National Aeronautics and Space Administration

From ESAS to Ares – *A Chronology*

NASA Program Managers Challenge

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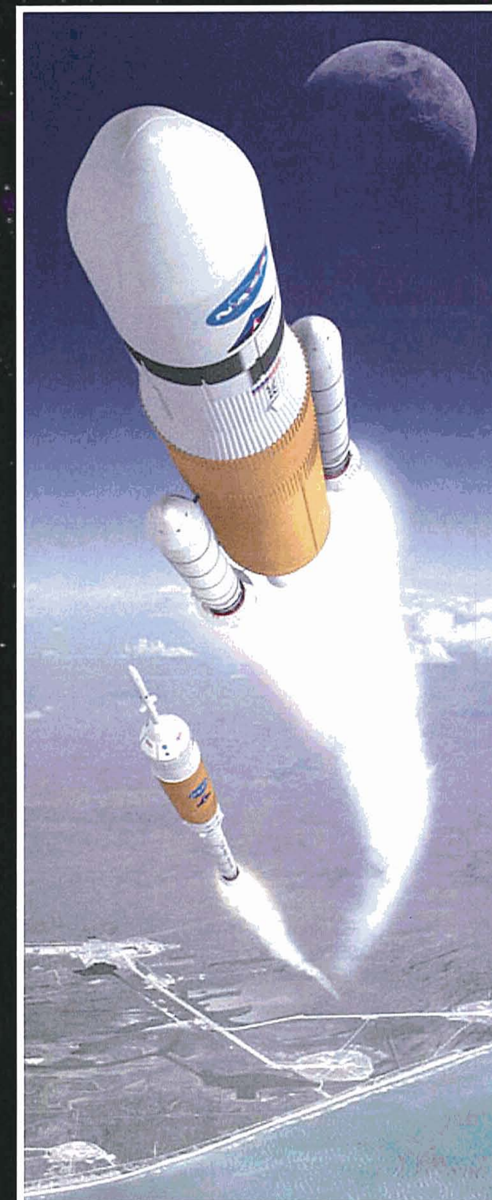
Ares: The Right Vehicle for NASA's Exploration Mission

- The Ares I Crew Launch Vehicle (CLV) and Ares V Cargo Launch Vehicle (CaLV) are being designed to reduce cost and development time while meeting safety and performance requirements.

- These Shuttle-derived vehicles will meet the Nation's goals of establishing a sustained presence on the Moon and then go on to Mars and other destinations.

- These vehicles will, literally, extend U.S. stewardship and regular access of space beyond the coastal regions of low-Earth orbit.

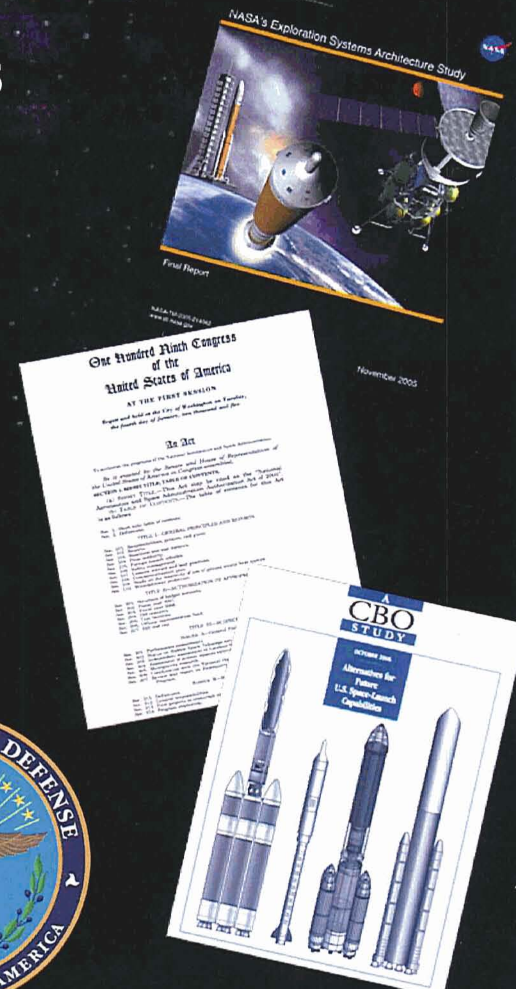
- Compared to other vehicle options, such as EELVs, this approach is by far the right one to meet the integrated cost, performance, and mission objectives.



