



# Test & Verification Approach for the NASA Constellation Program

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CONSTELLATION



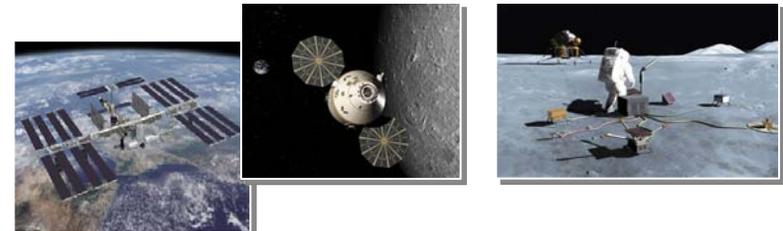
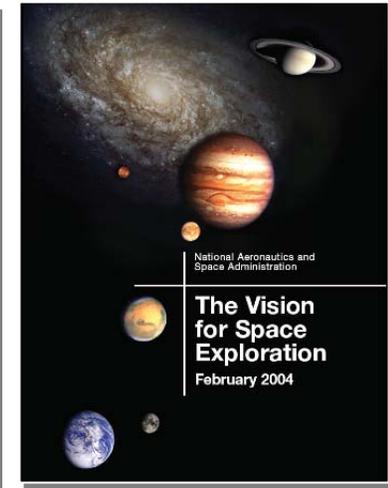
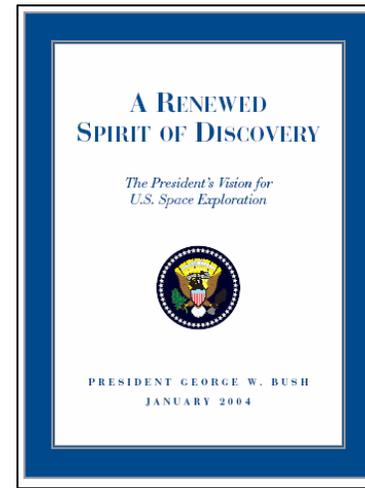
# Outline



- ◆ **NASA's Vision for Exploration**
- ◆ **Constellation Program Overview**
- ◆ **Constellation Vision for Test & Verification**
- ◆ **Test & Verification Implementation**

# The Vision for Space Exploration: Foundations for Exploration

- ◆ Complete the International Space Station
- ◆ Safely fly the Space Shuttle until 2010
- ◆ Develop & fly the Crew Exploration Vehicle no later than 2014
- ◆ Return to the Moon no later than 2020
- ◆ Extend human presence across the solar system & beyond
- ◆ Implement a sustained & affordable human & robotic program
- ◆ Promote international & commercial participation in Exploration



## NASA Authorization Act of 2005

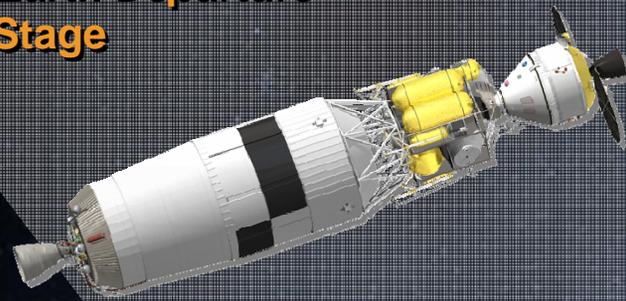
The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations.



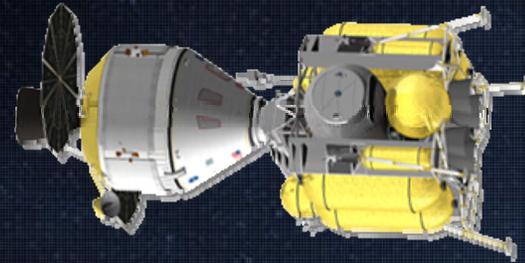
# Constellation Program Fleet of Vehicles



