Constellation Launch Vehicles Overview Part 2
Part 2 Agenda

♦ Progress on Key Ares I Risks – Dr. John Hutt

♦ Ares I-X Overview and Update – Stephan Davis

♦ Ares V Overview – Steve Creech

♦ Summary – Steve Cook
Progress on Ares Risks

Dr. John Hutt
Ares I Vehicle Integration
Chief Engineer
Progress on Key Risks

♦ Ares uses a thorough active approach to identifying and mitigating technical issues and risks
  • Applying appropriate resources in order to manage and retire risks and issues as they arise

♦ The current top Ares I systems risks analyzed and being actively mitigated are:
  • First Stage Thrust Oscillation
  • Mobile Launch Platform Lift-off Clearance
  • Separation System Pyro-shock
  • Upper Stage Vibroacoustics
  • Ares I Payload Mass Performance

♦ The program expects to retire these while identifying new challenges as the program proceeds to CDR
First Stage Thrust Oscillation (TO)

Background:
If system were rigid

Actual flexible system tunes with forcing function

Graphical Reference Only (Not to Scale)

Four basic ways to attack problem:
- Reduce forcing function
- Detune system response away from forcing function frequency
- Actively create an opposing forcing function
- Passively absorb forcing function

- Mitigation Options

0.16 g's

Pressure Oscillation

0.16 g's

Pressure Oscillation

100,000 lb

100,000 lb
First Stage Thrust Oscillation

**Status:**

- June Program Review was completed with decision to baseline and implement Dual Plane (DP) Isolation
  - Baseline design established as a DP isolation system with the first plane between first stage and upper stage with a reference stiffness of 8M lb/in and an upper plane between US and Orion, on the US side of the interface with a reference stiffness of 1.2M lb/in
  - The crew testing yielded in a requirement recommendation of 0.21 g’s root mean square over a 5-second period and not to exceed 0.7 g’s PEAK at 99.865% (in order to maintain Crew situational awareness)
  - The performance analysis shows that DP isolators are very close to meeting this requirement with 93.8% for Lunar and 98.1% for International Space Station (ISS) cases
  - Orion will provide the design changes necessary to achieve 99.865%
  - Upper Stage will begin design efforts to include the second plane isolator and coordinate interface design requirements with Orion

- Integrating project level risks into single program level risks

**Mitigation:**

- Crew testing
- Requirements for crew seat responses
- Design updates to the ISS Orion configuration
- Design/analysis/model verification of Loads Analysis 4 Finite Element Models
- TO forcing function verification
- Update Monte Carlo analysis for crew seat response
- Quantify TO mitigation baseline design margin required to cover structural uncertainty
Comparison of Mitigation Options

**Working Baseline**

- Dual-Plane Isolation

**Risk Mitigation Options**

- Propellant Damper Single-Plane Isolation
- Active RMAs plus Single-Plane Isolation
Tower Lift-Off Clearance

Background:
♦ First stage thrust misalignment and launch site winds result in launch vehicle drift and potential tower and/or launch mount re-contact
♦ Launch drift can result in tower damage due to plume impingement and can increase refurbishment cost and schedule between flights
♦ Apollo Saturn V had similar issues and used active steering

Mitigation:
♦ An active steering solution has been developed that reduces launch drift and meets tower re-contact requirements with no performance impact (Saturn V approach)
♦ The Mobile Launcher launch mount design has been modified to increase liftoff clearances
♦ Planned forward work to further mitigate this risk includes:
  • Pursue southerly wind placarding to increase tower clearance and reduce the probability of plume damage to the tower
  • The Ground Operations team is evaluating thermal protection (e.g., water deluge) and tower equipment hardening options to reduce plume damage as necessary

Status:
♦ Recent analysis refinements include specific updates to the nozzle configuration, flight control algorithm call rate, and thrust misalignment model. The analysis update confirmed the effectiveness of the active steering solution
Separation System Pyro-Shock

Background:
 ♦ The first stage–upper stage separation approach used a linear shaped charge (LSC) device with a pyrotechnic load of 55-grains/ft.
 ♦ Shock levels were conservatively predicted using 75 grains/ft, yielding very high pyro-shock levels, especially at nearby components.
 ♦ Shock panel testing showed that the 55-grains/ft shock levels were too high for the nearby avionics to tolerate without significant design and mass impacts.

Mitigation:
 ♦ The NASA Design Team, Boeing, and Ensign Bickford developed and traded several options for reducing the shock load. Two candidate approaches were traded: a 30-grains/ft frangible joint and a 30-grains/ft LSC.
 ♦ The frangible joint was selected because it generates the lowest shock levels and was judged to be a lower overall risk for the upper stage design.
 ♦ Further panel testing is planned to verify the shock levels at the avionics. It is expected that this testing will show that the shock levels at the avionics components are within acceptable limits.
Upper Stage Vibroacoustics

Background:
♦ Ares I has a high dynamic pressure trajectory resulting in significant induced vibroacoustic environments. This results in design challenges that may result in additional component development and / or qualification.

