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# System Lifecycle Cost Under Uncertainty as a Design Metric Encompassing the Value of Architectural Flexibility*

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**In this work, we develop an alternative metric and approach for system design and acquisition decisions that encompasses system flexibility called assured system lifecycle cost under uncertainty, or simply stochastic lifecycle cost. We use this metric to compare the overall lifecycle costs of an existing monolithic satellite system to a hypothetical fractionated satellite system that provides the same service. Different approaches to fractionation are investigated. Lifecycle cost calculations are derived in a non-deterministic form using Monte Carlo simulations incorporating launch and component failure uncertainty to produce mean values with associated variances for statistical comparison. We find that the total lifecycle cost of fractionated satellite architectures are comparable to monolithic satellite architectures when the individual satellite design lifetimes are longer and are allowed to be aligned with individual satellite expected mean mission durations based on component failure reliability.**

## I. Introduction

Since 2000, a body of research has emerged on value-based metrics for system acquisition and design decisions. Such metrics consider the net present value of the lifecycle value delivered by the system minus its lifecycle costs – where the value streams may encompass the operational utility or revenues of the system as well as other, less tangible sources such as the option value of architectural flexibility. This value-centric perspective is a significant improvement over traditional design and acquisition analysis techniques based largely on cost alone because it rewards modular, scalable, reconfigurable, and otherwise flexible designs that can substantially enhance a system's overall value to the operator with only a modest cost penalty.

In this work, we develop an alternative metric and approach as a basis for system design and acquisition decisions that encompasses system flexibility. We term this metric assured system lifecycle cost under uncertainty, or simply stochastic lifecycle cost. The underlying premise of our approach is that the cost to develop, procure, and operate a system with some assured minimum capability over its lifecycle is not a deterministic value. Instead, it is a random variable with a probability distribution resulting from a set of uncertainties introduced throughout the system's life. We argue that this random variable metric is a relevant basis for comparison between alternative system architectures and design choices. This metric alone may provide important information to decision makers, even before net lifecycle value (i.e., value delivered over a system's lifetime, minus the total lifecycle cost) can be calculated. This is important for systems (such as those purchased and fielded by the government) whose utility is not readily quantifiable through a market valuation or other such measure. In this work we illustrate our approach by modeling the stochastic lifecycle cost for several different space architectures intended to accomplish the same mission.