**Earth Departure Stage**



**Orion Crew Exploration Vehicle**



**Ares I Crew Launch Vehicle**



**Ares V Cargo Launch Vehicle**



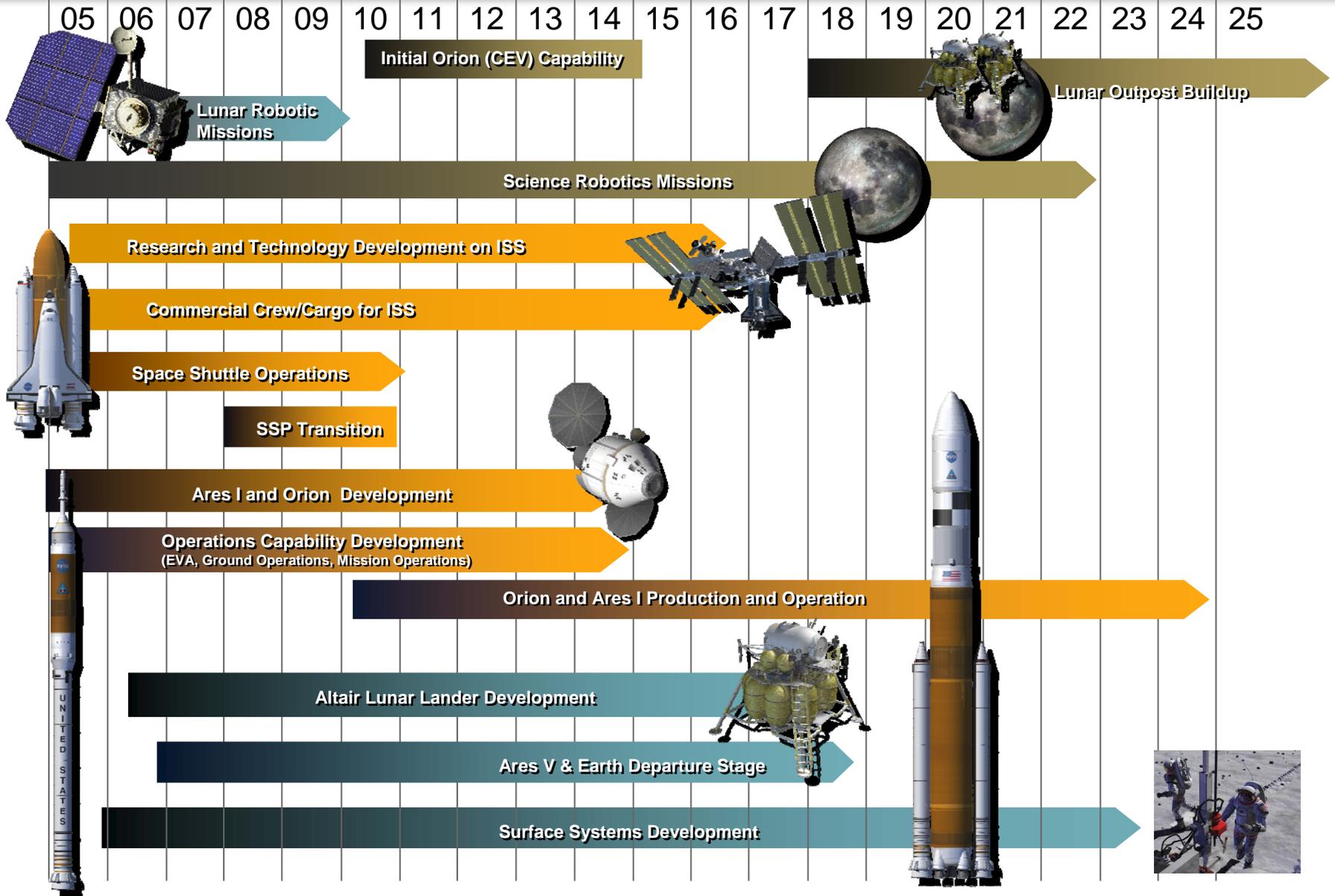
**Altair Lunar Lander**



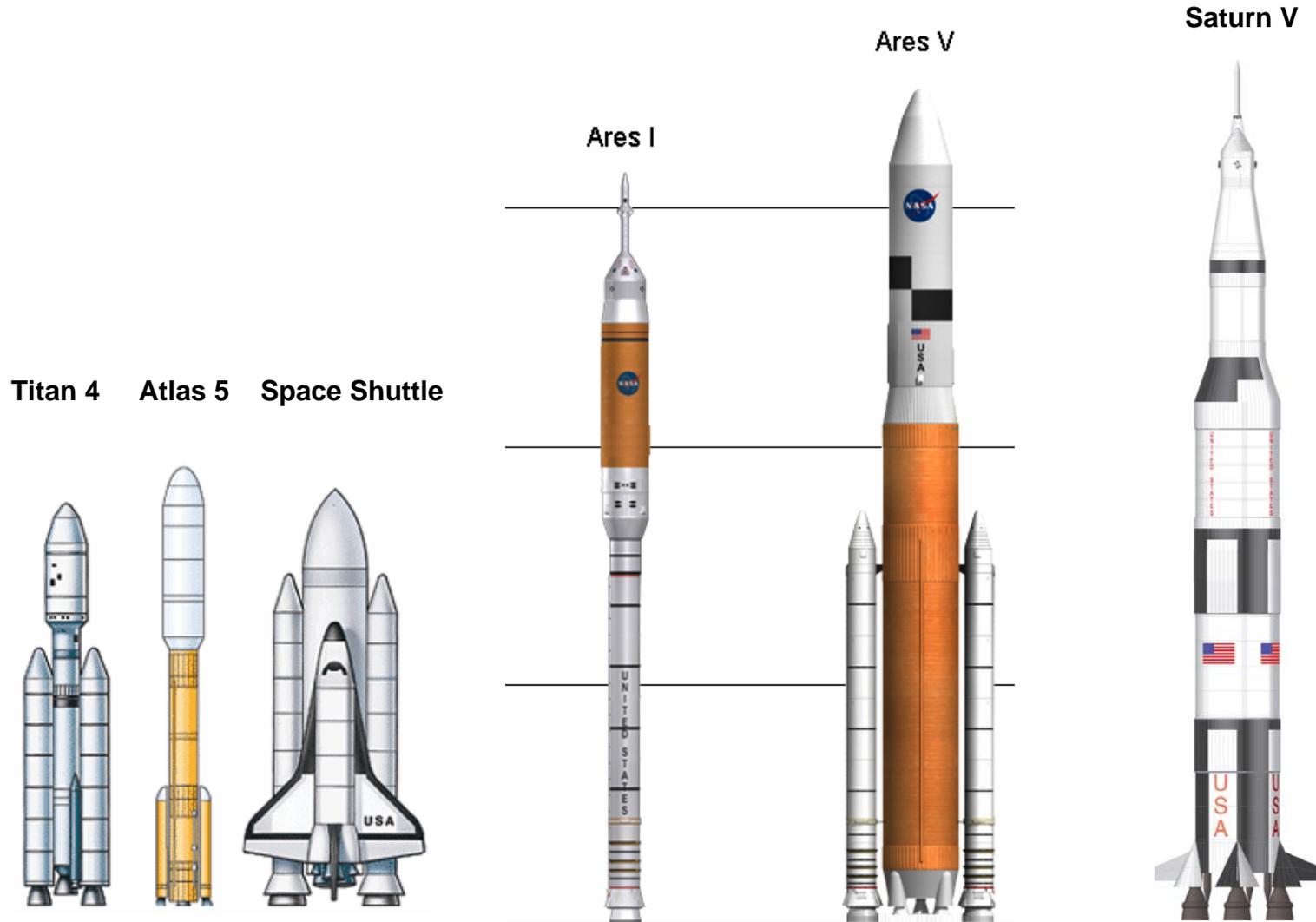


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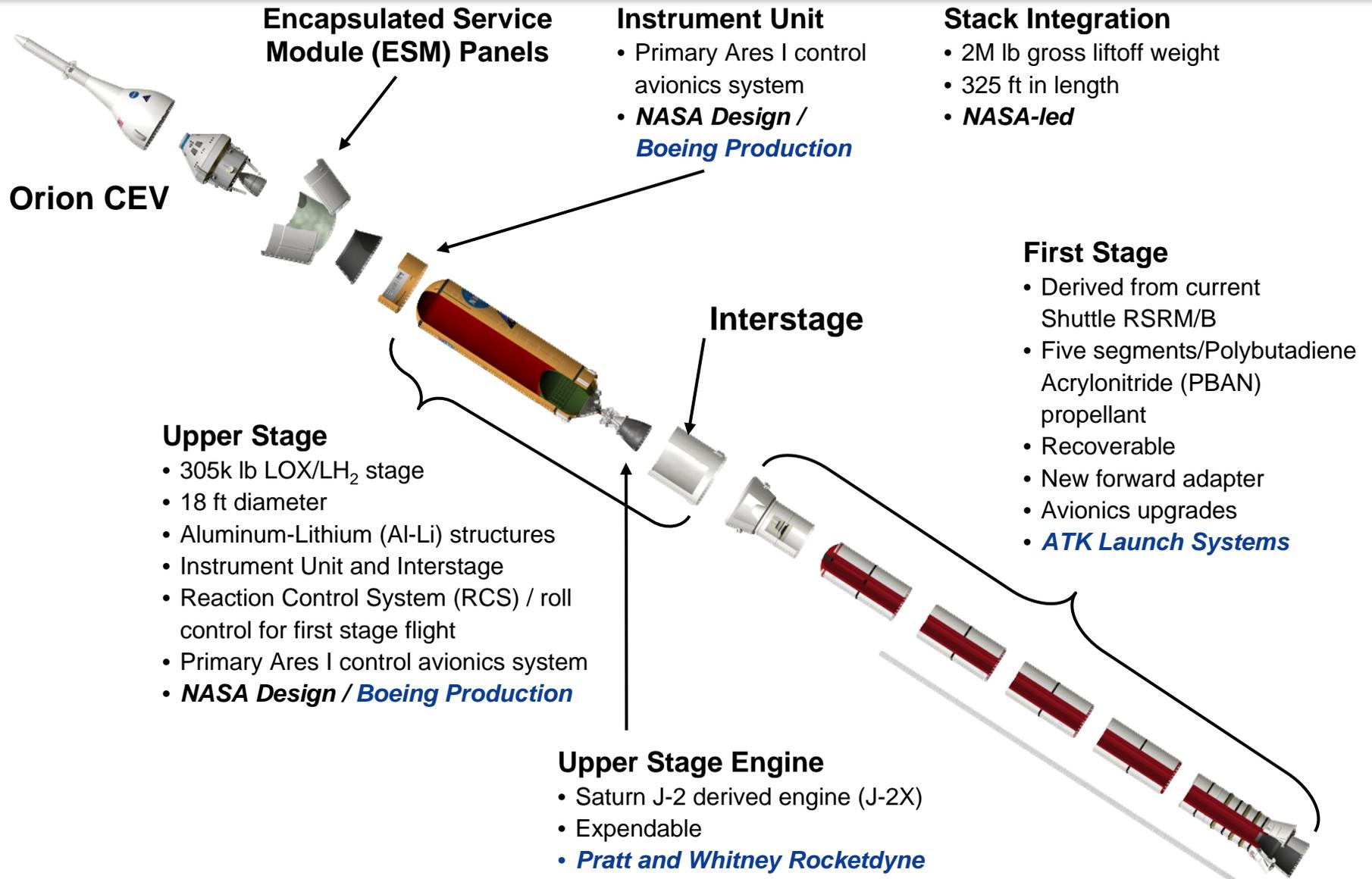
# Exploration Roadmap



# Constellation Vehicle Approximate Size Comparison



# Ares I Elements



## Orion Crew Exploration vehicle (JSC)

- *NASA Management and Integration*
- Prime contract Lockheed Martin: design , development, and production

### Crew Module (JSC)

- Crew and cargo transport
- Under Prime contract

### Launch Abort System (LaRC)

- Emergency escape during launch
- Under Prime contract

### Spacecraft Adapter (GRC)

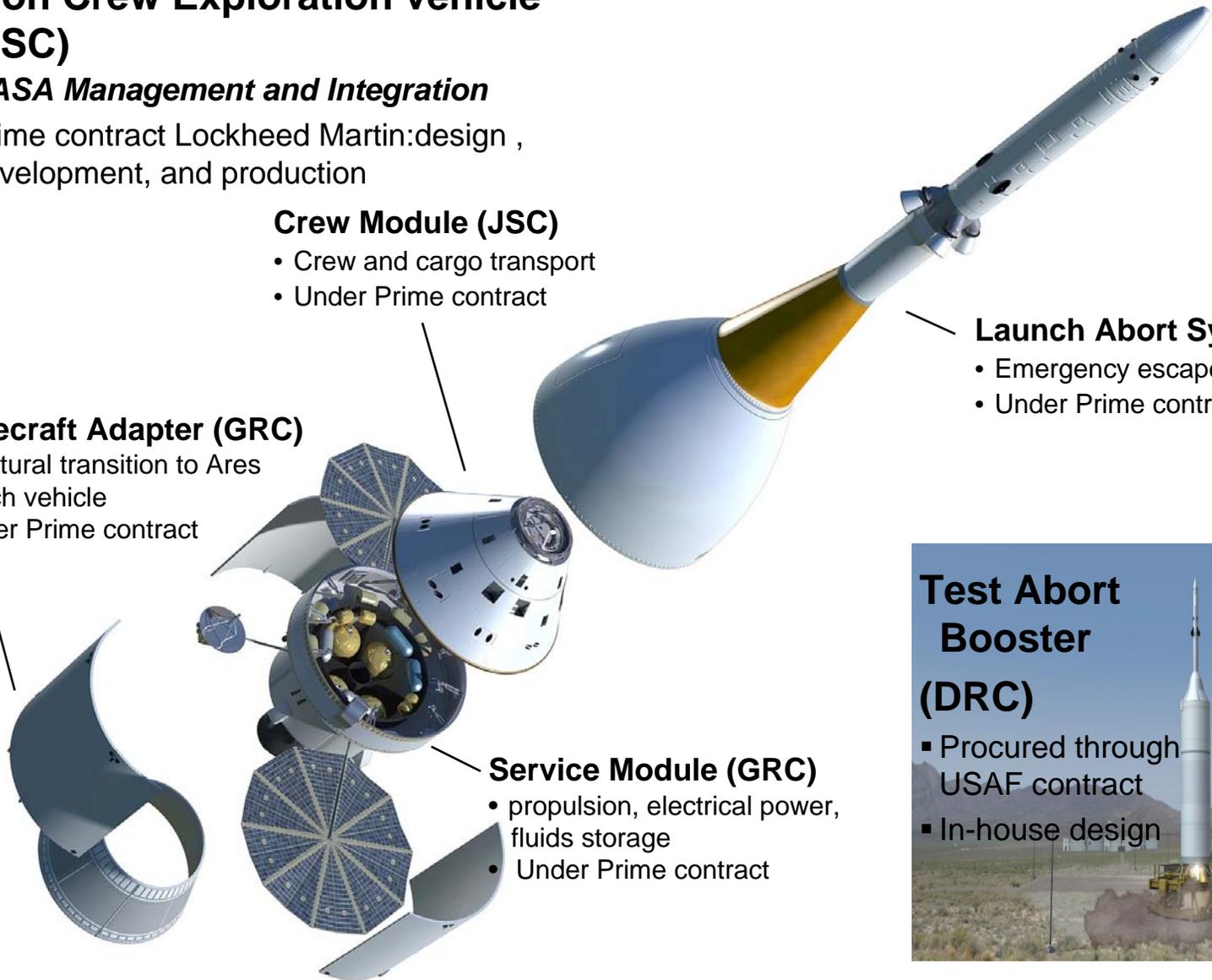
- Structural transition to Ares launch vehicle
- Under Prime contract

