Commercial Crew Program Overview

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https://www.flickr.com/photos/nasakennedy/albums/with/72157647244171004

COMMERCIAL CREW PROGRAM

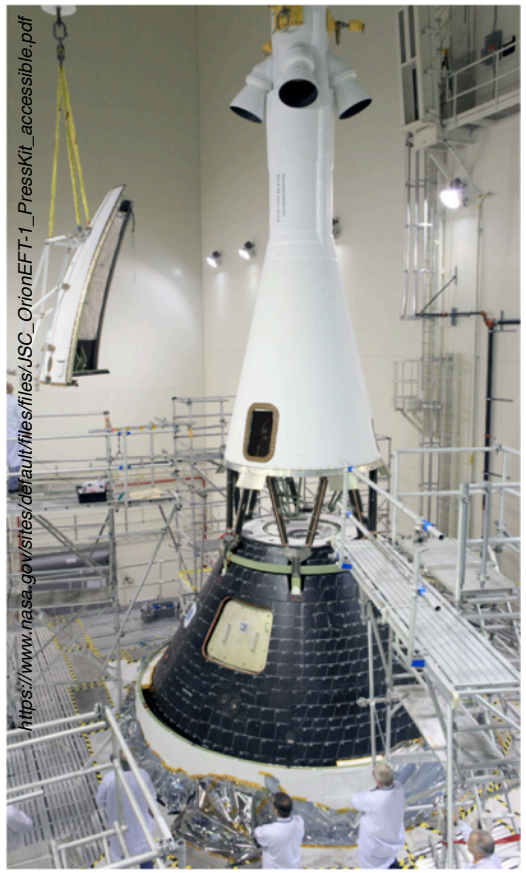
Agenda

- **Commercial Crew Program Overview**
  - Commercial Crew Program Roles and Responsibilities
- **Commercial Provider Overview**
  - Boeing
  - SpaceX
- **Independent Assessment of Commercial Providers**
  - Aerothermal Database Development
  - Targeted, Risk-based Assessments
- **Flight Tests and Operational Missions**

Commercial Crew Program Overview

https://commons.wikimedia.org/wiki/File:Space_Shuttle_Atlantis_launches_on_STS-132.jpg

Rockwell International



https://www.nasa.gov/sites/default/files/files/JSC_OrionEFT-1_PressKit_accessible.pdf

LOCKHEED MARTIN

https://commons.wikimedia.org/wiki/File:Artemis_1_SLS_Rollout_%28cropped%29.jpg

BOEING

- **NASA has worked with many companies, both prime contractors and subcontractors, throughout history to develop human-rated spacecraft**
  - Space Shuttle was built by Rockwell Aerospace
  - Orion is built by Lockheed Martin
  - SLS is built by Boeing
- ***So, what's different about CCP?***

Commercial Crew Program Overview

Buying a Vehicle vs. Buying a Service

- **In other programs (Shuttle, Orion, etc.), NASA pays a prime contractor to build a vehicle for a NASA mission**
  - NASA provides requirements for the vehicle
  - NASA owns and operates (or pays prime contractor to operate) the vehicle
- **In CCP, NASA is paying two commercial companies, Boeing and SpaceX, for a service (transportation to the ISS in this case)**
  - NASA provides requirements of the service
  - Commercial company owns and operates the vehicle
  - NASA pays for transportation on that vehicle

