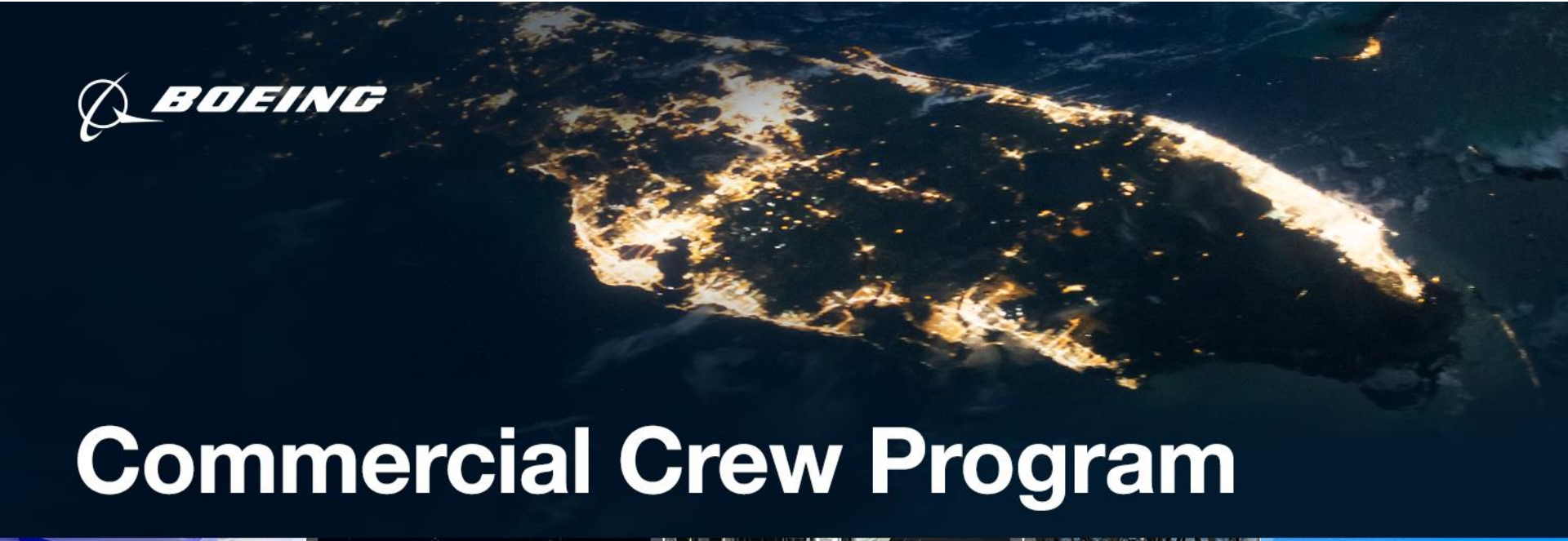


Commercial Crew Program



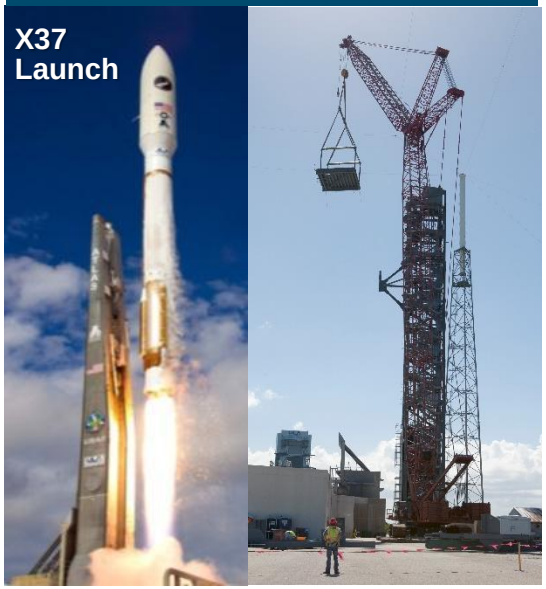

John Mulholland
Vice President/Program Manager, Commercial Programs

CST-100 STARLINER

Program Overview

Commercial Crew Program

Atlas V Launch Vehicle



- 58 successes, and counting!
- Proven rocket significantly reduces system risk
- CCTS integration and crew accommodations are well underway

Starliner Spacecraft

- Flight proven systems
- High TRL technologies
- Successfully completed CDR
- Verification Analysis Cycles underway

