Commercial Crew Program Status to NASA Advisory Council Human Exploration and Operations Committee

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COMMERCIAL CREW PROGRAM

CCP NAC HEO Committee Quarterly Purpose & Agenda

- **Purpose: To brief the NASA Advisory Council HEOMD Subcommittee on the latest status and technical progress for the CCP CCtCap and CCiCap contracts**

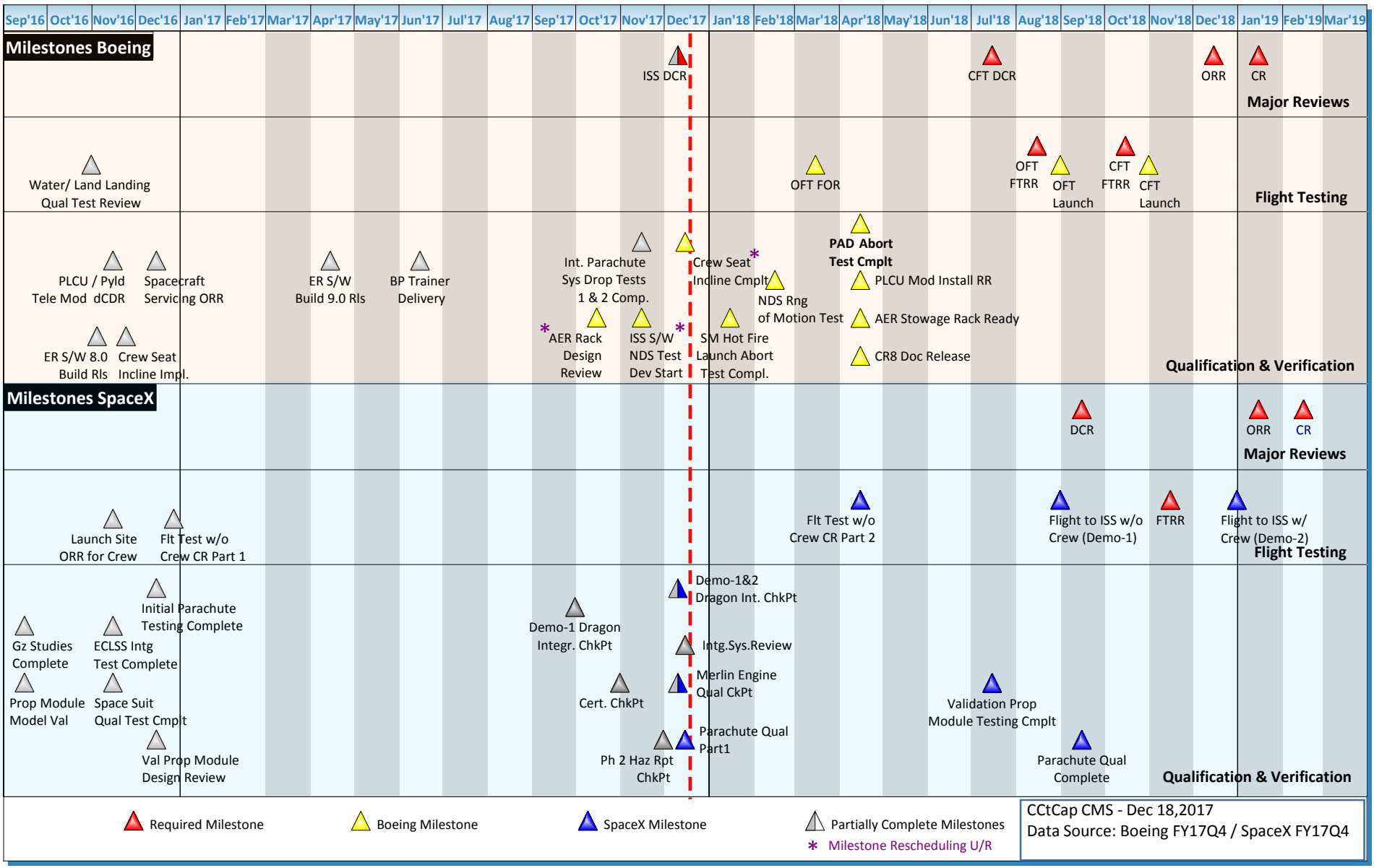
- **Agenda:**
  - **CCP Execution Status**
    - Program Progress
    - Milestone Summary
    - Top Risks
  - **CCtCap Status**
    - Boeing Commercial Provider Status
    - SpaceX Commercial Provider Status
  - **CCiCap Status**
    - Blue Origin Status
    - Sierra Nevada Status
  - **Summary**

