

Methodology for Identifying Key Parameters Affecting Reusability for Liquid Rocket Engines

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Outline

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Objective

- To use statistical techniques to identify which parameters are tightly correlated with increasing the reusability of liquid rocket engine hardware.

Reusability/Reusable Defined

Ideally

- “The ability to use a system for multiple missions without the need for replacement of systems or subsystems. Ideally, only replenishment of consumable commodities (propellant and gas products, for instance) occurs between missions.” (Jefferies, et al., 2015)

For purposes of this research

- Any space flight hardware that is not only designed to perform multiple flights, but actually accomplishes multiple flights.

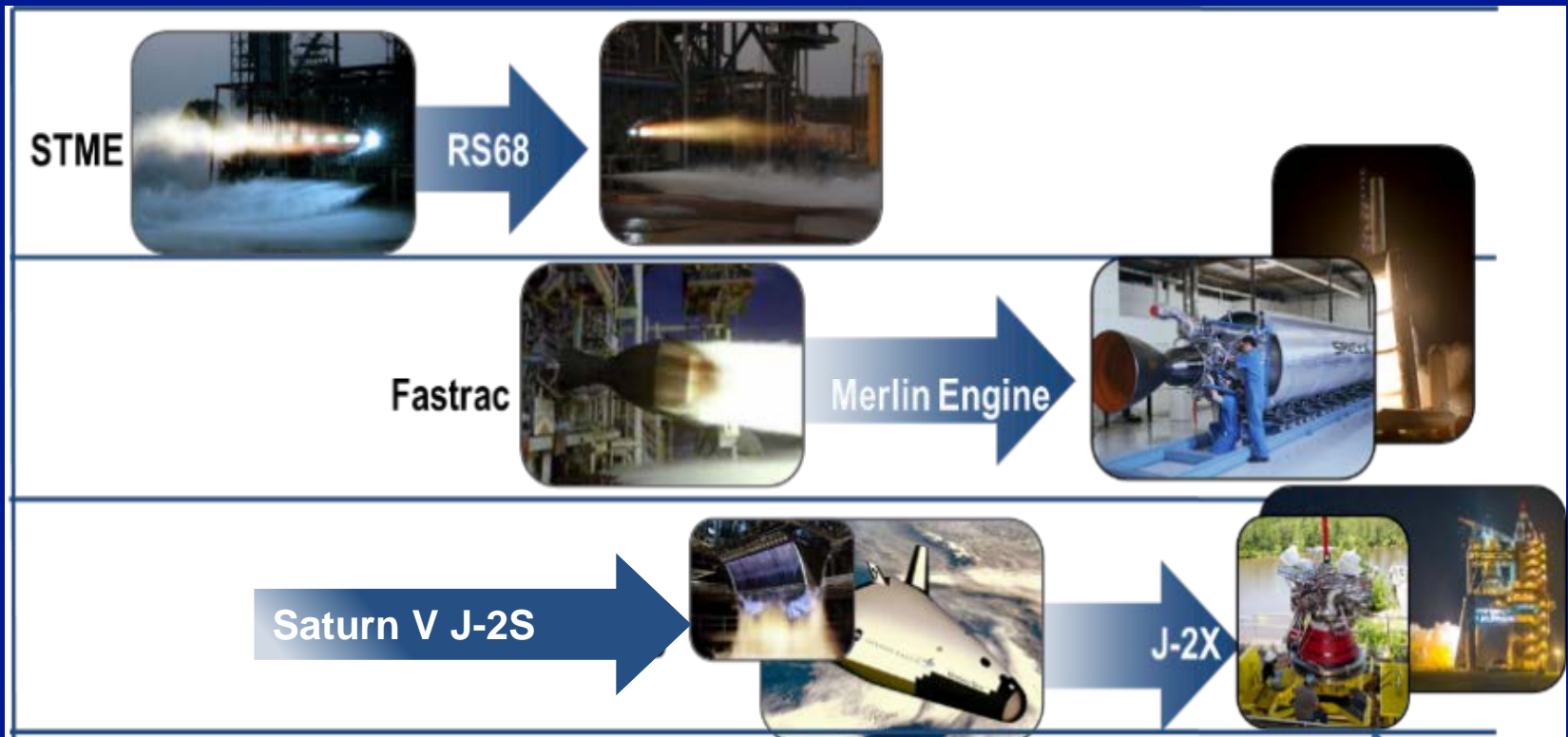
Benefits of Reusability

- Forces inspections of returning hardware
- Offers insight into how a part actually performs
- Allows the development of databases for future development
- Validates ground tests and analyses
- Allows the expensive hardware to be used multiple times

Previous Research – Identification of Features Conducive for Reuse Implementation

1. Reusability Requirement Implemented at the Conceptual Stage
2. Continuous Test Program
3. Minimize Post-Flight Inspections & Servicing to Enhance Turnaround Time
4. Easy Access
5. Longer Service Life
6. Minimize Impact of Recovery
7. Evolutionary vs. Revolutionary Changes

MSFC Legacy of Propulsion Excellence (Evolutionary Changes)



1970

1980

1990

2000

2010

2015

Challenges

- Engine data difficult to locate
- Limited data for reusable engines (i.e. Space Shuttle, Space Shuttle Main Engine (SSME) and Solid Rocket Booster (SRB))
- Benefits of reusability have not been validated
- Industry standards do not exist

Approach

- Performed multiple regression analysis to determine correlation (if any) of parameters to reuse (Stepwise regression/Partial F-test)
- Engines selected for analysis (due to data availability)
 - F-1,
 - J-2
 - RL-10
 - LR-87
 - LR-91
 - SSME
 - RS-68
- $y = B_0 + B_1x_1 + B_2x_2 + \dots + B_kx_k + \varepsilon$ with the dependent variable y – reusability
- Independent variables were:
 - Time from program start to qualification (years)
 - Total test duration, firings (sec)
 - Mission nominal time, burn (sec)
 - Design cycles (number of starts)
 - Design life (sec)

Preliminary Results

- The resulting analysis indicated that both design life and the number of starts (design cycles) were significant indicators of reusability. Since the SSME is the only reusable engine with somewhat readily available data, there is an on-going effort to locate additional data for reusable development engines.

Next Steps

- Locate data for other engines
 - Specifications and design data for reusable engines that were not flown such as the COBRA, FASTRAC, RS-84 etc.
 - Specifications for expendable engines
- Identify common characteristics between the SSME and other reusable engines and determine why these factors are considered important for designing reusable hardware
- Examine the modifications/enhancements (and rationale for mod) of the derived development engines from the SSME
- Perform a comparative analysis between reusable and expendable engines characteristics to determine the line of demarcation for reuse
- Find test data (number of firings) and determine relationship with reuse

Summary

- Reuse is not simple and must be intentional
- Rather than an afterthought, reuse must a requirement beginning in the conceptual phase and implemented throughout the design
- It is not free nor easy