An Architecture Selection Grounded in Analysis

Several recent studies demonstrate that a Shuttle-derived architecture makes the most sense for NASA from a life-cycle cost, safety, and reliability perspective.

- NASA Exploration Systems Architecture Study (ESAS) in 2005 recommended this approach based on significant analysis.
- Supported in Law through the NASA Authorization Act of 2005 (Section 502).
- Department of Defense (DoD) validated this conclusion in August, 2005 (letter to John Marburger* from Ronald Sega** and Michael Griffin***).
- The October 2006 Congressional Budget Office report entitled "Alternatives for Future U.S. Space-Launch Capabilities" is consistent with NASA's analysis and decisions.



* Director, White House Office of Science and Technology Policy
** Under Secretary of the Air Force
*** NASA Administrator

NASA's Exploration Systems Architecture Study
Summer 2005

- Complete assessment of the top-level Crew Exploration Vehicle (CEV) requirements and plans to enable the CEV to provide crew transport to the International Space Station and to accelerate the development of the CEV and crew-launch system to reduce the gap between Shuttle retirement and CEV initial operational capability.

ESAS
EXPLORATION SYSTEMS ARCHITECTURE STUDY

- Definition of top-level requirements and configurations for crew and cargo launch systems to support the lunar and Mars exploration programs.

- Development of a reference exploration architecture concept to support sustained human and robotic lunar exploration operations.

- Identification of key technologies required to enable and significantly enhance these reference exploration systems and a reprioritization of near-term and far-term technology investments.

ESAS Crew Launch Family Comparison

	Human-Rated Atlas V/New US	Human-Rated Delta IV/New US	Atlas Phase 2 (5.4-m Core)	Atlas Phase X (8-m Core)	4 Segment RSRB with 1 SSME	5 Segment RSRB with 1 J-2S	5 Segment RSRB with 4 LR-85
Payload (28.5º)	30 mT	28 mT	26 mT	70 mT	25 mT	26 mT	27 mT
Payload (51.6º)	26 mT	23mT	25 mT	67 mT	23 mT	24 mT	25 mT
DDT&E*	1.18**	1.03	1.73**	2.36	1.00	1.3	1.39
Facilities Cost	.92	.92	.92	.92	1.00	1.00	1.00
Average Cost/Flight*	1.00	1.11	1.32	1.71	1.00	.96	.96
LOM (mean)	1 in 149	1 in 172	1 in 134	1 in 79	1 in 460	1 in 433	1 in 182
LOC (mean)	1 in 957	1 in 1,100	1 in 939	1 in 614	1 in 2,021	1 in 1,918	1 in 1,429

LOM: Loss of Mission   LOC: Loss of Crew   US: Upper Stage   RSRB: Reusable Solid Rocket Booster   SSME: Space Shuttle Main Engine

* *All cost estimates include reserves (20% for DDT&E, 10% for Operations), Government oversight/full cost*

** *Assumes NASA has to fund the Americanization of the RD-180.*
Lockheed Martin is currently required to provide a co-production capability by the USAF.

