BUILDING OPERATIONS EFFICIENCIES

INTO NASA'S ARES I CREW LAUNCH VEHICLE DESIGN

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ABSTRACT

The U.S. Vision for Space Exploration guides the National Aeronautics and Space Administration's (NASA's) challenging missions that expand humanity's boundaries and open new routes to the space frontier. With the Agency's commitment to complete the International Space Station (ISS) and to retire the venerable Space Shuttle by 2010, the NASA Administrator commissioned the Exploration Systems Architecture Study (ESAS) in 2005 to analyze options for safe, simple, cost-efficient launch solutions that could deliver human-rated space transportation capabilities in a timely manner within fixed budget guidelines. The Exploration Launch Projects (ELP) Office, chartered by the Constellation Program in October 2005, has been conducting systems engineering studies and business planning to successively refine the design configurations and better align vehicle concepts with customer and stakeholder requirements, such as significantly reduced life-cycle costs. As the Agency begins the process of replacing the Shuttle with a new generation of spacecraft destined for missions beyond low-Earth orbit to the Moon and Mars, NASA is designing the follow-on crew and cargo launch systems for maximum operational efficiencies. To sustain the long-term exploration of space, it is imperative to reduce the $4 billion NASA typically spends on space transportation each year. This paper gives top-level information about how the follow-on Ares I Crew Launch Vehicle (CLV) is being designed for improved safety and reliability, coupled with reduced operations costs. These methods include carefully developing operational requirements; conducting operability design and analysis; using the latest information technology tools to design and simulate the vehicle; and developing a learning culture across the workforce to ensure a smooth transition between Space Shuttle operations and Ares vehicle development.

INTRODUCTION

NASA is revitalizing the Nation's space fleet and is re-vectoring the way the Agency does business. It is seeking potential efficiencies across the Agency's mission portfolio by providing a routine, steady market for logistics and crew rotation services to the Space Station through the Commercial Orbital Transportation Services demonstration.[1] Yet, while being flexible, the Agency has an overriding responsibility to assure U.S. access to space, as is evidenced in its methodical pursuit of a new human-rated transportation system that can be ready for crew travel to low-Earth orbit in the 2014 timeframe, as well as crew and cargo transportation to the Moon no later than 2020. These systems will be extensible to future systems that one day will enable the first human footprint on Mars. The Ares I Crew Launch Vehicle will carry the Orion Crew Exploration Vehicle to low-Earth orbit, while the Ares V Cargo Launch Vehicle will carry the Lunar Surface Access Module and other heavy equipment for America's return to the Moon, with mission objectives that range from harnessing potential resources resident there, to preparing for longer missions while relatively close to home (see Figure 1).

Figure 1. The Ares I (right) and the Ares V will provide human space transportation capabilities (artist's concept).

Given these strategic goals and objectives, as are outlined in the U.S. Vision for Space Exploration and the Constellation Architecture Requirements Document, NASA's Exploration Launch Projects Office has enacted implementation tenets that include utilizing current and proven technologies to the maximum extent possible (see Figure 2).[2,3] Areas of potential recurring cost savings being investigated include designing a robust system with automated processing for reduced touch-labor, easy access to components for maintenance, commonality among ground support equipment, and the ability to perform standard automated mission profiles without undue operator intervention. Sample requirements that address such issues include launch-on-time probability and launch availability in relation to weather constraints.

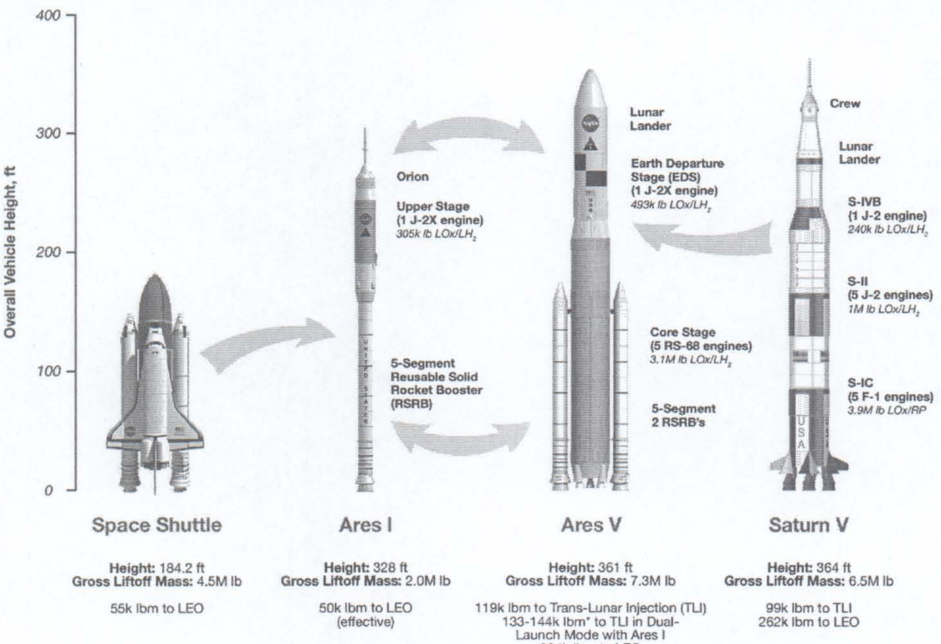

Figure 2. Comparison of the Shuttle and Saturn to the Ares I and Ares V (arrows indicate hardware evolution and commonality).

It is estimated that 80 percent of operations costs are determined during the concept development phase.[4] Therefore, the Ares I design work is in the phase of highest leverage to affect change. With this knowledge as a foundation, this paper addresses how the Exploration Launch Projects Office is designing operational efficiencies into the Ares I, which was selected based on figures of merit that include safety and reliability, coupled with significant decreases in operations costs to sustain the Nation's space exploration mission across the decades ahead. It includes a summary of the systems engineering approach to delivering capabilities that fulfill well-defined customer and stakeholder requirements, including trade studies conducted against the initial recommendations made by the Exploration Systems Architecture Study team of aerospace experts in mid 2005, during the Ares I first design analysis cycle and its subsequent System Requirements Review (SRR), which was completed in December 2006.[5,6]

As is shown in Figure 3, the Ares I Project is making measurable progress according to the systems engineering practices followed by NASA to ensure integration among major organizational elements, as well as between hardware and software elements. As directed in NASA Procedure and Regulation (NPR) 7123, NASA Systems Engineering Procedural Requirements, the Ares I SRR examined "the functional and performance requirements defined for the system and the preliminary program or project plan and ensures that the requirements and the selected concept will satisfy the mission."[7] Based upon these findings, the Ares Project believes that operability must drive the vehicle's design, and that a number of design challenges, including system mass and reliability, must be addressed as part of the progress to Preliminary Design Review (PDR).

