METHODOLOGY FOR ASSESSING REUSABILITY OF SPACEFLIGHT HARDWARE

In 2011 the Space Shuttle, the only Reusable Launch Vehicle (RLV) in the world, returned to earth for the final time. Upon retirement of the Space Shuttle, the United States (U.S.) no longer possessed a reusable vehicle or the capability to send American astronauts to space. With the National Aeronautics and Space Administration (NASA) out of the RLV business and now only pursuing Expendable Launch Vehicles (ELV), not only did companies within the U.S. start to actively pursue the development of either RLVs or reusable components, but entities around the world began to venture into the reusable market. For example, SpaceX and Blue Origin are developing reusable vehicles and engines. The Indian Space Research Organization is developing a reusable space plane and Airbus is exploring the possibility of reusing its first stage engines and avionics housed in the flyback propulsion unit referred to as the Advanced Expendable Launcher with Innovative engine Economy (Adeline). Even United Launch Alliance (ULA) has announced plans for eventually replacing the Atlas and Delta expendable rockets with a family of RLVs called Vulcan. Reuse can be categorized as either fully reusable, the situation in which the entire vehicle is recovered, or partially reusable such as the National Space Transportation System (NSTS) where only the Space Shuttle, Space Shuttle Main Engines (SSME), and Solid Rocket Boosters (SRB) are reused. With this influx of renewed interest in reusability for space applications, it is imperative that a systematic approach be developed for assessing the reusability of spaceflight hardware. The partially reusable NSTS offered many opportunities to glean lessons learned; however, when it came to efficient operability for reuse the Space Shuttle and its associated hardware fell short primarily because of its two to four-month turnaround time. Although there have been several attempts at designing RLVs in the past with the X-33, Venture Star and Delta Clipper Experimental (DC-X), reusability within the spaceflight arena is still in its infancy. With unlimited resources (namely, time and money), almost any launch vehicle and its associated hardware can be made reusable. However, an endless supply of funds for space exploration is not the case in today's economy for neither government agencies nor their commercial counterparts. Therefore, any organization wanting to be a leader in space exploration and remain competitive in this unforgiving space faring industry must confront shrinking budgets with more cost conscious and efficient designs. Therefore, standards for developing reusable spaceflight hardware need to be established. By having standards available to existing and emerging companies, some of the potential roadblocks and limitations that plagued previous attempts at reuse may be minimized or completely avoided.

The decision must be made early in the process whether to reuse the previously flown hardware or discard it. Before this decision can be made, there are several considerations that must be addressed. For instance, it must be determined if the hardware being scrutinized has the integrity (i.e. reliability, etc.) for multiple flights. Another consideration is the cost effectiveness of the decision to reuse the hardware. In some cases, it may be cheaper to simply replace some of the components of the system being evaluated rather than refurbishing a specific part. Even the location of components with high failure rates can have either a positive or negative influence on reusability metrics. If components that need to be serviced frequently are not easily accessible, the maintenance time increases. This inefficiency increases turnaround time, which in turn has an adverse effect on operability. To address these concerns, a model was built to assess the reusability of the spaceflight hardware.

Previous work identified several attributes key to enhancing the successful implementation of reusability for space applications. Currently, the list of attributes includes: (1) reusability as a primary requirement, (2) continuous test program, (3) minimized post-flight inspections and servicing to enhance turnaround time, (4) easy access to components, (5) increased service life, (6) minimized impact of recovery, and (7) evolutionary changes (rather than revolutionary completely new designs). Identifying these attributes is the first step towards establishing much needed standards for spaceflight hardware reusability. Although these attributes were validated to ensure worthiness of assessing reusability, as more information and/or data becomes available other attributes may be added to the list as new attributes or as possible replacements for those currently on the list. To evaluate the effectiveness of each attribute as a good indicator for reuse, discriminators were assigned. To quantify the attributes, metrics were given to each attribute. Then, statistical techniques were used to validate the attributes for reusability. Now that the parameters that were identified as essential for successful reuse have been validated, the next step is to generate the model to evaluate the efficacy of each component for reuse.

This paper presents the approach used to examine spaceflight hardware towards its propensity for reuse. Whether the hardware being evaluated is fully reusable, as in the case of a launch vehicle, or a partially reusable system, as with main engines or avionics modules, the approach for assessing its reusability is the same. For simplification, the SSME was chosen to validate the model. Rather than applying this approach to an entire reusable launch vehicle, the major components of the SSME are used to validate the methodology. Once validated and verified on a smaller scale, the model can be applied to a reusable stage or vehicle. The aforementioned attributes were used in the assessment of the spaceflight hardware. The model employed statistical methods for each engine component to determine if the metrics for reuse associated with each component had a positive correlation for reusability. Results from the model allowed sensitivity analyses to examine “what if” scenarios to offer potential alternatives to strengthen and/or minimize undesired results for the incorporation of reusability. This model serves as a tool to identify the aspects of a reusable system (be it launch vehicle, stage, or component) that are most viable candidates for reuse. Both existing designs and those that are early in the lifecycle can benefit from the application of this tool, which allows the user to obtain a better understanding of the reusability of the hardware.