



Commercial Crew Program



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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

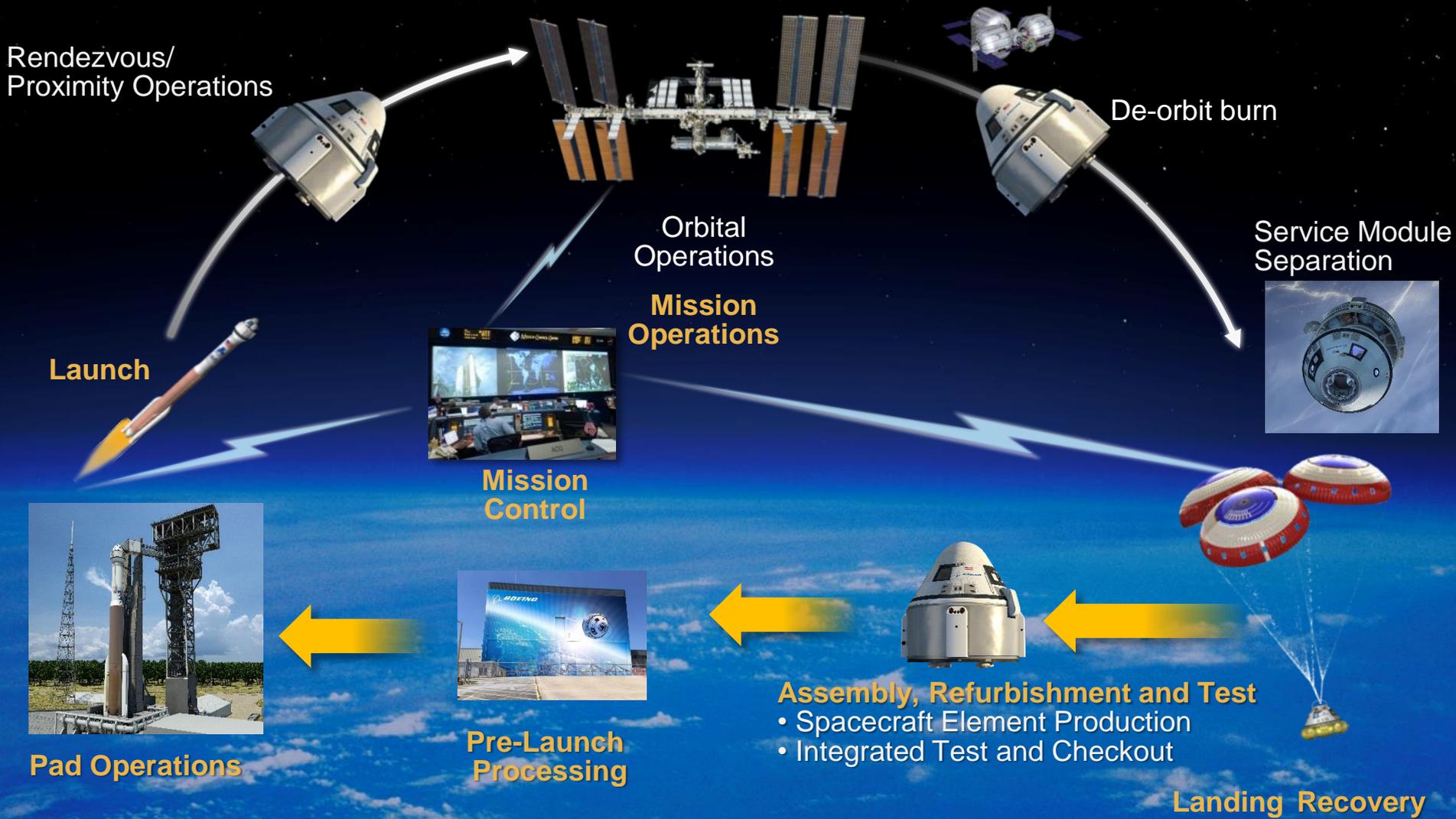
Ground Processing