Mission Operations

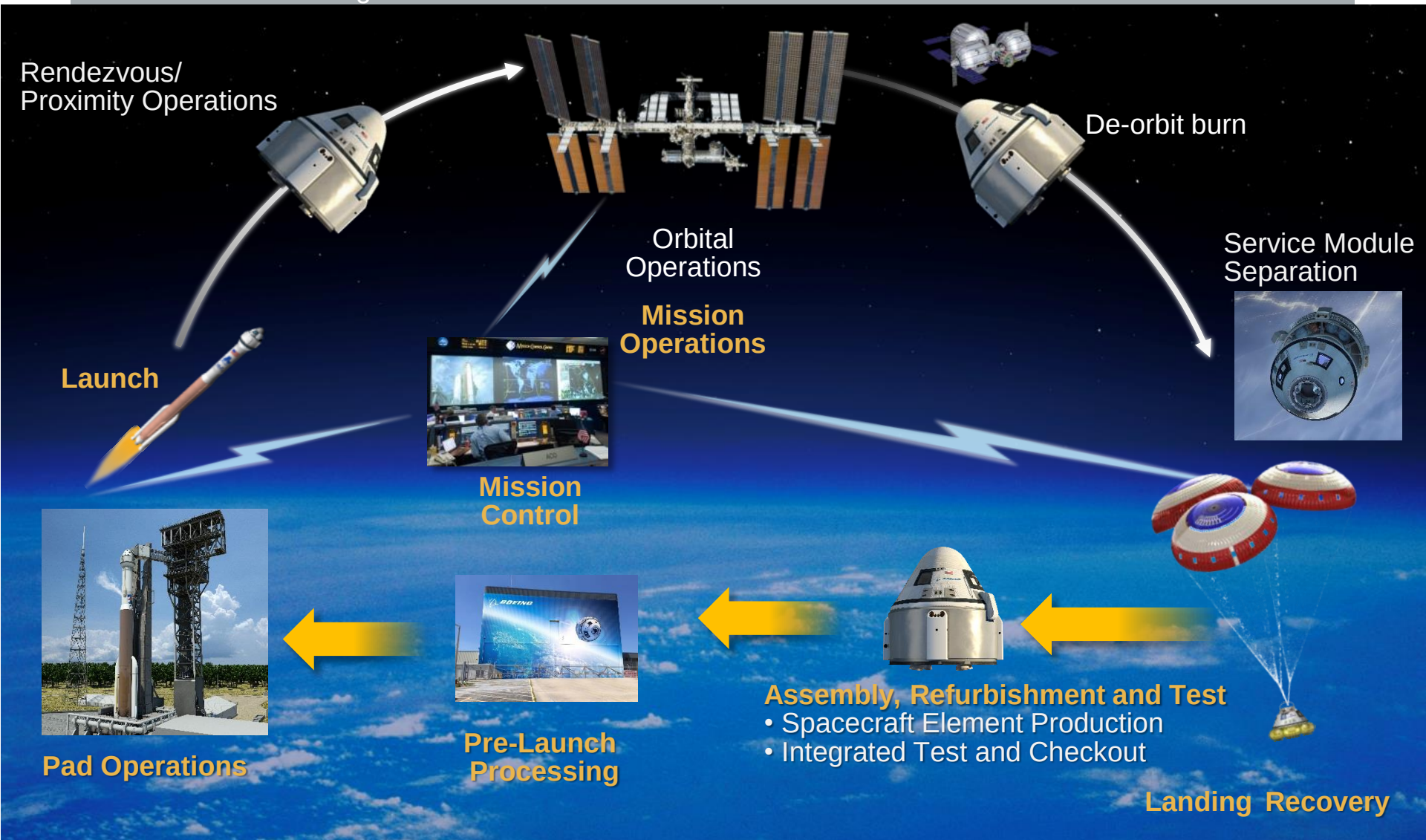
- CCTS approach incorporating world's expert on mission control: NASA Mission Operations Directorate
- Crew engagement throughout planning process

Ground Processing

- Orbiter Processing Facility 3 (OPF3) modifications underway
- Lean production based on Boeing commercial approach
- Integration, testing, and quality processes based on Shuttle and Station approaches

