Commercial Crew Program Status to NASA Advisory Council

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COMMERCIAL CREW PROGRAM

Agenda

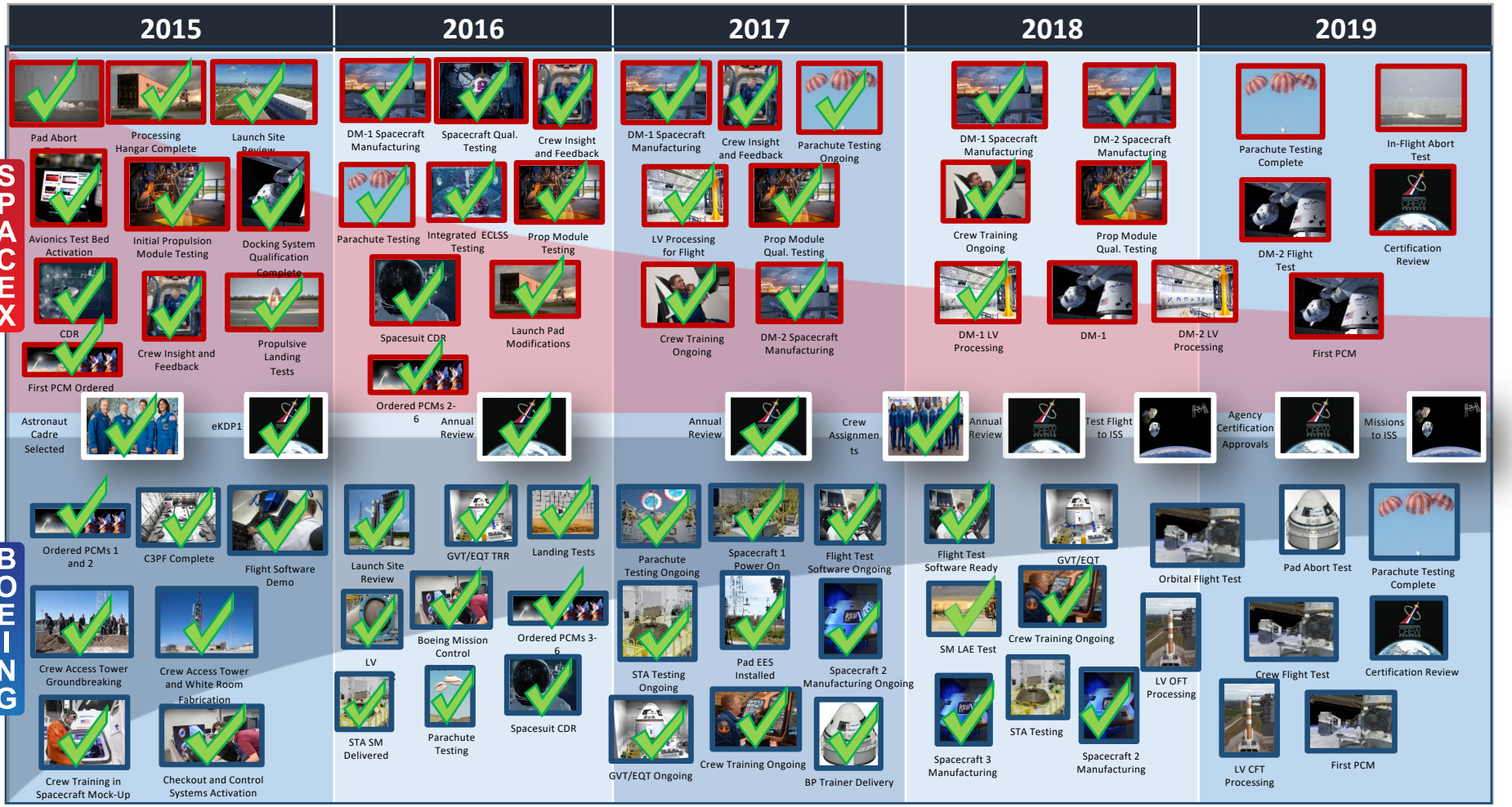
- **Agenda**
  - **CCP Status**
    - Program Progress
    - Timeline to the International Space Station
    - Crew Assignments
  - **Boeing OFT/CFT Mission Status**
  - **SpaceX Demo-1/Demo-2 Status**
  - **Space Act Agreement Status**
    - Blue Origin Status
    - Sierra Nevada Corporation Status
    - Enabling Commercial Space
  - **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:
    - Late 2018/ Early 2019: Orbital Flight Test (unmanned demo)
    - Mid 2019: Crewed Flight Test (demo)
    - PCM-1 awarded May 2015
    - PCM-2 awarded in December 2015
    - PCM-3,4,5,6 awarded in January 2017
  - Official Dates For SpaceX:
    - November 2018: Flight to ISS without crew (Demo Mission 1)
    - April 2019: Flight to ISS with crew (Demo Mission 2)
    - PCM-1 awarded November 2015
    - PCM-2 awarded July 2016
    - 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 CCP team 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

