Paper ID: 10365
student

44th SYMPOSIUM ON SAFETY AND QUALITY IN SPACE ACTIVITIES (D5)
A Big Challenge : Safety in Aerospace Missions (1)

Author: Mr. Frank Engelen
Delft University of Technology (TU Delft), The Netherlands, F.M.Engelen@student.tudelft.nl

Dr. Erwin Mooij
Delft University of Technology (TU Delft), The Netherlands, e.mooij@tudelft.nl

QUANTITATIVE RISK ANALYSIS OF ROCKET TRAJECTORIES

Abstract

In the last few years the number of commercial and student rockets has significantly increased. Launching these vehicles will pose a certain risk to the general public. To estimate this risk this paper presents a generic method to quantify the risks of rocket flight. To calculate the (stochastic) impact footprint a Monte Carlo analysis based on numerical trajectory simulation is executed. To accurately incorporate the effects of (random) wind and spin stabilization the simulation model includes 6-degrees-of-freedom equations of motion for bodies with varying mass. In other words, the Coriolis (Jet damping) and relative moment due to the varying mass are added. To keep the simulation valid for a large range of rockets the Earth is modelled as a rotating, flattened sphere. The atmosphere model is based on the U.S. Standard atmosphere 1976. To do a Monte Carlo simulation it is necessary to describe (part) of the model with stochastic variables, which vary due to real randomness and due to modeling errors. Which parameters are included and how they vary will be described in this paper. To speed up the Monte Carlo simulation, first a parametric variation based on design of experiment principles is done to identify which parameters will contribute most to the result and which have so little influence that they can be eliminated. To keep the tool versatile it is modular and partly based on the TUDelft Astrodynamics Toolbox that provides a generic toolset of mathematics and astrodynamics functions. From the resulting data analysis the following information can be extracted: first, the footprint for nominal flight due to randomness in measurements and modeling of the mass, geometry, thrust, aerodynamics and wind. Second, a larger, worst-case footprint due to in-flight failure of certain sub-systems, like failed stage ignition, failed parachute deployment or in-flight destruction resulting into debris. Third, the data can be used to analyze the sensitivity of the result for variations in the input parameters. This information can be used during the design phase of the rocket and trajectory: once the sensitivity is known one can focus on the most important design parameters. The developed software tool is used to estimate the risk of the DARE Stratos II rocket.. The presented analysis shows that the footprint has an acceptable size to launch it from the Esrange Space Center and that it is also small enough to launch it safely in other parts of Europe.