

National Aeronautics and
Space Administration



COMMERCIAL CREW

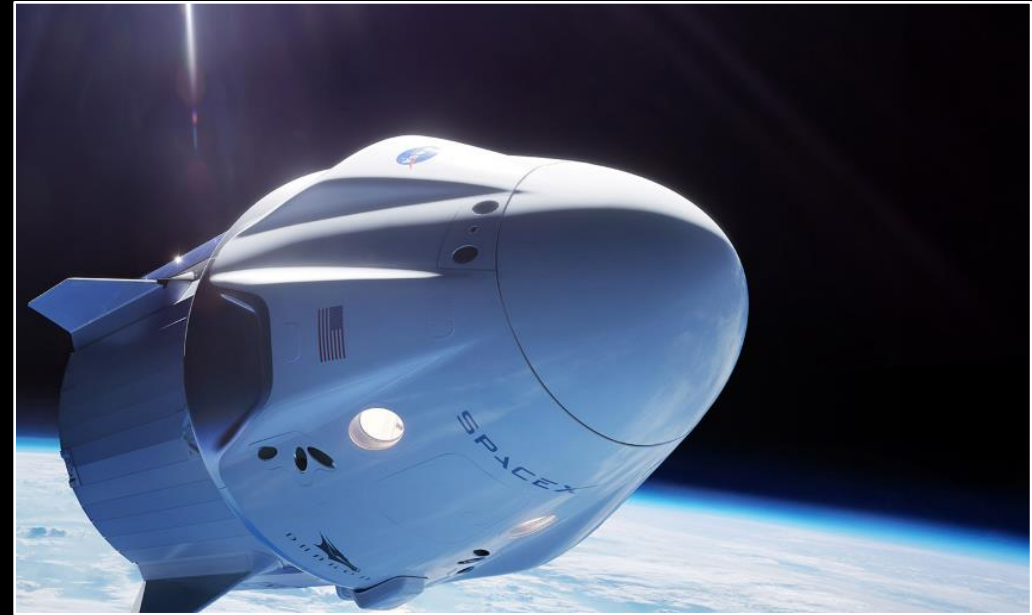


Briefing to NASA Advisory Committee

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Agenda

- Overall CCP Goals
- Timeline to the International Space Station
- Strategy to Support ISS Crew Transportation to 2030
- 2021 Achievements
 - Crew-1
 - Crew-2
 - Avionics Software Integration Lab Demonstration
 - Joint Independent Review Team (IRT) Closure
 - Crew-3
- 2022 - Year Ahead
 - Crew-3/Crew-4 Handover
 - OFT-2
 - CFT Path to Flight
 - Crew-5
- Suborbital Crew (SubC)
- CCP Lessons Learned
- Summary