- 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

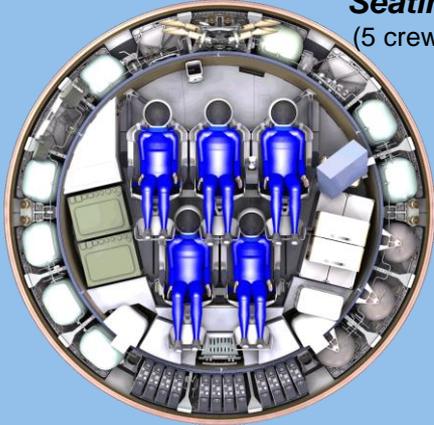
Commercial Crew Program



Spacecraft Segment Features

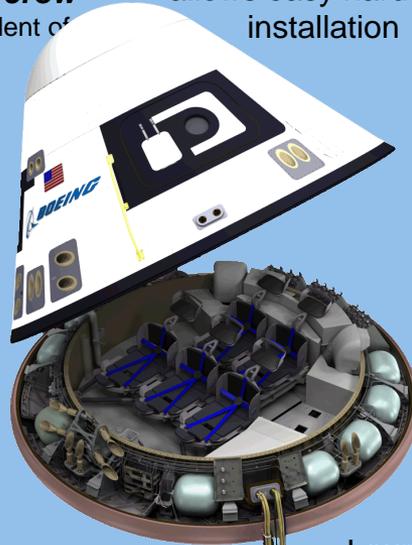
Commercial Crew Program