Concept of Operations

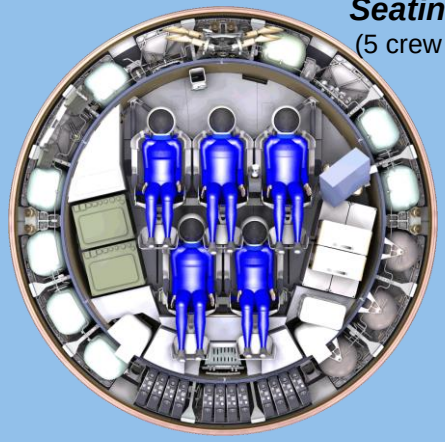
Commercial Crew Program



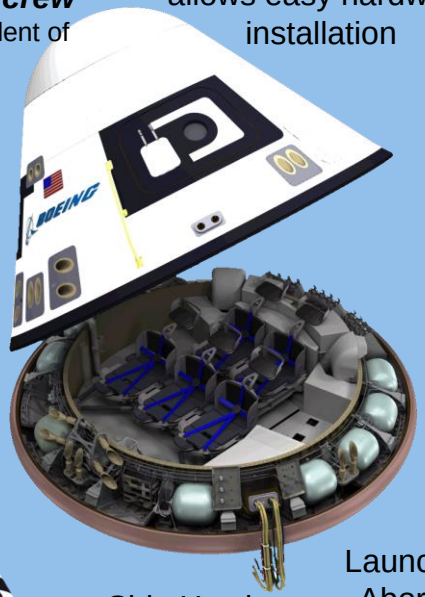
Spacecraft Segment Features

Commercial Crew Program

Seating for up to 5 crew
(5 crew + 2 crew equivalent of cargo shown)