Program Progress

CCP has made significant progress over the last quarter, notably:

- **Mission planning and preparations for eight CCP missions are in work:**
  - Official Dates For Boeing:
    - August 2018: Orbital Flight Test (unmanned demo)
    - November 2018: Crewed Flight Test (demo)
    - PCM-1 awarded May 2015; Completed 5 milestones to date
    - PCM-2 awarded in December 2015; Completed 4 milestones to date
    - PCM-3,4,5,6 awarded in January 2017
  - Official Dates For SpaceX:
    - August 2018: Flight to ISS without crew (Demo Mission 1)
    - December 2018: Flight to ISS with crew (Demo Mission 2)
    - PCM-1 awarded November 2015; Completed 4 milestones to date
    - PCM-2 awarded July 2016; Completed 3 milestones to date
    - PCM-3,4,5,6 awarded in January 2017
- **Space hardware manufacturing, testing and qualification are underway**
- **Both providers are making tangible progress toward flight tests and crewed missions to the International Space Station**
- **Continued engagement as the providers perform critical test and verification events**
- **Continue to make progress in the burn down of key certification products with the providers**
  - Progress for each provider is included in provider-specific sections of this briefing

CCtCap Combined Milestone Summary Official – FY17Q4

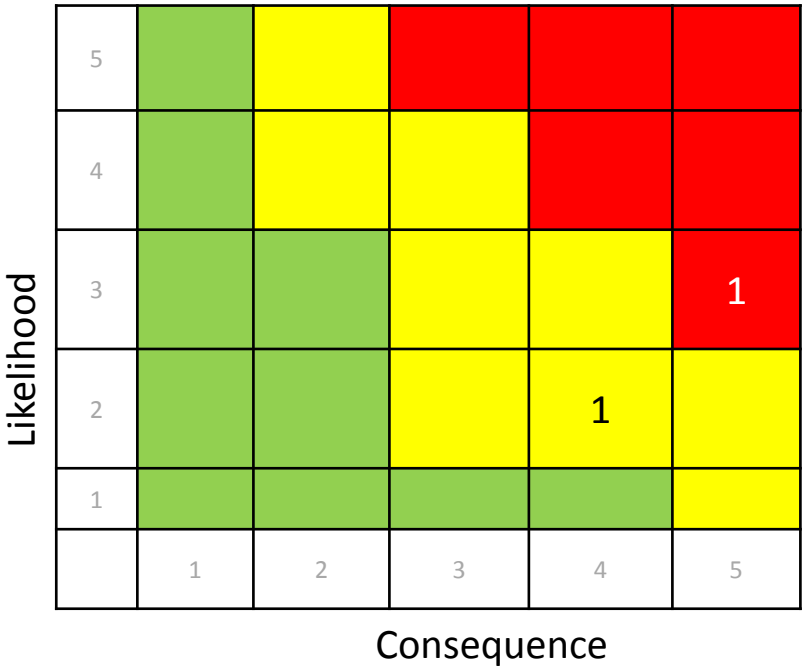


CCP Top Programmatic Risks (Updates from 9/5/17 to 1/30/18)

Programmatic Risk = Likelihood x (Highest of Non Safety Consequences (Cost, Schedule, Performance))

LxC	Trend	Risk Title	Risk ID Number	Office
3x5	NC	Inability to Meet LOC	CCP-SEI-2015-1	SE&I
2x4	NC	DoD Search and Rescue Training Schedule	CCP-GMO-2015-4	GMO
	C	Cost of Government Provided Services (ISS CR-15654)	CCP-GMO-2017-1	GMO
	C	Ammonia Emergency Response	CCP-SC-2016-3	SC