### Service Module (GRC)

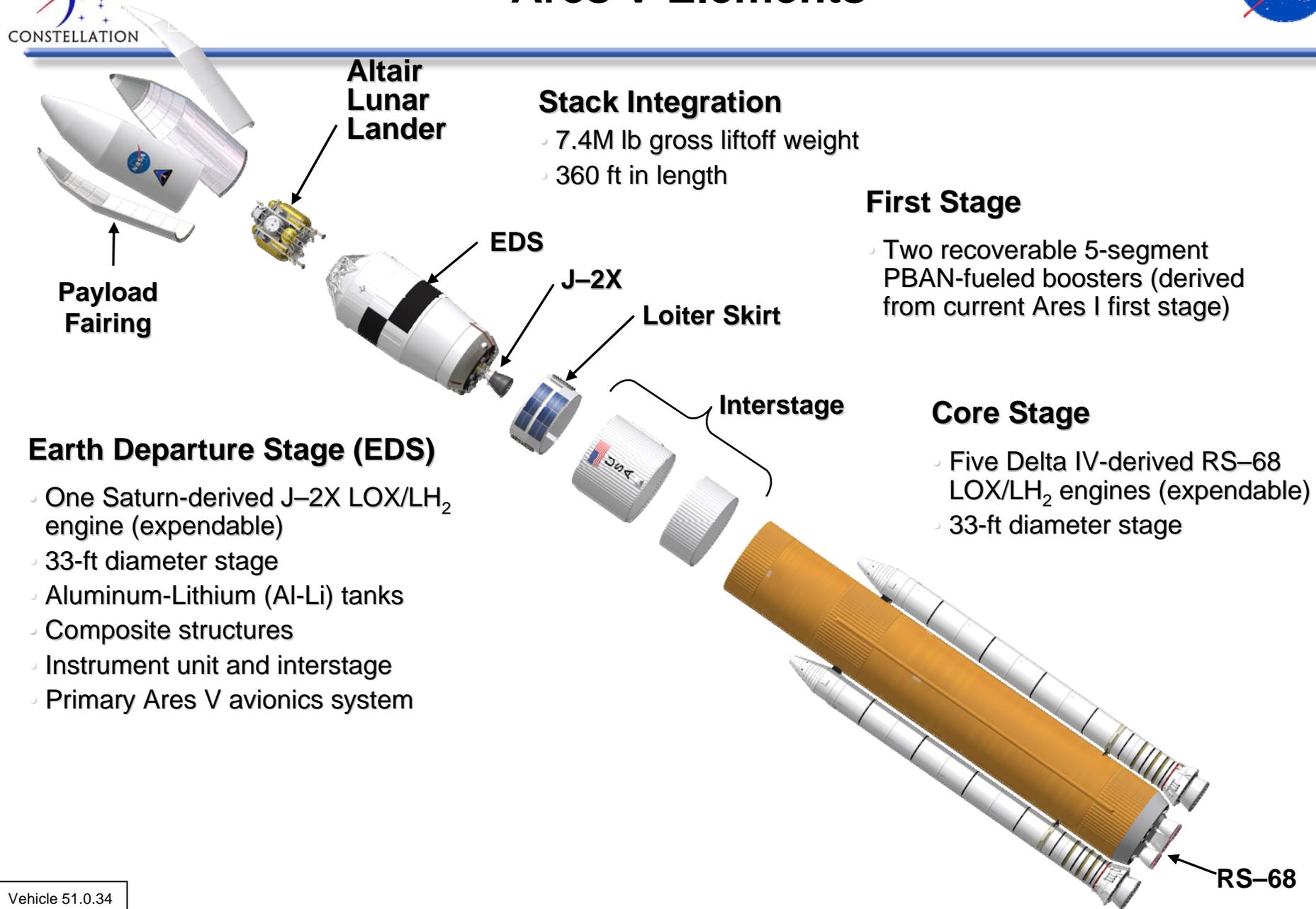
- propulsion, electrical power, fluids storage
- Under Prime contract

### Test Abort Booster (DRC)

- Procured through USAF contract
- In-house design



# Ares V Elements



**Altair Lunar Lander**

## Stack Integration

- 7.4M lb gross liftoff weight
- 360 ft in length

## First Stage

- Two recoverable 5-segment PBAN-fueled boosters (derived from current Ares I first stage)

## Core Stage

- Five Delta IV-derived RS-68 LOX/LH<sub>2</sub> engines (expendable)
- 33-ft diameter stage

## Earth Departure Stage (EDS)

- One Saturn-derived J-2X LOX/LH<sub>2</sub> engine (expendable)
- 33-ft diameter stage
- Aluminum-Lithium (Al-Li) tanks
- Composite structures
- Instrument unit and interstage
- Primary Ares V avionics system

# Lunar Lander



- ◆ **Transports 4 crew to and from the surface**
  - Seven days on the surface
  - Lunar outpost crew rotation
- ◆ **Global access capability**
- ◆ **Anytime return to Earth**
- ◆ **Capability to land 20 metric tons of dedicated cargo**
- ◆ **Airlock for surface activities**
- ◆ **Descent stage:**
  - Liquid oxygen / liquid hydrogen propulsion
- ◆ **Ascent stage:**
  - Storable Propellants



# Map of Constellation content across NASA



## Ames

- ◆ Lead Thermal Protection System ADP
- ◆ Aero-Aerothermal database
- ◆ Ares Abort simulations
- ◆ Software and GN&C support



## Glenn

- ◆ Lead Service Module and Spacecraft Adapter integration
- ◆ Flight Test Article "Pathfinder" fabrication
- ◆ Ares I-1 upper stage simulator lead
- ◆ Ares power, TVC and sensors lead
- ◆ J-2X altitude/inspace testing
- ◆ SE&I Support



## Goddard

- ◆ Communications Support



## Dryden

- ◆ Lead Abort Flight Test Integration/Operations
- ◆ Abort Test Booster procurement
- ◆ Flight Test Article Development/Integration

## Langley

- ◆ Ares 1-X
- ◆ Lead Launch Abort System integration
- ◆ Lead landing system ADP
- ◆ Ares I-1 vehicle integration
- ◆ Ares aerodynamics lead
- ◆ SE&I Support



## JPL

- ◆ Thermal Protection System support



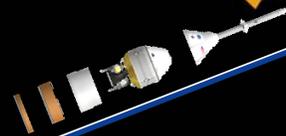
## Kennedy

- ◆ Home for Ground Ops Project
- ◆ Ground processing
- ◆ Launch operations



## Johnson

- ◆ Home for Program
- ◆ Home for Projects: Orion, Mission Ops, EVA, Lunar Lander
- ◆ Lead Crew Module integration
- ◆ Orion Spacecraft Integration
- ◆ GFE projects management
- ◆ Flight Test Program



## Stennis

- ◆ Rocket Propulsion Testing for Ares



## Marshall

- ◆ Home for Ares Project
- ◆ Ares I and V development and integration lead
- ◆ LAS and SM SE&I Support





## *CxP T&V Implementation*



- ◆ **Mission and Vision**
- ◆ **Organization**
- ◆ **Documentation**
- ◆ **Processes**
- ◆ **Integrated Testing**
- ◆ **Flight Testing**



# Challenges in CxP T&V Program



- ◆ **Attrition of workforce experienced in human spaceflight development**
  - Aging of existing human spaceflight programs as well as previous programs
- ◆ **Application of lessons learned**
  - Must ensure lessons learned are applicable to CxP
- ◆ **Developing integrated approach among multiple organizations**
  - Differing practices, documentation, vocabulary
- ◆ **New Information technology environment**
  - Requires shift in thinking from paper processes
- ◆ **Extensive use of heritage hardware envisioned for CxP**
  - Must be applied carefully when mission differs from original



# T&V Strategic Emphasis and Key Tenets



- ◆ **Reinvigorate T&V – thinking, experience, discipline, culture**
  - T&V planners and practitioners get educated via OJT
  
