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A NEW APPROACH TO ACCELERATING CONVERGENCE ON RANGE SAFETY ANALYSIS ISOPLETHS

Abstract

Historically companies and Space Agencies the world over have relied in part on brute force methods to calculate population risk exposure levels for rocket launch events. While the creation and use of high fidelity six-degree of freedom models representing the rockets and resultant fly-out trajectories have become routine , the collation and analysis of large numbers of generated Ground Impact Points has not. One of the most contentious, and open-ended problems facing the industry 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, it is only when an infinite number of simulations have been completed, that the underlying risk exposure for the proposed rocket launch has been captured. While statistical methods exist to estimate the sample size needed 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 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, hence many companies have approached the problem with a brute force approach, blindly executing hundreds of thousands, if not millions of simulations in an effort to satisfy a statistics generated requirement. While the use of kernel density estimation is not new to the calculation of rocket launch risk analyses, the authors have come up with a unique process of overcoming the inherent problem 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 calculating an analytic solution describing how each of the Monte Carlo parameters effect the risk isopleth. This new approach to simulation convergence is tested and proven on two exemplar rocket launch events, a suborbital two stage solid rocket launch from the Koonibba Test Range, and an orbital liquid rocket launch from the Whalers Way Orbital Launch Complex.