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PREDICTING THE REUSABILITY OF SPACE SYSTEMS

Abstract

In recent years there has been renewed interest in reusable space systems with several organizations already operating such vehicles. This new trend is most prominent with launch vehicles, where companies have incorporated varying levels of reusability into their designs, most notably SpaceX with their Falcon 9 and Blue Origin with their New Shepard. Although several organizations have successfully reused launch vehicles over several flights, there is currently no widely accepted method to predict the lifetimes of these vehicles. Currently, the lifetimes of reusable launch vehicles are determined by inspecting systems after each flight to observe if a critical failure has occurred. For this work, we define the lifetime of a reusable system as the number of flights the vehicle can perform before a critical failure that does not make economic sense to repair. To realize the true potential of reusable space systems, we have to operate them as we would airplanes where only minimal inspections and maintenance are performed before each use. To reach this state, we must first understand how a system changes over several flights to predict when it will fail.

To achieve this aim, this paper presents a method to estimate the degradation of a reusable space system. First, we identify the critical systems within a vehicle and determine the lifetime cycling processes that act on these systems. Next, we model these lifetime limiting processes to estimate their impact on each critical system during a flight. We then apply these models to each of their critical systems identified to derive their respective failure rates. Last, we compare each system's failure rate to its expected use per flight to identify the system that will fail first and thus define the reusability of the entire vehicle.

To demonstrate the method developed, we apply it to a generalized launch vehicle to estimate its lifetime. We also investigate the impact of adding additional margin to a critical system to see how it increases a vehicle's lifetime. The results can assist designers of reusable space systems to understand if a vehicle will achieve a desired level of reusability.