SPACEX

BOEING

Commercial Crew Program Roles and Responsibilities

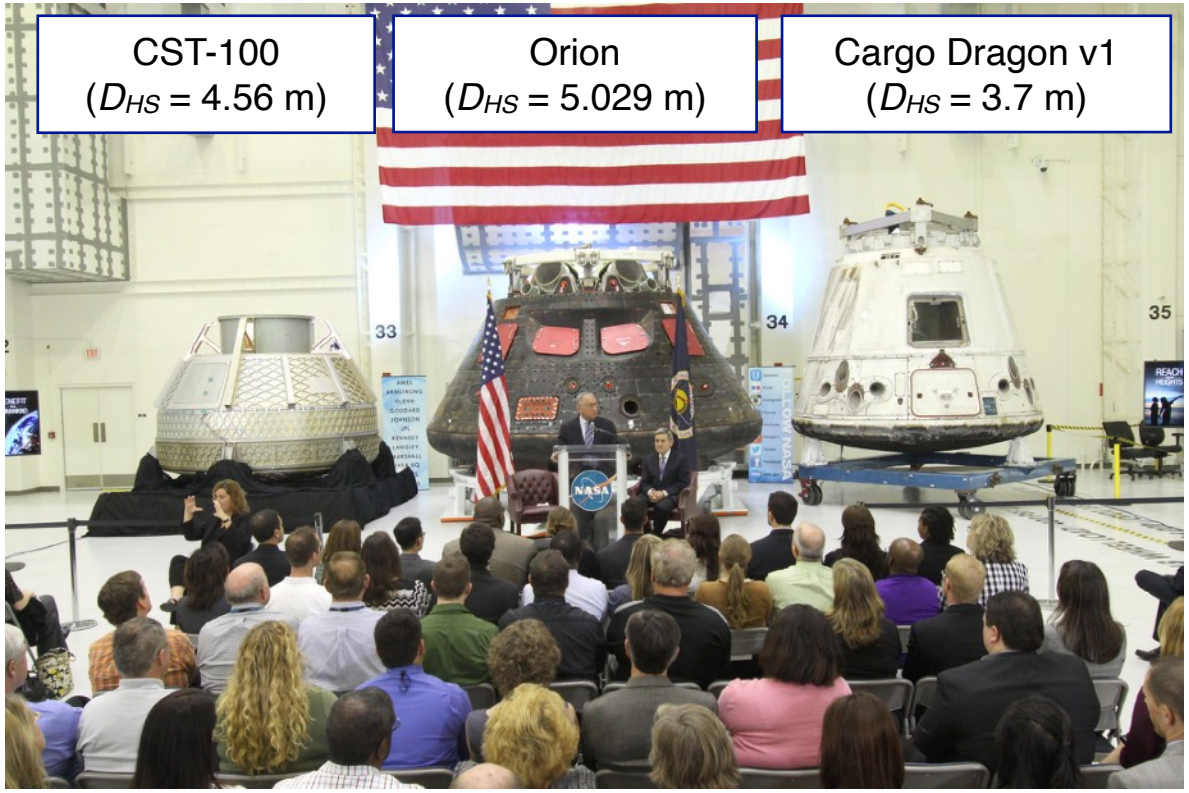
Ensure a safe ride to and from the International Space Station for our NASA and International Partner crew members!

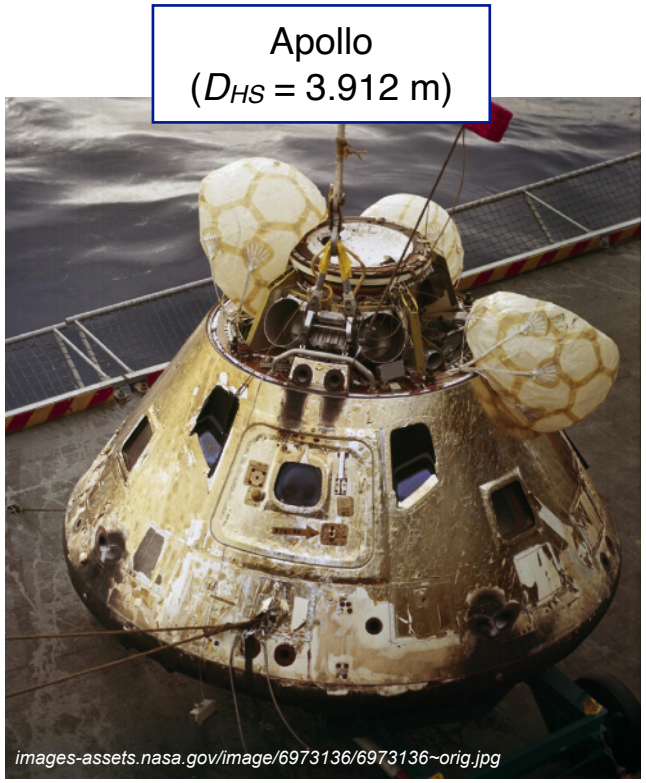
- **Requires NASA oversight to assure safety of our crew during the missions.**
  - In the aerosciences department, this includes:
    - Aerodynamics, aerothermodynamics, parachutes, and aborts
    - Independent analysis with CFD and wind tunnel testing for greater insight into provider designs
- **Discipline Technical Authority for Entry Aerothermal Environments Design**
  - Understand all aspects of the design related to Entry Aerothermodynamics
  - Understand all NASA standards/CCP requirements related to Entry Aerothermodynamics
- **Responsible for Certification of the Commercial Provider Aerothermal Environments Design (*are the aerothermal environments sufficient to support thermal protection system design for a safe vehicle?*)**
  - Assessment of the Design to the CCP requirements
  - Assessment of the Provider's analysis to support requirements closure
  - Assessment of Hazard Reports and Derived Requirements
  - Active in production, manufacturing, and test
- **Responsible for Flight Readiness Assessment and Certification of Flight Readiness (CoFR) for every NASA mission**
- **Responsible for identifying technical risks to the Program**

