# COMPUTATIONAL EFFICIENCY IN PROBABILISTIC OPTIMIZATION

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Design of modern engineering systems is a complex process requiring analysis and optimization across multiple disciplines. In many cases, relatively mature (high and low fidelity) disciplinary analysis tools are available. These disciplinary analyses cannot be taken in isolation since they are coupled to one another through shared input and output. Furthermore, system design objectives and constraints may span several disciplines. Thus, the optimization methodology needs to address issues relating to the coupled multidisciplinary system. Integrating disciplinary analyses into a multidisciplinary framework and finding practical ways to solve system optimization problems is a serious challenge.

This paper presents a probabilistic optimization methodology for conceptual design of aerospace vehicles that takes into account linkages between global and local design requirements. Multiple disciplinary analyses such as geometry, weights, structures, aerodynamics, trajectory, propulsion, thermal protection, operations and maintainability etc. are involved in the overall conceptual design. The global design considered in this paper optimizes the geometry for minimum weight while satisfying aerodynamic constraints. The local design illustrated here relates to structural sizing of vehicle components, e.g., liquid hydrogen tank. The optimization formulation includes probabilistic constraints, which are evaluated using the limit state-based reliability analysis methodology. The global and local designs are linked through probabilistic data flow relating to vehicle geometry and component weight, and the optimization at both levels is achieved through an iterative process.

One specific challenge that surfaces for integrated multidisciplinary systems involves feedback coupling. In this case, iterative convergence loops are needed to resolve inconsistencies in feedback state variables. In a ‘black box’ or fully coupled approach, the multidisciplinary analysis convergence loops are nested inside the loops for probabilistic analysis and optimization. The resulting computational effort is unacceptable for most high fidelity analyses. Therefore, several alternatives to the ‘black box’ approach are explored, using methods that exploit a decoupled formulation of reliability analysis. These include combination of Markov chain Monte Carlo simulation with the well-known first-order reliability analysis, and reformulation of the first-order reliability analysis as a multiple constraint problem through the inclusion of the feedback state variables. Both alternatives are found to significantly increase the efficiency of the inner loop reliability analysis.