Trend Key (since last quarter): New = New Risk, NC = No Change, I = Increase in Risk, D = Decrease in Risk, C= Closed, A = Accepted

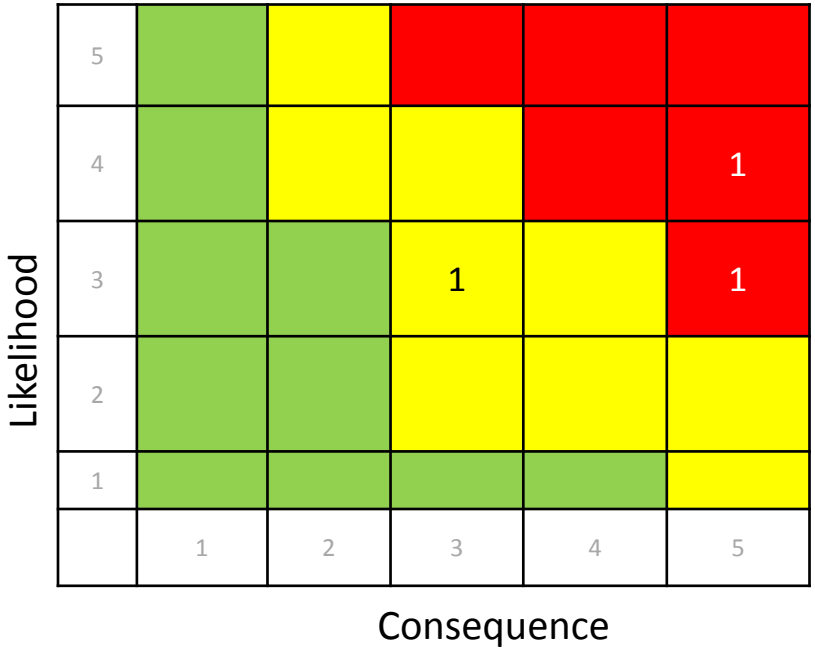


CCP Top Program Safety Risks (Updates from 9/5/17 to 1/30/18)

Safety Risk = Safety Likelihood x (Highest of Safety Consequences (Personnel, Environmental, Facilities))

LxC	Trend	Risk Title	Risk ID Number	Office
4x5	NC	Inability to meet LOC	CCP-SEI-2015-1	SE&I
3x5	NC	Aborting into Sea States with Unsafe Rescue	CCP-GMO-2016-3	GMO
3x3	NC	Crew Entry Accelerations and Spaceflight Associated Neuro-ocular Syndrome (SANS) Exacerbations	CCP-IP-2016-3	IP
	C	Ammonia Emergency Response	CCP-SC-2016-3	SC

Trend Key (since last quarter): New = New Risk, NC = No Change, I = Increase in Risk, D = Decrease in Risk, C= Closed, A = Accepted



