Commercial Crew Program

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CST-100 STARLINER
Program Overview

Commercial Crew Program

Atlas V Launch Vehicle
- X37 Launch
- Flight proven systems
- High TRL technologies
- Successfully completed CDR
- Verification Analysis Cycles underway
- 58 successes, and counting!
- Proven rocket significantly reduces system risk
- CCTS integration and crew accommodations are well underway

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

Mission Operations
- 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

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Concept of Operations

Commercial Crew Program

• Assembly, Refurbishment and Test
  • Spacecraft Element Production
  • Integrated Test and Checkout

Rendezvous/Proximity Operations

Orbital Operations

Mission Operations

Pre-Launch Processing

Mission Control

Launch

Service Module Separation

De-orbit burn

Pad Operations

Landing Recovery
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

Cargo & Crew Provisions

Flexible cabin design
Accommodates mix of crew & cargo

Ascent Cover
Forward Heatshield
Side Window
Side Hatch
CM/SM Umbilical
LAS Roll Thrusters
LAS Pitch/Yaw Thrusters
LAS Escape Thrusters
Launch Abort System (LAS)

MMOD Shields
Solar Panels

Glacier
Launch Segment Features

Commercial Crew Program

Legend:
Black=Heritage Systems
Blue = New Systems

- Environmental Seal
- Crew Access Arm (CAA) and White Room
- Emergency Egress System
- Crew Access Tower (CAT)
- CST-100
- Emergency Detection System (EDS) and EDS Software
- Dual Engine Centaur (DEC)
- Two RL 10A-4-2
- Atlas Booster
- Launch Vehicle Adapter
- Centaur Forward Adapter (CFA)
- Common Centaur
- Centaur Aft Stub Adapter
- 400 Series Interstage Adapter
- Solid Rocket Boosters (2)
- Aft Transition Structure
- Heat Shield
- RD-180 Engine
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

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

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

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

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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

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Key Focus Areas

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

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
Boeing Starliner
Verification, Test, and Certification

- 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

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CCT-PLN-1120 Appendix D

- Requirements and Verifications Developed
- 100% Traceability to 1130 and 50808
- Verification Activities
- Validation Activities
- Schedule of V&V
- Variances

Boeing DCC1-000005-01 V&V Plan

- DCC1-00005-01, Appendix A
- Verification Planning Matrix developed for each 1130/50808
- DCC1-00005-01, Appendix B
- VAs mapped to VEs with VEs tracked in Requirements Database
- Variance submission near completion – identified in V&V plan

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

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
Boeing Verification Requirement Maturity

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✔ 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

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- 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

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- 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

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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.