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



Clam Shell CM Design

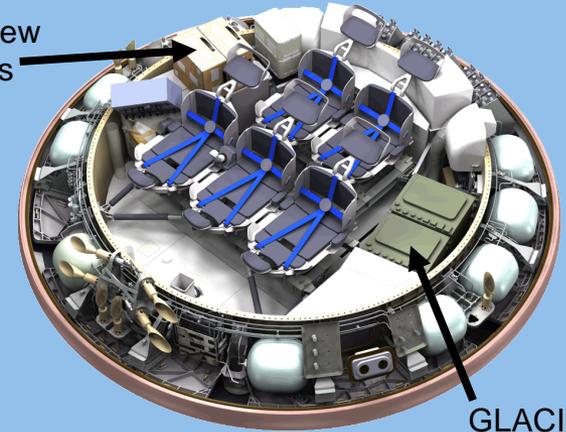
allows easy hardware installation



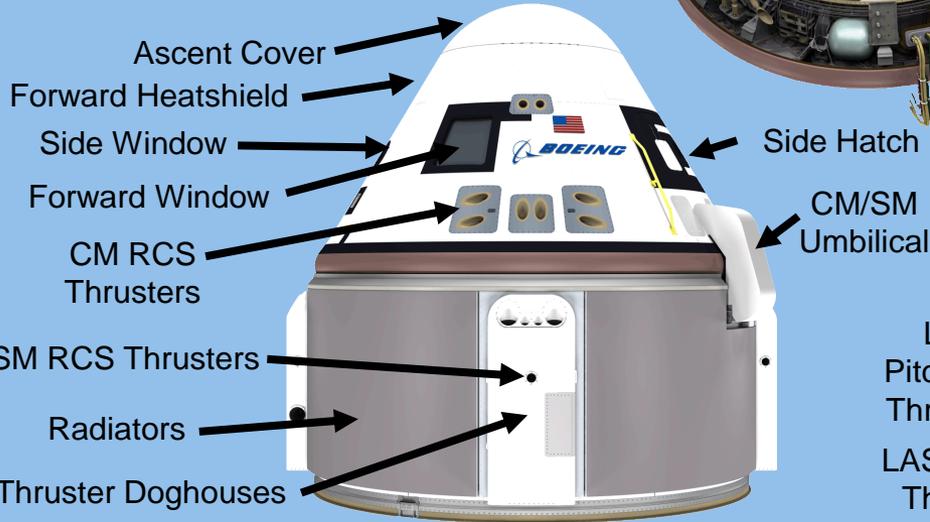
Flexible cabin design

Accommodates mix of crew & cargo