Timeline to the International Space Station



Last Updated
Aug 2018

Crew Assignments

- **Nine U.S. astronauts have been assigned to fly the initial test flights and post certification missions to the International Space Station aboard America's first commercially built spacecraft**

Boeing Crew Flight Test

Eric Boe
Nicole Mann
Chris Ferguson(Boeing)

SpaceX Demo-2

Bob Behnken
Doug Hurley

Boeing First Mission

Josh Cassada
Suni Williams

SpaceX First Mission

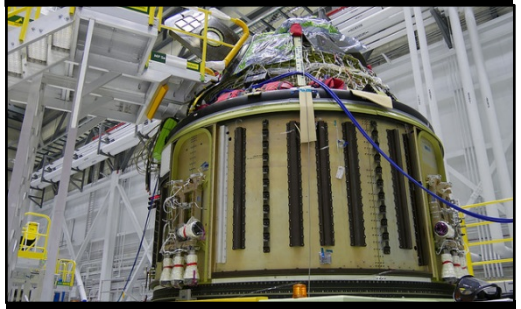
Victor Glover
Mike Hopkins

Boeing OFT/CFT Mission Status

Boeing Accomplishments

- **Design, Development, Test, and Evaluation**
  - **System Level**
    - Structural Test Article (STA) testing progressing at Huntington Beach 12 of 15 tests completed
      - Completed CM/SM Base Heat Shield jettison test series
    - Remaining test campaigns:
      - Ascent Cover Separation series planned start in late fall
      - Forward Heat Shield / Parachute Impact testing planned start in fall
      - CM Fixed Tunnel test series planned start late summer, test concludes STA campaign
        - Major vehicle reconfiguration underway and required to support Fixed Tunnel test start
  - **Subsystem Level**
    - Land Landing Qualification Testing completed (all 14 tests), Report completed
    - Parachute System Qualification Testing underway (3 of 5 completed)
      - Remaining 2 tests planned thru summer
    - Launch Abort Engine Hot Fire ATP completed
    - Service Module Hot Fire testing nearing completion at White Sands Test Facility
      - Test series 1 Cold Flow complete and series 2 Propellant Servicing complete
      - Test series 3 Low Altitude Hot-Fire testing complete
        - Remaining Tests: High altitude aborts and nominal mission sequence
  - **Joint Tests (JT) and analysis with ISS**
    - Joint testing and analysis required for ISS integration is progressing
    - Completed Joint Tests:
      - JT1 SW input output, JT6 Remote Terminal validation,
      - JT7 power qualification and electromagnetic compatibility,
      - JT 9A RF compatibility, JT 2 command & telemetry routing
      - JT 8 CST-100 to NDS interface test complete (EQT/CFT SC#3)
    - Remaining Joint Tests:
      - JT 4 Integrated Software Stage Test
      - JT 8 CST-100 to NDS interface acceptance test (OFT SC#3)
      - JT9B C2V2 RF Interface test: Data & Audio verification test
      - JT 9C C2V2 RF Interface test: CST-100 Encryption verification test
      - JT 10 Crew Equipment Interface Test (CEIT)
      - JT 11 Microbial and Fungal Sampling
      - JT 13 ISS/CST-100 Flight Article Validation Test