ESAS Lunar Cargo Launch Family Comparison

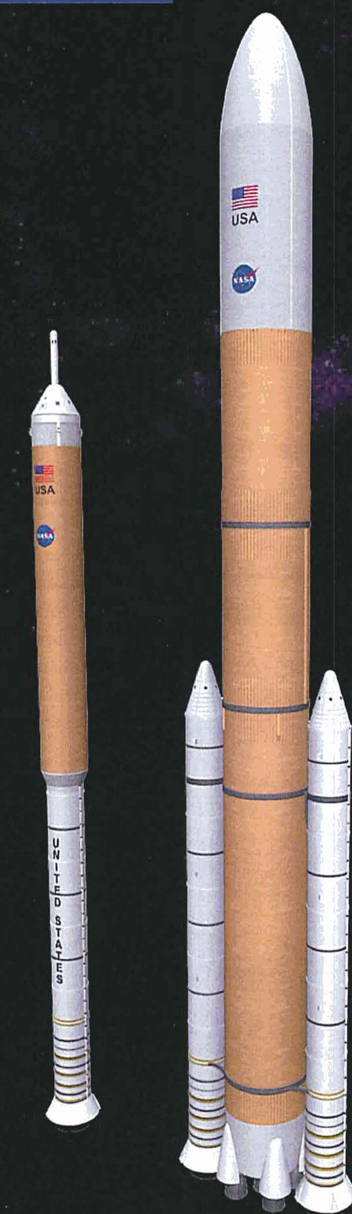
	5 Segment RSRB In-Line with 5 SSME Core - Cargo	Atlas Phase X (8-m Core)	Atlas Phase 3A (5.4-m Core)	5 Segment RSRB In-Line with 4 SSME Core	4 Segment RSRB In-Line with 3 SSME Core	5 Segment RSRB Side-mount with 2 SSME	4 Segment RSRB Side-mount with 3 SSME
Payload to 28.5	106 mT (125 mT w/ upper stage)	95 mT	94 mT	97 mT	74 mT	80 mT	67 mT
Lunar LV DDT&E*	1.00	1.29	.59	.96	.73	.80	.75
CLV+Lunar Crew/Cargo DDT&E (family op)*	1.00 (4 Seg RSRB w/1 SSME)	1.26 (Atlas V)	1.02 (Phase 2)	.98 (4 Seg RSRB w/ SSME)	.83 (4 Seg RSRB w1 SSME)	1.03 (5 Seg RSRB w/J2S-LR85)	.85 (4 Seg RSRB w/1 SSME)
Lunar LV Facility DDTE	1.00	1.33	2.25	1.00	* All cost estimates include reserves (20% for DDT&E, 10% for Operations), Government oversight/full cost; Average cost/flight based on 6 launches per year. ** Production costs are higher than in-line due to production of separate side-mount cargo carrier.		
CLV+Lunar Facilities Cost	1.00	1.12	1.56	1.00			
Lunar LV Average Cost/Flight*	1.00	1.08	1.19	.87	.78	1.13**	1.13**
LOM — Cargo (mean)	1 in 124	1 in 71	1 in 88	1 in 133	1 in 176	1 in 172	1 in 173
LOC (mean)	1 in 2,021	1 in 536	1 in 612	1 in 915	1 in 1,170	N/A	N/A

ESAS Launch System Selection Summary

- **Continue to rely on the EELV fleet for scientific and International Space Station cargo missions in the 5-20 metric ton range to the maximum extent possible.**

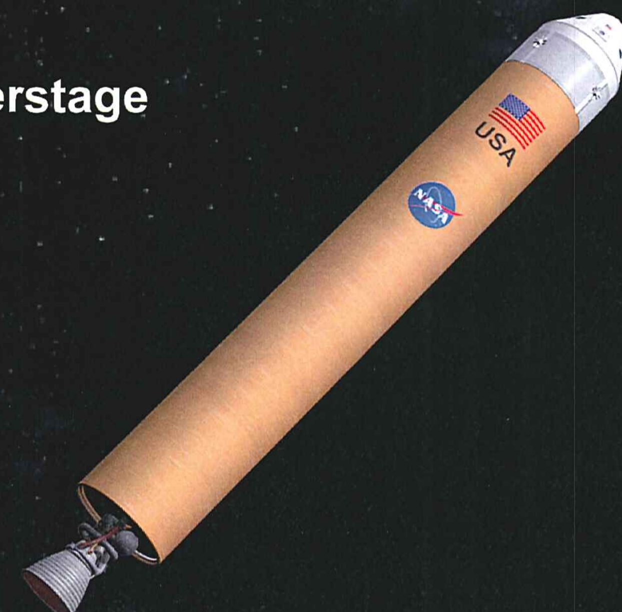
- **The *safest, most reliable, and most affordable* way to meet exploration launch requirements is a 25 metric ton system derived from the current Shuttle solid rocket booster and liquid propulsion system.**
  - Capitalizes on human rated systems and 85% of existing facilities.
  - The most straightforward growth path to later exploration super heavy launch.

