Reusability Studies for Ares I and Ares V Propulsion

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Abstract

With a mission to continue to support the goals of the International Space Station (ISS) and explore beyond Earth orbit, the United States National Aeronautics and Space Administration (NASA) is in the process of launching an entirely new space exploration initiative, the Constellation Program. Even as the Space Shuttle moves toward its final voyage, Constellation is building from nearly half a century of NASA spaceflight experience, and technological advances, including the legacy of Shuttle and earlier programs such as Apollo and the Saturn V rocket. Out of Constellation will come two new launch vehicles: the Ares I crew launch vehicle and the Ares V cargo launch vehicle. With the initial goal to seamlessly continue where the Space Shuttle leaves off, Ares will firstly service the Space Station. Ultimately, however, the intent is to push further: to establish an outpost on the Moon, and then to explore other destinations. With significant experience and a strong foundation in aerospace, NASA is now progressing toward the final design of the First Stage propulsion system for the Ares I. The new launch vehicle design will considerably increase safety and reliability, reduce the cost of accessing space, and provide a viable growth path for human space exploration. To achieve these goals, NASA is taking advantage of Space Shuttle hardware, safety, reliability, and experience. With efforts to minimize technical risk and life-cycle costs, the First Stage office is again pulling from NASA's strong legacy in aerospace exploration and development, most specifically the Space Shuttle Program. Trade studies have been conducted to evaluate life-cycle costs, expendability, and risk reduction. While many first stage features have already been determined, these trade studies are helping to resolve the operational requisites and configuration of the first stage element. This paper first presents an overview of the Ares missions and the genesis of the Ares vehicle design. It then looks at one of the most important trade studies to date, the "Ares I First Stage Expendability Trade Study." The purpose of this study was to determine the utility of flying the first stage as an expendable booster rather than making it reusable. To lower the study complexity, four operational scenarios (or cases) were defined. This assessment then included an evaluation of the development, reliability, performance, and transition impacts associated with an expendable solution. The paper looks at these scenarios from the perspectives of cost, reliability, and performance. The presentation provides an overview of the paper.

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Agenda

- Introduction
- Ares Overview
- Ares First Stage Design Overview
- Reusability Studies
- The Cases
- Cost
- Reliability
- Screening Methodology
- Crit Items
- Post Flight Assessment Report Causes by Category
- Performance
- Conclusions

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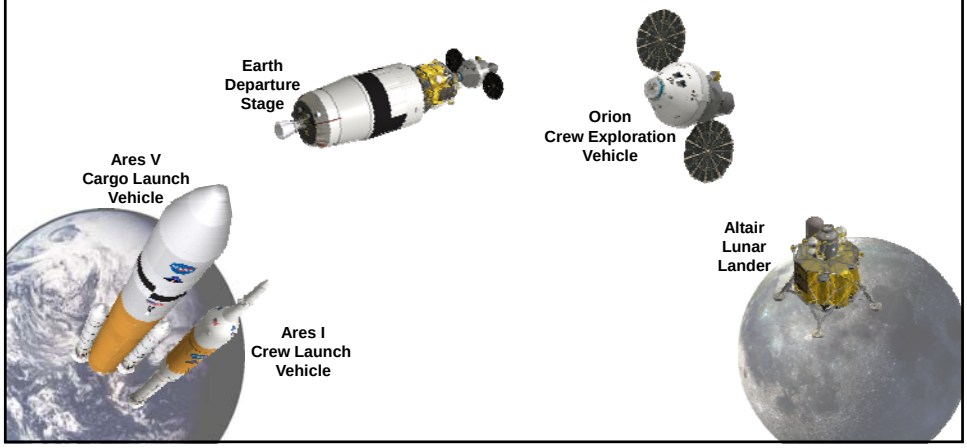
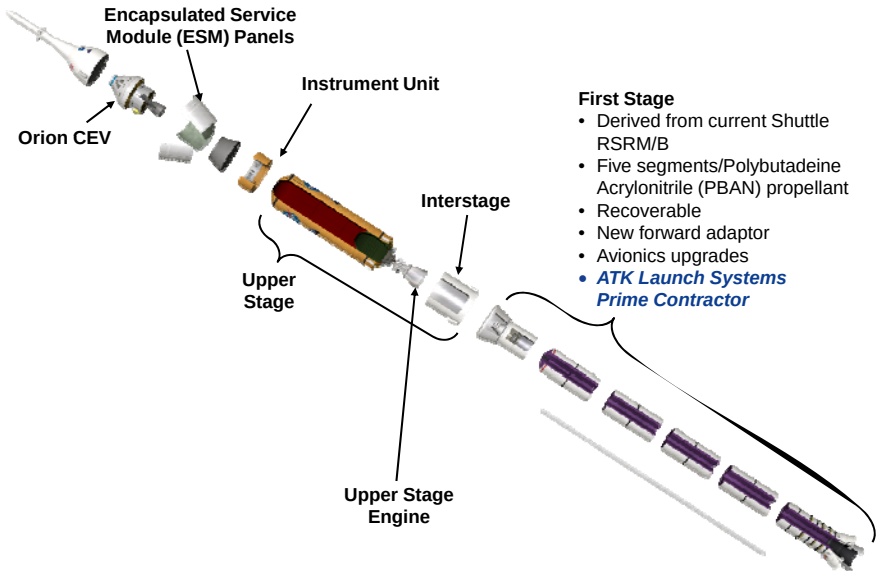
Introduction: NASA and Ares