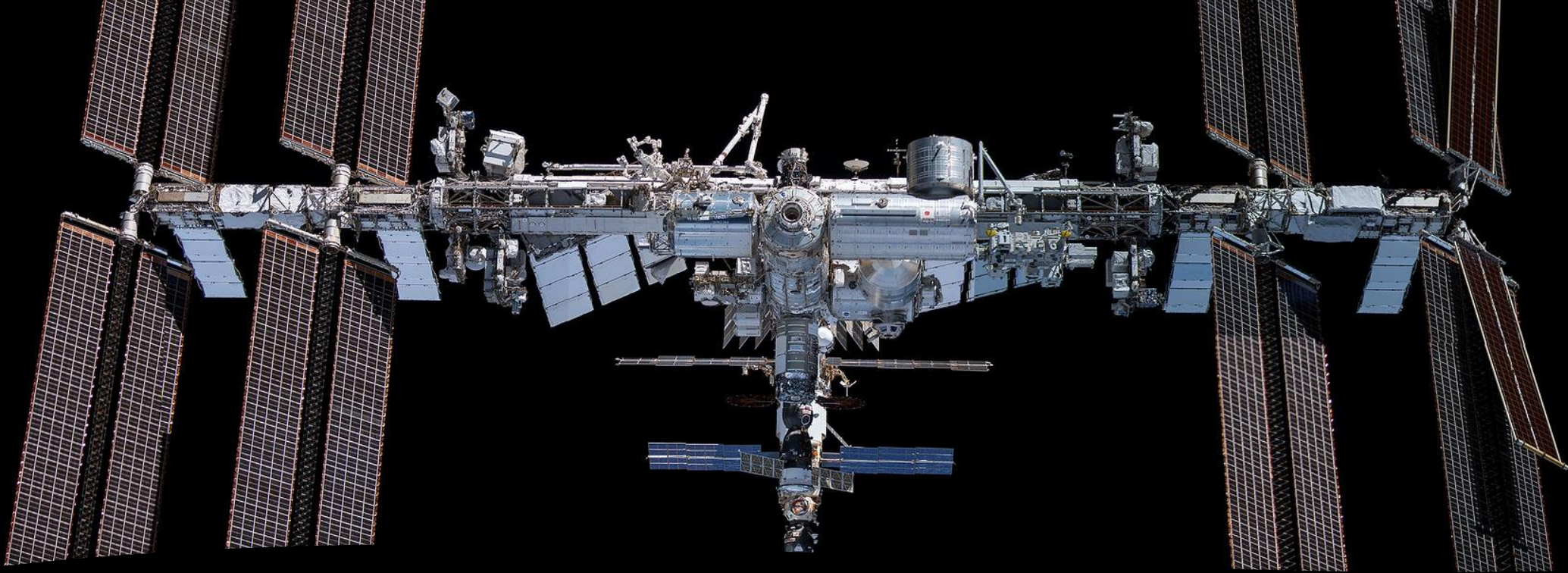
BUILDING UPON SUCCESSES

- NASA's Commercial Crew Program has partnered with commercial companies, Boeing and SpaceX, for human space transportation to and from low-Earth orbit and the International Space Station. NASA required the systems carry up to four astronauts and 220 pounds of cargo to the International Space Station.
 - Goal: NASA's Commercial Crew Program will provide safe, reliable and cost-effective transportation to and from the International Space Station and low-Earth orbit.
 - New Era: A new era of human spaceflight began as American astronauts launched on the SpaceX Crew Dragon spacecraft and Falcon 9 rocket – the first commercially-owned and operated American rocket and spacecraft to launch from American soil.
 - Partnerships: NASA's partnership with American private industry is changing the arc of human spaceflight history by opening access to low-Earth orbit and the International Space Station to more people, more science and more commercial opportunities.
 - Maximize Station: NASA's Commercial Crew Program enables expanded International Space Station use, additional research time and broader opportunities of discovery aboard the orbiting laboratory.