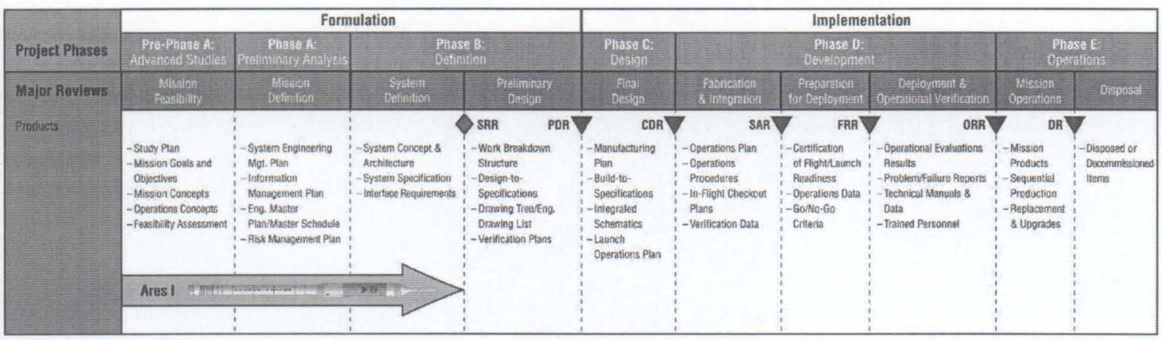

Figure 3. Ares I progress according to systems engineering plan.

The objective of the Ares I PDR, slated for 2008, is to provide a solid set of design-to specifications, preliminary designs, and verification plans to take the design forward into the final design phase of the project. The SRR demonstrated that the Constellation Architecture Requirements Document requirements have been properly analyzed, functionally decomposed, allocated, validated, and assure that the Crew Launch Vehicle System Requirements Document (SRD) is clear, achievable, responsive, and appropriate to fulfill the mission needs.[8] The PDR will demonstrate that the hardware design is capable of meeting those vetted requirements, as well as satisfy issues of cost, operability, and robustness of the system.

RESULTS AND DISCUSSION: DESIGNING FOR OPERABILITY

The Exploration Launch Projects Office, which was chartered to design, develop, and deliver the Ares I and Ares V, is acutely aware that the cost of access to space limits the budget that can be invested in the missions that space transportation enables. The business of delivering new space transportation capabilities includes operations concepts that reduce both recurring costs, such as propulsion element production and sustaining engineering and processing the launch vehicle stack, and nonrecurring costs, such as modifying the existing launch infrastructure to accommodate these new systems. By studying the pros and cons of past and present launch vehicle processing, including the Evolved Expendable Launch Vehicle (EELV) design and operations approaches, plans are for the various hardware elements to arrive at the launch facility in pre-configured sets (i.e., the engine will be mated with the upper stage element) for streamlined handling.

The current Ares I concept, shown in Figure 4, is a two-stage in-line configuration that places the Orion crew capsule on top of the integrated stack. The Launch Abort System on top of the capsule is designed to move the crew away from the stack in case of a launch emergency. As stated above, the Agency's hardware approach is to build upon existing technologies to the maximum extent possible — the Ares I first stage is a 5-segment Reusable Solid Rocket Booster, similar to the 4-segment used on the Space Shuttle today — and the in-house designed upper stage will be powered by a J-2X engine, an evolution of that used on the Saturn V upper stages. Likewise, hardware commonality with the Ares V is a development approach that is expected to reduce both nonrecurring and recurring costs (refer to Figure 2). The Ares I vehicle system designers also are planning for operations efficiencies utilizing various approaches, such as modeling and simulation, and through a number of avenues, such as early flight testing in real-world mission environments.

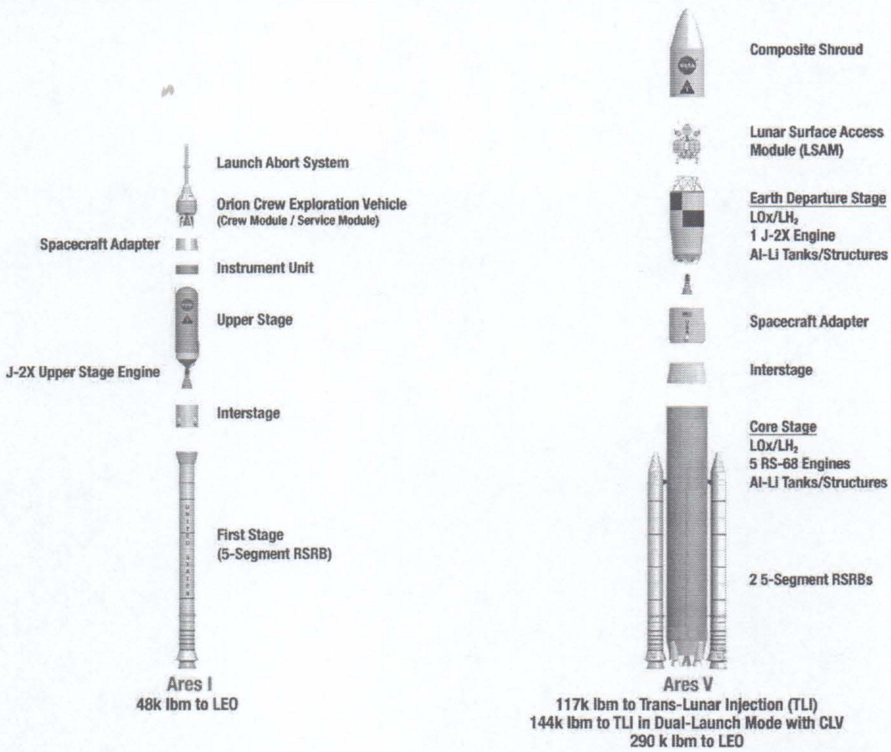

Figure 4. Expanded views of the Ares I and the Ares V.