Mitigation:
♦ A layered mitigation strategy has been developed to mitigate the redesign risk to the Program, including:
  • Confirm vibroacoustic environments are accurate and appropriate, given the Ares I trajectory and configuration based on the latest trajectory, wind tunnel data, and latest configuration. This activity is underway but not yet complete
  • Investigate possible global solutions for affected subsystems and components. This activity includes removing external protuberances, if possible, and is complete unless an unforeseen opportunity is found
  • Design components and subsystems to survive the environment. To date, four components are being assessed in detail RCS thrusters, RCS propellant tank, interstage avionics, and aft skirt avionics

Rigid buffet model testing in transonic dynamic tunnel
Langley Research Center, VA
Mitigation:

♦ Several options are available to mitigate the high vibration, including:
  • Moving components to an area with less stressing environments
  • Developing systems to absorb transmitted energy and isolate components from the environment. The figures illustrate the concept of using a group of wire rope isolators to reduce vibration loads on the panelized components. Early testing has shown a 50–60% reduction in transmitted energy. This activity is underway and additional tests are planned
  • Combining components into panels or manifolds to change the structural response. As components are combined, detailed analysis will be conducted to determine the effectiveness and the resulting structural loads on the connecting and the primary structures
  • Hardening the components to withstand the vibration levels or develop the isolation system
Ares I and Orion for ISS Ascent Target (130 km/70 nmi)
with Orion 4 Crew Estimates

Initial Capability (ISS Mission) Injected
June 2009

**Color** of arrow indicates current status: **Green** is compliant; **Yellow** is acceptable but at risk; **Red** is noncompliant

**Direction** of arrow indicates trend from last data point: Up is improved; Right is unchanged; Down is worsened

**Status/Trend***
- Ares I Total Margin: 22.5%
- Orion Total Margin: 21.1%
Progress on Key Risks

♦ The current top Ares I systems risks analyzed and being actively mitigated are:

• First Stage Thrust Oscillation – Plan in place, baseline selected and being implemented
• Mobile Launch Platform Lift-off Clearance -- Re-Contact resolved mitigating plume tower interaction
• Separation System Pyro-shock – Mitigation in place with selection of separation system
• Upper Stage Vibroacoustics – Using total vehicle approach to refine environments and develop component solutions
• Ares I Payload Mass Performance – Meeting requirements and holding adequate mass margins. Mass is continually monitored as a top performance metric.

♦ The program expects to retire these while identifying new challenges as the program proceeds to CDR
Ares I-X Overview

Stephan Davis
Deputy Manager, Ares I-X
Mission Management Office
Ares I-X Flight Test Overview

♦ Ares I-X is a Constellation Program developmental flight test for the Ares I project
  • There are five primary flight test objectives – P1 through P5
  • Ares I-X is an un-crewed suborbital test

- P1) Demonstrate controllability
- P2) Perform in-flight separation/staging ~130,000 feet
- P3) Demonstrate assembly and recovery of an Ares I similar first stage
- P4) Demonstrate first stage entry dynamics and post staging sequencing of events (e.g. employ booster tumble motors and deploy parachutes)
- P5) Characterize integrated vehicle roll torque

Flight Test Profile

- Vehicle Height: 327 feet
- Weight at Ignition: 1.8 M-lbm
- Max. Acceleration: 2.5 g
- Max. Speed: Mach 4.8

First Stage recovery

Upper Stage/Crew Module/Launch Abort System Simulator free fall into ocean
Ares I-X Status

♦ **First Stage**: Motor from Space Shuttle inventory delivered to Kennedy Space Center (KSC) in March 2009. Aft skirt and forward structures completed in May 2009. Turned over to System/Ground Operations in June 2009

♦ **Upper Stage Simulator (USS)**: Hardware completed and delivered to KSC in November 2008

♦ **Roll Control System (RoCS)**: Modules A and B delivered to KSC April 2009. Installed in the USS interstage

♦ **Avionics**: Sensor, harnesses, airborne avionics boxes, and support ground subsystems delivered to KSC except for inertial navigation unit (INU). INU in test

♦ **Crew Module/Launch Abort System Simulator**: Hardware completed and delivered to KSC in January 2009


♦ **Ground Systems**: Launch Pad modification to be complete August 2009

♦ **Launch** scheduled for October 31, 2009
Ares V Elements
Current Point-of-Departure

Earth Departure Stage (EDS)
- One Saturn-derived J-2X LOX/LH\textsubscript{2} engine (expendable)
- 33 ft diameter stage
- Aluminum-Lithium (Al-Li) tanks
- Composite structures, instrument unit, and interstage
- Primary Ares V avionics system

Core Stage
- Six Delta IV-derived RS-68B LOX/LH\textsubscript{2} engines (expendable)
- 33 ft diameter stage
- Composite structures
- Al-Li tanks