- ◆ **Incorporate lessons learned**
  - Plan a project & THEN plan T&V is a current norm
    - This practice has piles of lessons written on it
  - Planning for T&V must MOVE LEFT
    - CONCURRENTLY with formulation of concepts and requirements
    - Enough work early enough
      - T&V effort INCLUDED in the plan, not added later
  
- ◆ **Rules, standards, practices aimed/set for FAR more reliable exploration systems**
  - Integrated T&V guiding policy, general requirements, standard practices, and cooperative implementation plans and processes



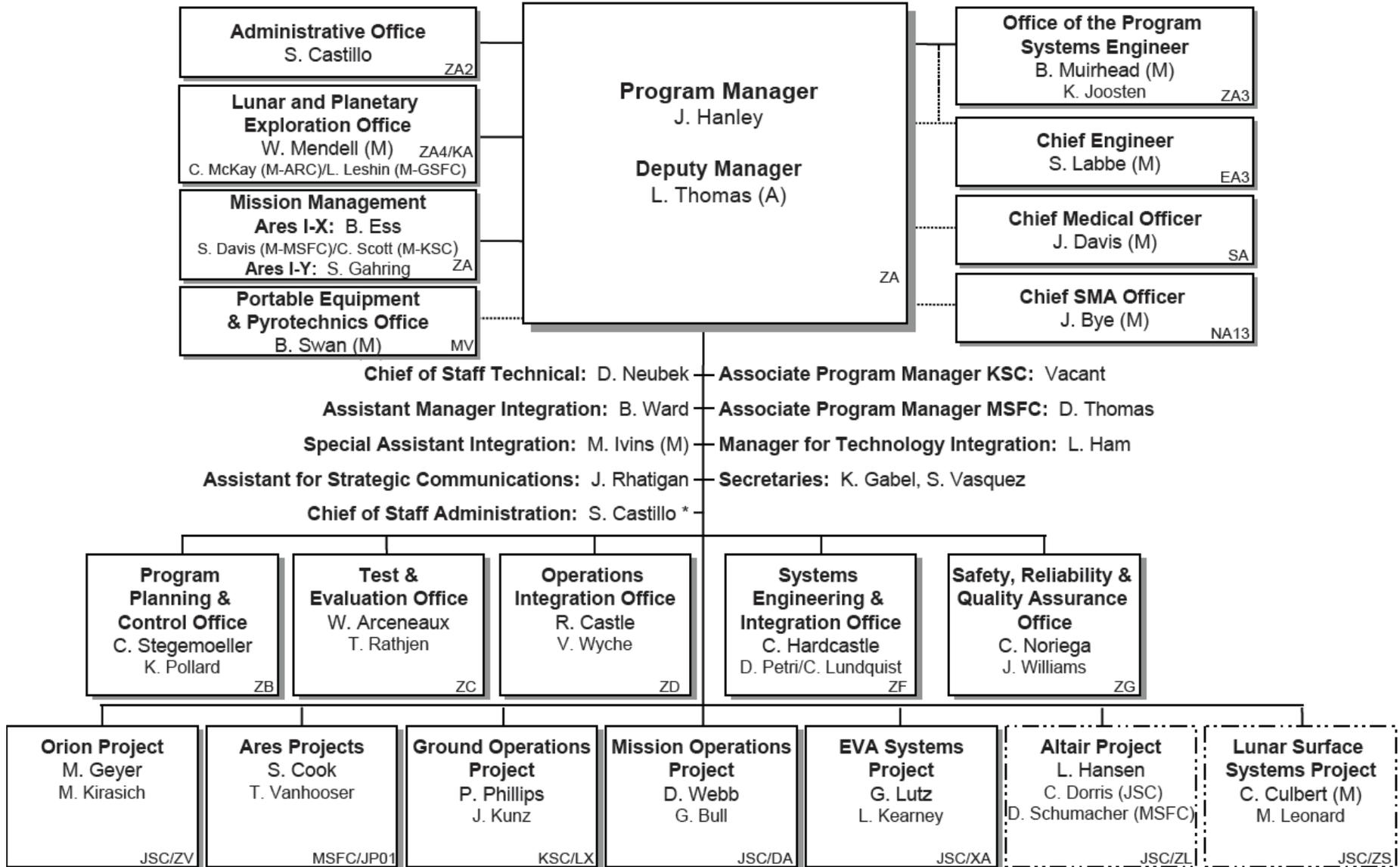
# CxP T&V Mission & Vision



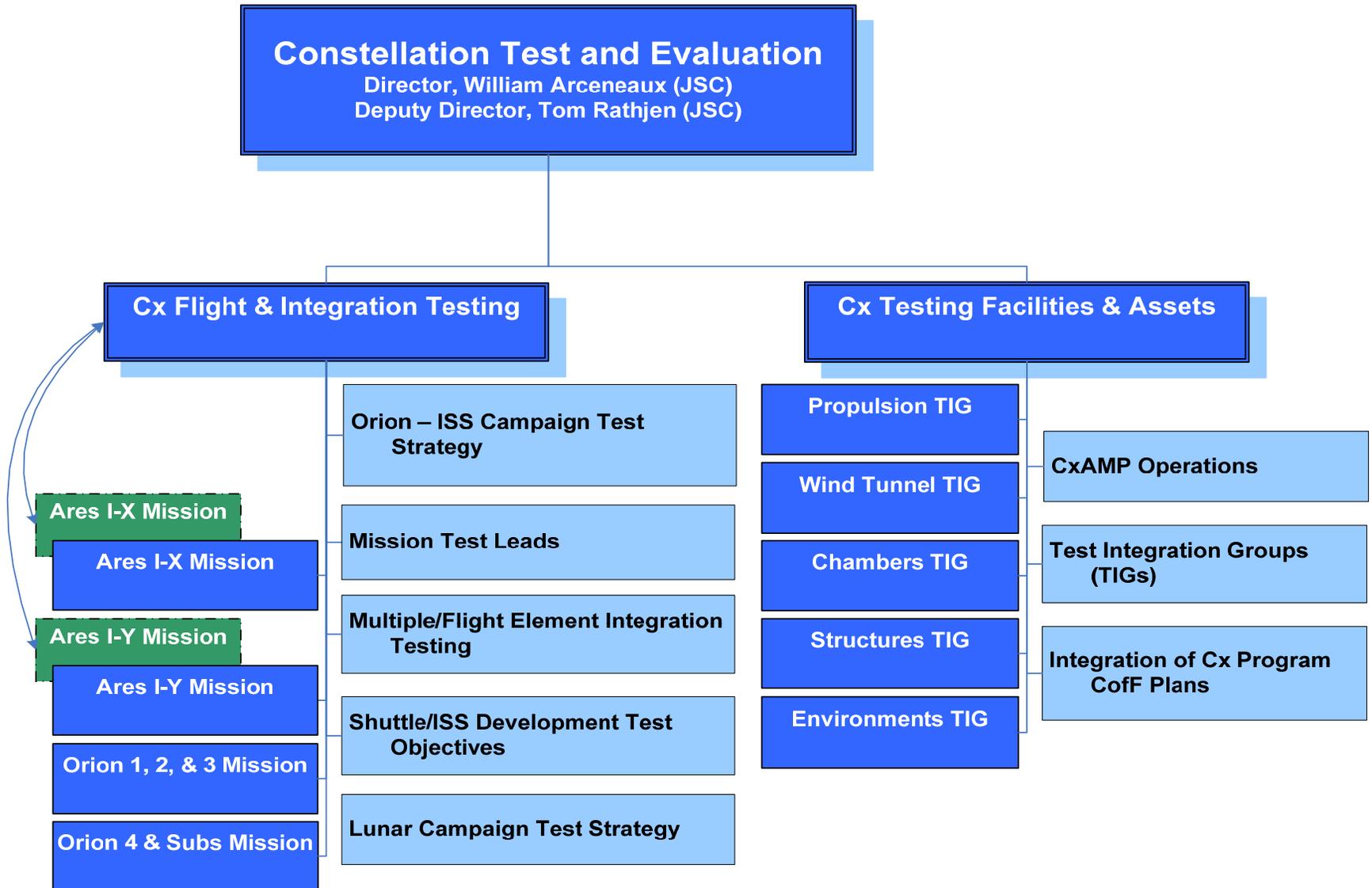
- ◆ **The primary mission of the CxP T&V function is to ensure the following objectives are accomplished through the life of the CxP:**
  - Verification that the Constellation Architecture satisfies the CARD and associated IRDs
  - Verification that each 'end item' meets its specified requirements
  - Verification that the 'end items' appropriately integrate with other end products and "systems", as required (e.g., CEV integration with ISS)
  - Validation that the Constellation Architecture satisfies its stakeholders' needs
  
- ◆ **The vision of the CxP T&V function is that the following items be established, integrated, maintained, and be readily retrievable for all levels of the CxP Architecture throughout the life of the CxP:**
  - A formalized verification process that ensures CxP HW/SW complies with applicable design-to/performance/build-to specifications (e.g., CARD, SRD, ERD, IRDs/ICDs)
  - A complete and readily accessible "materiel history" for all CxP 'end items'
  - A complete "certification baseline" that encompasses all CxP flight HW/SW
  - Processes and tools to support the planning, execution, and assessment of effectiveness for verification activities performed throughout the mission integration lifecycles of each DRM
  - A formalized validation process that confirms that CxP HW/SW and processes fulfill their intended capability, functionality, and performance