CM/SM Stack for Sep Test

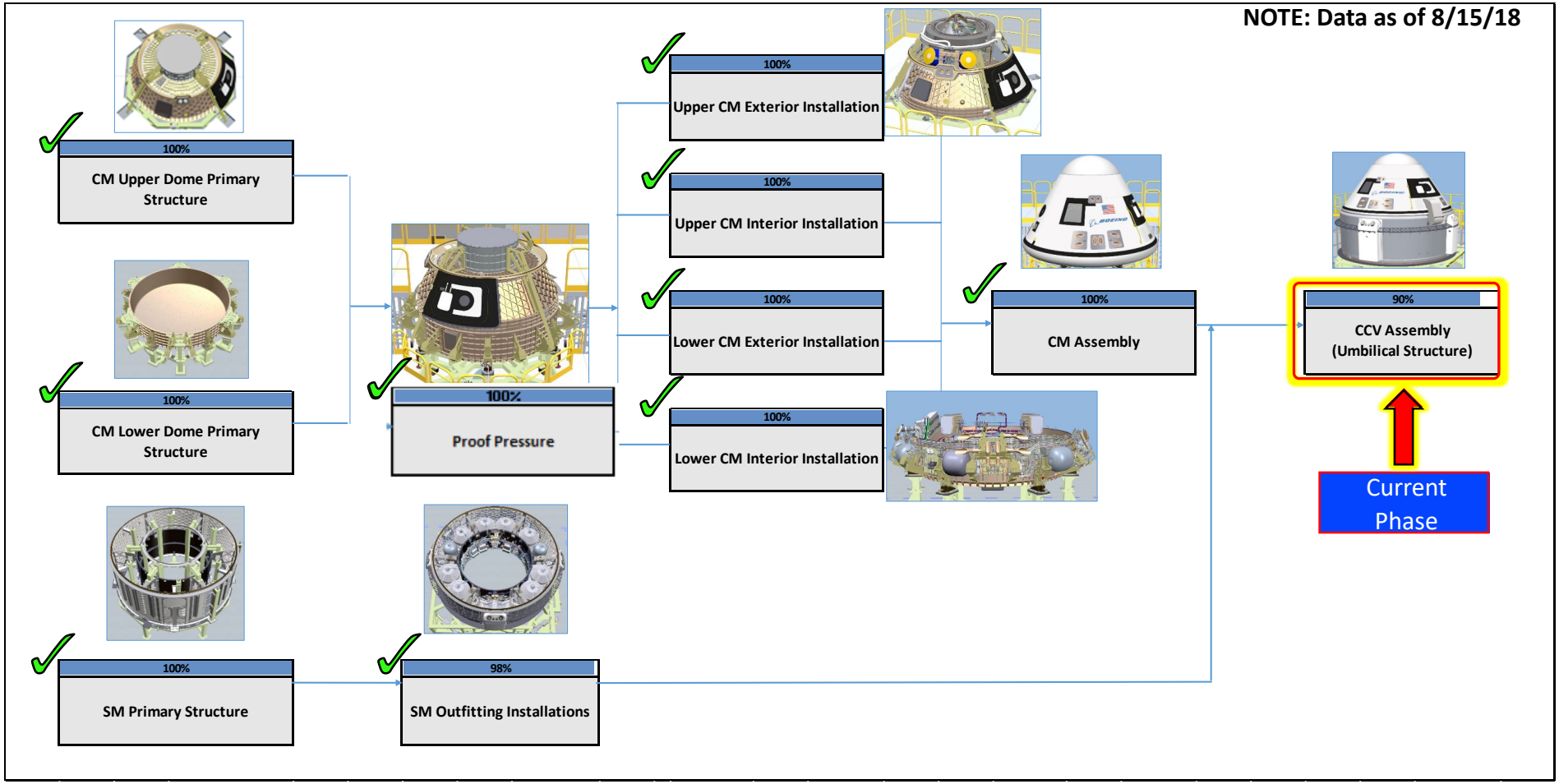


SC #1 PAT Test Article

SMHF Cold Flow Prop Tank Skid & Flow Control Valves

Boeing Spacecraft Production Status

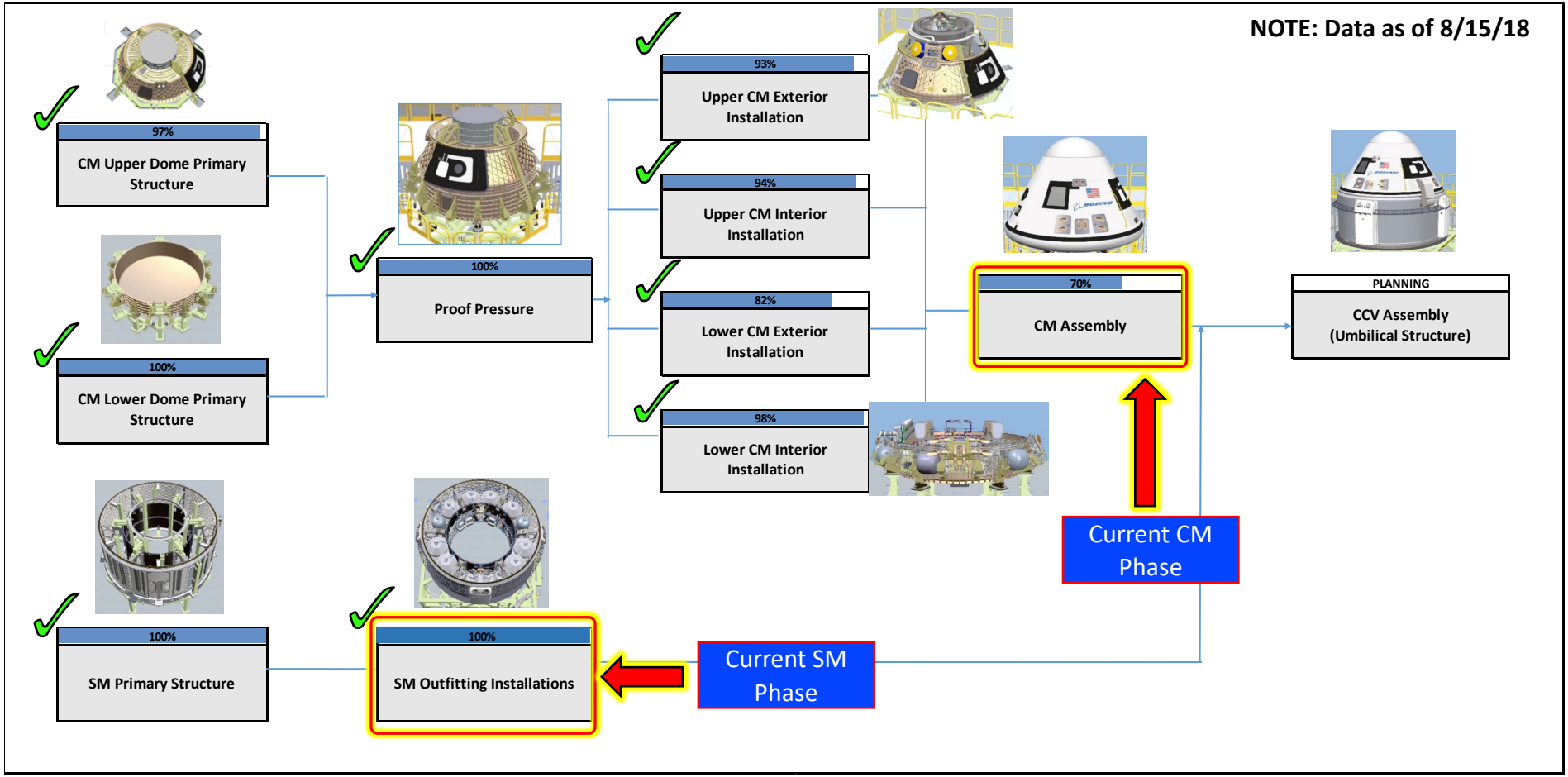
- **Spacecraft #1 (SC#1): Pad Abort Test (PAT) vehicle production build progress**