Cargo & Crew Provisions

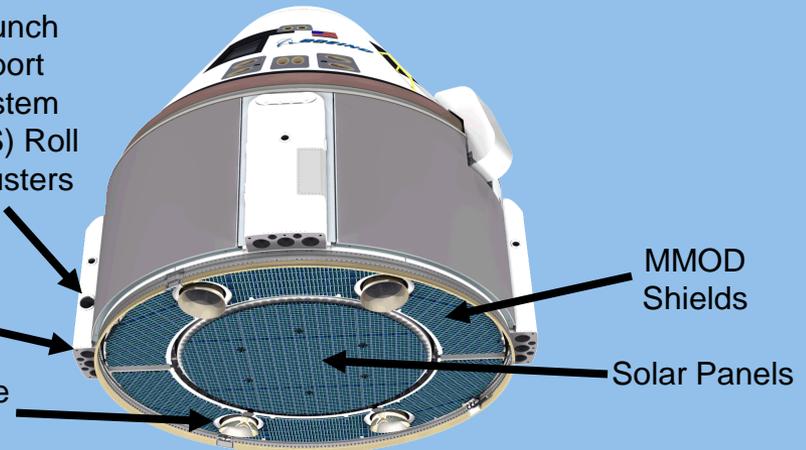


GLACIER



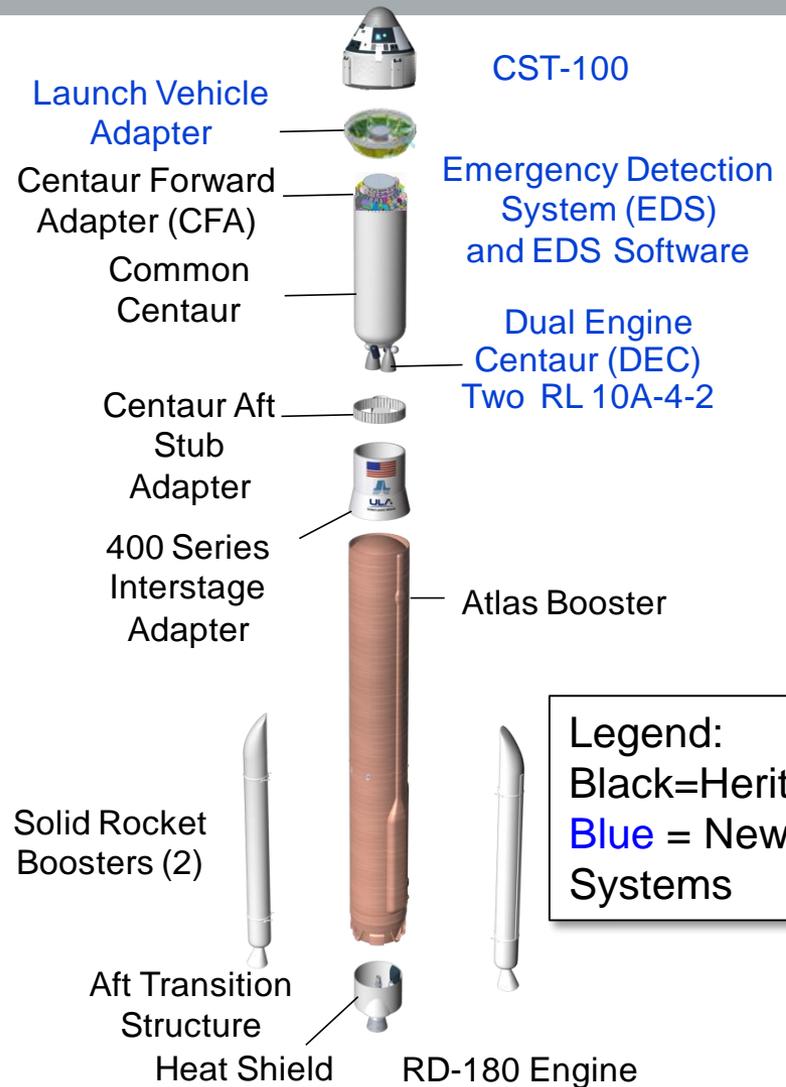
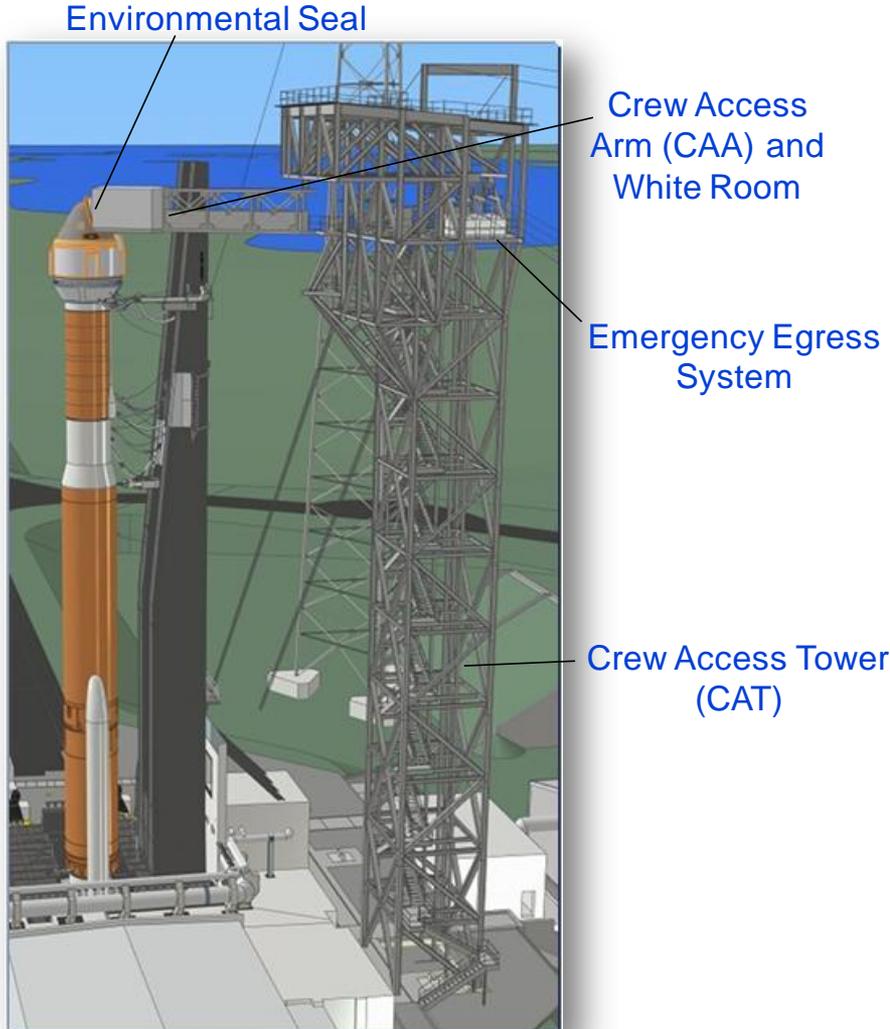
Launch Abort System (LAS) Roll Thrusters