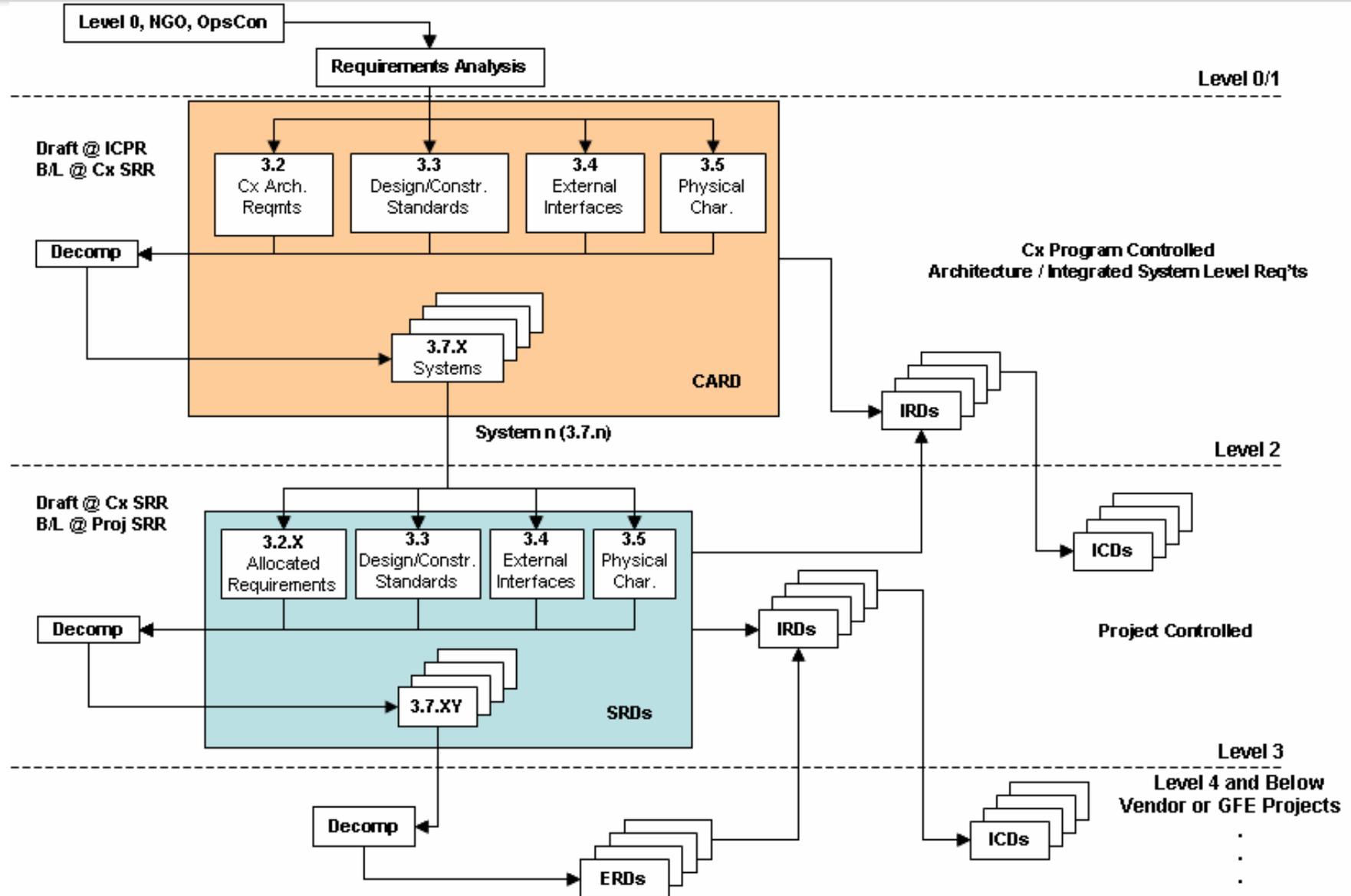
# Constellation Program Organization

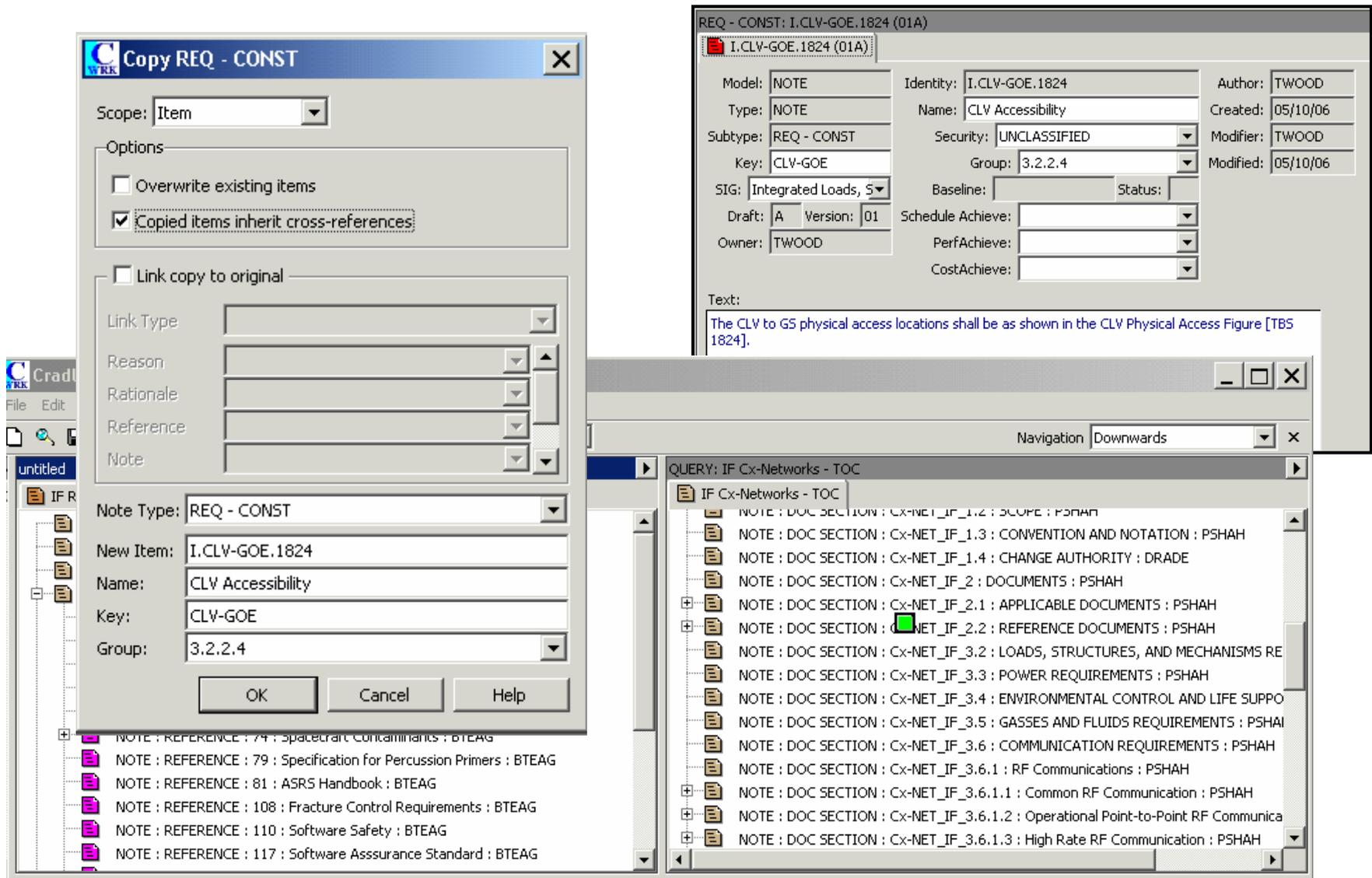


# Test and Evaluation Organization



# CxP Requirements Flowdown

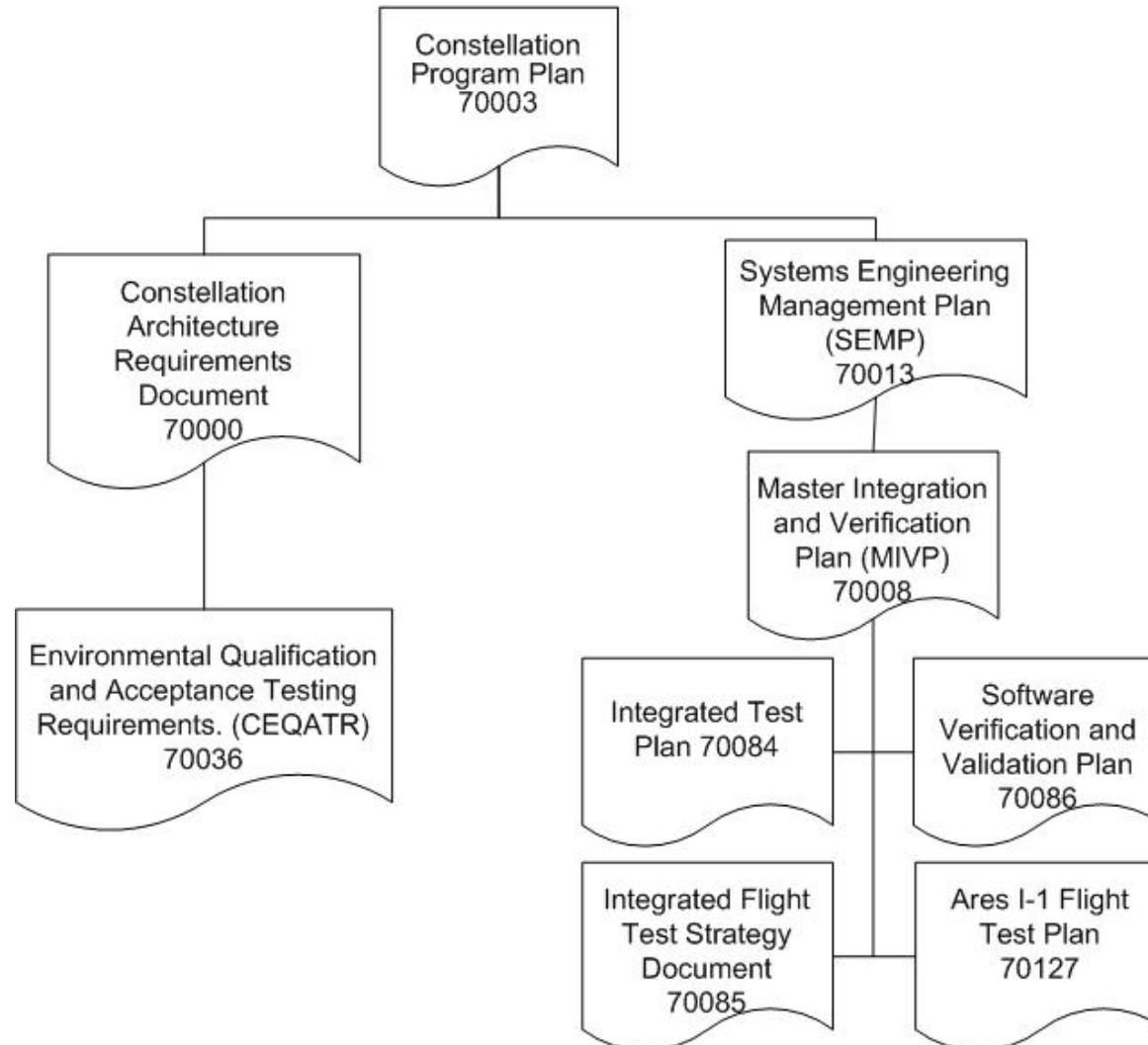




The screenshot displays a software interface for managing requirements. It features three main windows:

- Copy REQ - CONST Dialog:** A dialog box for copying requirements. The 'Scope' is set to 'Item'. Under 'Options', 'Copied items inherit cross-references' is checked. The 'Link Type' is set to 'Reference'. The 'Note Type' is 'REQ - CONST'. The 'New Item' is 'I.CLV-GOE.1824', the 'Name' is 'CLV Accessibility', the 'Key' is 'CLV-GOE', and the 'Group' is '3.2.2.4'. Buttons for 'OK', 'Cancel', and 'Help' are at the bottom.
- REQ - CONST: I.CLV-GOE.1824 (01A) Property Window:** A window showing the properties of the selected requirement. Fields include:
  - Model: NOTE
  - Type: NOTE
  - Subtype: REQ - CONST
  - Key: CLV-GOE
  - SIG: Integrated Loads, 5
  - Draft: A
  - Version: 01
  - Owner: TWOOD
  - Identity: I.CLV-GOE.1824
  - Name: CLV Accessibility
  - Security: UNCLASSIFIED
