

Tardivel, Simon Charles Vincent (Ph.D., Aerospace Engineering)

The Deployment of Scientific Packages to Asteroid Surfaces

Thesis directed by Prof. Dr. Daniel J. Scheeres

A strategy for the deployment of landers to asteroid surfaces is described. The landing pods are scientific packages with no guidance, navigation and control system, and no specific landing apparatus, so as to minimize onboard platform and maximize payload. The landers are jettisoned from a main spacecraft at high altitude over the target. They impact its surface, bouncing multiple times before finally coming to rest.

The amended gravity field of an asteroid is described in general and regions favorable to a deployment are found close to saddle equilibrium points. For elongated bodies and for binary systems, a linearization shows that a branch of the unstable manifold intersects the surface of the body; the strategy then consists of choosing initial conditions that will express this branch. For quasi-axisymmetric bodies, the initial velocity of the lander is increased to guarantee an impact. The efficacy of the strategy is numerically verified.

A model of the asteroid surface and of the interaction between the pod and this surface is detailed. The asteroid surface is represented with three layers. The asteroid is first modeled using a mesh of triangular facets that can represent its global shape down to the presence of large boulders (greater than 1m). The presence of smaller rocks is accounted for via a stochastic model that generates random collisions with rocks, at impact with the surface or during lasting contact motion (rolling). Finally the interaction with the regolith is handled with a model of contact dynamics, including surface forces and torques (reaction, friction and rolling resistance). The rolling resistance force and torques experienced on regolith are defined and justified. Their coefficients are measured by experiments and explained by theory and finite-element simulations.

Practical mission case studies are presented and discussed, for asteroid Itokawa, 2008 EV5, 1999 KW4 Alpha and Beta.