MSFC-401-Abstract

Exploration Launch Projects RS-68B Engine Requirements for NASA's Heavy Lift Ares V

John P. Sumrall[1], J. Craig McArthur.[2], and Matt Lacey[3]
NASA Marshall Space Flight Center, Huntsville, AL 35812

Abstract

NASA's Vision for Exploration requires a safe, efficient, reliable, and versatile launch vehicle capable of placing large payloads into Earth orbit for transfer to the Moon and destinations beyond. The Ares V Cargo Launch Vehicle (CaLV) will provide this heavy lift capability. The Ares V launch concept is shown in Fig. 1. When it stands on the launch pad at Kennedy Space Center late in the next decade, the Ares V stack will be almost 360 feet tall. As currently envisioned, it will lift 133,000 to 144,000 pounds to trans-lunar injection, depending on the length of loiter time on Earth orbit. This presentation will provide an overview of the Constellation architecture, the Ares launch vehicles, and, specifically, the latest developments in the RS-68B engine for the Ares V.

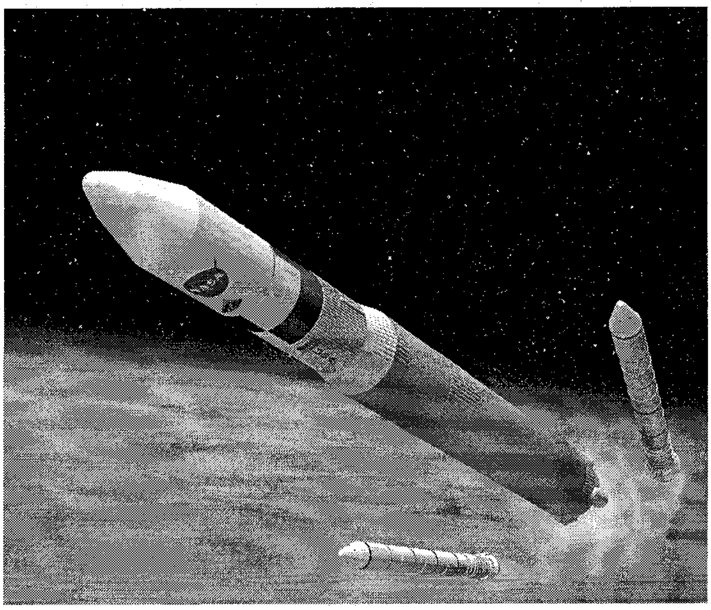


Fig. 1. Ares V launch concept.

[1] Manager, Advanced Planning, Exploration Launch Projects Office.
[2] Manager, Ares V Core Stage Element, Exploration Launch Projects Office.
[3] Aerospace Engineer.

MSFC-401 Presentation

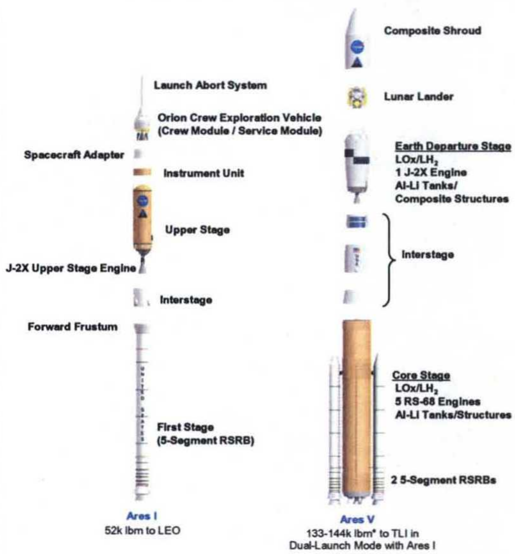
Agenda

- Overview of the Ares Launch Vehicles
- Vehicle comparison
- Engine choice refinement
- RS-68B results so far
- Forward work and conclusions

Overview of the Exploration Launch Projects Architecture

- Safe, reliable, affordable space transportation
- Based on heritage hardware and legacy knowledge
- Separates cargo from crew
- Ares V (left) delivers heavy exploration cargo to Low Earth Orbit (LEO)
- Ares I (right) delivers crew and cargo to LEO for International Space Station and lunar missions

Exploration Launch Projects Architecture (cont'd)