- With a mission to continue in its service to the goals and support of the International Space Station, NASA is in the process of launching an entirely new space exploration initiative, a new fleet of space exploration vehicles



The Ares V and Ares I

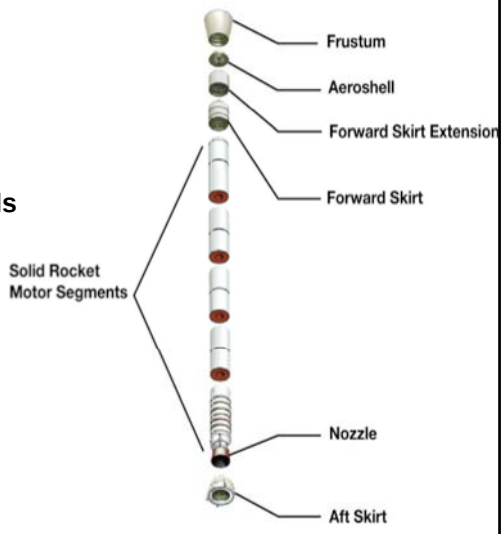
Ares I



First Stage
- Derived from current Shuttle RSRM/B
- Five segments/Polybutadeine Acrylonitrile (PBAN) propellant
- Recoverable
- New forward adaptor
- Avionics upgrades
- ***ATK Launch Systems Prime Contractor***

Ares I First Stage Overview

- **Legacy motor casings, aft skirt**
- **New forward structures**
  - Forward Skirt
  - Forward Skirt Extension
  - Aeroshell
  - Frustum
- **Metal and composite materials**
- **Shuttle-derived five-segment solid rocket motor**
  - Increased performance
  - Extensibility to Ares V