Given below is a summary of risk reduction work, including the concept of operations and the design-for-operations roadmap. Several specific activities and approaches are discussed, along with an overview of the first flight test mission, known as the Ares I-X mission, which is scheduled for April 2009 and is aimed at delivering data to designers before the Critical Design Review, while giving operators real-world experience with processing and launching the new system.

OPERATIONS AND OPERABILITY RISK REDUCTION

The NASA Fiscal Year 2008 (FY08) budget request includes over $4 billion for flying the Shuttle to the International Space Station and for a servicing mission to the Hubble Space Telescope. It is estimated that it costs over $3 billion per year to maintain the Shuttle fleet, whether flying missions or not. The FY08 budget request for the Exploration Systems Mission Directorate (ESMD) is $3.9 billion to support continued development of new U.S. human spaceflight capabilities and supporting technologies, and to enable sustained and affordable human space exploration after the Shuttle is retired in 2010.[9]

Staying within the budget prescribed, and delivering in the 2014 timeframe target, drives NASA's 21st century space transportation fleet to draw on decades of lessons learned from operating human spaceflight systems and on evolutionary technologies to the maximum extent possible. Much of the budget allocated to the Ares I effort is investing in programmatic and technical risk reduction, including a focus on vehicle operability and streamlined operations concepts and implementing a number of innovative ways of reducing operations costs through such things as common tooling, manufacturing, and processing of components, subsystems, and systems.

Reflecting its commitment to bringing down the price of space transportation while maintaining performance parameters, the Exploration Launch Projects Office has appointed an Operations Manger who functions on the same level as its Chief Architect. These individuals are invested with the responsibility to reach across and into the Ares I design activities in a way that results in a safe, reliable, and cost-efficient system. The Operations Working Group, as a subset of the Vehicle Integration function and part of the Constellation Program's Ground and Mission Operations Systems Integration Group, ensures that logistics and other details are considered as part of the overall system requirements development and resulting operations concept.

CONCEPT OF OPERATIONS

Today's launch operations are complex, time-consuming, and require a great deal of hands-on labor. When the Ares I begins its operational phase in the 2014 timeframe, it will be the culmination of a detailed process that involves launch vehicle design engineers working in tandem with their operations counterparts to ensure that the system delivered meets requirements, goals, and objectives (see Figure 5).

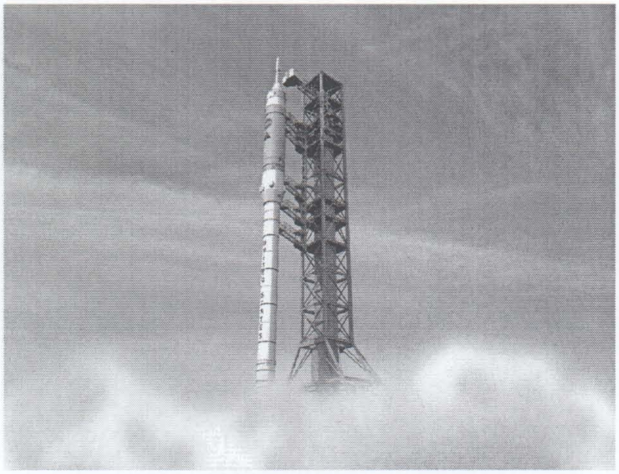

Figure 5. Ares I on the launch pad (artist's concept).

As currently envisioned, the Ares I will support five missions to the ISS each year: two crewed missions and three pressurized cargo missions, for a total of five launches. After completion of the ISS missions and after the Ares V comes on line late next decade, the Ares I will support two lunar missions annually. This section provides a frame of reference for the interfaces across the Constellation Program's multiple projects and gives a top-level overview of the ground and flight operations goals, primarily to acquaint the reader with plans that are unfolding to reduce complexity.[10]

The Constellation Program consists of multiple systems that are all addressed by the Ares Operations Concept. These systems are grouped into four categories:

1. Crew Vehicles and Systems category includes the Orion crew capsule, the Lunar Surface Access Module (LSAM), the Suit Systems (for Extra-Vehicular Activities), and Flight Crew Equipment. In the future, the Mars Transfer Vehicle (MTV) and the Mars Descent Ascent Vehicle (DAV) will be added to the active program.
2. Launch Vehicles and Systems category includes the Ares I for crew and the Ares V for cargo.
3. Ground and Mission Systems category consists of the hardware and software systems.
4. Future Destination Surface Systems category consists of the habitat, surface mobility, power, and robotic and resource utilization systems.

Ares I ground and flight operations concepts and goals are driven by the mission manifest; Design Reference Missions (DRMs); Constellation Program constraints; the Constellation Program's Needs, Goals, and Objectives document; and Ares I design decisions. Operations goals are established as a target for improving upon existing capabilities. The operations requirements are based on operations analyses and timelines (such as, turnaround time, launch availability probability, and so forth) using the mission manifest, DRMs, and Program constraints as inputs, including management margin. Analysis results are compared to the operations goals, and programmatic decisions will be made to establish the final requirements.

The Ares I ground and flight operations goals are summarized below:

- Achieve a significant reduction in operations cost from legacy systems, with the goal to operate at a steady-state flight rate of 5 flights per year, for no more than $1.2 billion annually.
- Simplify and minimize ground processing and integration operations such that the system can be launched within 45 calendar days from start of assembly.
- Effectively size the system to support various mission types (ISS, lunar sortie, etc.) and number of missions in any given year; support up to 6 (5 plus surge) flights per year.
- Be interchangeable with either mission type (crew or cargo) such that no significant changes in processing flow or element hardware are required.
- Elements should arrive at the Kennedy Space Center (KSC) without open factory work.
- Achieve the appropriate balance between the use of Line Replaceable Units (LRUs), reliable component selection, and maintenance operations to support a launch availability of not less than 98 percent (not including natural environmental impacts).
- Minimize launch pad processing time such that it is ready for launch within 7 days from the integrated system's arrival at the launch pad.
- Reduce, to the maximum extent practical, any launch pad maintenance during the 4-day launch window.
- Be capable of a 24-hour turnaround following a launch scrub.
- Be capable of supporting the next Trans-Lunar Injection (TLI) window following a missed
- launch attempt.
- Use common, reusable ground support equipment throughout pre-launch processing and launch operations.
- Incorporate common parts and tooling as much as practical.