Shared heritage, shared hardware

- **Ares I**
  - 1 Shuttle-derived Reusable Solid Rocket Booster (RSRB) First Stage
  - 1 J-2X LOx/LH_2 Upper Stage Engine

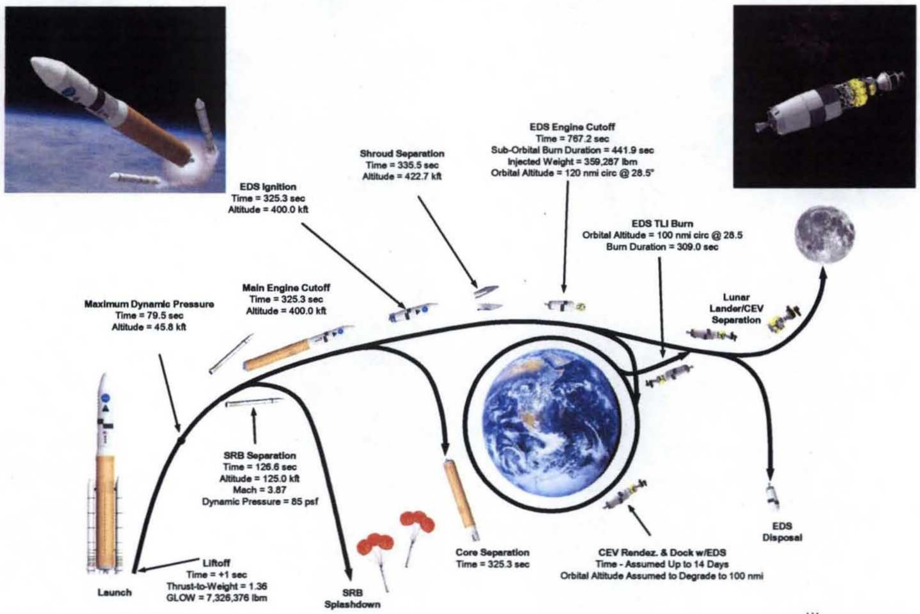
Ares V

- **Core Stage**
  - 5 RS-68 LOx/LH_2 Core Stage engines
  - 2 Ares I-derived RSRBs
- **Earth Departure Stage (EDS)**
  - 1 J-2X LOx/LH_2 Upper Stage Engine

  - Common hardware and procedures with Ares I to reduce development and operations costs

