Physics-Based Coupled-Domain Models for Performance and Risk Analysis.

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Missions involving multiple phases/domains (e.g. Landing, Rover Mobility) typically partition the system and mission design problem in an ad-hoc manner. This can result in key coupled-domain trades being missed and a consequent over-design of the system for each phase. For example, in the Landing/Rover domains, the performance of a precision landing sensor (which could allow landing closer to a science site) can be traded against the investment in a fast-driving rover (which in a time-bound mission can still get to the science site from a far-away landing point).

Coupled-Domain models address the modeling requirements for these problems, and the accompanying probabilistic framework provides a rigorous approach to performance analysis, design trade-offs, and risk assessment. An approach which allows for performance optimization (e.g. minimization of rover drive distance) with guaranteed satisfaction of risk constraints (e.g. probability of landing failure) has been developed and exercised on a variety of landing/rover scenarios. We specifically address entry, descent and landing scenarios (EDL) with hypersonic guidance to an aim point on the surface, decision variables related to chute-cutoff and subsequent initiation of powered flight, availability of landmark-based navigation and large powered-flight maneuvers to divert to safe landing sites, hazard detection and avoidance during terminal descent, and landing slope/rock tolerances. For rover mobility we address the path generation and accessibility issues related to visiting multiple science targets, execution error from slip and navigation errors, and drivability as a function of surface slopes and hazards. High performance algorithms to perform the multi-stage, risk constrained optimization are outlined and a variety of example scenarios related to a possible sample return mission from Mars are presented. We also briefly discuss simulation tools used to generate some of probability distribution functions related to the analysis, and mapping tools used to generate the surface topography and feature information. Extensions to other coupled domains are also briefly discussed.