2015	2016	2017	2018	2019	2020-21
Pad Abort Test Processing Hangar Complete Launch Site Review	DM-1 Spacecraft Manufacturing Spacecraft Qual. Testing Crew Insight and Feedback	DM-1 Spacecraft Manufacturing Crew Insight and Feedback	Parachute Testing Ongoing DM-1 Spacecraft Manufacturing DM-2 Spacecraft Manufacturing	DM-1 DM-2 Spacecraft Manufacturing	In-Flight Abort Test DM-2 Flight Test
Avionics Test Bed Activation Initial Propulsion Module Testing Docking System Qual Complete	Parachute Testing Integrated ECLSS Testing Prop Module Testing	LV Processing for Flight Tests Prop Module Qual. Testing	Spacesuit Testing Crew Training Ongoing	DM-2 LV Processing Complete Certification Review	Certification Review
CDR First PCM Ordered	Crew Insight and Feedback Propulsive Landing Tests Spacesuit CDR	Launch Pad Modifications Crew Training Ongoing	DM-2 Spacecraft Manufacturing DM-1 LV Processing Complete Prop Module Qual. Testing	Parachute Testing Complete First PCM Crew-1	First PCM Crew-1
Astronaut Cadre Selected	eKDP1 Ordered PCMs 2-6	Annual Review	Annual Review Crew Assignments	Annual Review Test Flights to ISS Beginning	Agency Certification SpaceX
Ordered PCMs 1 and 2 C3PF Complete Flight Software Demo	Launch Site Review GVT/EQT TRR Landing Tests	Parachute Testing Ongoing Spacecraft 1 Power On Flight Test Software Ongoing	Flight Test Software Ready GVT/EQT Pad Abort Test	OFT LV Processing Complete OFT LV Processing Complete	Agency Certification Crew Flight Test
Crew Access Tower Groundbreaking Crew Access Tower and White Room Fabrication Crew Training in Spacecraft Mock-Up	Checkout and Control Systems Activation LV Processing STA SM Delivered	Boeing Mission Control Ordered PCMs 3-6 STA Testing Ongoing	Pad EES Installed Spacecraft 2 Manufacturing Ongoing BP Trainer Delivery	Crew Training Ongoing Spacecraft 3 Manufacturing Spacecraft 2 Manufacturing	CFT LV Processing Complete Certification Review
	Parachute Testing Spacesuit CDR	GVT/EQT Ongoing Crew Training Ongoing		Orbital Flight Test IRT Orbital Flight Test IRT	Parachute Testing Complete First PCM

4



SUPPORTING STATION

Celebrating 21 years of human presence on the International Space Station:

- CCP certifies the commercial crew transportation system design and mission operations to transport NASA and NASA-sponsored crew to ISS
- CCP has twelve (12) Post Certification Missions (PCMs) awarded on CCtCap
- CCP is pursuing acquisition of up to three (3) additional PCMs from SpaceX in the near-term to maintain an uninterrupted U.S. capability for human access to the space station through 2024
- CCP is evaluating options to competitively purchase additional PCMs required for ISS crew rotation through 2030

2021 ACHIEVEMENTS

CREW-1

Crew-1 Mission: November 15, 2020 - May 2, 2021

Crew: Shannon Walker, Victor Glover, Mike Hopkins, Soichi Noguchi

Falcon 9

Crew Dragon - *Resilience*: 167 days docked to ISS/168 days in orbit

- Port Relocate on ISS: April 5, 2021, from Forward to Node-2 Zenith
- First direct crew handover (Dragon *Resilience* and *Endeavour* both docked at same time)

Crew recovery by *GO Navigator*, Gulf of Mexico (off coast of Panama City, FL)

- First nighttime splashdown since Apollo 8

Top Program Lessons Learned:

Crew Dragon flight with full complement of crew, Port Relocation, Direct Crew Handover, Nighttime Recovery with enhanced public protection, Operational experience



CREW-2



Crew-2 Mission: April 23, 2021 - November 8, 2021

Crew: Megan McArthur, Thomas Pesquet, Akihiko Hoshide, Shane Kimbrough

- First time that NASA astronauts flew in a combined crew with JAXA and ESA astronauts

Falcon 9

Crew Dragon: *Endeavour* docked to ISS for 199 days 17 hours

- First crewed flight of a reused Crew Dragon and Falcon 9 booster
- Port Relocate on ISS: July 21, 2021, from Forward to Zenith
- Broke previous on-orbit record by Crew-1
- First direct crew handover (Crew-1/Crew-2)
- First indirect crew handover (Crew-2/Crew-3)
- First ISS fly-around since Space Shuttle

Crew recovery by GO Navigator, Gulf of Mexico (off coast of Pensacola, FL)

Top Program Lessons Learned:

Direct Crew Handover (Crew-1/Crew-2),
Indirect Crew Handover (Crew-2/Crew-3),
Fly-Around Imagery, Use of Safe Haven
Capability, Waste Management System
Inspections and Operational Workaround