* Depending on length of on-orbit LEO loiter time

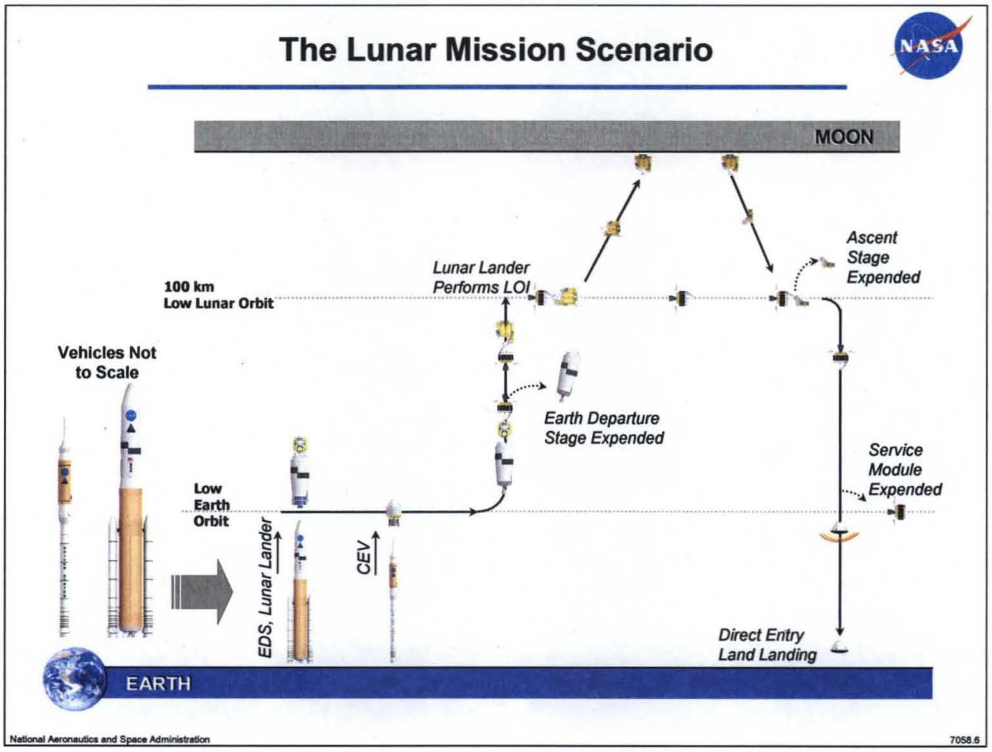
Ares V mission profile



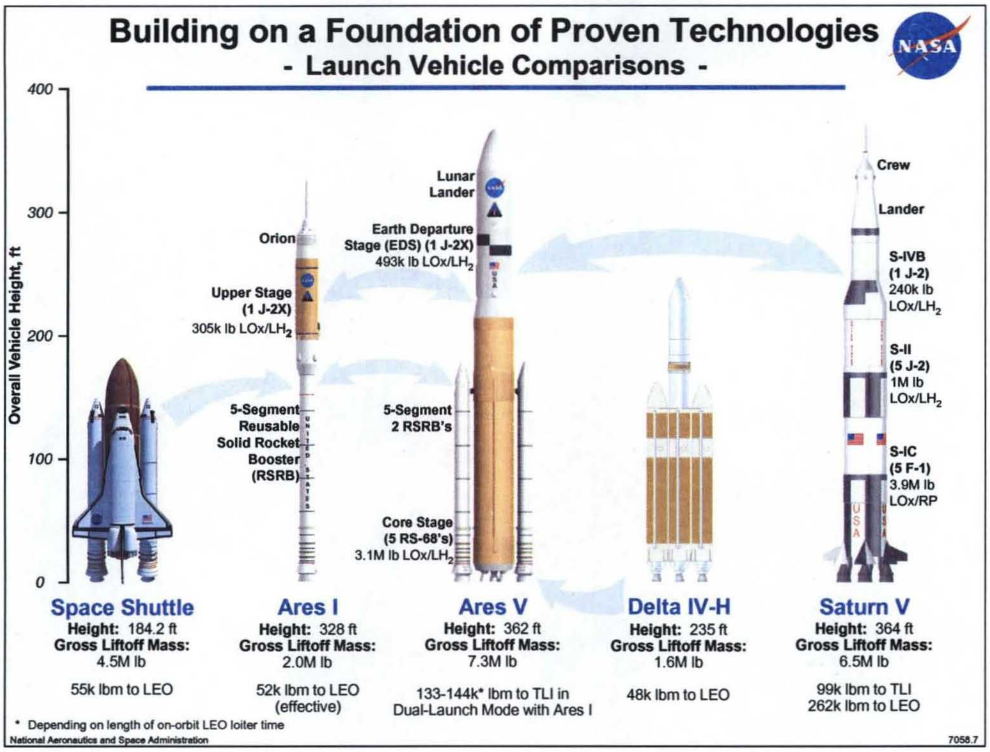
National Aeronautics and Space Administration

LV
33.8.64

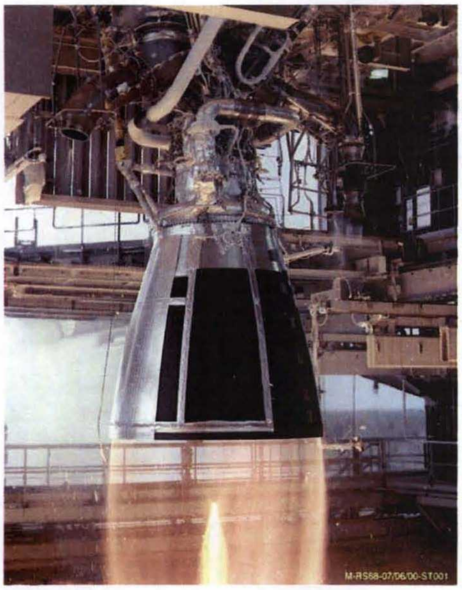
5



The Lunar Mission Scenario
NASA
MOON
Ascent
Stage
Expended
Lunar Lander
Performs LOI
100 km
Low Lunar Orbit
Vehicles Not
to Scale
Earth Departure
Stage Expended
Service
Module
Expended
Low
Earth
Orbit
EDS, Lunar Lander
CEV
Direct Entry
Land Landing
EARTH
National Aeronautics and Space Administration
7058.6