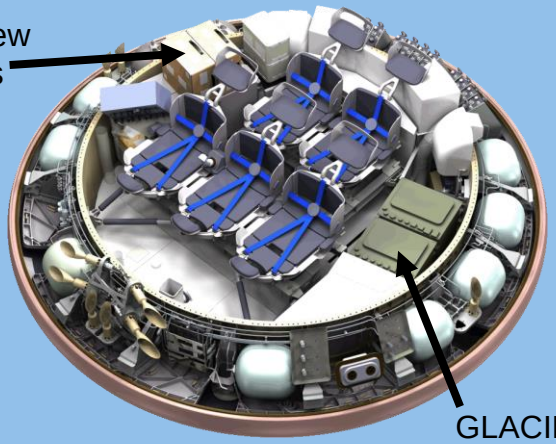


Clam Shell CM Design
allows easy hardware installation

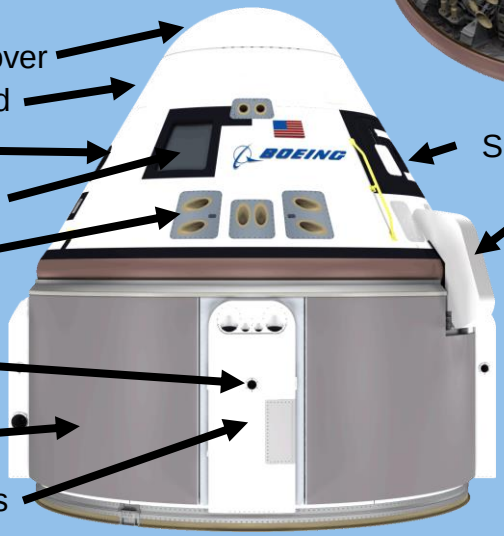


Flexible cabin design
Accommodates mix of crew & cargo

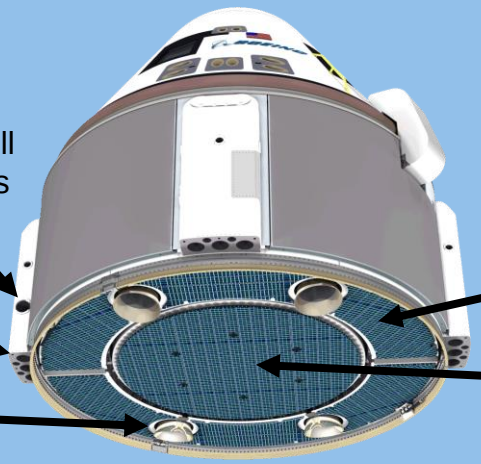
Cargo & Crew Provisions



GLACIER



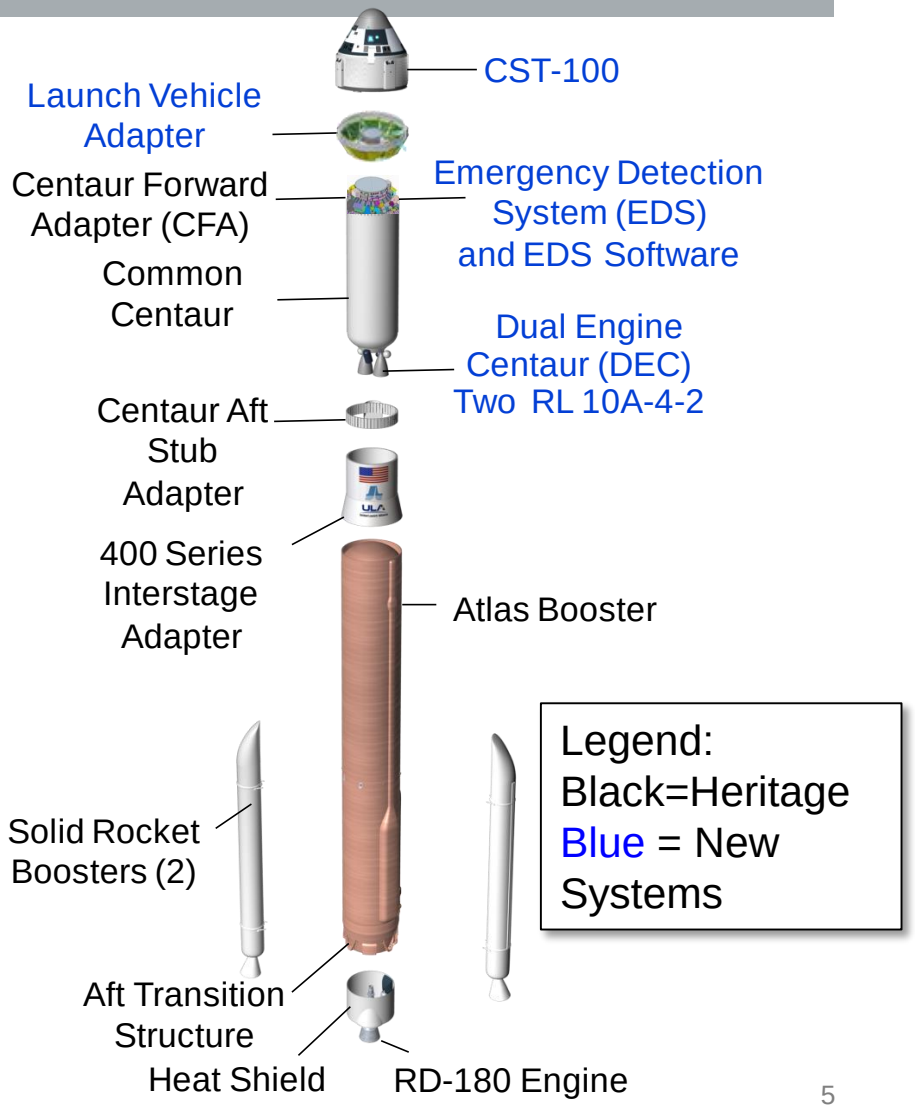
Ascent Cover
Forward Heatshield
Side Window
Forward Window
CM RCS Thrusters
SM RCS Thrusters
Radiators
Thruster Doghouses
Side Hatch
CM/SM Umbilical



Launch Abort System (LAS) Roll Thrusters
LAS Pitch/Yaw Thrusters
LAS Escape Thrusters
MMOD Shields
Solar Panels

Launch Segment Features

Commercial Crew Program



Atlas V-100th Launch

Commercial Crew Program

Ground Segment Features

Commercial Crew Program

Commercial Crew & Cargo Processing Facility

- CM and SM Production & Processing
- CST-100 Integration, Test, and Servicing
- Nominal Cargo Stowage

Boeing Mission Control Center

- CST-100 Checkout & Control System
  - AIT & Prelaunch command and monitoring
  - Backup for audio during free flight ops
- Mission Support Room
  - Engineering support
  - Mission Management Team

Ground Communication

- Comm. between CST-100 and Ground Facilities

Landing Sites

- Crew Egress, Med Eval, and Transport
- Time Critical Cargo Removal and Turnover
- CM Recovery & Transport

Training System

- Boeing Engineering Simulator
- Boeing Part Task Simulator
- Mockup Trainer
- Water Recovery Trainer