SpaceX Demo 1/Demo 2 Status

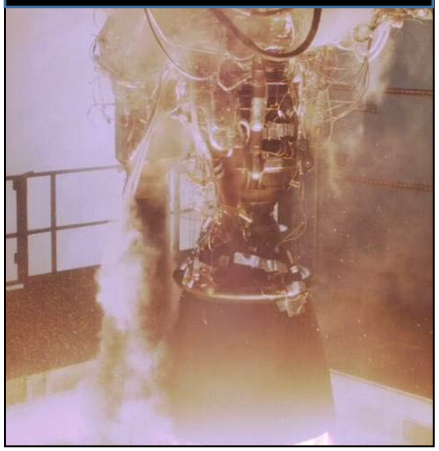
SpaceX Accomplishments

- **Development progress**
  - **Dragon**
    - Fire Suppression test campaign completed
    - Radiator slat build development in progress
    - Validation Prop Module nearly complete
    - Performed end-to-end spacesuit comm test
    - Crew Display Evaluation 5 completed – DE6 in March
    - C2V2 Comm with Crypto testing complete & good
    - Splashdown +Z loads structural qual complete & good
    - Parachutes: High Q, 2 drogue-3 main test complete/good
  - **Falcon 9 (Block 5)**
    - Demonstrated significant run time on Crew Configuration engines including new blisk turbine wheel
    - Octaweb 3.0 (bolted) qual is complete & good
    - COPV 2.0
      - Development test program complete
      - Significant qualification testing is complete
      - Manufacture of Demo-1 flight bottles is beginning
  - **In-Flight Abort Test**
    - Test plan, test configuration, instrumentation, conops and loads analysis delivered and in review
    - Trunk manufacture in work

Dragon crew display evals

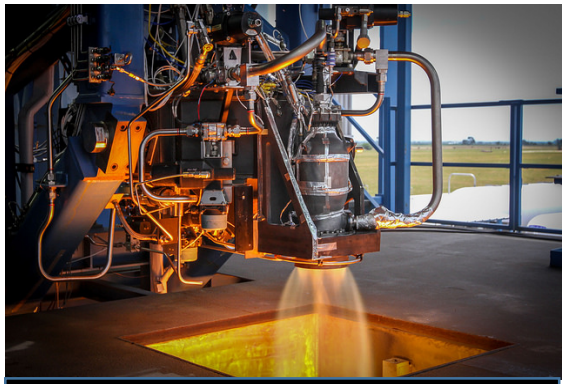
Parachute test 5

Merlin development firing

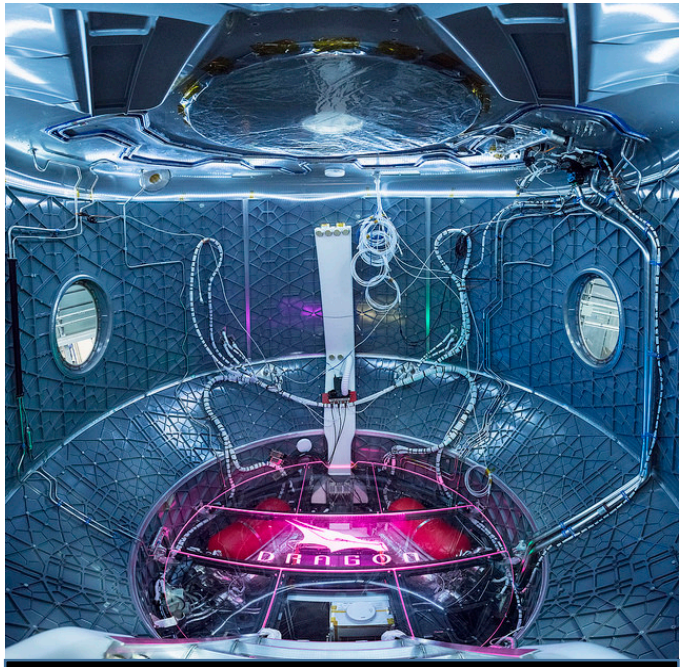


SpaceX Accomplishments

- **Demo-1 vehicle progress (SN 2-1)**
  - **Dragon**
    - Avionics Bay fully populated and in test
    - All cabin sub-floor equipment installed
    - All Draco/SuperDraco prop tanks installed
    - All SuperDraco engines ATP hot fired successfully
    - 1st SuperDraco "jet pack" assembly complete
      - 2nd & 3rd in work
    - Ox/Nitrox delivery panel installed for flight
    - Trunk doublers for radiator mounting complete (late change)
    - Side hatch build complete
    - Control panels fabricated & protoqual complete, ready to install
    - 120 of 240 solar arrays build complete
    - SpaceX docking system build 90% complete
  - **Falcon**
    - Building Demo-1 booster (SN 1051): Stage 1 tanks in Vertical Integration
  - **Ops**
    - Flight Test Plan updated
    - Completed second docking joint simulation and have had successful integrated simulation docking checkouts.
    - Received concurrence on ISS attitude control plan for docking and undocking.