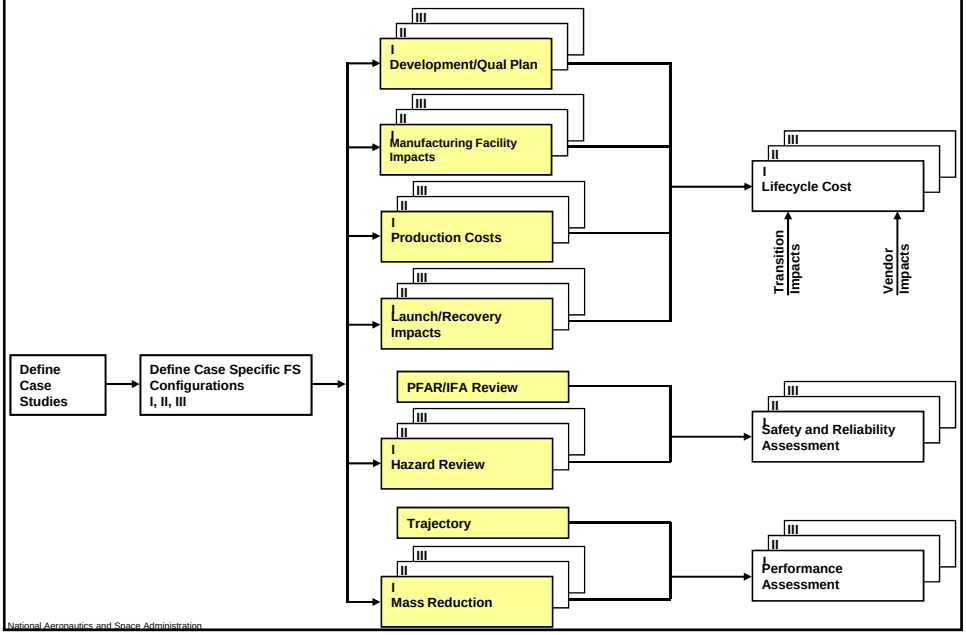
First Stage Expendability Introduction

- **Objective – Perform a life cycle cost study to evaluate expendable vs. reuse of the Ares I First Stage and Ares V Solid Rocket Boosters.**
- **This assessment will include an evaluation of the technical impacts in development, reliability, performance and transition of an expendable vs. reusable first stage solution**

Study Cases

- **Case 0**
  - Baseline reference case
  - Recover and reuse
  - Ares I hardware interchangeable with Ares V
    - Heritage forward structures for Ares V
- **Case I**
  - Fly out current hardware and replace with current design
  - Modified design for expendability
    - No chutes, no fwd. skirt extension, no booster tumble motors, etc.
- **Case II**
  - Recover for 7 flights
  - Driven by potential need for insulation flight performance bias
  - Maintain outer mold line (fwd skirt extension = 5394 lbm) to minimize vehicle delta certification
- **Case III**
  - Hardware with design for expendable application
  - Implement for Ares V with block change on Ares I when first metal part runs out

Main Production Line



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Reusable vs Expendable Manifest

PPBE 09 Ares I and Ares V First Stage Flights and FSMs

	FY08	BY10	BY11	BY12	EY13	EY14	BY15	AY16	BY16	FY17	BY18	BY19	BY20	BY21	EY22	EY23	BY24	AY25	BY26	EY27	FY28	BY29	BY30	BY31	EY32	EY33	BY34	AY35	BY36	EY37	FY38	BY39	BY40	Total
Ares I Flights		1			1	1	3	2	2	2	3	3	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	62
Ares V Flights										1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	45

