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Integrated System Test Approaches for the NASA Ares I Crew Launch Vehicle



Ares Launch Vehicles



◆ Ares I Crew Launch Vehicle

- Carries Orion crew exploration vehicle with crew of 6 to International Space Station or 4 to Moon
- LH2/LOX upper stage
 - Powered by a single engine derived from the Saturn J-2
- Single 5-segment RSRM first stage

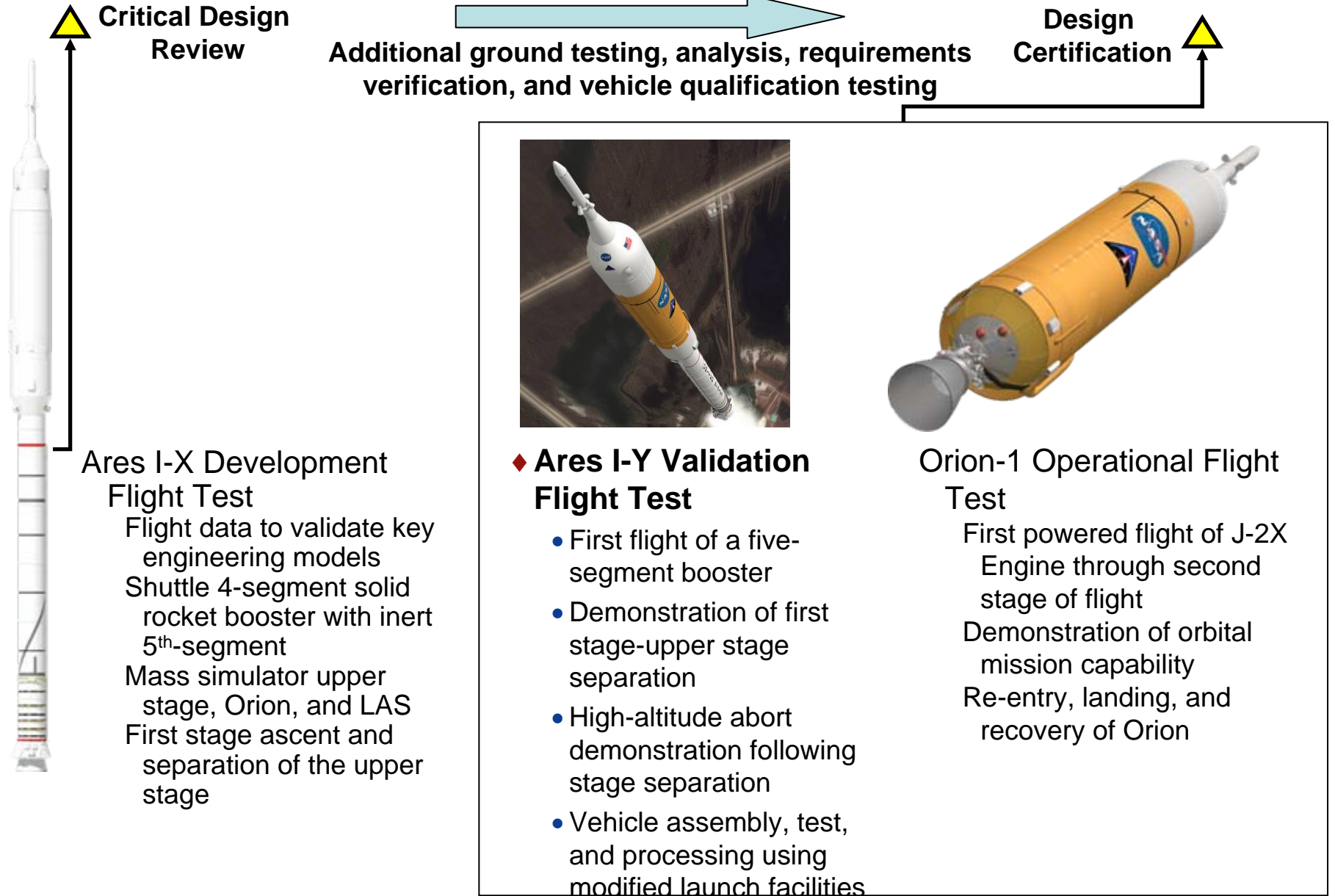
◆ Ares V Cargo Launch Vehicle

- Carries Altair lunar lander and performs trans-lunar injection burn to send Orion and Altair to Moon
- Twin 5.5-segment RSRM first stage
- Core stage derived from the external tank (ET) and Saturn V, powered by six RS-68 engines
- Ares I-derived avionics
- Earth departure stage (EDS)
 - Powered by a single J-2X upper stage engine – completes orbital burn and performs trans-lunar injection
 - Ares I-derived Main Propulsion System (MPS) and avionics