SuperDraco test firing



Demo-1 Dragon cabin interior closeout

SpaceX Accomplishments

- **Demo-2 vehicle progress (SN 2-3)**
  - Dragon weldment completed
  - Structural acceptance testing complete & post test inspections are in work
  - Heatshield assembly in progress
  - Forward bulkhead feedline welding in progress
  - Flight radial bulkheads (RBHs) installed in backbone tooling for prop tubing fit-up – welding in progress
  - Prop tank manufacture in work
- **LC-39A**
  - Site work is resuming after Falcon-Heavy launch
  - Demolition of the rotating service structure – contractor on-site to resume work
  - Addition of fixed service service structure levels – contractor on-site to resume work
  - Crew access arm and fluid system fabrication is in progress

Demo-2 vehicle

NASA Crew in LC-39A Crew Access Arm

Boeing OFT/CFT Mission Status

Boeing Accomplishments

- **Design, Demonstration, Test, and Evaluation**
  - Completed Launch Segment Design Certification Review (DCR) w/ ULA
  - Conducted the ISS DCR to establish design baseline for PCM missions
    - Partnered verification products delivery schedule with monthly Joint Program Management progress review
  - Prioritizing and started series of Outgassing tests for ISS compatibility
  - Structural Test Article (STA) progress continues
    - Shock Development Series completed
    - Integrated Loads completed
  - Parachute Systems Qualification Test # 2 completed in November
    - 3 additional qualification and 6 additional reliability drop tests planned
  - WSTF hot fire testing
    - Completed LAE acceptance testing for CFT engines
    - SMHF cold flow series progressing
    - SMHF LAE firing ~ March
  - Boeing Mockup Trainer (BMT) outfitting completed in January w/ TRR in March
  - Boeing Engineering Simulator (BES) operational w/ test execution started in Feb
  - Joint Testing w/ ISS continues
    - Test 9A complete (joint RF compatibility test)
    - Test 2 repeated w/ remote testing over fiber network (joint test for commanding, telemetry routing, and SW functionality across interfaces)

LAE Hot Fire ATP


STA Integrated Loads Test

Boeing Accomplishments

- **Spacecraft 3 (SC#3) – Orbital Flight Test (OFT) Vehicle**
  - **Production & Operations underway to support Lower Dome First Light, mid-March (initial vehicle power)**
    - **Crew Module**
      - Lower dome harness outfitting underway
      - Side hatch and IVA hatch assembly and buildup in work
      - Base Heat Shield in assembly
    - **Service Module**
      - Primary structure in work; radiator support installation underway
  - **Atlas V (AV-080) OFT Launch Vehicle**
    - **Booster**
      - Tanks joined and system integration, assembly, check out in work
      - RP Feedline installation complete
      - RD-180s installed, testing in March
    - **Centaur**
      - LH2 & LO2 Tanks pressure test complete
      - Foam applications complete
      - RL-10s delivered, verification testing complete, install in work
      - Centaur Forward Adapter complete less coax cable installation

Spacecraft #3 (OFT) Upper Dome

Spacecraft #3 (OFT) Service Module

Atlas V Booster AV-080 (OFT)

Boeing Accomplishments

- **Spacecraft 2 (SC#2) – Environmental Qual Test (EQT) and Crewed Flight Test (CFT) Vehicle**
  - **Production & Operations converging to support Lower Dome First Light in March (initial vehicle power)**
    - **Crew Module**
      - Lower dome avionics and harness outfitting nearing completion
      - Upper dome avionics and harness outfitting in work
      - Side hatch installation in work
      - Forward Heat Shield in TPS installation
    - **Service Module**
      - Primary Structure complete, transferred to outfitting area for Active Thermal Control System (ATCS) and Propulsion outfitting
  - **Atlas V (AV-082) OFT Launch Vehicle**
    - **Booster**
      - RP tank moved to integration, assembly, check out work center
      - RP Feedline installation complete
      - LO2 tank delivered
    - **Centaur**
      - RCS build up in pressure test
      - RL-10s delivered, verification testing starting February
      - Centaur Forward Adapter staged in clean room