STARLINER AVIONICS AND SOFTWARE INTEGRATION LAB (ASIL) MISSION DRESS REHEARSAL (MDR)



- ASIL MDR completed in April 2021 – essentially flying OFT-2 on the ground
 - Provided an opportunity to run Starliner's software end to end with the highest fidelity hardware and mission controllers in the loop
 - Served as an additional confidence and integration test recommended by the joint NASA/Boeing Independent Review Team
- Five-day, end-to-end mission simulation of Orbital Flight Test-2 to the ISS
 - Participation from CCP, ISS, Boeing, ULA
 - Mission operations teams commanded the simulation with flight procedures
 - NASA astronauts participated and monitored dynamic events on crew displays in the lab
- Integrated teams overcame challenges from COVID-19 and winter storms in Houston causing power outages and network connectivity issues
- Boeing to conduct an ASIL mission dress rehearsal before every future flight
 - Conclusion of MDR represented completion of all IRT software actions from OFT
 - Upgrades to support the ASIL MDR have increased the lab's fidelity and testing capabilities for Boeing's future software needs

JOINT INDEPENDENT REVIEW TEAM (IRT) CLOSURE

- The Joint IRT and OFT post-flight reviews identified areas of improvement to reduce the risk for future flights
 - Strengthening Boeing software and Mission Data Load processes
 - Strengthening Boeing systems engineering and systems integration
 - Strengthening NASA's assessment and mitigation of identified risks
 - NASA CCP and stakeholders reviewed the Starliner team's IRT action closures
- NASA CCP implemented SE&I and Software insight/oversight actions to complement the actions planned by the Boeing Starliner team
 - NASA CCP software team was augmented to significantly increase insight and strengthen oversight
- These combined actions should significantly reduce the risk to OFT-2, CFT, and other CCP flights
- All Boeing IRT Flight Software and Communication actions were closed
- NASA CCP and stakeholders reviewed all Boeing IRT actions for concurrence with closure



CREW-3

Crew-3 Mission: Launch November 10, 2021

Crew: Raja Chari, Tom Marshburn, Matthias Maurer, Kayla Barron

Falcon 9

Crew Dragon: *Endurance* currently docked to ISS, up to 180 days planned

- First reuse of Crew Dragon nose cone
- Launched 2 days after Crew-2 landing
- First indirect crew handover (Crew-2/Crew-3) following post flight assessment

Crew recovery planned in Atlantic Ocean

Top Program Lessons Learned:

Indirect Crew Handover, Waste Management System design change, Weather-related considerations on launch and landing, Balancing multiple missions in flow (including commercial missions), software reentry enhancements





2022 YEAR AHEAD

CREW-4

Crew-4 Mission: Launch NET April 15, 2022

Crew: Kjell Lindgren, Robert “Bob” Hines, Jessica Watkins, Samantha Cristoforetti

Falcon 9

- First four flight Falcon 9 First Stage Booster for CCP

Crew Dragon – up to 180 days planned on orbit

- New Spacecraft with reuse of more Dragon composite components
- Crew recovery planned in Atlantic Ocean or Gulf of Mexico



ORBITAL FLIGHT TEST-2

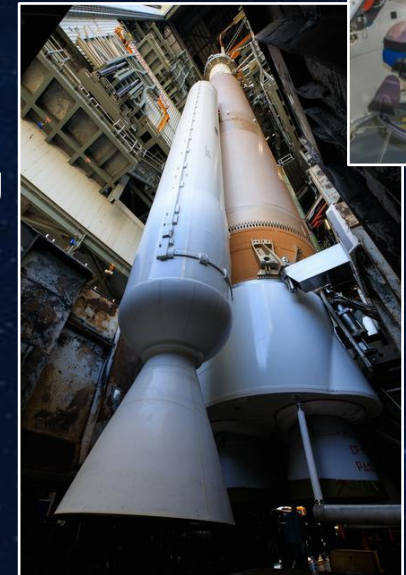
Starliner Orbital Flight Test-2: Uncrewed test flight