- **SC#1 Status: CM & SM stand alone builds complete. Currently in CM Integrated Assembly phase**
  - Completed CCV acceptance testing
  - Completing preps for shipment
  - PAT Test Article target ship to WSMR TBD to support Pad Abort Test

Boeing Spacecraft Production Status

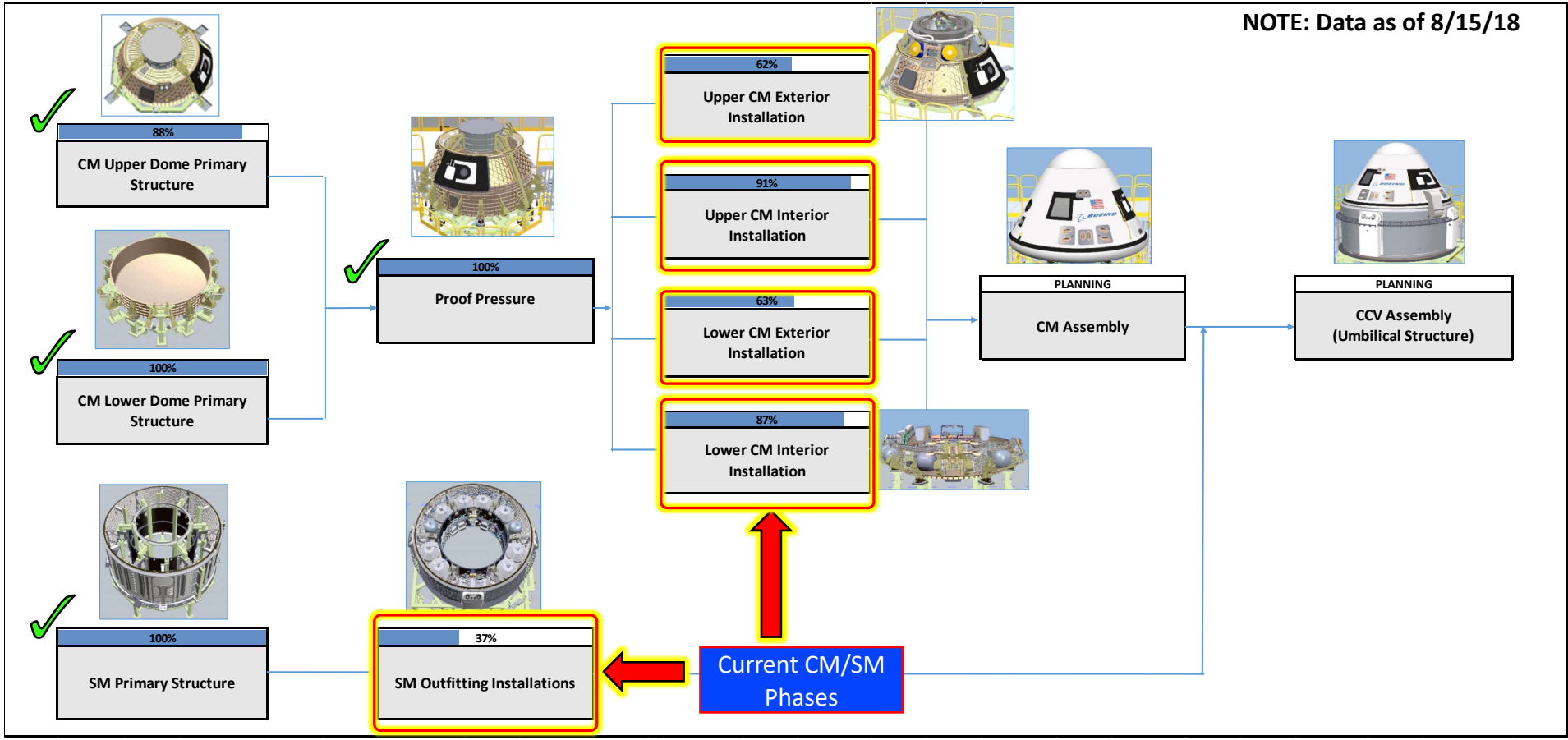
- **Spacecraft #2 (SC#2): Environmental Qualification Test (EQT) vehicle and Crewed Flight Test (CFT) production build progress**