SC #2 NASA Docking System

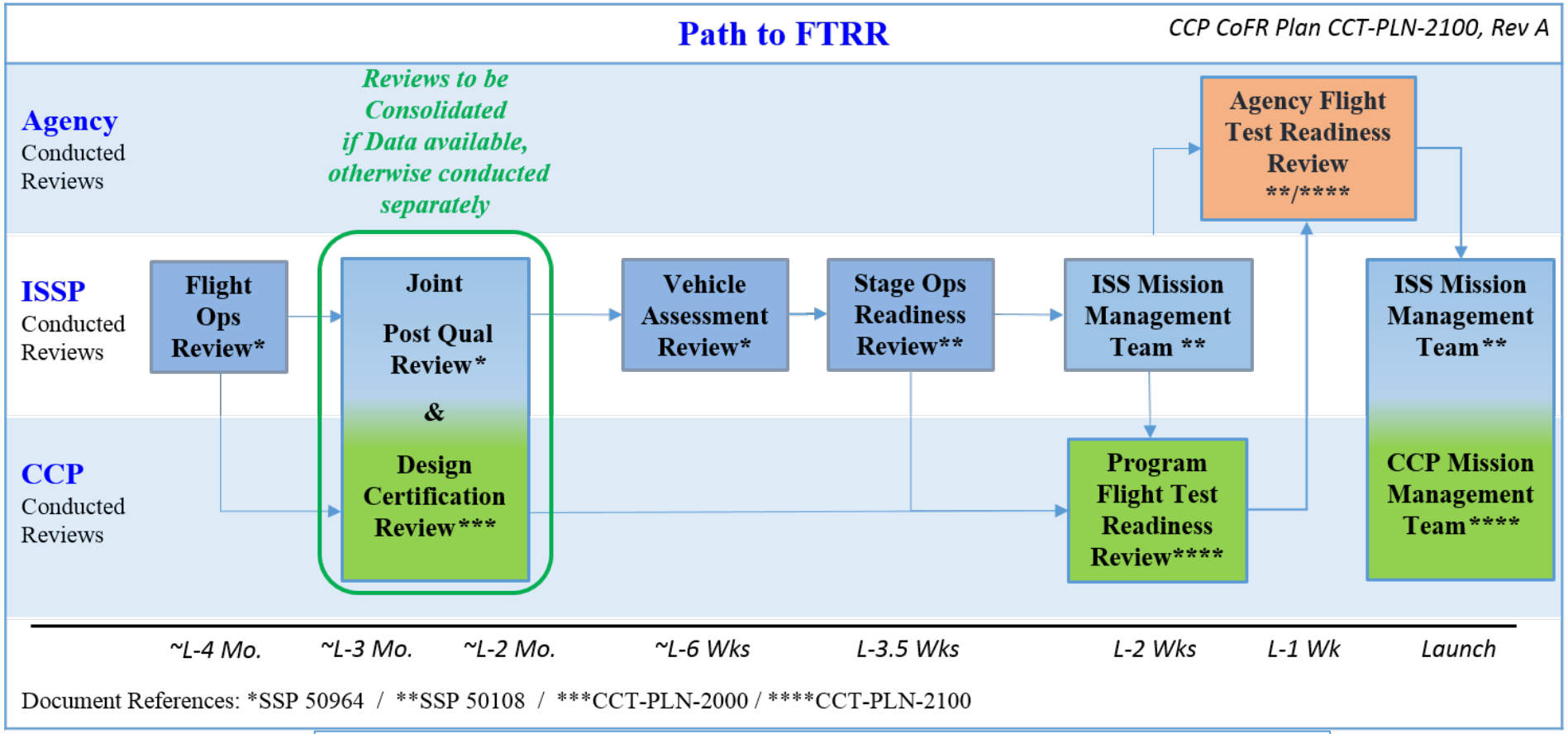
SC #2 Upper Dome

Atlas V Booster AV-082 (CFT)

Path to Agency Flight Readiness

Integrated Flight Test Readiness Review Process

Series of CCP/ISS Program reviews culminate in integrated CCP Agency FTRR



DCR is not intended to be a final data drop of all certification work required for flight test. As such, agreements are made with the Providers to incrementally buy off products as the work is completed.