  - Group: 3.2.2.4
  - Baseline: (empty)
  - Status: (empty)
  - Author: TWOOD
  - Created: 05/10/06
  - Modifier: TWOOD
  - Modified: 05/10/06
  - Schedule Achieve: (empty)
  - PerfAchieve: (empty)
  - CostAchieve: (empty)
- QUERY: IF Cx-Networks - TOC Tree View:** A tree view showing a table of contents for a query. The root is 'IF Cx-Networks - TOC'. It contains several 'NOTE : DOC SECTION' entries, such as 'Cx-NET\_IF\_1.2 : SCOPE : PSHAH', 'Cx-NET\_IF\_1.3 : CONVENTION AND NOTATION : PSHAH', and 'Cx-NET\_IF\_2.2 : REFERENCE DOCUMENTS : PSHAH'. The 'Cx-NET\_IF\_2.2' entry is highlighted with a green square.

# CxP Verification Planning Documents



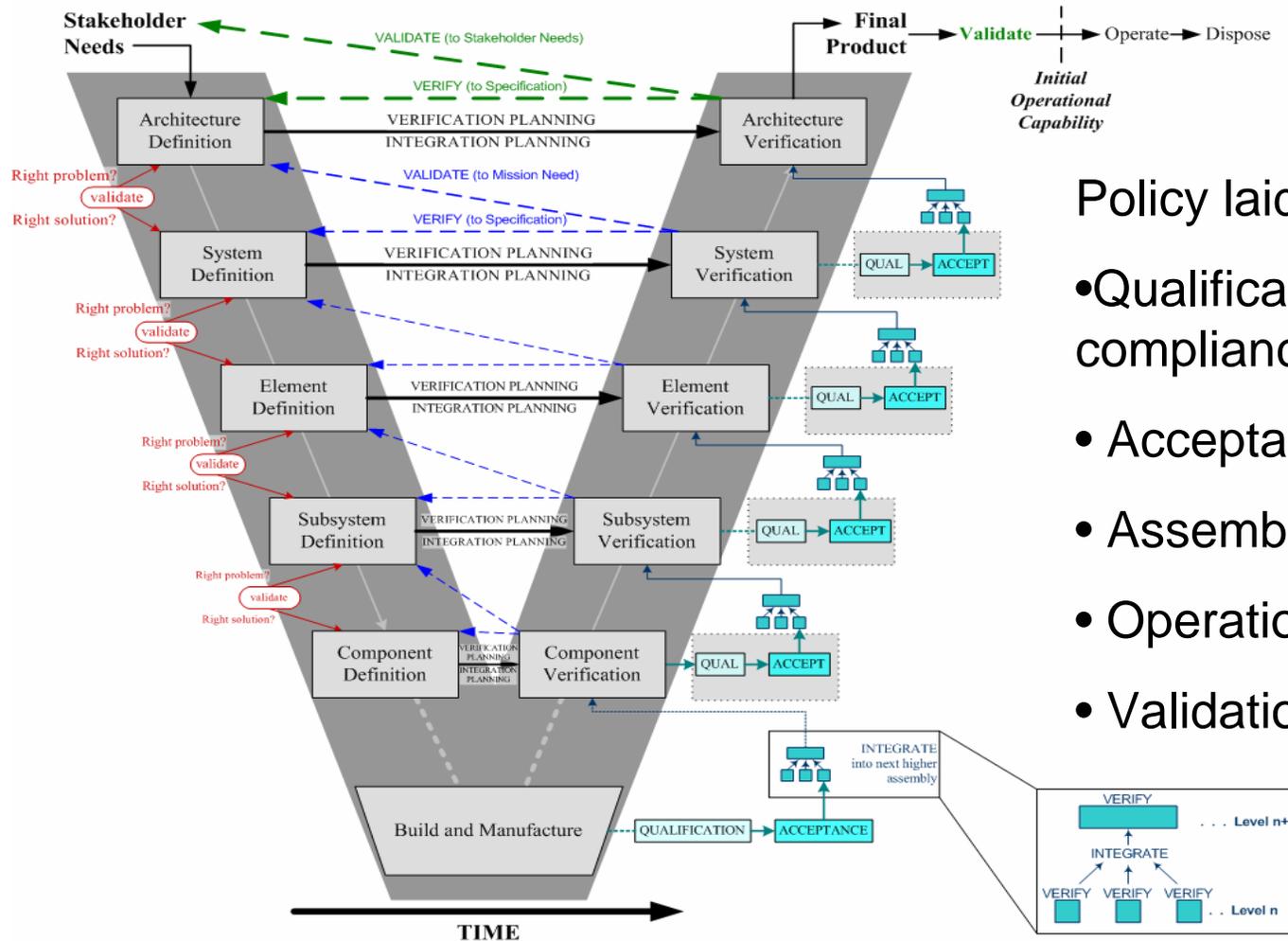


# Environmental Testing



- ◆ **Developed CxP 70036 CxP Environmental Qualification and Acceptance Test Requirements**
- ◆ **Roughly equivalent to MIL-STD-1540, but many practices differ from DoD**
- ◆ **Utilizes Risk-based tailoring process**
- ◆ **Document addressed varying test practices within NASA community**
- ◆ **Resulted in formation of Environmental Testing Community of Practice (CoP)**

