Mascot: Analyses of the Descent and Bouncing Trajectories to Support the Landing Site Selection

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The Japanese mission Hayabusa-2 has been launched in December 2014 towards the near Earth asteroid 1999JU3, also called Ryugu. This carbonaceous asteroid considered to conceal unchanged traces of the Solar System's origin will be reached by the JAXA space probe in 2018. As done by its predecessor for the asteroid Itokawa a few years ago, Hayabusa-2 will observe Ryugu during several months and perform a touchdown to gather samples before returning them to Earth. In addition to the three Japanese micro-landers MINERVA taken on board, the probe carries the German-French lander Mascot (Mobile Asteroid Surface Scout). This shoe-box sized spacecraft of 10 kg is equipped with four scientific instruments aiming at improving the knowledge of mineralogical, geological, magnetic and thermal characteristics of Ryugu. It has no propulsive system and is planned to land onto Ryugu's surface by the end of 2018 after a passive descent from an altitude of a few tenths of meters.

In the frame of the collaboration between the German Aerospace Centre (DLR) and the French Space Agency, the CNES is responsible for the activities related to Mascot landing trajectory prediction and optimization. The simulated trajectories resulting of the dispersions analysis are essential inputs for the preparation of the operational phase and for the selection of a landing site satisfying constraints imposed by technical aspects (thermal, communications) as well as by scientific interest. Since Mascot has only a limited mobility capacity using a hopping system, the choice of the landing site has to be carefully planned.

The achievement of such objectives poses several challenges. First, the environment that will be found at the end of Hayabusa-2 interplanetary travel is very uncertain: the characteristics of the asteroid, like its shape or its density, are just roughly known and their knowledge will improve only after arrival, that is to say just a few weeks before landing. This context imposes to perform mission analysis covering a wide range of possible situations and to implement tools and procedures flexible enough to take into account last minutes updates. Secondly, Mascot does not have any anchoring mechanism and will bounce – on purpose - on the asteroid surface causing the lander to possibly stop far from its first touchdown point. So modelling the rebounds is mandatory for the prediction of the final rest position. For such modelling, a good compromise has to be made between a reasonable computation time compatible with the constraints of the operational timeline, and a sufficient representativeness to be confident in the selection of the landing site. Finally, technical requirements and scientific objectives of the mission are not the only drivers for the landing site selection process. A major constraint for the release of Mascot is also to avoid the areas selected by JAXA for the sampling touchdown of Hayabusa-2, in order not to contaminate the place before sampling and not to disturb the probe descent process using a dedicated target marker. This constraint requires a close interaction with JAXA in order to select both landing sites in a consistent way. The optimization of the Mascot trajectory will finally consist in taking into account all these constraints to tune at best in pre-defined and limited ranges the exact time of release and the exact position of release, with the intention of maximizing the chances to have Mascot resting in a suitable place for valuable scientific experiments without endangering Hayabusa-2 sampling.

The paper will present the principles and results of dispersion analyses performed for the preparation of Mascot landing in the context described here above, from the descent phase to bouncing and final rest on the surface of Ryugu. The landing site selection process will also be described, including the presentation of the Mascot release optimization process and the main principles of its operational implementation.