MCC-CST

- Mission Operations
- Mission Planning
- Training

The Campaign

Commercial Crew Program

2015/1016

- Component qualification
- STA test initiation – Spring 2016
- QTV first power-on – Summer 2016
- SMHF – test initiation 2016

2017

- Pad Abort
- First Uncrewed Flight
- First Crewed Flight
- Certification

Integration & Test

Commercial Crew Program

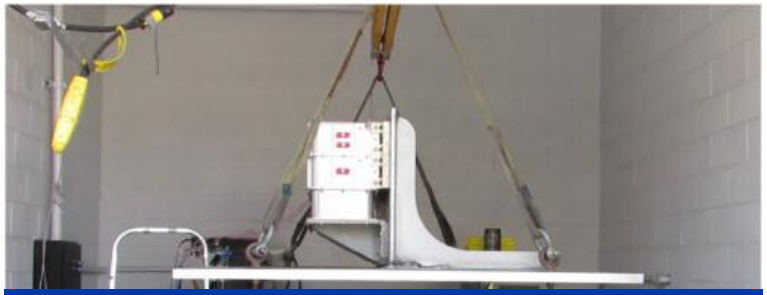
The Campaign

- Component Tests
- Subsystem Tests
- Wind Tunnel Tests

Design Development
Qual Risk Reduction

- Hardware & Software Integration
- Integrated System Verification Tests
- Qualification Test Vehicle
- Structural Test Article
- Service Module Hot Fire
- 3 Flight Tests

STA Upper Dome, Tunnel & Hockey Sticks Assembly Well Underway



Humidity Control System Qual Shock First Component to Complete Qual

CM-SM Near-field Wind Tunnel Testing at AEDC

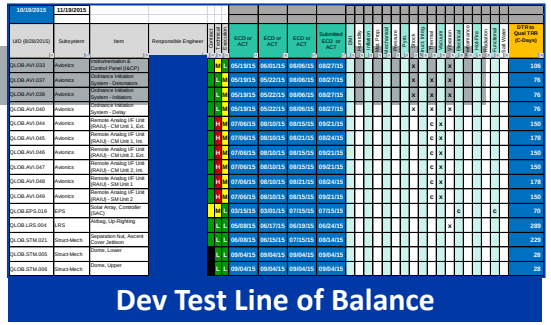
SM Hot Fire Test Stand

Preps for 1st time Spacecraft Activations

Key Focus Areas

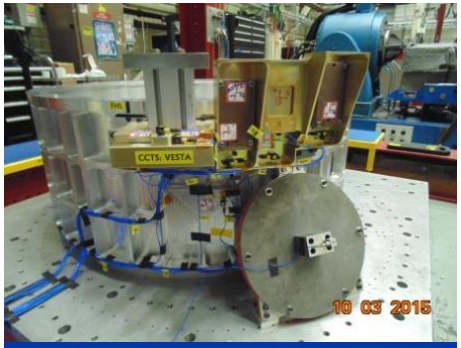
Commercial Crew Program

- **Component Test Performance**
  - Development Tests: Shock, Vibe, Thermal &/or Vac
    - 39 completed this year
    - 15 completed in past 90 days
    - 14 components in test



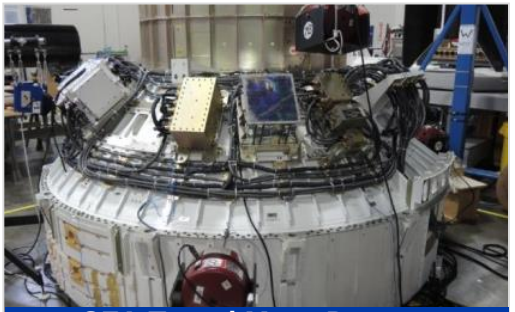
Dev Test Line of Balance

Battery and PCA Development Testing



VESTA Shock Setup

SureSEP Success,12 of 12 Runs



CFA Tuned Mass Damper Development

Targeted Investments in Component Development Testing Paying Dividends in Retiring Substantial Risks to Qualification

Key Focus Areas (Cont)