- **SC#2 Status: Currently, in the CM Assembly Phase and the SM Integrated Assembly**
  - First Light testing completed early summer, progressing towards CM/SM mate
  - EQT Test Article shipped to El Segundo August 13 to support EQT start
  - EQT Crew Module target ship to El Segundo late summer

Boeing Spacecraft Production Status

- **Spacecraft #3 (SC#3): Orbital Flight Test (OFT) production build progress**



- **SC#3 Status: Currently, in the Upper Dome Assembly Phase, the Lower Dome Assembly Phase, and the SM Integrated Assembly**
  - Lower Dome 1st light completed (initial vehicle power)
  - Progressing towards CM/SM mate fall

Boeing Launch Vehicle Production Status

- **Launch Vehicle Build Progress**
  - **Atlas V (AV-080) OFT Launch Vehicle**
    - **Booster, Centaur, and Launch Vehicle Adapter nearing final build completion with target ship to CCAFS late summer**
    - Booster
      - Production Complete
      - Target ship to CCAFS fall
    - Centaur
      - Final harness installs in work
      - Production complete target mid summer
      - Ship to CCAFS target late fall
  - **Atlas V (AV-082) CFT Launch Vehicle**
    - Booster
      - RP/LOX tank splice planned for mid summer
      - Avionics box installations remain in work
      - Production complete target late fall
    - Centaur
      - RL-10 engine build up and verification testing complete
      - Install planned for mid summer
      - Production complete target late fall


Atlas V Booster AV-080 (OFT)

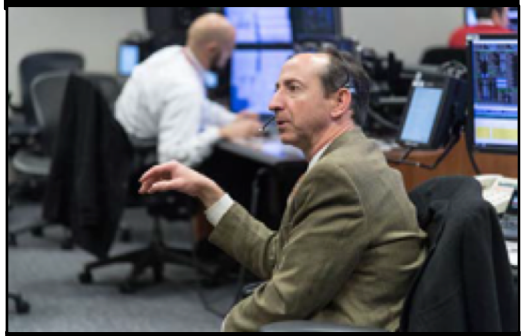

Atlas V DEC AV-080 (OFT)


Atlas V Booster AV-082 (CFT)

Boeing Operations Status

- **Flight Operations Reviews**
  - **ISS Joint Flight Operations Review**
    - Completed June 25th – 29th
    - Focused on ISS Joint Ops Product definition:
      - LCCs, Flight Rules, Joint Operations Interface Procedures, Operations Data Files
  - **Boeing Flight Operations Review**
    - Completed July 9th – 12th
    - Focused on Boeing stand-alone Ops Product definition:
      - Ground and Pre-Launch Procedures, LCCs, Flight Rules, Flight Data Files
- **Simulations**
  - **Joint Ascent Simulations with ULA and NASA**
    - Completed OFT Integrated Crew Exercise (ICE) #1
    - Completed On-Pad Crew Emergency Egress Testing
    - OFT Systems Rehearsal planned for summer
    - OFT ICE #2 planned for fall
    - OFT Mission Dress Rehearsal (MDR) #1 planned for fall
    - OFT Wet Dress Rehearsal Planned (WDR) for fall
    - OFT Final MDR Planned for fall
  - **Joint Simulations with ISS**
    - Completed (2) generic Joint Rendezvous docking sims with ISS
  - **Landing Simulations**
    - Completed field equipment integration & training at WSMR site
    - Completed Landing Recovery Team Paper Sim #5
    - Landing Systems Rehearsal #1 planned for fall
    - Landing Systems Rehearsal #2 planned for fall