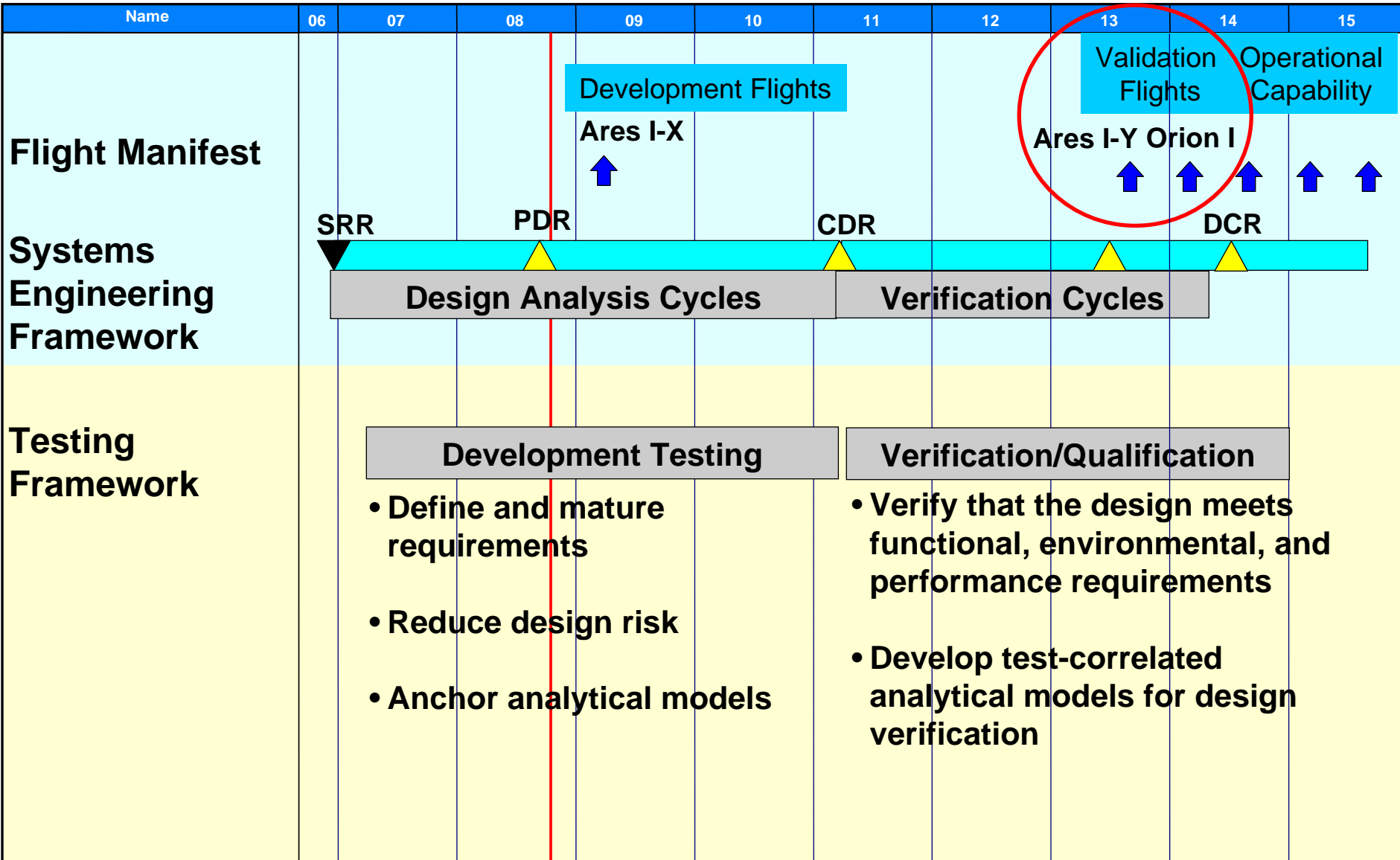


Flight Test Events Leading to Design Certification



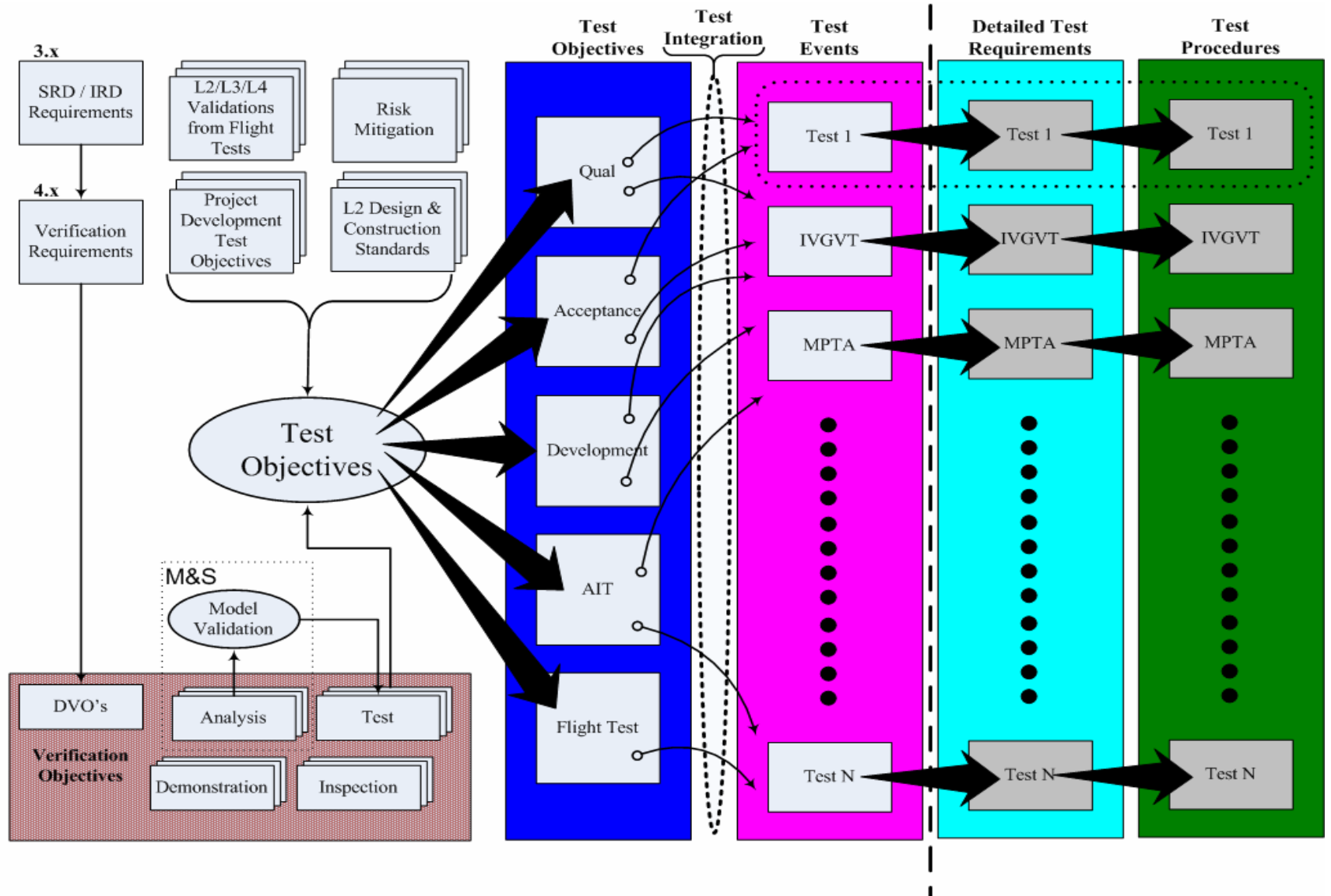


Test and Verification Framework





Development of Test Requirements





First Stage Test and Evaluation



Jumbo Drop Test Vehicle (JDTV)



First Stage DDT-1



Solid Rocket Motor Test Firing

- ◆ **Drogue Parachute Drop Test (DDT-1) successfully completed**
 - First drop test of the new Ares I first stage booster reentry drogue parachute
 - Jumbo Drop Test Vehicle (JDTV) extraction from C-17 aircraft
 - Descended to test condition
 - Deployment and inflation of the drogue test parachute was successful

- ◆ **Ares I-X will provide flight testing for main parachutes**

- ◆ **Development test motor series**
 - Four development motor firings planned
 - DM-1 fabrication is underway

- ◆ **Qualification test motor series**
 - Three qualification motor firings planned



J-2X Engine Test and Evaluation



J-2X PPA-1A

◆ Early risk reduction testing

- Power Pack Assembly 1A (PPA-1A) testing with heritage J-2 turbomachinery and gas generator completed in May 2008
- Subscale injector testing complete
- Workhorse gas generator testing is underway