Building on a Foundation of Proven Technologies
- Launch Vehicle Comparisons -
NASA
Overall Vehicle Height, ft
400
300
200
100
0
Orion
Upper Stage
(1 J-2X)
305k lb LOx/LH2
5-Segment
Reusable
Solid Rocket
Booster
(RSRB)
Lunar
Lander
Earth Departure
Stage (EDS) (1 J-2X)
493k lb LOx/LH2
5-Segment
2 RSRB's
Core Stage
(5 RS-68's)
3.1M lb LOx/LH2
Crew
Lander
S-IVB
(1 J-2)
240k lb
LOx/LH2
S-II
(5 J-2)
1M lb
LOx/LH2
S-IC
(5 F-1)
3.9M lb
LOx/RP
Space Shuttle
Height: 184.2 ft
Gross Liftoff Mass:
4.5M lb
55k lbm to LEO
Ares I
Height: 328 ft
Gross Liftoff Mass:
2.0M lb
52k lbm to LEO
(effective)
Ares V
Height: 362 ft
Gross Liftoff Mass:
7.3M lb
133-144k* lbm to TLI in
Dual-Launch Mode with Ares I
Delta IV-H
Height: 235 ft
Gross Liftoff Mass:
1.6M lb
48k lbm to LEO
Saturn V
Height: 364 ft
Gross Liftoff Mass:
6.5M lb
99k lbm to TLI
262k lbm to LEO
* Depending on length of on-orbit LEO loiter time
National Aeronautics and Space Administration
7058.7

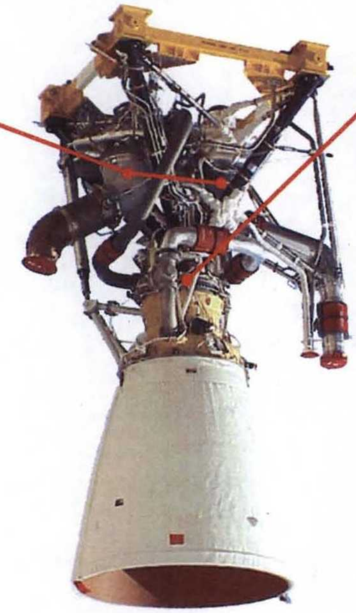
Refining the Concept



- **Exploration System Architecture Study**
  - Ares V baseline:
    2 RSRBs,
    5 Space Shuttle Main Engines (SSMEs),
    27.5 foot diameter Shuttle-derived Core Stage
- **Bottom-Up Review**
  - RS-68 replaces SSME
    - Fewer parts
    - Less labor
    - Simpler to modify
    - Synergy with USAF engine upgrades
    - Delta IV flight experience reduces technical risk
  - 33 foot diameter Saturn V-class Core Stage

RS-68A: Higher Performance and Reliability

Redesigned turbine nozzles to mitigate cracking and increase maximum power level by ≈2%



Higher element density main injector improving specific impulse by 2% and thrust by 4%

Assured Access Items:
- Bearing material change
- New Gas Generator igniter design
- Improved Oxidizer Turbo Pump temp sensor
- Improved hot gas sensor
- 2nd stage Fuel Turbo Pump blisk crack mitigation
- Cavitation suppression
- ECU parts upgrade