OFT ICE #1 Sim



Joint Rendezvous Mission Ops Sequence Test

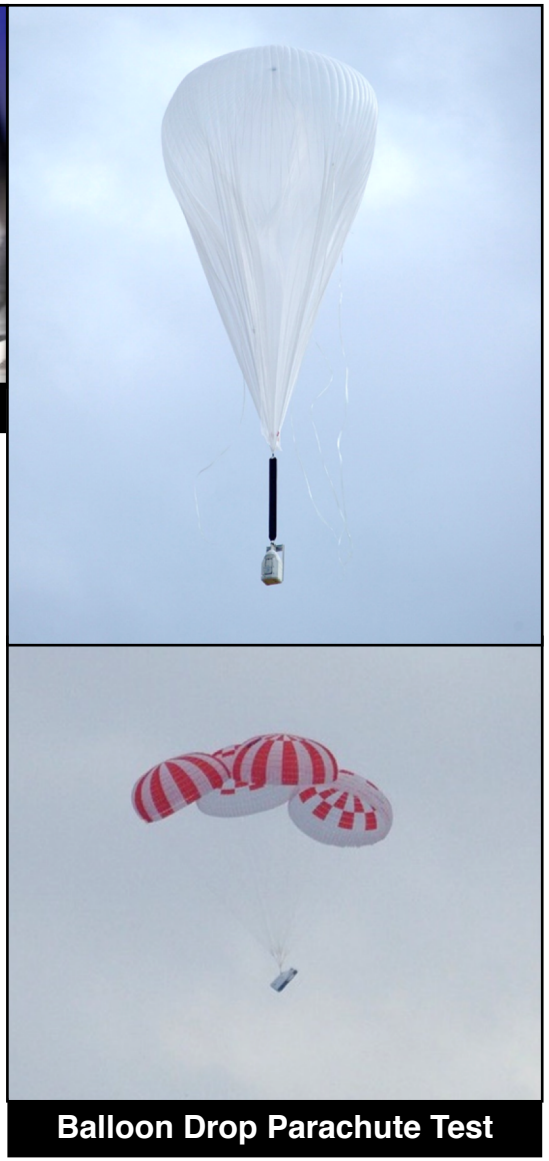
Landing Site Field Training

SpaceX Demo-1/Demo-2 Mission Status

SpaceX Accomplishments

- **Development progress**
  - **Dragon**
    - Dragon stacked testing completed
      - RF/EMI
      - TVac
      - Modal & Acoustic
    - Validation Prop Module
      - Low flow testing complete
      - High flow testing in work
    - Suit quals ongoing
    - Crew Display Evaluation 5 completed
    - Completed Training Events 1, 2 and 3: suited simulations with the cadre in buck, functioning displays, flight software, audio comm systems; launch and ascent, and approach through docking
    - Software Stage Test with ISS complete
    - Parachutes: balloon drop test complete, 45k feet
  - **Falcon 9 (Block 5)**
    - M1D qual turbine wheel tests in work
    - COPV 2.0
      - Qualification complete, safe-life demonstration ongoing
      - 50 LOX cycles, 200 LN2 cycles, 10 flight cycle life testing complete
      - Demo-1 flight bottles installed
  - **In-Flight Abort Test**
    - Test plan, test configuration, instrumentation, conops and loads analysis delivered
    - Trunk manufacture in work

Crew Training Event



Balloon Drop Parachute Test

SpaceX Accomplishments

- **Demo-1 vehicle progress (SN 2-1)**
  - **Dragon**
    - Capsule delivered to Cape and in final processing
    - VRIO R&R completed, testing post R&R upcoming
    - Trunk at Hawthorne for solar array install
  - **Falcon**
    - F9 1st stage on track for fall shipping
    - In Lane 4 integration
    - Center Pusher installed
    - Interstage mated to tank
    - Octaweb fully populated with hot-fired Merlins
  - **Ops**
    - Completed final Flight Operational Readiness reviews
    - Three joint ops sims completed
    - First Mission Management Team training sim completed