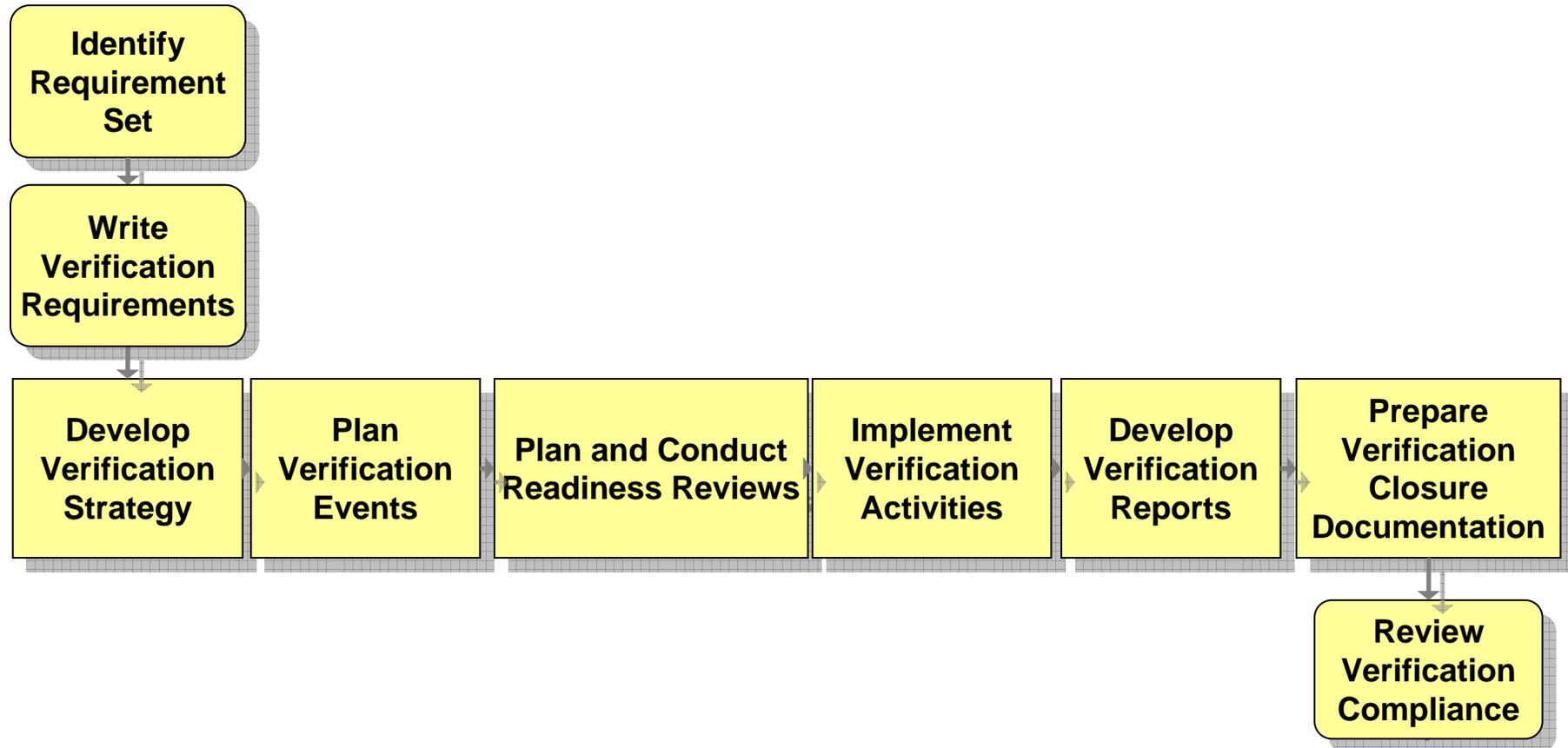
# Scope of CxP Verification



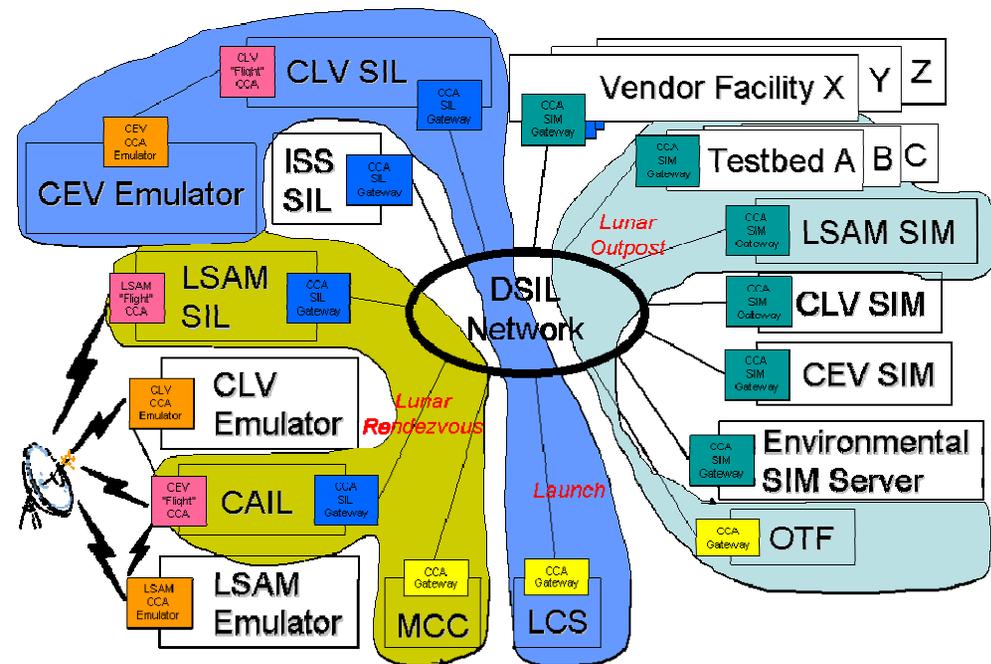
Policy laid out for -

- Qualification (specification compliance)
- Acceptance (N+1)
- Assembly and checkout
- Operations
- Validation

# CxP Verification - General Process Flow



- CxP will use distributed approach for avionics and software integration and verification
- Utilizes high speed networks to leverage existing test facilities rather than developing a standalone integrated test facility



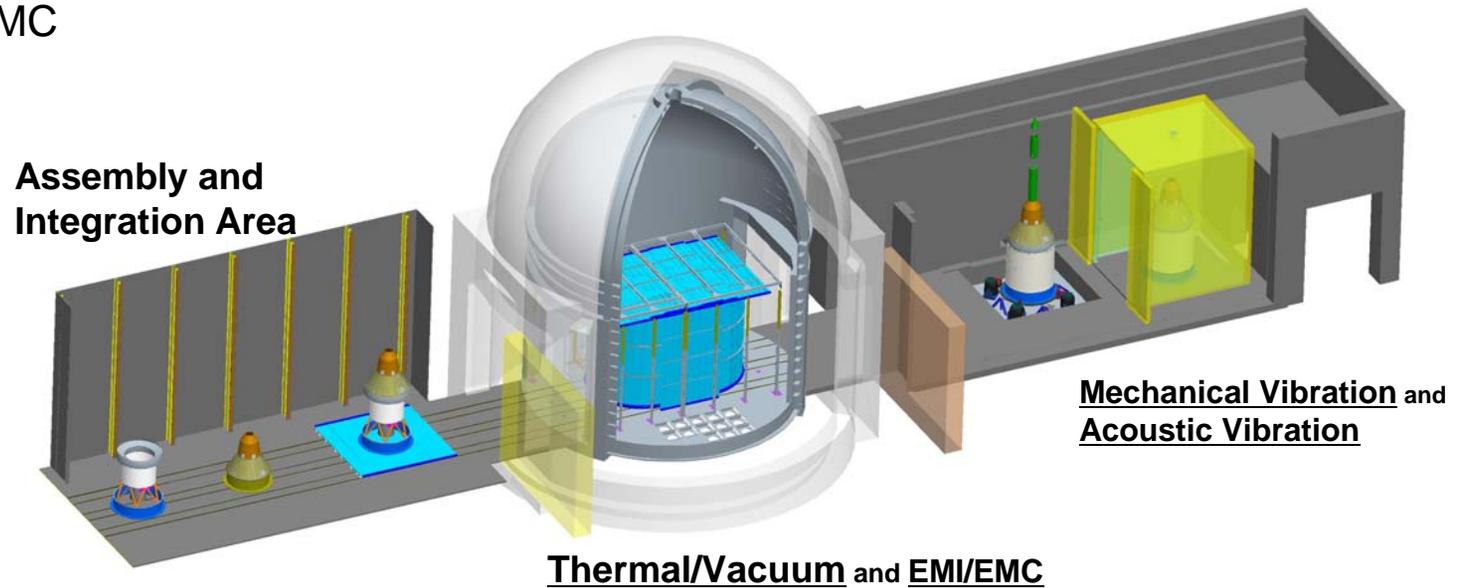
## A-3 Test Stand

- ◆ Located at Stennis Space Center
- ◆ Will be used to test J-2X engine
- ◆ First large test stand built at the center since the 1960s
- ◆ 300-foot-tall, open-frame design will allow engineers to simulate conditions at different altitudes in order to test the J-2X's ability to function as a second stage engine for the Ares I and the Earth Departure Stage engine for the Ares V
- ◆ Test stand will generate approximately 4,620 pounds per second of steam to reduce the engine test cell pressure.



