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A NEW APPROACH TO ACCELERATING CONVERGENCE ON RANGE SAFETY ANALYSIS ISOPLETHS

Abstract

Businesses and space agencies throughout the world over have traditionally relied, in part, on brute force methods to calculate population risk exposure levels for rocket launch events. The creation and use of high fidelity six-degree of freedom models representing the rocket systems, subsystems and resultant fly-out trajectory have become routine practise. The same cannot be said of the collation and analysis of large numbers of generated Ground Impact Points (GIPs). One of the most contentious, and open-ended problems facing a modern space fairing company or space agency is how much time, effort and resources should be spent executing Monte Carlo simulations of a launch vehicle before enough simulations capture all potential outcomes from the proposed launch event. Ultimately, only when an infinite number of simulations have been completed is the underlying risk exposure for the proposed rocket launch captured. While statistical methods exist to estimate the required sample size to satisfy a given confidence level and interval for an infinite population, these methods do not take into account the application of kernel density estimation algorithms used to aggregate together GIPs into risk isopleths and the application of modern information theory. Executing an infinite number of simulations within a commercially relevant timeframe is not possible. As a consequence, many industry actors approach the issue with a brute force nature. Such industry actors often blindly execute hundreds of thousands, if not millions, of simulations attempting to satisfy a statistically generated requirement. While the use of kernel density estimation is not new to the calculation of rocket launch risk analyses, the authors propose a unique process which overcomes the inherent challenge of calculating a potentially large data set of GIPs by using the MAGIC code. MAGIC uses the world leading ASTOS software to perform the six-degree of freedom simulations and uses a modified Kullback–Leibler divergence method, coupled with an Analysis of Variance to track the rate of entropy addition within a risk isopleth and quantify when the simulated distribution has tended towards the true solution, i.e. has converged. The inclusion of an Analysis of Variance method adds a second axis to quantify overall convergence, as well as calculate an analytic solution describing how each of the Monte Carlo parameters effect the risk isopleth. This new approach to simulation convergence is proven on two exemplar rocket launch events occurring in Australia: a suborbital two stage solid rocket launch from the Koonibba Test Range, and an orbital liquid rocket launch experiment from the Whalers Way Orbital Launch Complex.