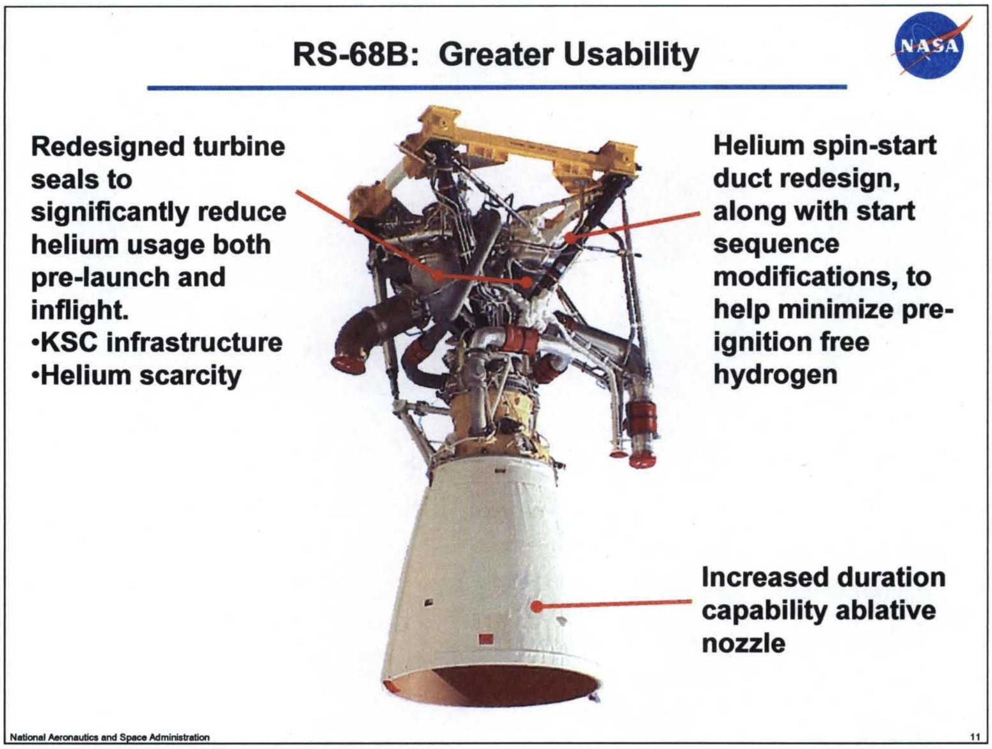
The Department of Defense is already pursuing changes to improve power level (turbine inlet nozzles) and performance (ISP – higher injector element density). The Air Force, through its Assured Access to Space program, is seeking changes to improve the engine's robustness (eliminate cracking of second stage blisk). NASA's desired upgrades would improve engine operations and safety (free hydrogen reduction). The proposed common engine, designated RS-68B, would build on the RS-68A upgrades on a non-interference basis.

Early Testing

- RS-68 (left) and J-2X (right) subscale injector testing at MSFC, 2006-2007
- 29 RS-68-focused, 32 J-2X-focused
- 28-, 40-, & 58-element injector inserts
- Thrust levels: less than 20,000 lbf
- Chamber pressures: 850-1,500 psig
- Mixture Ratios: 4.8-6.9
- Fuel manifold temperatures: 100-300°.Rankin
- Commonality

Bench and subscale testing was used to further drive risk out of the project early. Subscale testing was very cost effective. Data obtained could be leveraged by several projects at a cost of roughly $250,000.

Bench and subscale testing was used to further drive risk out of the project early. Subscale testing was very cost effective. Data obtained could be leveraged by several projects at a cost of roughly $250,000.



The Department of Defense is already pursuing changes to improve power level (turbine inlet nozzles) and performance (ISP – higher injector element density). The Air Force, through its Assured Access to Space program, is seeking changes to improve the engine's robustness (eliminate cracking of second stage blisk). NASA's desired upgrades would improve engine operations and safety (free hydrogen reduction). The proposed common engine, designated RS-68B, would build on the RS-68A upgrades on a non-interference basis.

Helium consumption: A future challenge

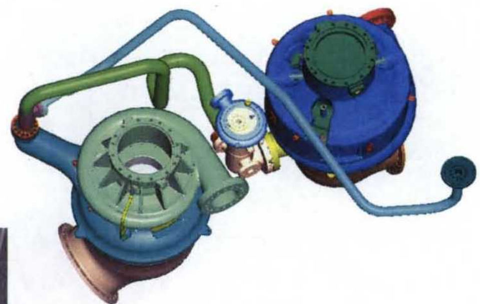
- Common engine / do no harm as a guide star
- Prior experience – Key Issues
- Current quantifiable cost-benefit
- J2X leading the charge

Totals for Seals & Engine Purges	Five Engine Requirement	Current Design	IPS Floating Carbon Ring Design & LOS	IPS Floating Carbon Ring Design only	Segmented Carbon Ring IPS Only
Nominal Flow	<300 SCFM				
Peak Flow	<900 SCFM				
Nominal Total Consumed	<55,000 CF				
Peak Time	<60 seconds				

A key part of the Ares V effort is driving risk and cost out of the system early on by evaluating the impact of design on operational and recurring costs. Some examples are shown here. Facility trade studies sought to ensure the lowest fixed cost. Analyses are used to help refine requirements. For instance, analyses showed that hardware mods, as well as software mods, would be required to significantly reduce free hydrogen on the launch pad, a risk to the safety of the vehicle.