Demo-1 Dragon Arrival at the Cape

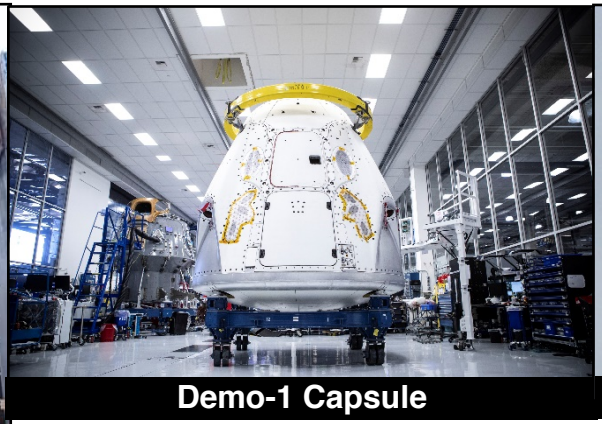
Demo-1 Acoustic Test

Demo-1 Falcon

Demo-1 Octaweb

SpaceX Demo-1 Accomplishments

Demo-1 Capsule at the Cape



Demo-1 Capsule

Parachute Testing

- Crew Training Event 3 completed August
- Completed Launch & Ascent, and Approach through Docking Sims with suited cadre, functioning displays, flight software, & audio comm systems; Software Stage Test with ISS complete
- Parachutes: balloon drop test complete, 45k ft
- Capsule delivered to Cape, in final processing
- VRIO R&R completed, testing post R&R upcoming
- Trunk at Hawthorne for solar array install
- Completed final Flight Operational Readiness reviews
- Three joint ops sims completed
- First & second Mission Management Team training sim complete, third planned

SpaceX Demo-2 Accomplishments

- **Demo-2 vehicle progress (SN 2-3)**
  - Integration mate complete
  - Ongoing integration in cleanroom
  - Trunk primary structure complete
  - Cabin build out started
- **LC-39A**
  - Successful dry run of Day of Launch Closeout Crew procedures with representative crew members, space suits, and Model X's.
  - Successful Crew Arm Seal Testing; demonstrated that the seal can keep out the environment (performed a water test) and will adhere to Dragon when the vehicle translates
  - Crew Access Arm installation complete
  - On track for final Launch Site Operational Readiness Review in September

Demo-2 vehicle

Demo-2 Display Testing

Demo-2 Vehicle Status

Crew Training for Demo-2

Demo-2 Trunk

Demo-2 Capsule Integration

Demo-2 Dragon

- Pressure Section to Service Section integration mate complete
- Ongoing vehicle integration in cleanroom
- Trunk primary structure complete
- Cabin build out started

Crew Ops & LC-39A

- Successful dry run of Day of Launch Closeout Crew procedures with representative crew members, space suits, and Model X's.
- Successful Crew Arm Seal Testing; demonstrated that the seal can keep out the environment (performed a water test) and will adhere to Dragon when the vehicle translates.
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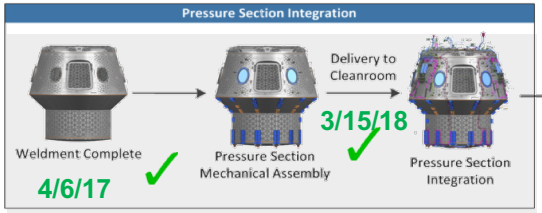
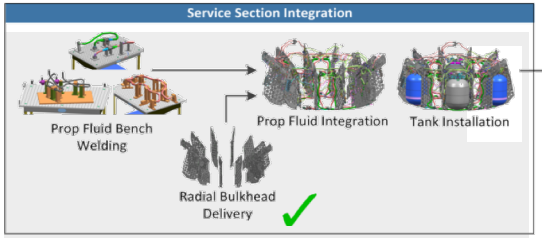
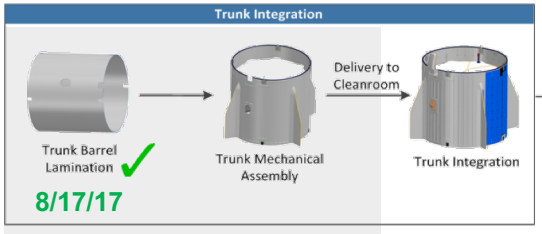
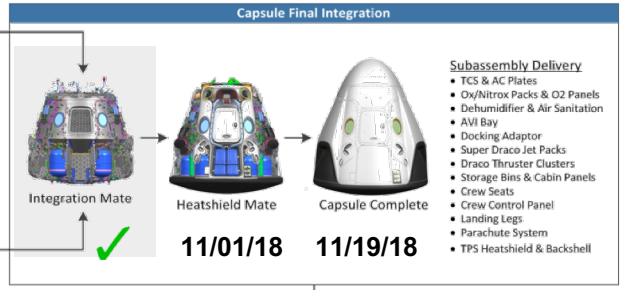
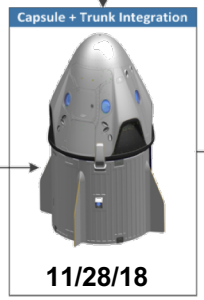