- Be capable of remaining in a stacked configuration for up to 180 days.
- Minimize ground system diagnostic, maintenance, and umbilical interfaces.
- Implement a logistics support concept with the appropriate balance between just-in-time shipment, certification life, and hardware spares to minimize the launch site logistics footprint (storage facilities, equipment, and personnel) and to eliminate the need for on-site hardware recertification.

Operations scenarios are described in the Ares Operations Concept document, based on the sequence of activities for each of the operational phases, as is shown in Figure 6. These top-level scenarios assist in determining Ares launch vehicle segment and supporting systems capabilities, interfaces, and operational timelines.

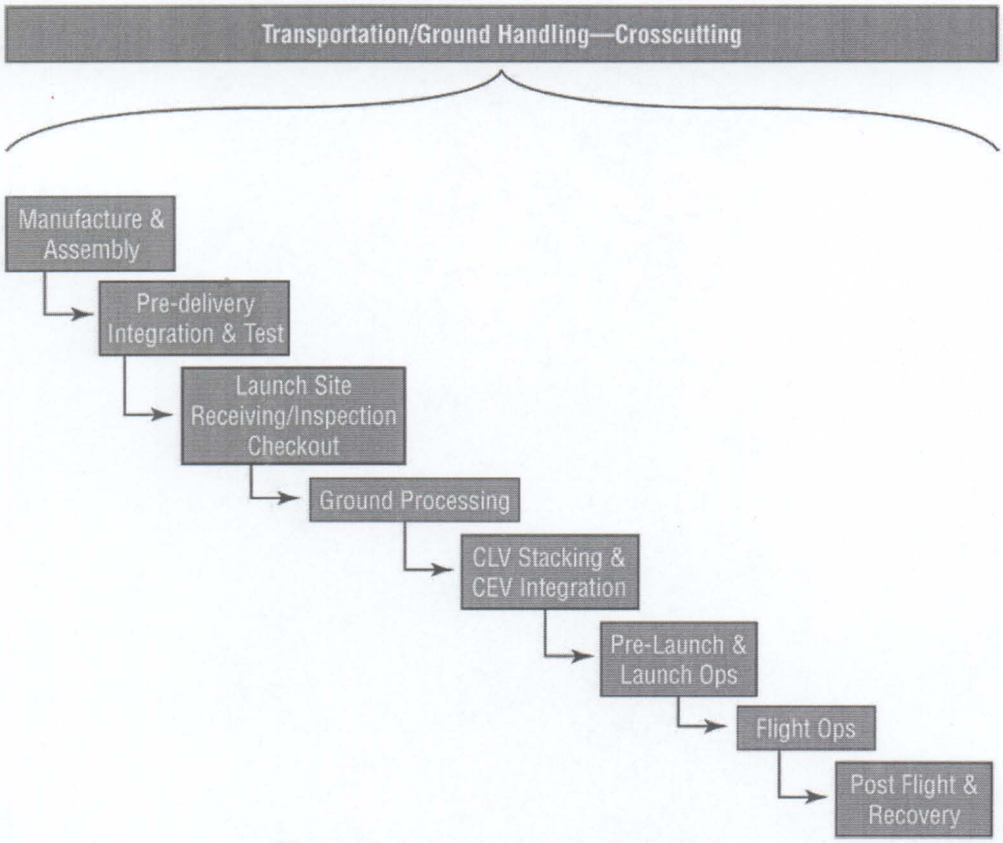

Figure 6. Ares I operational phases.

By methodically decomposing the activity steps that must occur at each operational phase, the Ares team has a better understanding of how to reduce complexity for efficient launch solutions. These and other variables are used as inputs for the Ares design-for-operations approach, which is summarized below.

Challenges exist to meeting the Program and Project derived operability requirements for the Ares I, including reliability and operations processing time. The current configuration has achieved a substantial improvement in predicted reliability due to changes in engine turbopump design and upper stage main propulsion system. KSC processing has been substantially improved by the decision to switch to a monopropellent system for both first stage and upper stage roll control systems, using a single common propellant. However, the incorporation of the common bulkhead and helium liquid oxygen tank pressurization into the upper stage design has introduced some complexities into the vehicle processing at KSC. An operations processing technical interchange meeting was held with KSC and all vehicle elements leading into the

Design Analysis Cycle2 (DAC-2) activities, including developing a detailed operations timeline flow. DAC-2 activities, now in progress.will further refine the operability assessments for the Ares I launch vehicle.

DESIGN-FOR-OPERATIONS ROADMAP

As mentioned earlier, the Exploration Launch Projects Office has empowered an operations champion and various working groups to focus on simplifying the factors that drive launch processing. As defined here, operations include such things as manufacturing, logistics, transportation, flight processing, engineering and project support, and refurbishment activities. The design-for-operations objective is to reduce system support costs, both hardware and non-hardware by performing trade studies that analyze recurring and non-recurring costs.

The design-for-operations roadmap is a three-step process involving: (1) requirements, (2) design, and (3) manufacturing and site operations. The first step is to understand operations cost drivers, including Shuttle operations and infrastructure and EELV performance. Using these inputs, the team assembles data into easily digestible formats as an input to Ares I requirements that address operations cost drivers. The second step is to ensure that requirements are addressed during the design process through activities such as personnel training, allocating requirements to system elements, including system responsibility for operational costs, and designing for manufacturing and operations. Progress toward these requirements is tracked through engineering management reviews and at targeted opportunities such as quarterly operations management reviews. The third step involves utilizing lean techniques to improve quality, while simultaneously reducing cycle time and associated costs. This approach is aimed at minimizing defects in workmanship throughout the range of operations activities, as well as maximizing resource utilization by eliminating non-value-added waste. The team monitors activities as a natural part of the pre-planned product improvement cycle.