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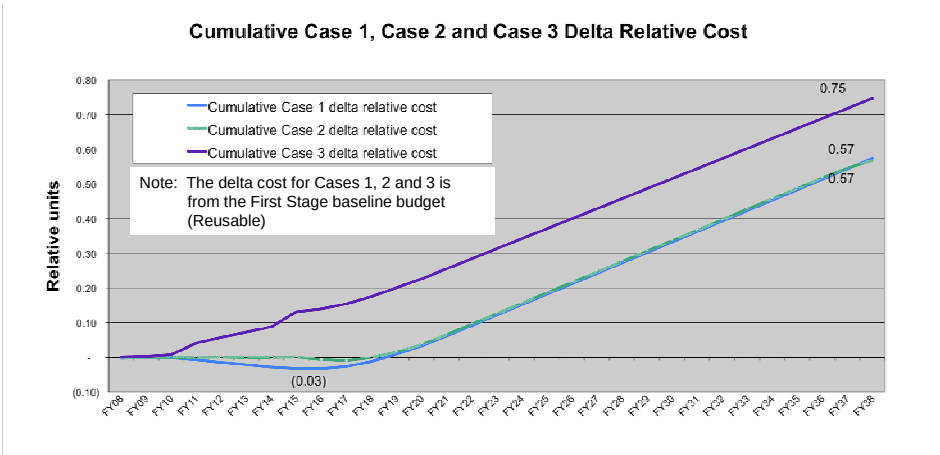
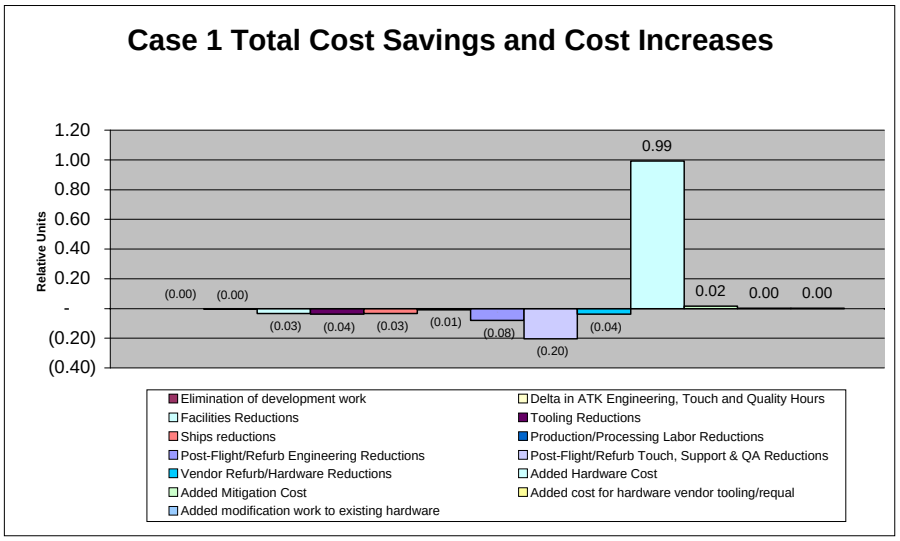
Cost Model

- **Cost model developed and populated with Case 1, Case 2 and Case 3 information**
  - Hardware Costs
    - Proposal values for new hardware, escalated actuals for heritage, learning curve applied to account for high rate production (reduces average unit cost by 20-25%)
    - FWC based on Titan costs escalated to FY08 constant dollars
  - Non-recurring cost for hardware vendor certification and delta qualification
    - ATK and USA provided
  - KSC and Clearfield facility O&M and GSE cost reductions
    - Florida facility inputs from KSC budget estimates
  - Recovery ships operations, maintenance, training and periodic dry dock
    - Actuals
  - Elimination of refurbishment labor costs (Touch labor, Support and Quality)
    - KSC (eliminated for Hanger A-F, Hanger N, and PRF)
    - ATK (reduced Clearfield refurbishment substantially)
    - 100 percent reduction of touch and support for refurbishment at KSC and 45 percent reduction of touch and support for refurbishment at ATK, cannot eliminate due to case hardware acceptance at Clearfield
    - Based on KSC and ATK budget estimates
  - Design Engineering reduction costs
    - Refurb and postflight issue dispositioning
    - 20 percent reduction of total engineering at USA and ATK
  - Cost model does not include
    - Economic value for performance increase
    - Transfer of cost deleted from First Stage to other NASA projects for Ships and Hanger-N

Cost Results



Case 1 Total Cost Savings and Cost Increases



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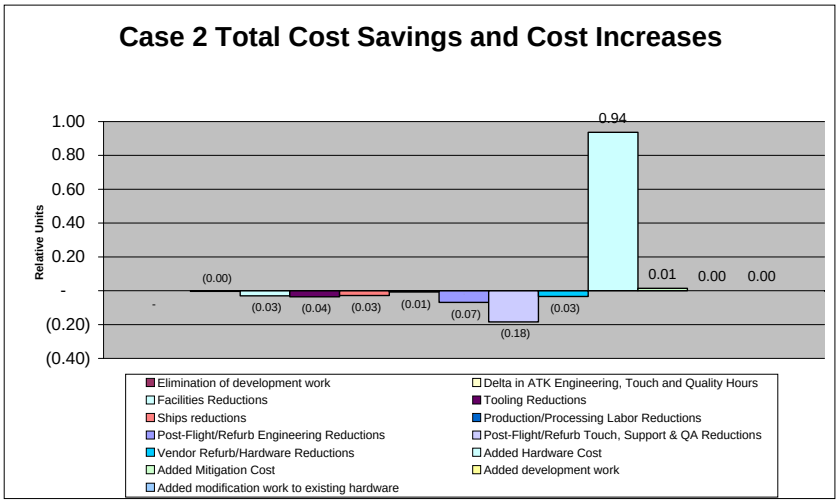
Case 2 Total Cost Savings and Cost Increases