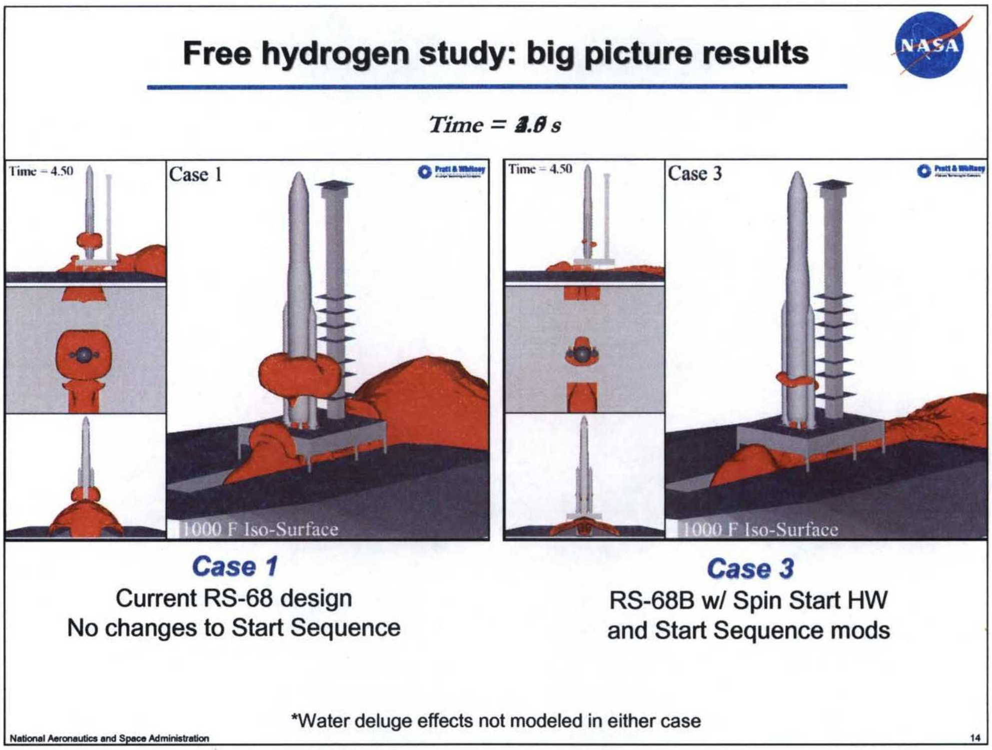
Free hydrogen study: Prompt combustion

- **Hardware changes**
  - Modified Gas Generator, or
  - Rerouted Spin Start Line



National Aeronautics and Space Administration 13

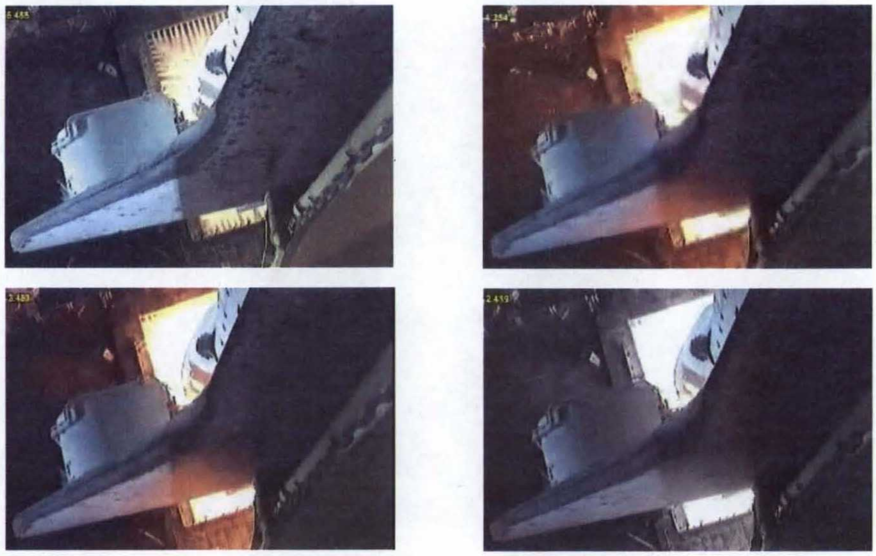
A key part of the Ares V effort is driving risk and cost out of the system early on by evaluating the impact of design on operational and recurring costs. Some examples are shown here. Facility trade studies sought to ensure the lowest fixed cost. Analyses are used to help refine requirements. For instance, analyses showed that hardware mods, as well as software mods, would be required to significantly reduce free hydrogen on the launch pad, a risk to the safety of the vehicle.