One example of the extensive work conducted in this area over the last few months is a vehicle processing technical interchange meeting, which focused on the processing flow at the Kennedy Space Center. Discussions included:

- Ares vehicle operability philosophy and drivers
- KSC ground infrastructure overview
- KSC operations concept flow overview
- KSC processing flow review
- Forward planning

A follow-on technical interchange meeting addressed stretch goals put in place to assist the Constellation Program in reducing overall life-cycle costs. Topics addressed were:

- Key operations concept statements that might be captured in the Constellation Architecture Requirements Document.
- Items that are not found to be significant factors in reducing life-cycle costs.
- Required trade studies to complete Program-level task descriptions.
- Consistency between the Program operations concepts and proposed requirements.

In the spirit of integration, design teams include manufacturing, operations, and safety personnel working together to implement system-level operations approaches. An operability workshop conducted to develop risk-mitigation steps included representatives from the Operability Design and Analysis, Integrated Operations and Logistics, KSC, and Ares Elements (First Stage, Upper Stage, and Upper Stage Engine) to gain consensus on the steps needed to effectively address requirements related to operability outcomes.

Eventually, design activities such as these will culminate in an expression of the "test as you fly, and fly as you test" philosophy. The Ares team draws on analysis results from a variety of sources, including subscale wind tunnel models and from computer aided design applications that test integrated avionics software and simulate vehicle dynamics in cyberspace, leading to real-world testing with increasingly flight-like hardware to gain confidence in the system before orbital tests that will yield even more information on which to base critical hardware decisions related to long-term, sustainable flight operations.

FLIGHT TESTING STRATEGY

As part of Ares I development, NASA will perform a series of flight tests. The tests will provide data that will inform the engineering and design process, as well as verify the flight hardware and software. The data gained from the flight tests will be used to certify the new Ares/Orion vehicle for human space flight.

The primary objectives of this first flight test (Ares I-X) are to:

- Demonstrate control of a dynamically similar integrated Ares CLV/Orion Crew Exploration Vehicle using Ares Crew Launch Vehicle ascent control algorithms.
- Perform an in-flight separation/staging event between an Ares I-similar First Stage and a representative Upper Stage.
- Demonstrate assembly and recovery of a new Ares-like First Stage element at KSC.
- Demonstrate First Stage separation sequencing, and quantify First Stage atmospheric entry dynamics and parachute performance.
- Characterize the magnitude of the integrated vehicle roll torque throughout the First Stage (powered) flight.

The Ares I-X suborbital development flight test will encompass designing and developing a complete system, including a full-scale Flight Test Vehicle (FTV) and associated launch operations. The FTV comprises multiple elements (Figure 7), which are being developed at various NASA Centers and contractor locations. The elements and components will be delivered to KSC for assembly into an integrated, flight-ready FTV. Once the FTV is integrated and final checks are completed in the Vehicle Assembly Building (VAB) and at the launch pad, the FTV will be launched.

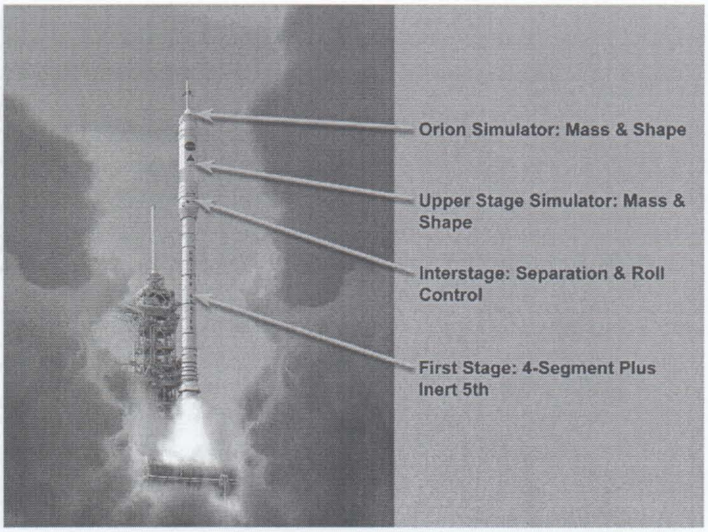

Figure 7. The Ares I-X flight test is planned for April 2009.

The various high-technology tools and techniques that are applied in the laboratory and research environments are no substitute for hands-on experience; therefore, the Ares I-X flight test also will try out new Ground Operations (GO) procedures at the launch site. Among the activities the GO team is studying are stabilizing the vehicle during rollout from the VAB; setting up electronic ground equipment; studying the operation of the FTS; and loading the propellants for the reaction control system. These and other operations objectives will be analyzed and quantified as an integral step on the path to a new era of human space flight.

SUMMARY AND CONCLUSIONS

NASA is accountable for delivering on the strategic goals set forth in the Vision for Space Exploration; therefore, it is investing its near-term resources in returning astronauts to the Moon as the logical first step toward the eventual human exploration of Mars — both events that will affect the future for generations to come. NASA's Exploration Launch Projects office is directing the magnitude of work needed to deliver improved transportation systems tailored to empower a new age of discovery, leadership, security, and global competitiveness.

NASA is committed to applying rigorous systems engineering and systems management processes and standards to ensure that technical performance is accurately reflected in, and inextricably connected to, budget allocations and schedule milestones. By building on a foundation of heritage knowledge and applying lessons learned from past and current missions, the probability of success is greatly increased. Focusing early and often on top risks and operations concepts in relation to performance parameters, is a key to meeting goals and objectives.

On the Moon, astronauts will gain the experience needed to travel to other worlds and learn to work productively while relatively close to home. These lunar missions will serve as test-beds for technologies and management practices that will enable the eventual first human trips to Mars, a planet much like Earth. While robotic spacecraft and rovers provide mapping data, scout potential landing sites, and locate *in situ* resources that can be utilized by the first Moon settlers and the first explorers on Mars, NASA and its partners are engaged in the task of designing, developing, testing, fielding, and operating the space transportation systems that will carry those for whom the journey of discovery has begun anew.