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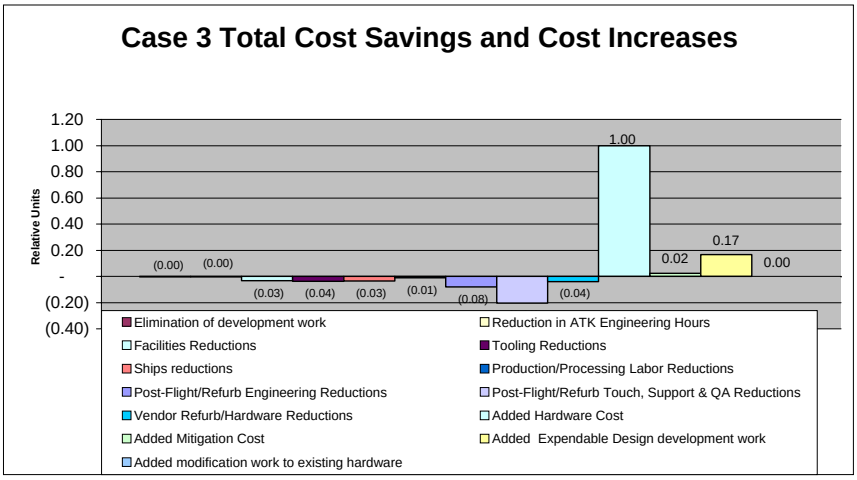
Case 3 Total Cost Savings and Cost Increases



Safety and Reliability Assessment Process

- **Primary effort associated with evaluation of postflight inspection results (1988 - 2007)**
  - Screening methodology for items, if left unattended, could result in Crit 1
  - Item(s) assigned probability and reliability impacts calculated
- **Evaluated hazards impacts based on current Shuttle RSRB FMEA hazards**
- **Evaluated ground hazards impacts**
- **Cursory evaluation of Case III FWC impacts**

RSRM PFAR Analysis for Credible Crit 1 Failure

PFAR Filtering Methodology

RSRM PFAR 1124

Total number of PFARs written against RSRM

RSRM PRACA ~350

All PFARs are evaluated against PRACA reporting criteria as defined in NSTS 08126. PFARs that meet the PRACA criteria are considered to be more critical

PRACA closed by corrective actions -- 96

PRACA reports are basically closed in one of two ways

1. Closed by Explanation: The item is understood to have No Significant Change in Risk to flight

2. Closed by Corrective Action: The risk level warrants a change to the hardware and/or process

PRACA that could propagate to Crit 1 failure -- 1

PRACA closed by corrective action evaluated for worst credible case condition which would result in a catastrophic failure of flight hardware

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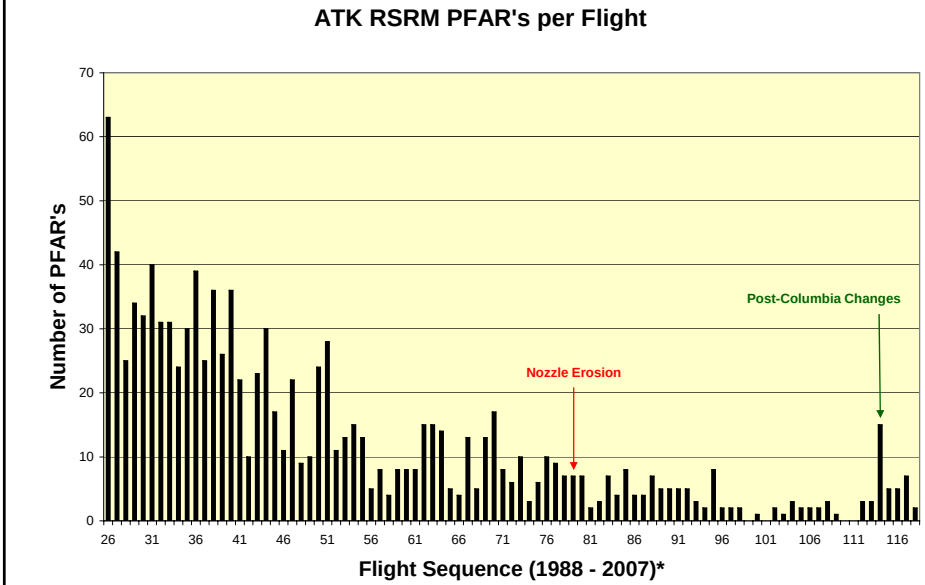
ATK RSRM PFAR (Post Flight Inspection)