Solid Rocket Boosters
- Two recoverable 5.5-segment PBAN-fueled, steel-case boosters (derived from current Ares I first stage)
- Option for new design

Payload Shroud
Altair Lunar Lander
Payload Adapter
Loiter Skirt
Interstage

Gross Liftoff Mass: 8,167.1K lbm
Performance to TLI: 157K lbm
Integrated Stack Length: 381.1 ft
Ares I and Ares V Commonality

- Builds Up Flight Reliability on the Smaller Vehicle Earlier
- Lowers Life Cycle Cost

Ares I

- Upper Stage-Derived Vehicle Systems
- J-2X Upper Stage Engine
- Elements from Shuttle
- First Stage (5-Segment RSRB)
- Elements from Ares I Range: full stage to case/nozzle/booster systems

Ares V

- U.S. Air Force RS-68B from Delta IV RS-68
Ares V Status

♦ NASA has begun preliminary concept work on vehicle. Over 1,700 alternatives investigated since ESAS
♦ Focused on design of EDS, payload shroud, core stage, and RS-68 core stage engines
♦ Recent point of departure update following the Lunar Capability Concept Review
  • Adds additional performance margin using an additional RS-68
  • Adds half segment on the first stage boosters
♦ Shroud size dictated by eventual size of Altair lunar lander
♦ Also investigating alternate uses for Ares V not related to human space exploration
  • Astronomy applications (e.g., large aperture telescopes)
  • Deep space missions
  • DoD applications
  • Other applications
Architecture Flexibility
Enables New Science Applications

At 5.7 mT, the Cassini spacecraft is the largest interplanetary probe and required a C3 of 20 km²/s² and several planetary flyby ‘gravity assist’ maneuvers. Ares V can support about 40 mT for this same C3.

“Exciting new science may be enabled by the increased capability of Ares V. The larger launch mass, large volume, and increased C3 capability are only now being recognized by the science community.”
– National Academy of Science’s “Science Opportunities by NASA’s Constellation Program”

“It is very clear from the outset that the availability of the Ares V changes the paradigm of what can be done in planetary science.”
– Workshop on Ares V Solar System Science

Current Capability
Ares V Enabled Capability
(>10x Collection Area)
Range of Architecture Options Enabled

A Few Examples (Payload to TLI)
Summary

Steve Cook
Manager, Ares Projects
Advancing Technology: Partnerships with Industry and Researchers

♦ Working with commercial, non aerospace industries (e.g., shipbuilding) to further mature/spinoff friction stir welding technology

♦ Innovative approach to dampening in-flight vibrations using on-board liquid oxygen

♦ Fabrication of large (10 m diameter) composites for Ares V Shroud, Earth Departure Stage (EDS), and Core Stages to save weight
  • Working with industry to identify innovative autoclave or “out of autoclave” approaches including assembly of smaller composites

♦ Development of asbestos-free insulation for Ares solids to reduce environmental impact and increase worker safety
  • Material may also be used in protective equipment for firefighters
Summary

Ares I and V development is the fastest and most prudent path to closing the human spaceflight gap while enabling exploration of the Moon and beyond

♦ Selection of the Ares architecture was made after systematic evaluation of hundreds of competing concepts and represents the lowest cost, highest safety/reliability, and lowest risk solution to meeting Constellation’s requirements
♦ Ares is built on a foundation of proven technologies, capabilities, and infrastructure
♦ The Ares I team has met all key milestones since Project inception, including four major prime contract awards and a successful Preliminary Design Review
  • Unanimous PDR Board and independent Standing Review Board (SRB), agreement that Ares I is ready to proceed to CDR
  • Progress includes release of over 1,800 Ares I design drawings
♦ Ares V project is well underway
  • Draft Phase I Request for Proposal released November 2008; Industry proposals under review
♦ Ares V will be considered a national asset with unprecedented performance and payload volume that can enable or enhance a range of future missions
  • Current architecture delivers ~60% more mass to TLI than Saturn V and ~35% more mass to LEO than Saturn V
♦ External assessments continue to validate the architectures
  • National Advisory Council: “The NAC is confident that the current plan is viable and represents a well-considered approach . . .” – October 2008
  • Government Accountability Office: “NASA has taken steps toward making sound investment decisions for Ares I.” – November 2007
  • Standing Review Board: “The SRB believes that the Project is managing and executing the vehicle development appropriately, including visibility of the individual risk items.”
  • National Research Committee: “The unprecedented mass and volume capabilities of NASA’s planned Ares V cargo launch vehicle enable entire new mission concepts.”
Ares Online Outreach

http://www.facebook.com/NASA.Ares

http://twitter.com/NASA_Ares

http://www.youtube.com/AresTV

http://streaming.msfc.nasa.gov/podcast/ares/ARES.xml
http://streaming.msfc.nasa.gov/podcast/ares/ARES_SD.xml

http://www.thefutureschannel.com/dockets/space/ares/


http://www.nasa.gov/ares