Mission success demands a disciplined, innovative approach to developing human space transportation systems that deliver greater safety and reliability, along with marked reductions in operations costs. Building on a foundation of proven hardware and legacy knowledge is a prime risk reduction strategy being applied by NASA's Exploration Launch Projects Office, which is dedicated to delivering launch vehicle solutions that foster America's long-term exploration of space.

REFERENCES

1. "NASA Selects Crew and Cargo Transportation to Orbit Partners," August 18, 2006, NASA News, www.nasa.gov.
2. United States Vision for Space Exploration, January 2004, www.nasa.gov.
3. CxP 00001, NASA Constellation Architecture Requirements Document, 2005.
4. NASA/TP-2001-2100992, Launch Vehicle Design Process: Characterization, Technical Integration, and Lessons Learned, J.C. Blair, et al, p. 150.
5. Exploration Systems Architecture Study, Final Report, Technical Manual 2005-214062, November 2005, www.sti.nasa.gov.
6. "NASA Completes Review Milestone for Ares I Vehicle," January 4, 2007, NASA News, www.nasa.gov.
7. National Aeronautics and Space Administration, *NASA Systems Engineering Procedural Requirements,* NASA NPR 7123.1.
8. National Aeronautics and Space Administration, *Crew Launch Vehicle System Requirements Document, 2006.*
9. NASA FY08 Budget Request, www.nasa.gov.
10. CxP 72032, NASA CLV Operations Concept, March 2007.

National Aeronautics and Space Administration

Exploration Launch Projects

Building Operations Efficiencies into NASA's Ares I Crew Launch Vehicle Design

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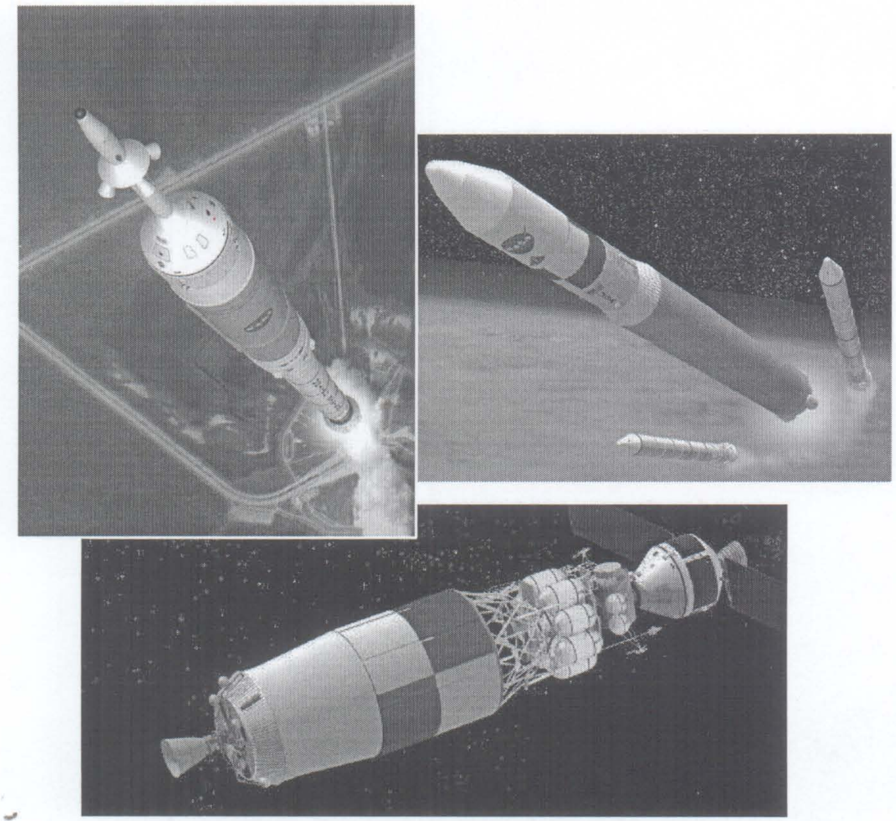
Agenda

- Overview of the Ares Launch Vehicles
- Designing for improved safety, reliability, and cost
- Developing operational requirements
- Conducting Operability Design & Analysis (ODA)
- Developing a learning culture to ensure a smooth transition from Shuttle to Ares

Overview of the Exploration Launch Projects Architecture



- Ares I Crew Launch Vehicle (CLV)
- Ares V Cargo Launch Vehicle (CaLV)
- Orion Crew Exploration Vehicle (CEV)
- Lunar Surface Access Module (LSAM)

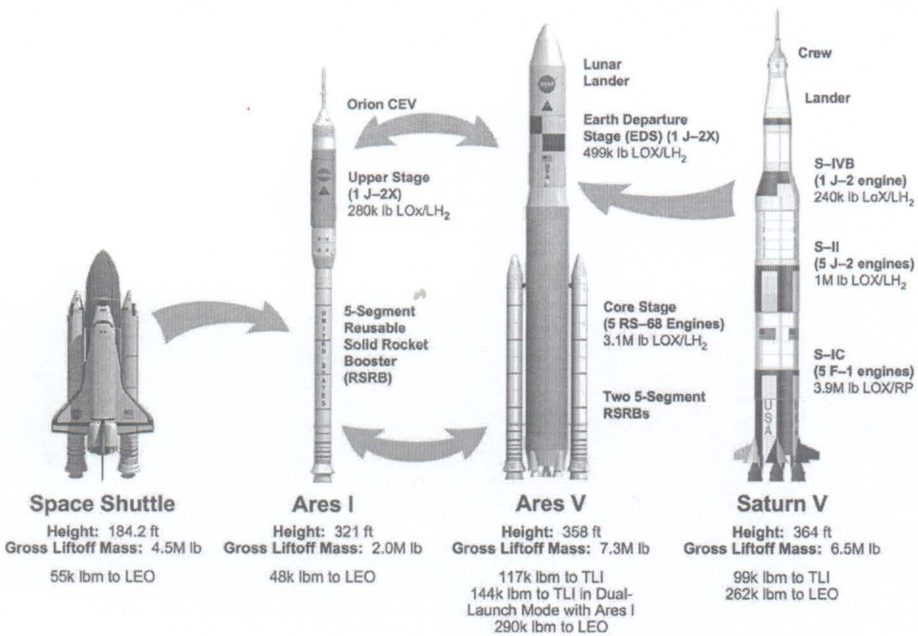
An ambitious exploration program must be financially sustainable