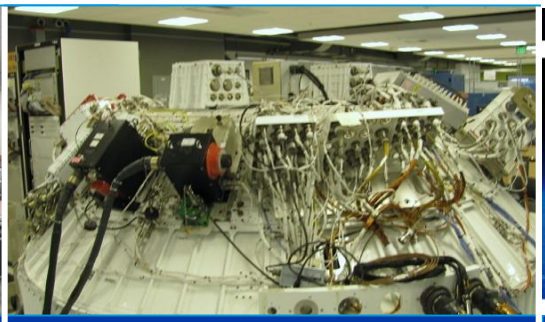
Commercial Crew Program

- **Flight SW, HSI & 1st Time Integration**
  - Spacecraft Activation Procedures now in Dry-runs
  - Right-sizing Flight Software Incremental Drops
  - 714 KSLOCs of 913 KSLOCs Developed
  - Completed Command & Control System V&V
  - Progressing on KSC Boeing Mission Control Build
  - Leveraging Boeing Avionics SIL, Training SIL & ULA SIL

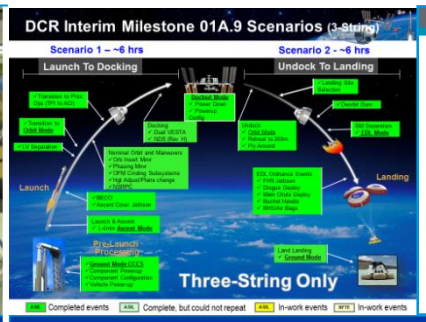
Houston Avionics SIL

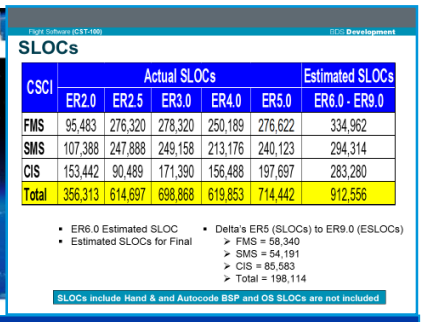
Houston Training SIL

Boeing Mission Control Center - KSC



ULA EDS SIL





Flight SW Maturation and E-t-E Demonstrations

Spacecraft/Architecture Activations & Checkout Emphasis

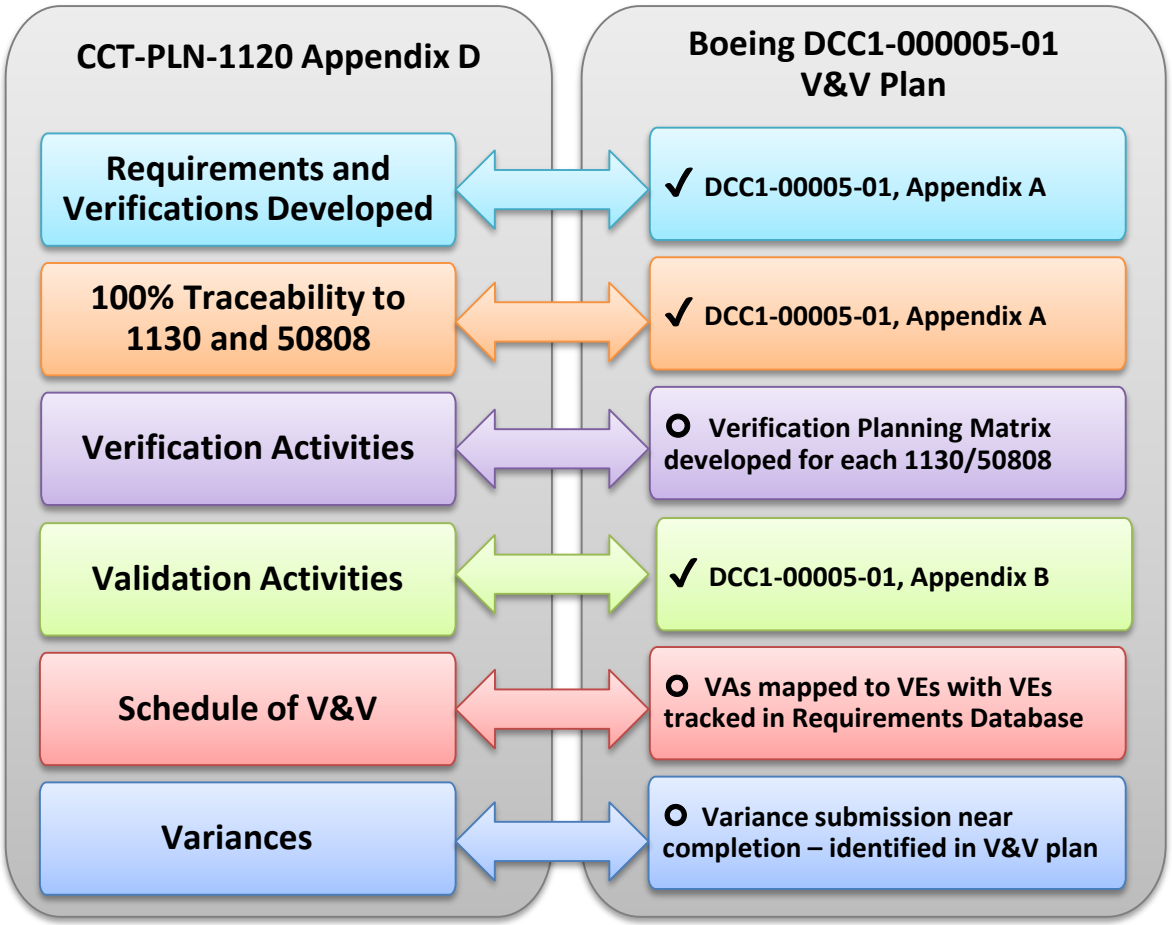
Boeing Starliner
Verification, Test, and Certification