- **125 metric ton lift capacity required to minimize on-orbit assembly and complexity — increasing mission success**
  - A clean-sheet-of-paper design incurs high expense and risk.
  - EELV-based designs require development of *two* core stages plus boosters - increasing cost and decreasing safety/reliability.
  - Current Shuttle lifts 100 metric tons to orbit on every launch.

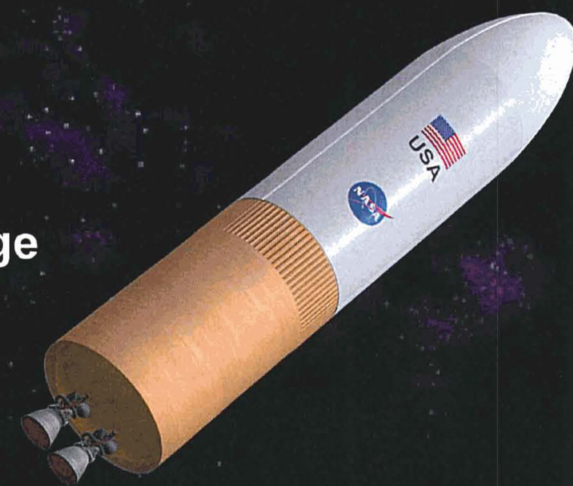


ESAS Crew Launch Vehicle Summary

- Serves as the long term crew launch capability for the U.S.
- 4 Segment Shuttle Solid Rocket Booster
- New liquid oxygen / liquid hydrogen upperstage
  - 1 Space Shuttle Main Engine
- Payload capability
  - ~25 metric tons to low-Earth orbit



ESAS Lunar Heavy Cargo Launch Vehicle Summary



- **5 Segment Shuttle Solid Rocket Boosters**
- **Liquid Oxygen / liquid hydrogen core stage**
  - Heritage from the Shuttle External Tank
  - 5 Space Shuttle Main Engines
- **Payload Capability**
  - 106 metric tons to low-Earth orbit
  - 125 Metric tons to low-Earth orbit using earth departure stage
  - 55 metric tons trans-lunar injection capability using Earth departure stage
- **Can be later certified for crew if needed**

ESAS Earth Departure Stage Summary

- **Liquid oxygen / liquid hydrogen stage**
  - Heritage from the Shuttle External Tank
  - J-2S engines (or equivalent)
- **Stage ignites suborbitally and delivers the lander to low Earth orbit**
  - Can also be used as an upper stage for low-Earth orbit missions
- **The CEV later docks with this system and the Earth departure stage performs a trans-lunar injection burn**
- **The Earth departure stage is then discarded**

Improving on the ESAS Launch Recommendations

- **ESAS was a "point of departure" exploration architecture.**

- **Post-ESAS analysis demonstrated there is a more streamlined way to regain access to the Moon**
  - NASA decided to reduce the total number of program developments required to enable the Ares launch vehicle family.