First launch attempt, Aug 3, 2021 / Second launch attempt, working toward a window in May
United Launch Alliance Atlas V

Starliner: New crew and service modules

Oxidizer Isolation Valve Anomaly Investigation Status:

- Investigation continues to validate most probable cause: oxidizer and moisture interactions
- NASA has been working alongside Boeing during the investigation
 - Leveraging materials and propellants expertise
 - Testing at White Sands Test Facility (WSTF) and Marshall Space Flight Center
 - Analyses of samples of corrosive material found in the valves, micro-CT scans and borescopes, exposure of valves to various conditions
- NASA/Boeing will continue analysis and testing of initial service module & components leading up to the launch
- Boeing accelerated production of service modules for OFT-2 and CFT following extensive testing and analysis
 - SM4 (planned for CFT) will fly OFT-2, SM5 (planned for Starliner-1) will fly CFT
 - Testing underway to ensure the health of the new service module hardware/systems
 - Preventative remediation efforts will be applied to the new service module



CREW FLIGHT TEST

Crew Flight Test Mission

Crew: Barry “Butch” Wilmore, Mike Fincke

United Launch Alliance Atlas V

Starliner: crew module *Calypso*, new service module

Path to Flight:

- NASA working to complete review and approval of certification products on critical path
- Launch date will be assessed after OFT-2 post-flight data assessments are complete
- Service module production will be a key schedule driver
- Parachutes
 - CFT configuration is baselined, no major redesign
 - System upgrades planned for rotational missions to further improve main parachute margins by reinforcing and increasing the strength of suspension line material and attachment points.
- Launch Abort Engine Hot Fire complete
- Simulations, crew transportation tests and ASIL Mission Dress Rehearsal forthcoming



CREW-5

Crew-5 Mission: Launch NET Fall 2022

Crew: Nicole Mann and Josh Cassada

- NASA decided it was important to make the reassignments of Mann and Cassada from Starliner to Crew Dragon to allow Boeing time to complete the development of Starliner while continuing plans for astronauts to gain spaceflight experience for the future needs of the agency's missions
- Mann and Cassada have begun training with SpaceX on Crew Dragon
- Expecting additional international partner astronaut assignments
- All hardware and pacing items currently on track for flight





SubC

- CCP developing an approach to a safety risk assessment for purposes of flying NASA personnel, along with an associated acquisition strategy
- CCP will use its existing resources, including expertise and program infrastructure to implement the SubC safety risk assessments

LESSONS LEARNED



- Safety, reliability and cost effectiveness of the resultant crew transportation system are key to developing a commercial capability
- NASA and industry have demonstrated that the public/private approach is viable
- Relationship between industry and NASA is imperative to success
 - Learning environment with continuous improvement in processes and communications
 - Mature and stable requirements, managed at a higher level
 - Smart application of design and construction standards
 - Efficient and effective government insight/oversight, including independent analysis and testing
 - Lean and agile program management
- CCP continues a series of “lessons learned” overviews, including those focused on hardware/software design and operation, for NASA’s human spaceflight programs to benefit from CCP’s experience and successes
 - Areas of shared lessons among providers: COPVs, hypergol material compatibility, parachute asymmetry, abort system, independent software validation and verification
 - Operations processes and performance results are reviewed and shared to ensure proficiency and reduce risk

SUMMARY

CCP continues to make significant progress and shares lessons learned for the benefit of other NASA human spaceflight programs:

Operational milestones complete:

- Crew-1 Landing
- Crew-2 Launch and Landing
- Crew-3 Launch

Ongoing fleet following operations:

- Commercial Human Spaceflight Missions
- Commercial Resupply Services Missions

Mission planning and preparations for CCP missions manifest:

Upcoming Launch Opportunities:

- Crew-4 (NET April 15, 2022)
- OFT-2 (NET May 2022)
- Crew-5 (Fall 2022)