First Cadre of Commercial Crew Astronauts

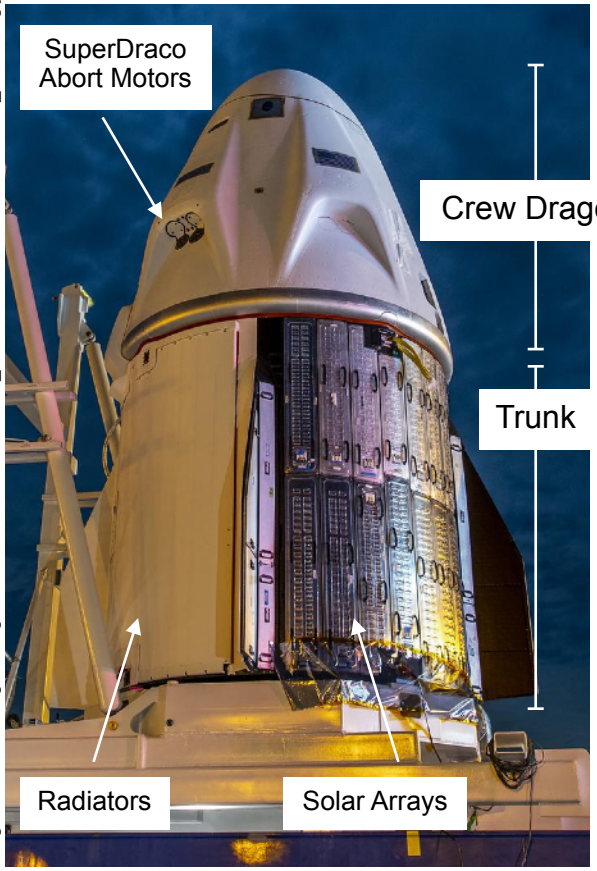
Commercial Provider Overview

- **Vehicles currently under development or used for ISS transportation are capsules that carry 4 crew members**
  - Vehicle sizes vary due to mission objectives and desired performance
  - All use ablative primary heatshields to dissipate the heat of reentry
- **Performance driven by mission objectives, and abort system architecture for each vehicle is unique**





