FLIGHT DYNAMICS ANALYSIS FOR PHILAE LANDING SITE SELECTION

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Philae, the lander of the ROSETTA mission has successfully reached the surface of the comet 67P - Churyumov-Gerasimenko on 12 November 2014. The controlled landing on the comet, accomplished by the joint work of the ESA, DLR, CNES and scientific teams, is an outstanding achievement and will probably mark the history of space exploration. The Science Operation and Navigation Center (SONC) located in CNES Toulouse was in charge of flight dynamics support for the lander team which consists of the Philae scientific community, Lander Control Center (LCC) and SONC.

Among the main challenges encountered by the flight dynamics teams for Rosetta and Philae missions was the selection of the landing site, considering the large amount of unknown data regarding the target body Churyumov-Gerasimenko before Rosetta arrives in the comet vicinity. Only at that moment the selection process could be started with the availability of measurements performed by the Rosetta instruments, in particular by the Rosetta scientific high resolution camera OSIRIS and by the NAVCAM (navigation camera). The timing for comet data availability and the fact that the Philae landing had to occur before the passage of the comet at a distance of 3 Astronomical Unit from the Sun (November 2014) had for consequence that the time allocated to comet observation and characterization was quite short. Therefore a tight collaboration between technical teams (LCC / SONC) and the scientific community was needed. The setup of an operational organization was mandatory in order to carry out this selection process under severe time constraints. The objective of the Philae Landing Site Selection Process was to find a nominal site and a backup that comply with the multiple constraints such as Rosetta constraints on the delivery orbit and navigability, the Philae requirements for descent trajectory and landing conditions and mission constraints for long term operations on the comet (illumination, orbiter lander visibilities). Of course, the site had also to be acceptable from a scientific point of view.

This paper addresses the operational context, the mission constraints as well as the flight dynamics analyses carried out for the Philae landing site selection process. The observations of 67P became more detailed as Rosetta could fly closer to the comet As a consequence the selection process was converging because of the improving the accuracy of the comet characterization. The models (comet rotation and orientation, comet shape with associated Digital

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Terrain Models, gravity field, outgassing model, boulders statistics…) have been developed by both the Rosetta Mission Operation Center and the Rosetta scientific community. Both sources provided models that have been used by SONC. This allowed comparison between models and also sensibility analyses of the results with respect to the models variations. The models will be presented in the paper as they were used as input data for flight dynamics analyses. Then, the nature of the flight dynamics analysis carried out at SONC will presented and the flight dynamics products that have been used for the landing site selection will be detailed. In a first step, analyses of the whole comet were carried out yielding products such as global illumination maps and accessibility analysis considering Rosetta, Philae and mission constraints. In the following steps, more detailed analysis considering selected sites has allowed to rank the sites and to evaluate the risks. The supporting studies were trajectory dispersion analysis in order to estimate the landing ellipses (complemented with of model sensibility analysis), landing site topography analysis and boulder analysis.