRACT

The paper aims at presenting the results obtained from the analysis and simulation of the Guidance and Navigation performances for the descent phase to asteroid 2008 EV5 in the MarcoPolo-R mission study. The activities carried out in this task were key to support the design of the mission GNC and operations architecture. Different navigation and guidance strategies were proposed and simulated in order minimize the touchdown dispersion, and to ensure compliance with the existing requirements on such parameter, taking into account the operational constraints and the available on-board measurements. The need for a cost effective approach, with low complexity and ground-based navigation, resulted in an effort to devise a descent strategy able to deliver the spacecraft at the final descent point with the necessary precision while avoiding autonomous GNC architectures.

A first set of calculations was performed to assess the impact of different measurement strategies on the achievable orbit determination performances for an asteroid-bounded orbit. The results of such analyses provided the initial conditions to be employed at the beginning of the descent leg which will bring the spacecraft down to the so-called Low Gate point (nominally 100 m above the asteroid surface), where the final vertical descent is started.

The effect of the operational delay due to inclusion of ground in the loop was assessed. Such delay proved to have a relevant impact on the achievable estimation performances then employed in de-orbiting and trajectory correction manoeuvres calculation, with therefore a relevant impact on final dispersion performances.

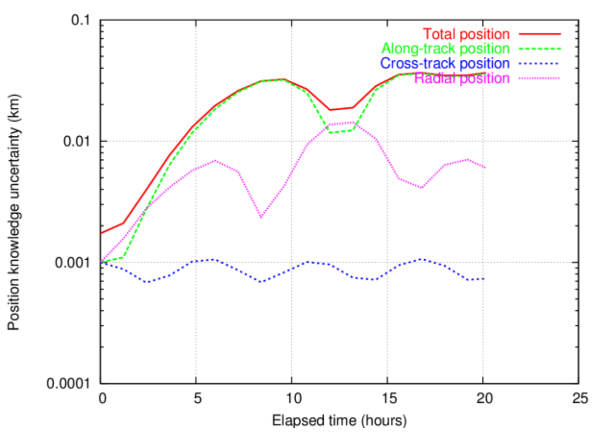

Figure 1: Position knowledge uncertainty growth during operational delay interval

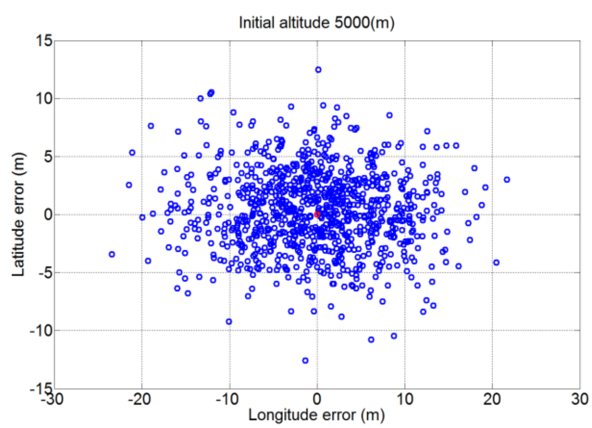

Figure 2: Errors at Low-Gate from Monte Carlo simulation with fixed time terminal guidance

A trade-off exists in the definition of the descent strategy as the descent branch altitude drives its duration which, coupled with the operational turnaround time, will determine whether trajectory corrections are possible in the course of the descent or not. In order to support the system design in this trade-off an analysis of the achievable dispersions at Low-Gate was carried out for variable initial de-orbiting altitudes. Monte Carlo simulations were executed with this purpose, simulating the evolution of the errors from de-orbiting to low-gate including mid-course correction manoeuvres. In the execution of such simulations, two conditions were considered for the triggering of the final vertical descent sequence: fixed altitude and fixed timing. In the first case, it is assumed that the low-gate is reached when the on-board altimeter indicates that the nominal altitude is reached, while in the second case a time fixed triggering (based on the nominal descent time) is employed. The fixed altitude option would result in the introduction of a timing error, which, due to the rotation of the asteroid, would be translated in longitudinal dispersions. On the other hand, the fixed time triggering would result in altitude errors at the beginning of the vertical descent. If such altitude errors are small enough not to pose a threat to the safety of the mission and to be dealt with by the vertical descent guidance system, the fixed time option is preferred, as it allows avoiding the longitudinal errors showed by the fixed altitude case.

Concerning the employed measurements, the effect of different sets of observables was assessed. Along with standard ground-based radiometric tracking, on-board altimeter data, feature tracking and ground-based landmark tracking data were included in the simulations executed. The impact of camera characteristics was assessed as well, providing dispersion errors at Low-Gate with ground-based landmark tracking navigation for different combinations camera Field of View and number of pixels.

Finally, a short discussion of the improvements coming from the adoption of an autonomous navigation architecture for the descent phase is carried out.