LAS Pitch/Yaw Thrusters
LAS Escape Thrusters



Launch Segment Features

Commercial Crew Program



Legend:
 Black=Heritage
 Blue = New
 Systems

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**

Ground Communication

- **Comm. between CST-100 and Ground Facilities**

Training System

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

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**

Landing Sites

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



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

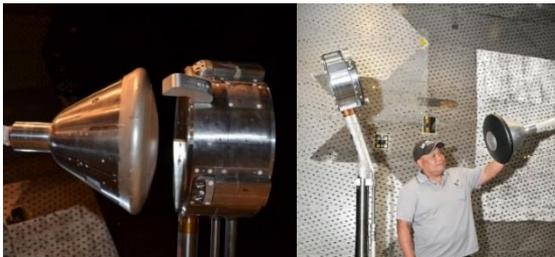
Design Development
Qual Risk Reduction



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 (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



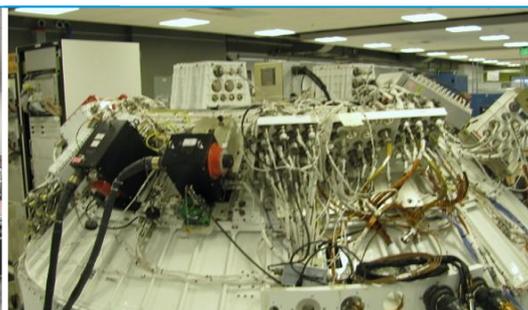
Houston Avionics SIL



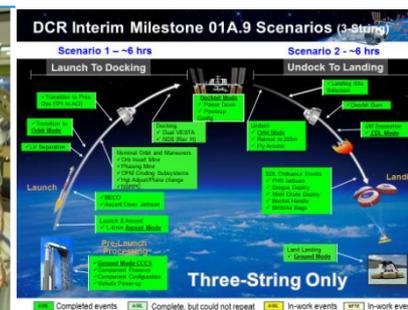
Houston Training SIL



Boeing Mission Control Center - KSC



ULA EDS SIL



Flight SW Maturation and E-t-E Demonstrations

Flight Software (CST-100) EDC Development

SLOCs

CSCI	Actual SLOCs					Estimated SLOCs
	ER2.0	ER2.5	ER3.0	ER4.0	ER5.0	ER6.0 - ER9.0
FMS	95,483	276,320	278,320	250,189	276,622	334,962
SMS	107,388	247,888	249,158	213,176	240,123	294,314
CIS	153,442	90,489	171,390	156,488	197,697	283,280
Total	356,313	614,697	698,868	619,853	714,442	912,556

- ER6.0 Estimated SLOC
- Estimated SLOCs for Final
 - Delta's ER5 (SLOCs) to ER9.0 (ESLOCs)
 - FMS = 58,340
 - SMS = 54,191
 - CIS = 85,983
 - Total = 198,114

