# PHILAE DESCENT TRAJECTORY COMPUTATION AND LANDING SITE SELECTION ON COMET CHURUYMOV-GERASIMENKO

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## ABSTRACT

Rosetta, the first space probe that will orbit a comet while it is heading to the inner Solar System, has been in its way to the comet 67P/Churuymov-Gerasimenko for more than 8 years now. After successful fly-by's of the asteroids Steins (2008) and Lutetia (2010), another extremely challenging objective of this European mission is to be fulfilled in November 2014: the first controlled touchdown on a comet nucleus.

The work presented in this paper deals with the development of new strategies for the optimization of descent trajectories to the comet and for the computation of ancillary quantities aimed at supporting the operational Landing Site Selection process. This process is rather complicated, as it has to take into account the orbiter and lander operational constraints both at separation and during descent, harmonize these technical aspects with the landing site preferences of the different scientific teams, as well as ensure the safety and back-up conditions that such a mission requires. Furthermore, the large amount of unknowns concerning the comet itself imposes the need for the strategies to be flexible and allow for parametric studies.

In the last weeks before the delivery of Philae (Rosetta's 100 kg lander), valuable information about the comet characteristics will be gathered by the instruments on-board the Rosetta orbiter. Updated cometary models of shape, gravity, outgassing and comet dynamics will then be generated. At this point, the choice of the landing site and the computation of descent trajectories come into scene. *Andromac* is the optimization tool that has been developed at CNES for computing the descent trajectories and the corresponding separation conditions, by using the cometary models given as an input and taking into account the technical constraints applicable to both the lander and the orbiter. If *Andromac* is able to find solutions reaching a given landing site, additional features of the site and the trajectory are analysed. In this way, not only can the feasibility of the landing be assessed, but also the risk associated with the descent trajectories and the suitability of the solutions according to operational and scientific criteria (duration from separation to touchdown, need for a $\Delta v$ from the active descent system, solar illumination once on the ground ...). Cartographies and charts summarizing the results will be distributed to the Landing Site Selection Group, who is responsible for providing a prioritized list of sites, after iterating with the technical and flight dynamics teams if necessary.

The knowledgeable choice of candidate landing sites is essential from an operational point of view, as the first sites in the list are going to determine the planning of all the operations until landing is complete. The best candidate in the landing site list will be given priority during the Close Observation Phase. That is to say that the trajectory and maneuvering of Rosetta will be tailored

to the observation of this site and its surroundings. Once more detailed models are available after close observation (relief, outgassing…), operational descent trajectories, as well as ephemeris and sequence of events files will be generated. If no significant difficulties are encountered, separation, descent and landing will be commanded and executed. In the unlikely event that a red light triggered after close observation for some reason that was not detected previously, observations and trajectory computations will be repeated for the next site in the list. The close observation of more than two potential landing sites is not foreseen at the moment.

The scientific activities of Philae will start during descent. After touchdown and establishment of the communication link, the lander will continue to perform science operations for several months. Meanwhile, Rosetta will escort the comet as it approaches the Sun. It is expected that by the end of 2015, the spacecraft will have completed its operational activities.