A key part of the Ares V effort is driving risk and cost out of the system early on by evaluating the impact of design on operational and recurring costs. Some examples are shown here. Facility trade studies sought to ensure the lowest fixed cost. Analyses are used to help refine requirements. For instance, analyses showed that hardware mods, as well as software mods, would be required to significantly reduce free hydrogen on the launch pad, a risk to the safety of the vehicle.

Free hydrogen study: Pad flow entrainment

- Other points of attack



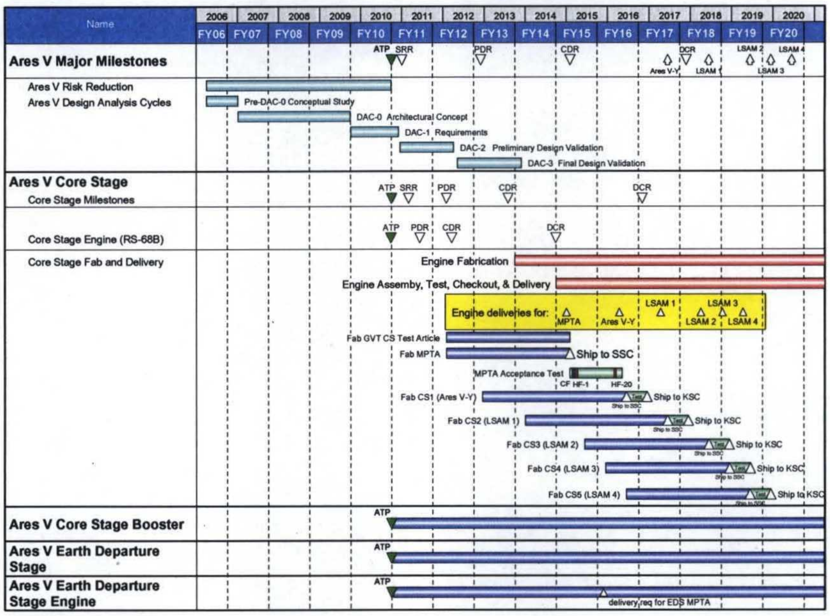
The path ahead: High Value Targets

- Risk reduction efforts
- Continued cooperation and insight
- Adapt to future funding opportunities and challenges

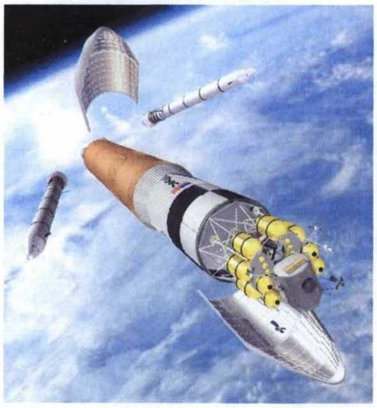
INTERAGENCY AGREEMENT
FOR COOPERATION ON RS-68A/B ENGINE UPGRADES
BETWEEN THE
U.S. AIR FORCE SPACE COMMAND,
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
AND THE NATIONAL RECONNAISSANCE OFFICE

Draft - Apr. 3, 2007

Ares V Consolidated Schedule



Summary



- Ares V remains the heavy-lift component of NASA's exploration architecture and a key component of "national strategy"
- The upgraded RS-68 is crucial to the technical viability of Ares V and the only option for an affordable booster engine.