*** No Flights in 2004**

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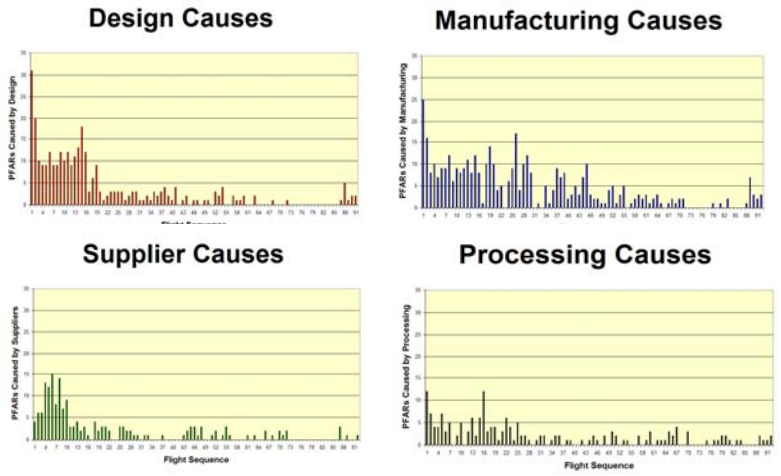
RSRM PFAR Causes by Category



The reliability decrease with an expendable design (due to loss of post-flight data) was assessed to be between 6.5 and 13 percent.

Performance Results

- **Performance (Delta payload to LEO)**
  - Ares I
    - Case I = 2,100 lbm (delta max Q = +21 psf)
    - Case II = 0 and 1,600 lbm (delta max Q = +16 psf)
    - Case III = 5,550 lbm (delta max Q = +56 psf)
    - Additional performance potential with MEOP increase from 1016 psi to 1066 psi
      - Addition of 2,010 lbm for Cases I, II, III (delta max Q = 136 psf)
  - Ares V
    - Case I = 2,725 lbm (delta max Q = +6 psf)
    - Case III = 9,700 lbm (delta max Q = +20 psf)
    - Additional performance potential with MEOP increase from 1016 psi to 1066 psi
      - Addition of 6,380 lbm for Cases I and III (delta max Q = +70 psf)

Conclusions

- **It is not Life Cycle Cost effective to adopt expendable over reusable Ares I FS and Ares V Boosters**
- **The need for performance drives this solution (if required).**
- **If performance remains an issue for Ares I and V, then expendability provides measurable performance benefits but at significant cost**
  - 1,600 to 5,500 lbm for Ares I
  - 2,725 to 9700 lbm for Ares V
- **The effect of the absence of post flight inspection does not drive this decision, however, it will have a small affect on FS reliability**
  - Assessment is subjective in evaluating Crit. 1 propagation and does not include combination interactions
- **With an expendable solution it is desirable to re-examine:**
  - Increased manufacturing and operations inspection and surveillance, material finger printing, etc
  - Increased numbers and extremes on static testing
- **The Team has completed the objective to evaluate the life cycle cost of expendable vs. reuse of the Ares I First Stage and Ares V Solid Rocket Boosters**

Questions

http://www.nasa.gov
http://www.nasa.gov/ares