◆ J-2X Power Pack Assembly #2 (PPA-2)

- Planned for early 2010
- Expand on the test results from the PPA-1 series with flight-design components
- Evaluate turbomachinery, inlet ducts, gas generator, and other components

◆ Development and certification engines

- More than 200 engine hot-fire tests with 9 engines planned
- Sea-level and simulated altitude conditions



Workhorse GG Test



**PPA-2
Concept**



J-2X Engine Facility Readiness



◆ SSC A-1 Test Stand

- Provides sea-level test capability (no diffuser)
- Power-pack and engine testing (no nozzle extension)



◆ SSC A-2 Test Stand

- Capable of sea-level testing or steady-state altitude simulation (no altitude start)
- Facility modifications to support J-2X

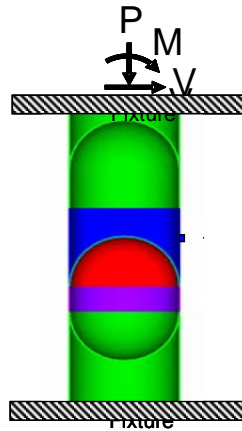
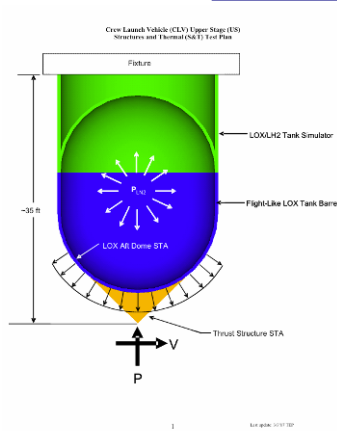
◆ SSC A-3 Test Stand

- New facility to provide altitude test capability for J-2X
- Tests the J-2X engine over the 500-sec duration burn at simulated altitudes over 100,000 feet
- Perform system start and shutdown without sea-level transient loads
- Development, certification, and acceptance testing





Upper Stage Structural and Thermal Test and Evaluation

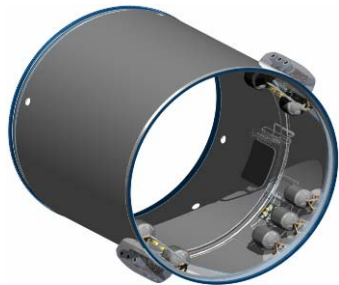
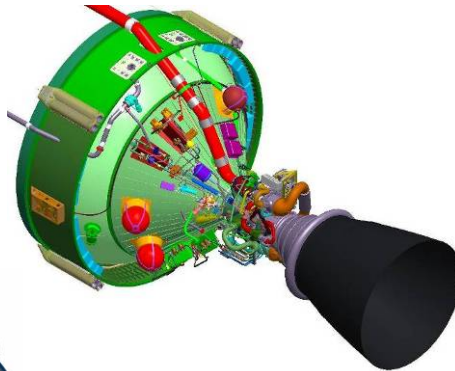
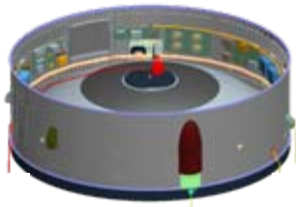


◆ Development test articles

- Common bulkhead
- LOX tank/aft dome/thrust structure
- Damage tolerance testing

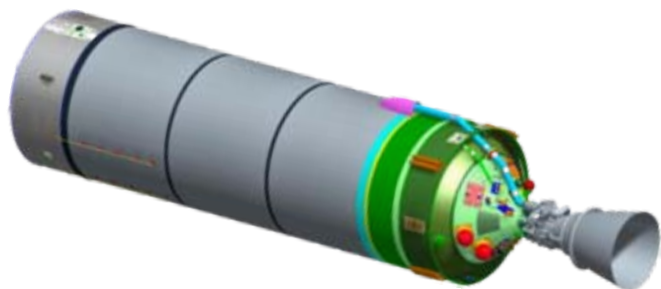
◆ Qualification Test Articles

- Instrument Unit
 - Structural qualification units for IU and avionics panels
 - Thermal qualification for IU avionics
- Interstage
 - Structural qualification
 - Life cycle testing
 - Thermal qualification
- Structural qualification test articles
 - LOX tank/aft dome/thrust structure
 - “Core” upper stage integrated stack with LH2 / LOX tanks, aft dome, and thrust structure





Main Propulsion Test Article (MPTA)



◆ Test purpose

- Test-bed for propellant management and stage operations of an Integrated Upper Stage (US and J-2X Engine)