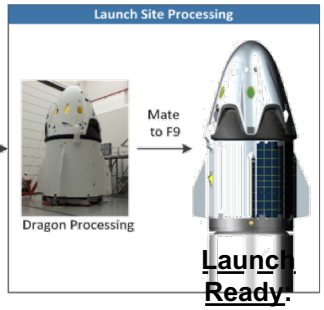








Ship to Launch Site



Launch Ready: January

Space Act Agreements

Blue Origin Status

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

- **Technical Exchanges**
  - Structures and Dynamics
  - Design Reviews
  - Launch Vehicle Materials
  - Historical STS data and reports
- **Data Exchange**
  - Various software requests and technical documentation exchanges in work
- **Look Ahead**
  - Milestone #6, Development Update of Ground and Mission Operations, Nov. 2018
  - Continued Technical and Data Exchange

***New Glenn*: First Stage Reentry**

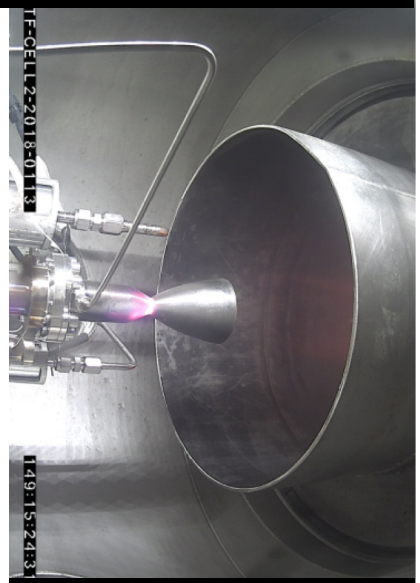
New Glenn

Sierra Nevada Corporation Status

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

- **CCiCap SAA Milestone 4b, Engineering Test Article Flight Testing #2 NASA outbrief - December 2017**
  - Successful uncrewed Dream Chaser engineering test article (ETA) approach & landing test (ALT-2) at Armstrong Flight Research Center - Edwards Air Force Base
  - SNC Post-flight data analysis is complete
    - All mission objectives achieved
    - ALT-2 in-flight performance nominal for orbital vehicle Avionics & FSW, FADS, and GN&C
    - Landing rollout performance validated by multiple range and taxi tests
    - Final ALT-2 Test Report sent to both NASA CCP and NASA CRS2 programs
- **Dream Chaser Design and Development Activities**
  - Dream Chaser systems level design at near-CDR maturity
  - Reaction Control System (RCS) has 20 thrusters and each can produce three thrust levels (Low=10psf monoprop, Med=55psf monoprop, High=110psf bi-prop)
    - Thruster performance exceeds expectations to date
  - Dream Chaser Aero Database update in progress includes ETA flight + Cubrc & AEDC WTT testing. ECD 4th Qtr 2018
  - Dream Chaser Tail #1 cabin/body assembly delivery expected Feb 2019
  - Multiple cargo demonstrations (using UDC) occur in Aug/Sep 2018

Dream Chaser ALT-2



DC Pathfinder 1 High Thrust 1.5 sec

Enabling Commercial Space

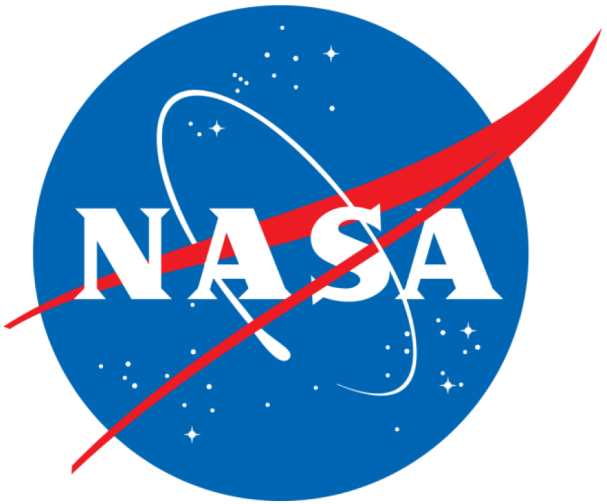
- **CCP helps to facilitate Inter-Agency, Intergovernmental and International partnerships, agreements, and legislation with the strategic goal of enabling the commercial space industry**
  - Inter-Agency Collaboration
    - Federal Aviation Administration (FAA)
    - Department of Defense (DoD)
    - Department of Commerce (DOC)
    - Federal Communications Commission (FCC)
    - National Telecommunications and Information Administration (NTIA)
    - National Transportation and Safety Board (NTSB)
  - Legislation and Regulation
    - “Government Astronaut” classification
    - Mission licensing to include launch, re-entry, launch site and operator
    - Public health and safety protections
    - Jurisdiction and authority during different phases of flight
    - Independent investigation authority
  - Spectrum Usage
    - Ensure secure communication pathway availability
  - Liability and Insurance
    - Cross waivers
    - Financial responsibility
    - Third-party indemnification
    - Government property

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
- **Crew members have been assigned to missions**
- **Inter-agency work continues to enable the commercial spaceflight industry**
- **In preparation for flight, there is significant work ahead**

Boeing CST-100 Starliner

SpaceX Crew Dragon


NASA