Ph.D. Thesis Defense
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A RECOURSE-BASED SOLUTION APPROACH TO THE DESIGN OF FUEL CELL AEROPROPULSION SYSTEMS

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ABSTRACT:

It is often the case that, from a time-phased view of engineering design, previously uncertain parameters become known with the passing of each milestone, and their effects on the system are realized. Should these impacts happen to be detrimental to critical figure of merits, then a compensatory action is taken to remedy any unwanted deviations from the target or required bounds. Anecdotal accounts of numerous real-world design projects confirm that such remedial activities are commonly practiced means to ensure the successful fielding of aerospace systems.

In formalizing the aforementioned practice of compensatory design into a new methodological capability, this research introduces the notion of *recourse*. The term is defined within the context of engineering an aerospace system, and refers to a set of corrective actions that can be implemented in stages later than the current design phase to keep critical system-level figures of merit within the desired target ranges, albeit at some penalty. A two-part strategy, which partitions the design activities into stages, is proposed to model this bi-phasal nature of recourse. The first stage is defined as the time period in which a system is designed before the exact values of the uncertain parameters are known. The second stage encompasses a period occurring some time after the first stage, when the least costly means of recourse is exercised upon the first-stage design, should the realized uncertainties impart infeasibilities. A further proposal is that this two-stage model be embedded inside a higher-level design loop with a stochastic programming structure, so that the design optimality in the present can be traded with the potential costs of future recourse in an anticipatory fashion. It is argued that such a solution is one that is well-hedged against the uncertain consequences of later design phases, while being less conservative than a system that is meant to be simply hedged against the risk of failing to meet certain target criteria.

As a proof-of-concept demonstration, the proposed solution approach is presented as applied to a contemporary aerospace engineering problem of interest: the integration of fuel cells into uninhabited aerial systems. The deterministic and algorithmic portion of the investigation highlights the thermodynamic scalability of downselected aeropropulsion alternatives, and illustrates how a specific-parameter based approach is applicable to synthesizing the design results at the propulsion level into the overall aircraft sizing framework. The particular formulations of the design stages, recourse, and uncertainties implemented in the example maritime border patrol application are shown to result in solutions that are balanced between unfounded optimism and unwarranted conservatism. Lastly, the concept of VSS (Value of Stochastic Solution) is showcased to be an intuitively appealing measure of accounting for recourse-causing uncertainties in an aerospace systems design environment.