◆ Specific test objectives

- Propellant management
- Thermal model validation
- Pressurization system performance
- Transient and main stage performance
- Terminal drain demonstration
- Cryogenic operation of MPS components
- Avionics demo
- TVC operations

◆ Approach

- Integration with J-2X development test Engine after engine sea-level testing
- Cold-flow test objectives complete prior to Ares I-Y
- Hot fire testing complete prior to Orion 1



Upper Stage Green Run Testing



◆ Test purpose

- Final acceptance of the integrated upper stage and upper stage engine configuration before eventual transport to launch site

◆ Objectives

- Hot fire test of the flight upper stages with the J-2X flight engine
- Possible verification testing for early stages leading to flight readiness

◆ Approach

- Potential cold-flow testing with Ares I-Y stage
 - Risk reduction for Ares I-Y tanking
 - Test stand activation
- First three stages beginning with Orion 1
 - Need for continued testing will be evaluated after Operational Capability is achieved





Upper Stage Facility Readiness



◆ MSFC Hazardous Structural Strength Test Facility

- LOX tank/aft dome structural development and qualification testing

◆ MSFC Cryo-structural Test Facility

- Core structural qualification test article

◆ MSFC Advanced Engine Test Facility

- Main Propulsion Test Article

◆ SSC B-2 Test Facility

- Stage green run testing
- Plans for further modification to support Ares V core stage testing



Integrated Vehicle Ground Vibration Test (IVGVT)



◆ Test purpose

- Provide test-verified models for structural dynamics and flight control system

◆ Specific test objectives

- Obtain and verify mode shapes, frequencies, generalized mass, and damping characteristics which are used in the stability equations
- Obtain experimental non-linear characteristics of the vehicle
- Obtain amplitude and phase response data at flight control sensor locations

◆ Approach

- Full-scale test articles to simulate flight-like Ares I vehicle dynamic response
- Test at NASA-MSFC Dynamic Test Stand



IVGVT Dynamic Test Stand Readiness



*Dynamic
Test Stand*



*Workers cutting a section of
the platform prior to removal*



*A section of the platform
being removed*



*Lowering of the crosswalk to
facilitate platform removal*



Aerodynamic Testing



◆ Testing at the Preliminary Design Review (PDR) stage

- Multiple facilities and speed regimes (subsonic, transonic, and supersonic) to support aerodynamic characterization for ascent, stage separation, and booster re-entry
- 0.5-percent and 1.0-percent scale models
- Completed approximately 60 percent of total wind tunnel test program (approximately 6,000 hours)

◆ Additional testing prior to CDR

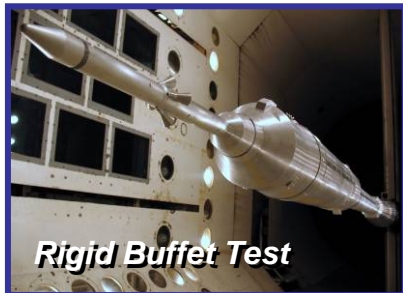
- Reynolds number scale effects
- Aerodynamic interference effects during stage separation
- Plume interactions from reaction control systems
- Higher fidelity configuration assessments



1.0-Percent Stack Test



FSB Re-Entry Testing



Rigid Buffet Test



Separation Testing



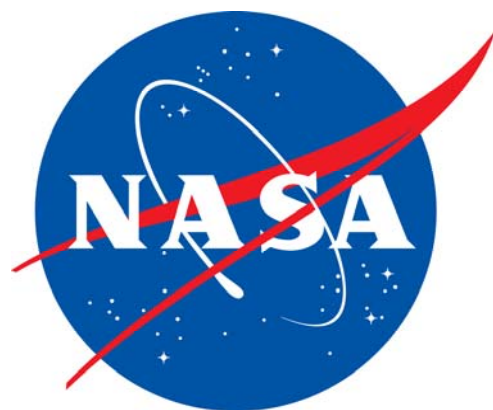
Summary



- ◆ **NASA is maturing test and evaluation plans leading to flight readiness of the Ares I crew launch vehicle**

- ◆ **Key development, qualification, and verification tests are planned**
 - Upper stage engine sea-level and altitude testing
 - First stage development and qualification motors
 - Upper stage structural and thermal development and qualification test articles
 - Main Propulsion Test Article (MPTA)
 - Upper stage green run testing
 - Integrated Vehicle Ground Vibration Testing (IVGVT)
 - Aerodynamic characterization testing

- ◆ **Test and evaluation supports initial validation flights (Ares I-Y and Orion 1) and design certification**



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