Blue Origin Accomplishments

Blue Origin
Commercial Space Capabilities Collaboration (CSCC)
Space Act Agreement (SAA)

- **Technical Exchanges**
  - Launch Vehicle Materials
  - NDE
  - Climatology Analysis
  - Structures Manufacturing
- **Data Exchange**
  - Various software requests and technical documentation exchanges in work
- **Look Ahead**
  - Milestone #5, May 2018
    - Development Update of Launch Site
  - Continued Technical and Data Exchange

BE-3 in Test Stand

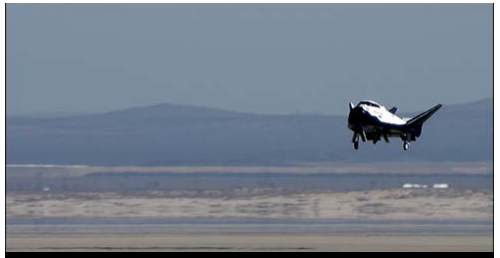
BE-4 Test Fire

Sierra Nevada Corp. Accomplishments

Commercial Crew Integrated Capabilities (CCiCap)
Space Act Agreement (SAA)

- **CCiCap SAA Milestone 4b, Engineering Test Article Flight Testing #2, NASA outbrief - Dec. 7, 2017**
  - Full scale Dream Chaser engineering test article (ETA) unpowered approach & landing test (ALT-2) at Armstrong Flight Research Center - Edwards Air Force Base on 11 Nov. 2017
  - NASA approved award of milestone 4b funding
  - SNC Post-flight data analysis is nearly complete
    - All mission objectives achieved
    - ALT-2 in flight performance was nominal for orbital vehicle Avionics & FSW, FADS, and GN&C
    - Landing rollout performance validated by multiple range and taxi tests
- **Development Activities**
  - Reaction Control System development and test currently underway; ECD 4th Qtr 2018
  - Analysis of aerodynamic data and wind tunnel aero model updates underway; ECD 4th Qtr 2018

ALT-2 Test Team

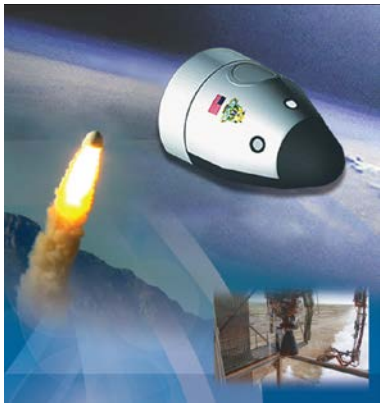


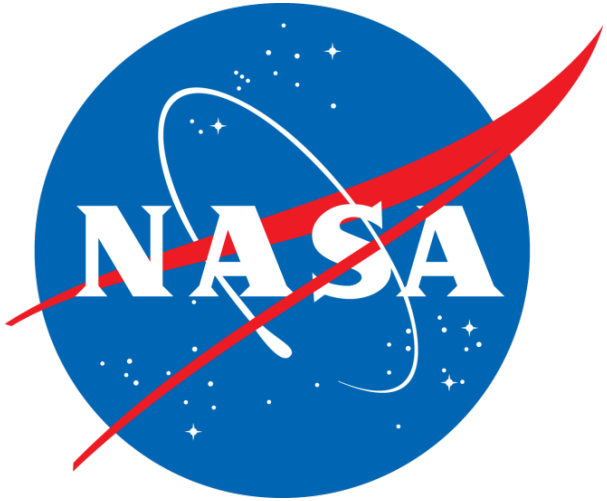
Dream Chaser ALT-2

Dream Chaser ETA

CCP Summary

- **CCP continues to facilitate the development and certification of U.S. industry-based crew transportation systems**
- **Boeing and SpaceX are meeting contractual milestones and maturing their designs**
  - A significant amount of hardware is in development, test and qualification in preparation for upcoming missions
  - Risks are being identified and important design challenges are being addressed
  - NASA is engaged in meaningful insight
- **Both providers are making tangible progress toward flight tests and crewed missions to the International Space Station**
- **CCP has robust and efficient processes for certification including addressing waivers and deviations**
  - Progress is being made in the burn down of key certification products with the providers
- **In preparation for flight, there is significant work ahead**