Commercial Crew Program

- Boeing's verification methods and activities directly trace to NASA CCT-REQ-1130 and ISS SSP-50808
- The vehicle test program is shaped to provide direct verification of design and hazard requirements and supply the data from testing to correlate the design analytical models.
- A robust Certification of design is derived from NASA 1100 series and assigned applicable documents leveraging Boeing Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA) reviews
- A one time Certification of Design is extrapolated and reviewed to execute a Certification of Flight Readiness (CoFR) for each mission and on-orbit flight tests

Verification &Validation (V&V) Status

Commercial Crew Program



✓ Complete O In Work

Status of In Work Items:

- VA's/VE's:
  - All Verification Activities linked to NASA requirements
  - All VA's linked to a verification event
  - Close coordination with NASA through review and comment
  - Boeing baseline Nov 2015
- Variances:
  - All variances submitted, save a few to be submitted by Nov 2015
  - Close coordination with NASA prior to submittal
  - A few variances will not close until test data received later in program

Direct Trace to NASA CCT-REQ-1130 and ISS SSP-50808

Boeing Verification Requirement Maturity

Commercial Crew Program

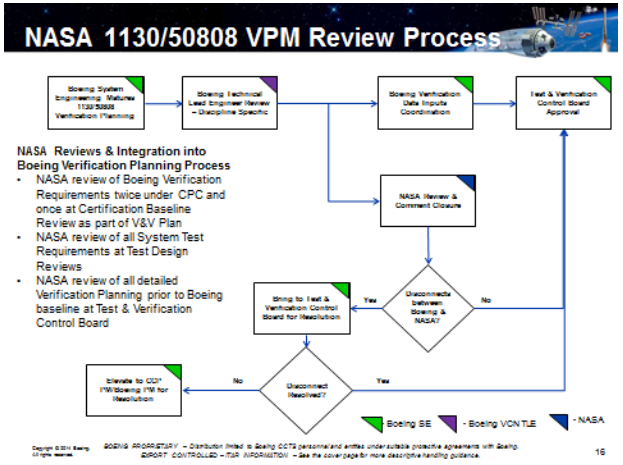
- ✓Boeing Certification Plan Approved
  - NASA Type 1 Document
  - Documents Boeing approach to certifying all elements of CCTS
- Boeing Verification & Validation Plan in NASA approval cycle
  - Program IPTs and Key Personnel engaged
  - NASA issues resolved, NASA Approval ECD Nov 2015
- ISS Joint Integrated Test Verification Plan at NASA for Vetting
  - Collaborated on all aspects to minimize joint impact
  - Anticipate receipt of revision via Contract ECD Nov 2015

With V&V Plan and JIVTP approval, Boeing will have agreement with full set of Verification Requirements

NASA 1130/50808 VCN Planning Maturity

Commercial Crew Program

- Top down verification planning for each 1130/50808 requirement
  - Captured in Verification Planning Matrix (VPM)
    - Requirement trace from NASA requirement to appropriate Boeing requirement(s)
    - Applicable Verification Requirements
    - Applicable Verification Activities
    - VA supporting products (jointly developed by requirement SME/owner and SE&I)