- ***Key Element:*** **Better focuses the architecture on exploration as the primary mission, vs. ISS then exploration.**

Improving on the ESAS Launch Recommendations

- **This approach focuses on developing key technologies sooner. For example:**
  - 5 segment stage for Ares I and V
    - Saves hundreds of millions of dollars
  - J-2X as the common upper stage engine for both Ares I and Ares V
    - Saves hundreds of millions of dollars
  - Use of the commercially developed RS-68 engine as the core engine for Ares V
    - Saves billions of dollars over the life cycle

Progress made on the Ares I is now a significant and direct "down payment" on the Ares V. Selecting common hardware reduces cost and gets us closer to enabling a lunar transportation system.

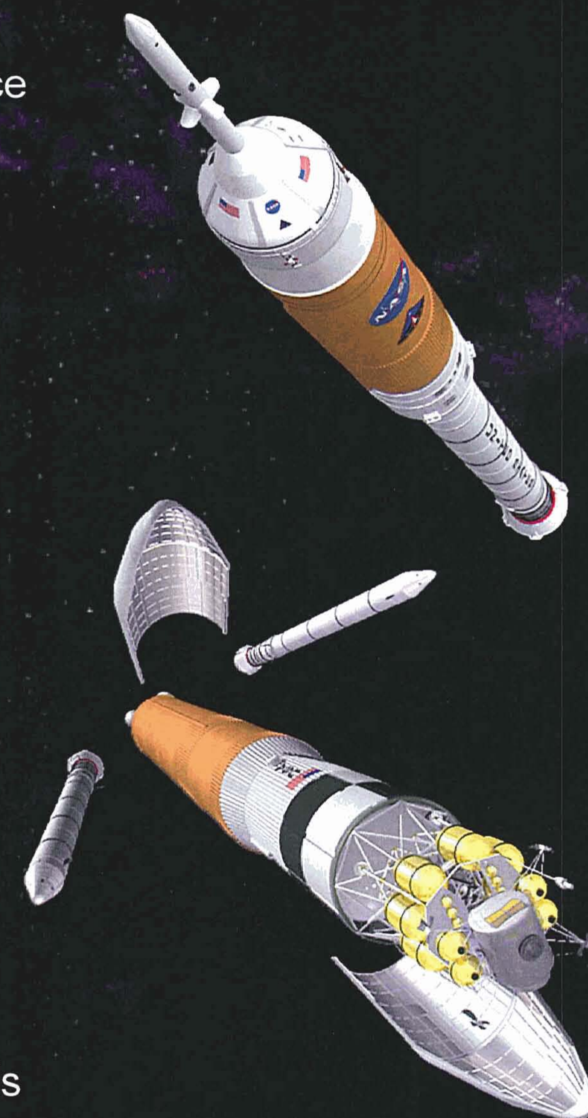
Ares: Building on Proven Capabilities

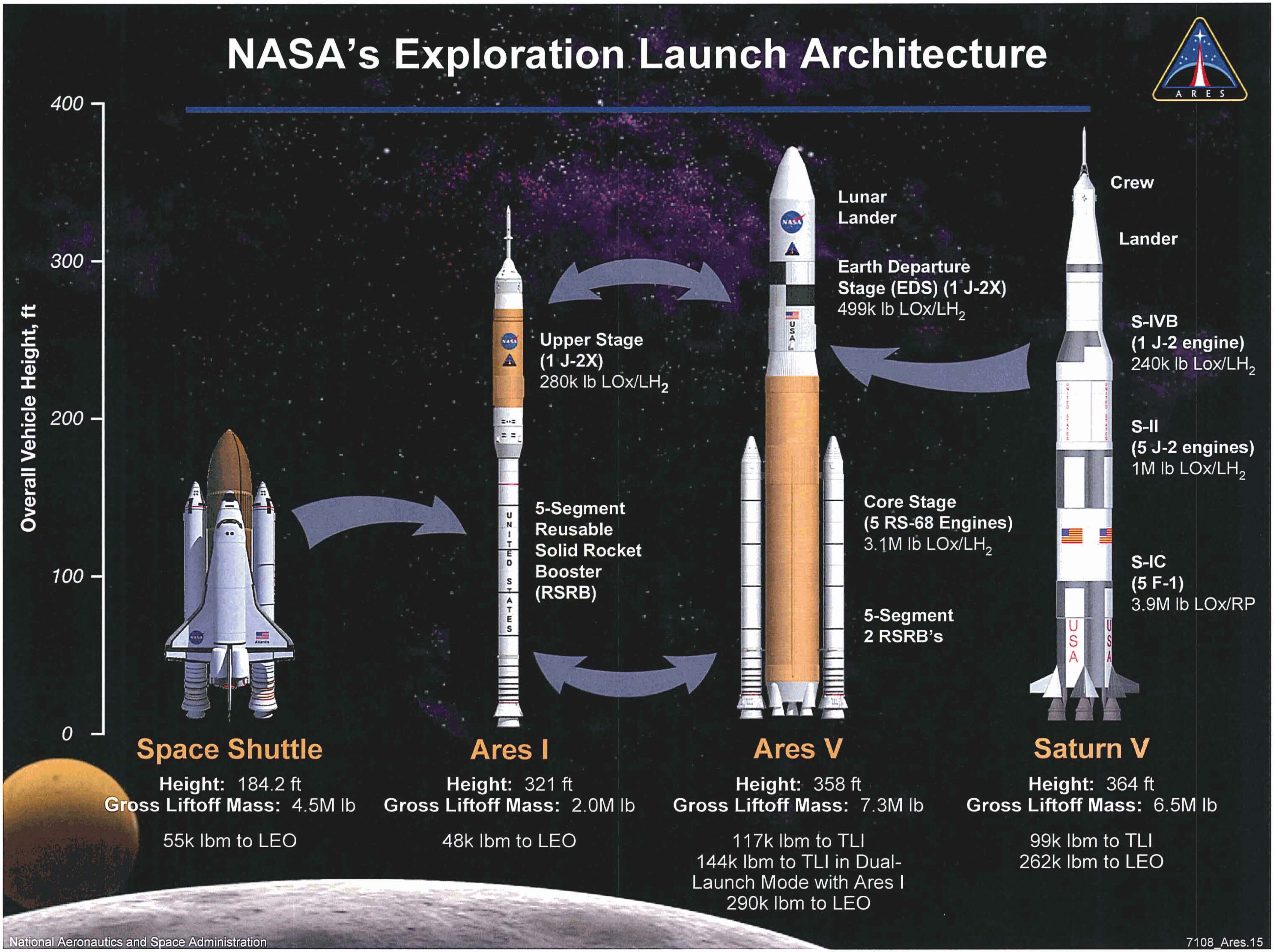
- A 5-segment solid rocket motor was test fired in October 2003 .
- The J-2X engine's predecessor made its debut during the United States' first round of Moon missions, and its turbomachinery was tested as part of the more recent X-33 Program.
- The Upper Stage will be assembled at the Michoud Assembly Facility, home of the Shuttle External Tank, using the same materials.
- The RS-68 engine, which powers the Delta IV, will boost the Ares V core stage.
- Using experienced human spaceflight workforce to process the Ares at the Kennedy Space Center using many Shuttle capabilities, such as booster processing and assembly, the Vehicle Assembly Building, and Launch Complex 39.

Using the Experienced Capabilities in a Streamlined Manner

A Robust Development Approach

- **Performance**
  - Ares I: Delivers 22mT to LEO plus ~15% Performance Margin
  - Ares V: Delivers 130mT to LEO / 65mT to Trans-Lunar Injection (with Ares I)
- **Flight Control**
  - While Ares is a long and slender vehicle, it is within the control dynamics experience base of previous programs, most notably the Saturn V
    - ~8x margin on the vehicle structural response to control frequency ratio
  - Results indicate a ~2x margin on first stage thrust vector control (angle and rate) and ~1.7x capability over predicted roll torque
- **Weather**
  - Designing for a 95% launch availability
  - Using conservative assumptions for natural environments, such as winds aloft
- **Structures and Loads**
  - Within the design of the existing Shuttle motor case, joints and aft skirt
  - Upper Stage/interstage is being designed for the loads