Designing for Operability

- Improving reliability
- Reducing risk
- Reducing costs
  - Recurring costs
    - Manufacturing propulsion elements
    - Sustaining engineering
    - Processing launch vehicle stack
  - Nonrecurring costs
    - Modifying launch infrastructure to accommodate new vehicle designs

By spending less on operations, NASA can concentrate more on exploration

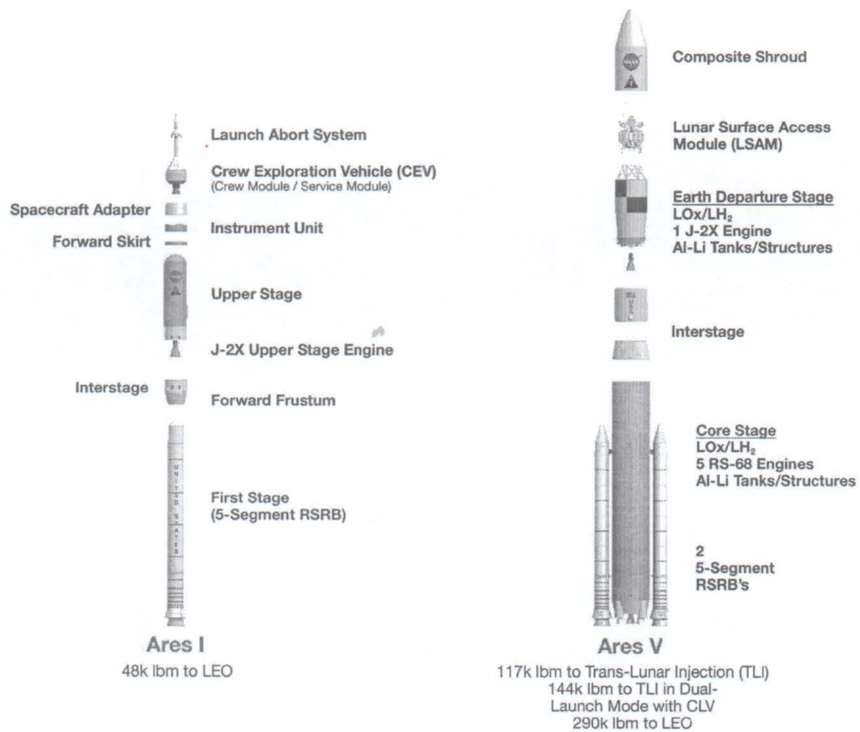
Improving Reliability



- Using proven technology to the maximum extent possible
- Reducing touch labor
- Developing and using common ground support equipment (GSE)
- Flying standardized mission profiles over wider range of launch conditions
- Determining operations costs up front
- Using existing NASA systems engineering processes

The Ares launch vehicles will be more reliable and sustainable by leveraging NASA's experience with legacy hardware

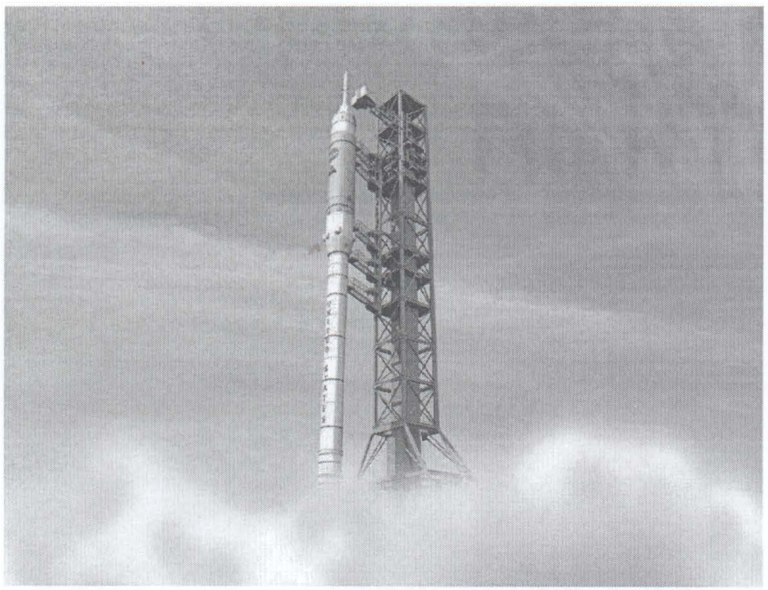
Reducing Risk



- In-line configuration (crew atop, not beside rocket)
- Launch Abort System (LAS) enables escape in event of emergency
- Using proven technologies (J-2, RSRB)
- Developing models and simulations before manufacturing hardware
- Conducting early flight tests

Ares I will be an order of magnitude safer than current human spaceflight systems

Operations and Operability Risk Reduction



Ares Concept of Operations

- ELP must work within limited budget
- Five missions/year to International Space Station
- Constellation systems include:
  - Crew vehicles and systems (e.g. Orion)
  - Launch vehicles and systems (e.g. Ares)
  - Ground and mission systems
  - Future destination surface systems
- Operations derived from Constellation requirements and design reference missions