SLOCs include Hand & Autocode BSP and OS SLOCs are not included

Spacecraft/Architecture Activations & Checkout Emphasis

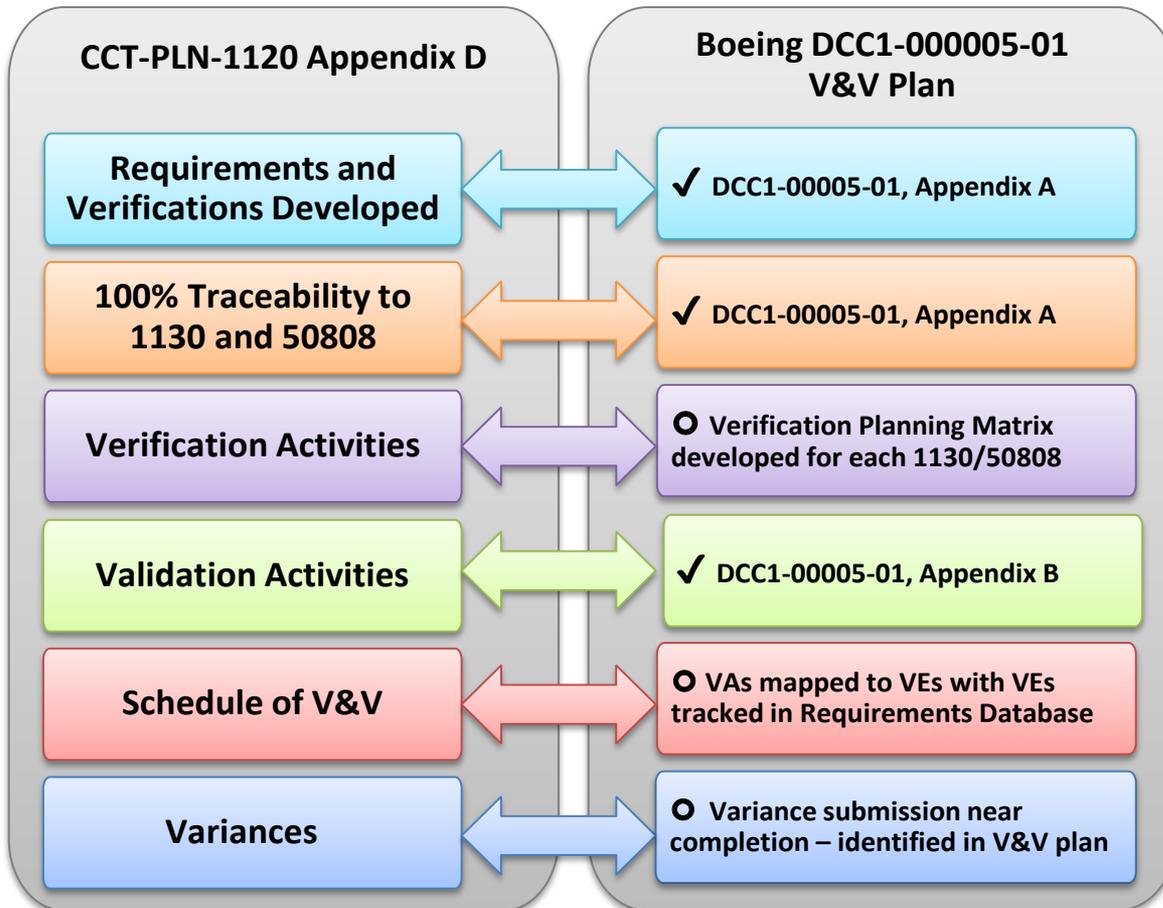
Boeing Starliner Verification, Test, and Certification

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 ○ 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

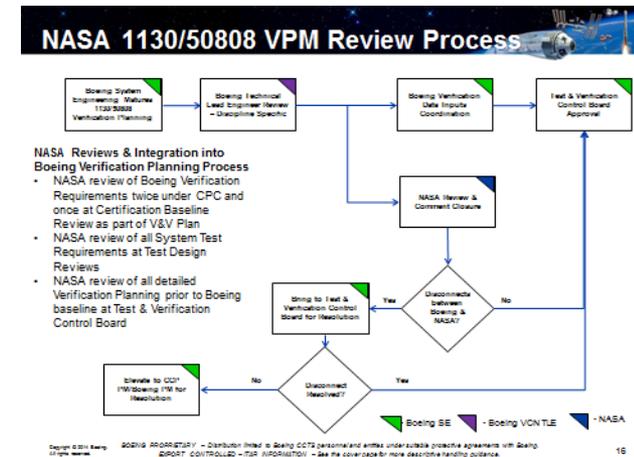
- ✓ Boeing Certification Plan Approved
 - NASA Type 1 Document
 - Documents Boeing approach to certifying all elements of CCTS
- Boeing Verification & Validation Plan in NASA approval cycle
 - Program IPTs and Key Personnel engaged
 - NASA issues resolved, NASA Approval ECD Nov 2015
- ISS Joint Integrated 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



**DCC1-00481-01
Rev. E**

**Commercial Crew Transportation
System (CCTS)
Master Test Plan**

22 January 2015

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

Commercial Crew Program

- 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