NASA

Acronyms & Abbreviations

- ALT: Approach & Landing Test
- AoA: Angle of Attack
- ATCS: Active Thermal Control Subsystem
- BP: Boilerplate
- Calysto: Risk Management tool
- C3PF:Commercial Crew and Cargo Processing Facility
- CCiCap: Commercial Crew integrated Capability
- CCtCap: Commercial Crew transportation Capability
- CDR: Critical Design Review
- CFA: Computational Fluid Analysis
- CFT: Crewed Flight Test
- CM: Crew Module
- COPV: Composite Overwrap Pressure Vessel
- CPWSR: Configuration Performance & Weight Status Report
- CSCS: Contingency Spacecraft Crew Support?
- CTS: Crew Transportation System
- DCR: Design Certification Review
- DDT&E: Design, Development, Test & Evaluation
- Det3: (USAF) Detachment 3
- DM: Demonstration Mission
- ECLSS: Environmental Control and Life Support System
- ECM: Electro-Chemical Machining
- EDM: Electron Discharge Machining
- EDS: Emergency Detection System
- ETA: Engineering Test Article
- FHS: Forward Heat Shield
- FLT: Flight
- FOD: Flight Operations Directorate
- FTCR: Flight Test Certification Review
- GMO: Ground & Mission Operations
- HAR: Hazard Analysis Report
- HITL: Human in the Loop
- HR: Hazard Report
- HRCP: Human Rating Certification Package
- IDA: International Docking Adapter
- IFA: In-Flight Abort
- IV&V: Independent Verification & Validation
- JIRA: Project management software tool
- JPRCB: Joint Program Requirements Control Board
- JT: Joint Test
- LAE: Launch Abort Engine
- LLQTL Land Landing Qualification Test
- LOC: Loss of Crew
- LOM: Loss of Mission
- LSC: Linear Shaped Charge
- LSORR: Launch Site Operational Readiness Review
- LV: Launch Vehicle
- LVA: Launch Vehicle Adapter
- MIR: Mission Integration Review
- MMOD: Micrometeoroid and Orbital Debris
- MVac: Merlin Vacuum Engine
- NDS: NASA Docking System
- NBL: Neutral Buoyancy Lab
- NESC: NASA Engineering & Safety Center
- NLA: Non-Linear Aero
- OFT: Orbital Flight Test
- OMAC: Orbital Maneuvering and Attitude Control
- OML: Outer Mold Line
- ORDEM: Orbital Debris Engineering Model
- ORR: Operational Readiness Review
- PAA: Product Assurance Analysis
- PAFB: Patrick Air Force Base
- PAT: Pad Abort Test
- PC&I: Program Control & Integration
- PCB: Program Control Board
- PCDTV: Parachute Compartment Drop Test Vehicle
- PCM: Post Certification Mission
- PDR: Preliminary Design Review
- PnP: Probability of No Penetration
- PSA: Probabilistic Safety Analysis
- PJ: Para Jumpers
- RCS: Reaction Control System
- RT: Rescue Trainer
- SC: Spacecraft
- SE&I: Systems Engineering & Integration
- SM: Service Module
- SOW: Statement of Work
- STA: Structural Test Article
- STRB: Safety Technical Review Board
- SureSep: LVA Jettison System
- TIM: Technical Interchange Meeting
- TM3: Targeted Mass 3
- TPS: Thermal Protection System
- TTP: Tactics, Techniques, & Procedures
- TRR: Test Readiness Review
- UDA: Universal Docking Adapter
- ULA: United Launch Alliance
- USAF: US Air Force
- VBR: Vehicle Baseline Review
- VCN: Verification Closure Notice
- VE: Verification Event
- VIIP: Vision Impairment/Intracranial Pressure
- WSTF: White Sands Test Facility
- WTT: Wind Tunnel Testing