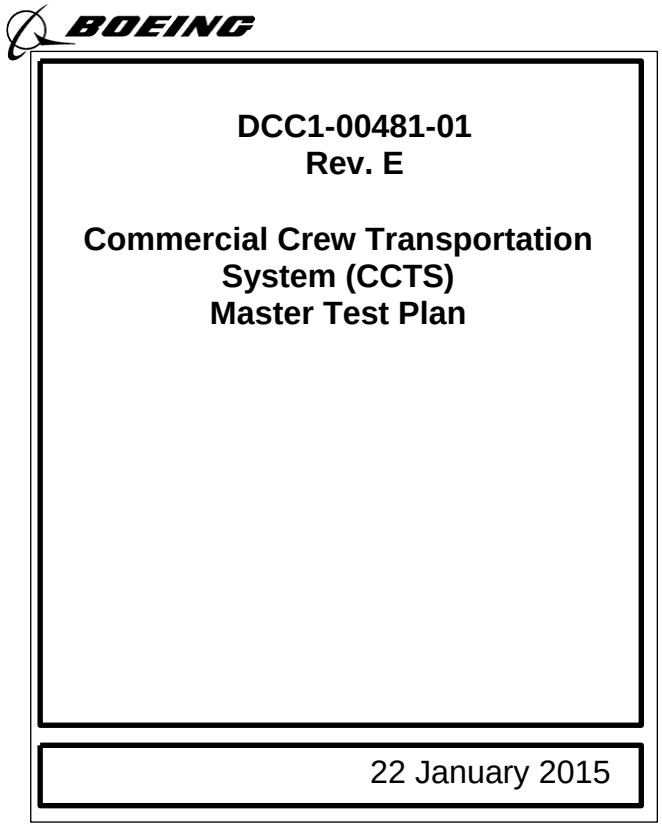
- Close coordination with NASA on VPM content
  - NASA receives at least 2 weeks of review on each VPM
  - Outstanding issues between NASA and Boeing will first be addressed at Test and Verification Control Board and then elevated to Engineering Control Board if a resolution cannot be achieved

Once VPMs are baselined at TVCB (currently Nov 2015), VCN closure schedule will show closure of all 1130/50808 requirements

Master Test Plan

Commercial Crew Program

- Defines and baselines the CCTS Program Test Architecture
  - Verification approach by test and demonstration
  - Validation by test and demonstration in an incremental approach
- Test Approach and Methodology
- Test Facilities and Test Article Definitions
- Test Processes and Data Products
- Test Management and Test Team Organization
- Tailored processes to meet MTP intent
  - MOD tests tailored for existing MOD/FDOC processes
    - NPR 7123.B
  - LS test processes contained within all V&V requirements
    - Atlas V Test Plan



Certification Approach

Commercial Crew Program

- Certification is guided by:
  - CCT-PLN-1120 Crew Transportation Technical Management Processes
  - CCT-PLN-2000 NASA CTS Certification Plan

- CCTS certification is accomplished using a four-step approach
  - Step 1: Define requirements baseline
  - Step 2: Compile evidence needed to develop certification data packages
  - Step 3: Complete certification assessment reports (CARs) and checklists documenting the module, segment, and system endorsements in support of CCTS certification review and approval
  - Step 4: Complete integration with and support of CCP and ISS boards gaining NASA's approval

- Certification takes place at the component, module, segment and system levels
  - Certification of Design (CoD) – Ensures that the verification of CCTS requirements are aligned to NASA CCT-REQ-1130, SSP 50808, CCTS design specification requirements, and vehicle configuration has been properly verified
  - Certification of Flight Readiness (CoFR) – Ensures that the V&V is complete, liens and constraints have been dispositioned with an acceptable level of risk to commit to flight, and mission specific loads are verified and ready

Summary

- Boeing is designing a safe and reliable spacecraft with detailed requirement verification evidence, system qualification execution, and robust certification vetting.
- The lineage from NASA CCT-REQ-1130 and SSP 50808 through Boeing CCTS design specification requirements, verification requirements, to verification closure is clearly defined
- Testing from components to major assemblies leverages multiple test articles and facilities to extract the correct system performance response across various environments.
- Test data is integrated to complete the validation of design models and close the analysis
- Increments of ground verification generate FCA, PCA, and Certification Assessment Reports which cumulatively facilitate the CoFR decision