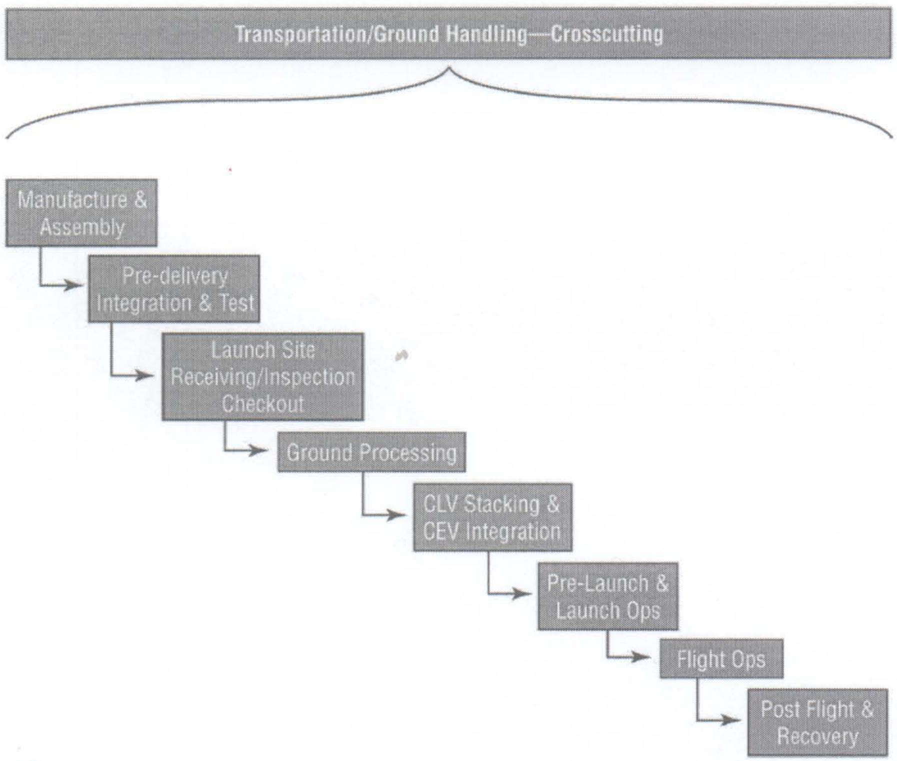
Ares is part of an overall Constellation effort to provide efficient operations

Ares I Ground and Flight Operations Goals

- Achieve a significant reduction in operations cost from legacy systems
- Simplify and minimize ground processing and integration operations
- Effectively size the system to support various mission types (ISS, lunar sortie, etc.) and number of missions in any given year
- Be interchangeable with either mission type (crew or cargo)
- Elements should arrive at the Kennedy Space Center (KSC) without open factory work
- Achieve the appropriate balance between the use of Line Replaceable Units (LRUs), reliable component selection, and maintenance operations
- Minimize launch pad processing time
- Reduce any launch pad maintenance during the 4-day launch window
- Be capable of a 24-hour turnaround following a launch scrub
- Be capable of supporting the next Trans-Lunar Injection (TLI) window following a missed launch attempt
- Use common, reusable ground support equipment
- Incorporate common parts and tooling as much as practical
- Be capable of remaining in a stacked configuration for up to 180 days
- Minimize ground system diagnostic, maintenance, and umbilical interfaces
- Implement a logistics support concept with the appropriate balance between just-in-time shipment, certification life, and hardware spares

Ground and flight operations will emphasize less labor, more efficient use of resources, and more frequent flights

Operations Capabilities



- Develop top-level scenarios to determine:
  - Launch vehicle and support system capabilities
  - Interfaces
  - Operational timelines
- Determine and decompose activity steps
- Reduce complexity
- Design for operations

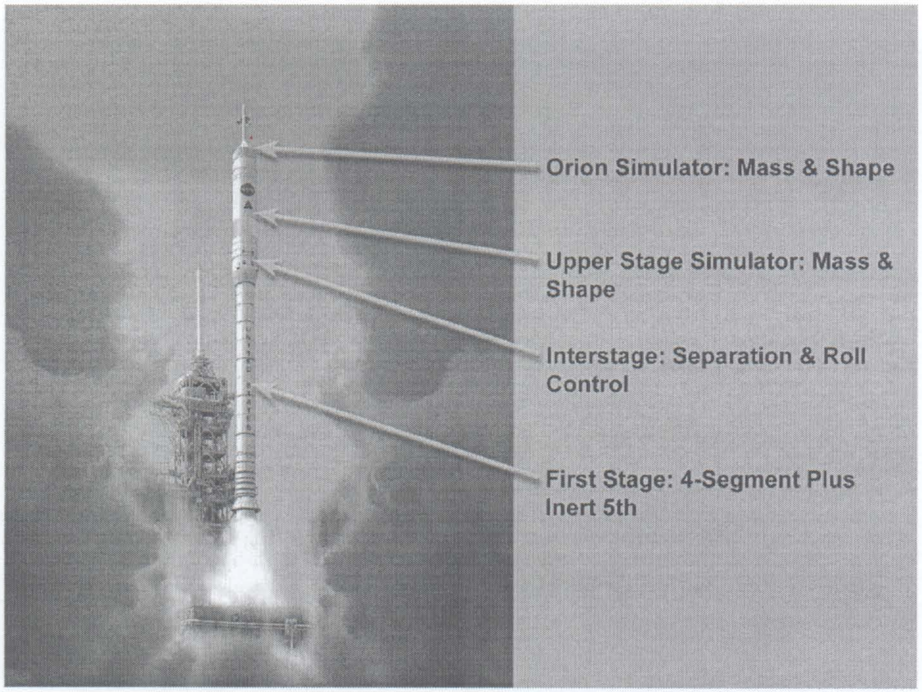
Up-front planning will reduce operational cost and complexity

Designing for Operations

- Requirements
  - Understand operational cost drivers
- Design
  - Incorporate requirements throughout design process
- Manufacturing and site operations
  - Use lean techniques to improve quality while reducing cycle times and associated costs

Designing for operations maximizes resource use and reduces waste

Flight Testing Strategy



- "Test as you fly, fly what you test"
- Primary objectives of Ares I-X flight test include:
  - Demonstrate control of a dynamically similar vehicle using Ares ascent control algorithms
  - Perform an in-flight separation/staging event
  - Demonstrate assembly and recovery of First Stage element at KSC
  - Demonstrate First Stage separation sequencing, quantify atmospheric entry dynamics and parachute performance
  - Characterize magnitude of integrated vehicle roll torque

Ares I-X will test our ability to fly new exploration vehicles

Testing Ground Operations

- Stabilizing vehicle rollout from VAB
- Setting up electronic ground equipment
- Studying operation of the flight termination system (FTS)
- Loading propellants for roll/reaction control system (RoCS/RCS)

There is no substitute for hands-on experience

Summary and Conclusions

- NASA is committed to applying rigorous engineering and systems management processes to meet budget and schedule constraints
- Missions to the Moon will test operational as well as exploration methods
- NASA's use of proven hardware and legacy knowledge is a prime risk reduction strategy that will ensure the continued human exploration of space

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