NASA's Exploration Launch Architecture
ARES
Overall Vehicle Height, ft
400
300
200
100
0
Upper Stage
(1 J-2X)
280k lb LOx/LH2
5-Segment
Reusable
Solid Rocket
Booster
(RSRB)
Lunar
Lander
Earth Departure
Stage (EDS) (1 J-2X)
499k lb LOx/LH2
Core Stage
(5 RS-68 Engines)
3.1M lb LOx/LH2
5-Segment
2 RSRB's
Crew
Lander
S-IVB
(1 J-2 engine)
240k lb Lox/LH2
S-II
(5 J-2 engines)
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: 321 ft
Gross Liftoff Mass: 2.0M lb
48k lbm to LEO
Ares V
Height: 358 ft
Gross Liftoff Mass: 7.3M lb
117k lbm to TLI
144k lbm to TLI in Dual-
Launch Mode with Ares I
290k lbm to LEO
Saturn V
Height: 364 ft
Gross Liftoff Mass: 6.5M lb
99k lbm to TLI
262k lbm to LEO
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Making Progress Towards Flight

1st Stage Parachute Testing

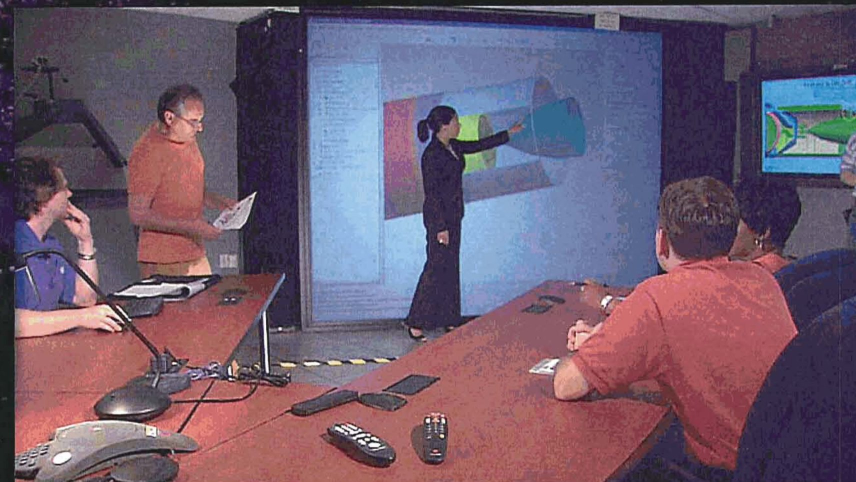
J-2X Injector Testing

1st Stage Nozzle Development

J-2S Powerpack Test Preparation

Making Progress Towards Flight

Over 1,500 Wind Tunnel Tests



Upperstage Initial Design Analysis Cycle

Fabrication of Ares I-1
Upperstage Mass Simulator

Ares I-1 1st Stage Hardware

NASA's Exploration Launch Approach

- Provides the best possibility of meeting stakeholder, Congressional law, and customer requirements within the funding available and timeframe desired
  - Smart evolution from ESAS baseline
- Lowest cost and highest safety/reliability for NASA's mission.
- Maximum leverage of existing, human-rated systems and infrastructure.
- Leveraged collaboration between the retiring Shuttle program and emerging Constellation projects
  - Sharing lessons learned
  - Transitioning valuable resources, ranging from a specialized workforce to launch infrastructure
- A robust capability for access to cis-lunar space and a straightforward growth path to later exploration launch needs (e.g. Mars).
- An industrial base for production of large solid rocket systems; high-performance liquid engine systems; large, lightweight stages; and critical, large-scale launch processing infrastructure.
- Team is making great progress.
- 1st test flight of Ares I-1 in April 2009!