SpaceX Crew Dragon



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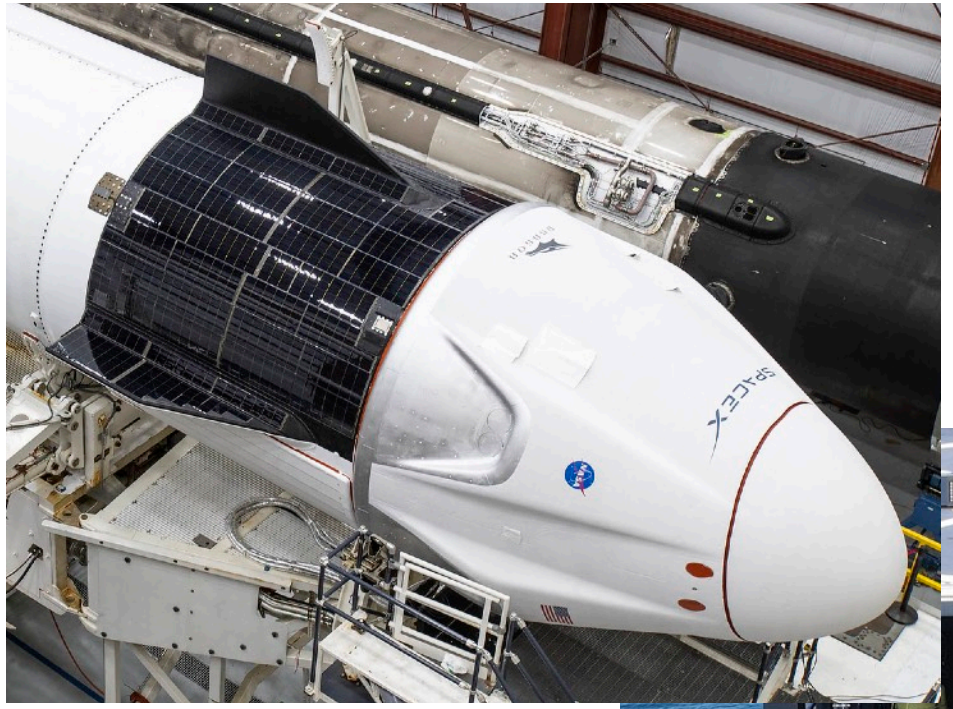
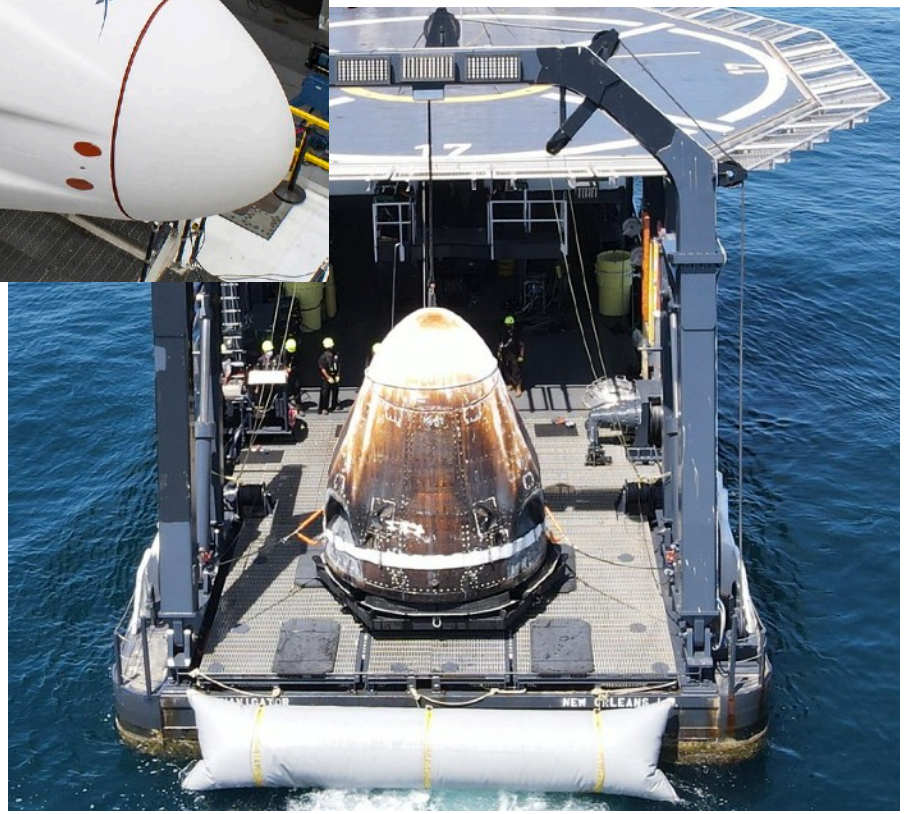
- **Crew Dragon was designed initially as a single-use vehicle, but many components have been re-certified for vehicle reuse after initial certification**
  - Primary deceleration following reentry provided by four main parachutes
  - Water landing at one of several sites in the Gulf of Mexico or off the Florida coast in the Atlantic Ocean
- **Launches from LC-39A at KSC on a Falcon 9 launch vehicle**
  - Vehicle integration occurs horizontally, the goes vertical at the launch pad
  - NASA crew missions can fly on boosters that have been previously flown up to 2 times

SpaceX Dragon TPS Overview

- **Thermal protection system uses primarily ablative materials**
  - Ablative TPS materials on Dragon differ on the primary heatshield and the backshell and are SpaceX proprietary formulations
    - Heatshield uses PICA 3.0
    - Backshell uses SPAM (SpaceX Proprietary Ablative Material)
  - High heating regions, such as the mudflaps where the SuperDraco abort motors impinge, are protected by carbon phenolic
- **TPS materials are removed from structural components after flight and replaced with new TPS prior to the next mission**





Boeing CST-100 Starliner

- **CST-100 Starliner was designed as a reusable vehicle for transportation to the ISS**
  - After return from ISS, a series of parachutes are deployed to slow the vehicle
  - Lands on land, cushioned by landing airbags, so base heatshield is deployed prior to landing
- **Launched from LC-40 at KSC on an Atlas V launch vehicle**
  - Vertical integration with launch vehicle at ULA VIF (vertical integration facility)