# Space Power Facility

- ◆ **Glenn Research Center Plumbrook Facility**
- ◆ **Will provide Orion Environmental Correlation Test (ECT) for the Ground Test Article (GTA) (vibro-acoustic) and Integrated Environmental Orion Qualification Testing in a “test as you fly” configuration.**
  - Acoustic Vibration
  - Mechanical Vibration
  - Thermal-Vacuum
  - EMI/EMC





## MEIT and FEIT

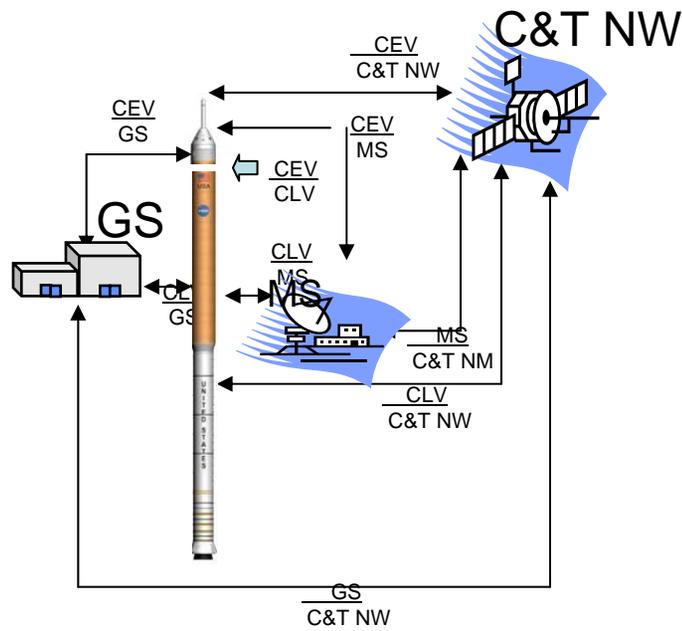


- ◆ **The MEIT and FEIT tests will confirm that the work done by the Projects to verify the interfaces are complete and the elements are ready to fly and support in flight operations.**
- ◆ **Plans for these tests will be outlined in the Integrated Test Plan (ITP)**

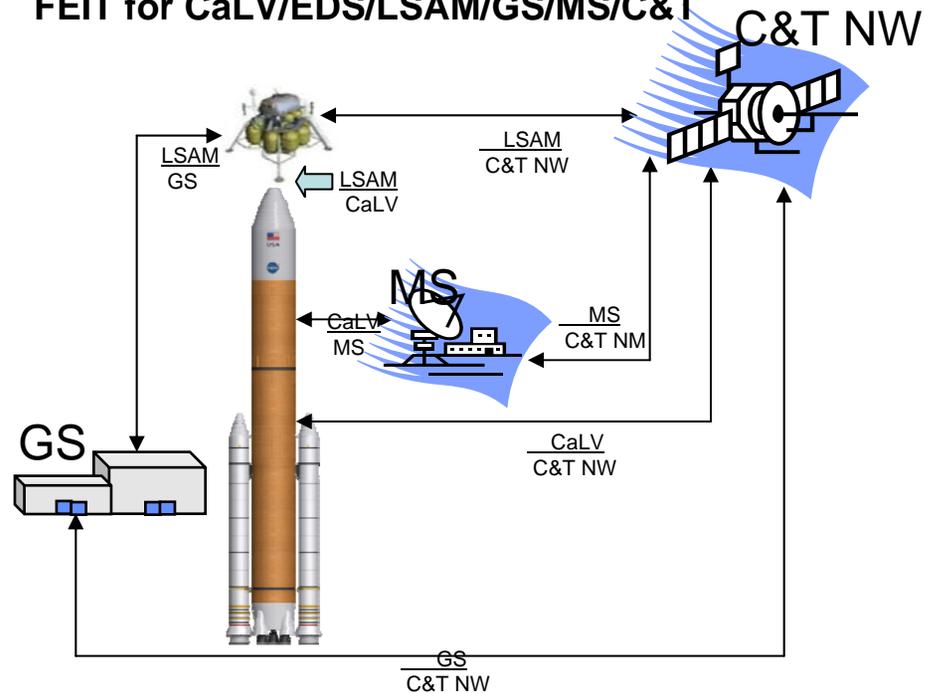
# Flight Element Integrated Test (FEIT)

- ◆ FEIT - An FEIT is an integration test between new or significantly modified systems, elements, and modules being assembled into an integrated launch vehicle for the **first time** (e.g., CEV and CLV; LSAM, Earth Departure Stage (EDS), and CaLV) for the purposes of operational testing (i.e., typically not development testing) or crewed flight.

FEIT for CEV/CLV/GS/MS/C&T

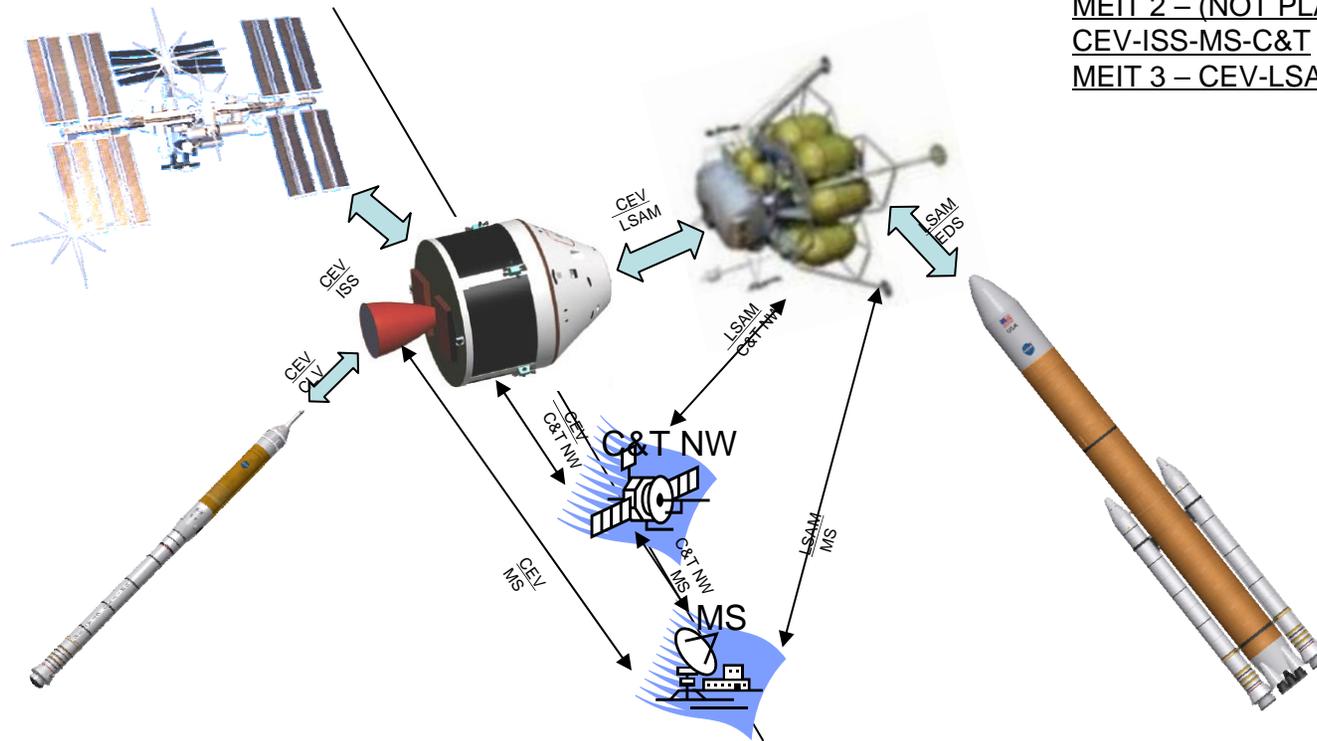


FEIT for CaLV/EDS/LSAM/GS/MS/C&T



# Multi-Element Integrated Testing (MEIT)

- ◆ MEIT - An MEIT is an integration test between two or more flight systems which will be launched on separate launch vehicles and integrated together for the **first time in space** (e.g., CEV and ISS; CEV and LSAM/EDS).



MEIT 1 – Manned CEV-ISS-MS-C&T  
 MEIT 2 – (NOT PLANNED) unmanned  
 CEV-ISS-MS-C&T  
 MEIT 3 – CEV-LSAM-MS-C&T

# Flight Test Driving Principles

- ◆ **Integrated flight test strategy encompasses development through operational validation**
- ◆ **Development tests inform design, models, adjustments**
- ◆ **Validation objectives:**
  - Does the system 'do what we want'?
  - Does the system 'behave as expected'?
  - Do we understand how to operate the system?
- ◆ **A mission's objectives (test, ops) are linked to manifested capability set**
- ◆ **Testing continues after transition into mission service**



# Constellation's Integrated Flight Test Strategy

## Low Earth Orbit Servicing Capability



Ares I-X

### Development Flight Tests

Orion Project

Orion Prime

AA-1  
Max q  
Abort

AA-2  
Transonic  
Abort

AA-3  
Tumble  
Abort

PA-1

PA-2

### Validation Flight Tests (Production Systems)

Ares I-Y Orion 1 Orion 2 Orion 3 Orion 4

High  
Altitude  
Abort