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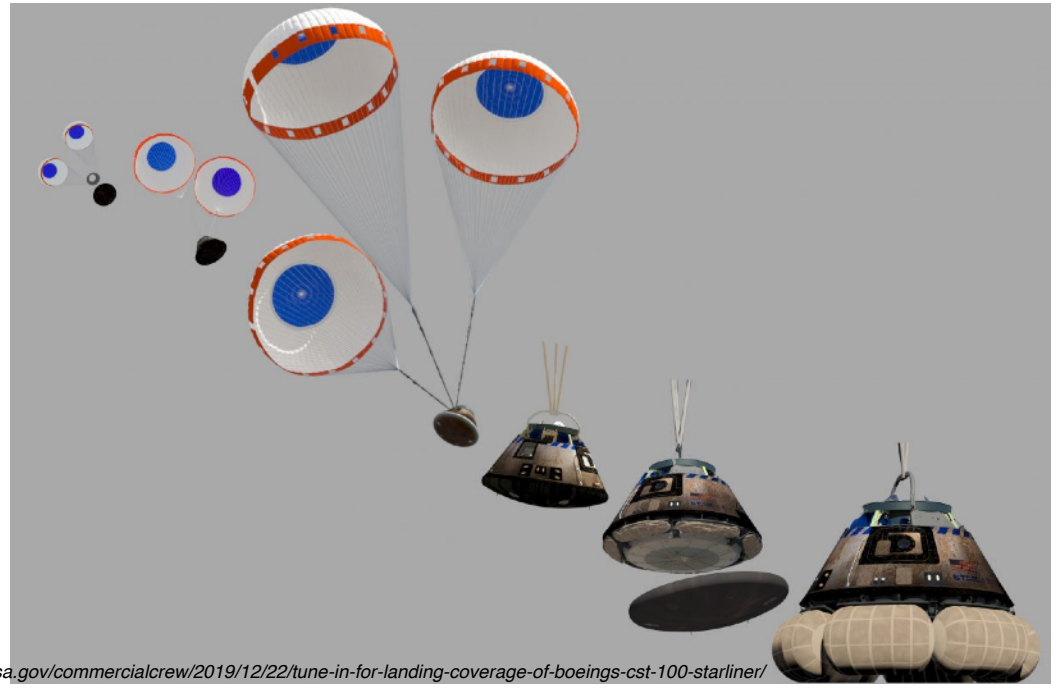

https://blogs.nasa.gov/commercialcrew/2019/12/22/tune-in-for-landing-coverage-of-boeings-cst-100-starliner/

Boeing CST-100 Starliner TPS Overview

- **Thermal protection system is a mix of ablative and non-ablative materials**
  - Primary base heatshield protected with BLA (Boeing Lightweight Ablator)
  - Backshell protected by a mix of blankets and tile with Shuttle heritage
- **Base heatshield is replaced each mission due to TPS ablation and destruction of structure during landing operations**
- **Non-ablative TPS is refurbished between flights**

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Independent Assessment of Commercial Providers

- **Responsible for certifying that the Commercial Provider aerothermal environments are adequate to support thermal protection system design for a safe vehicle.**
- **Entry Aerothermal subsystem takes a dual-path approach to gain insight into and confidence in the commercial provider designs.**

Independent Database Development

- Independent database developed for each commercial provider vehicle
- Database covers phases of flight most impactful to TPS design
- Provides a baseline set of aerothermal environments with which to perform Flight Readiness Assessments

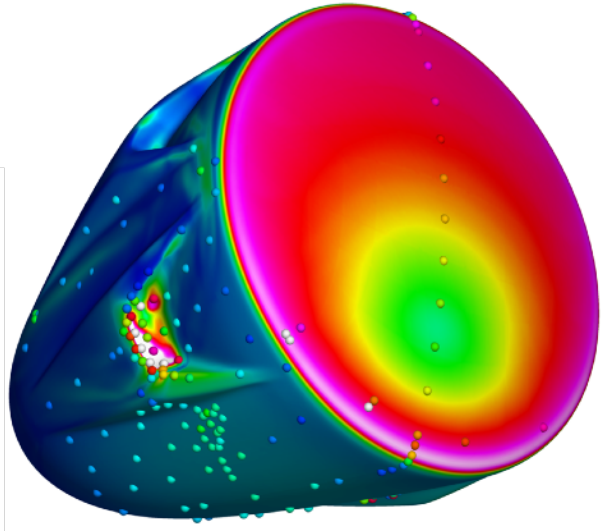
Targeted, Risk-Based Analysis

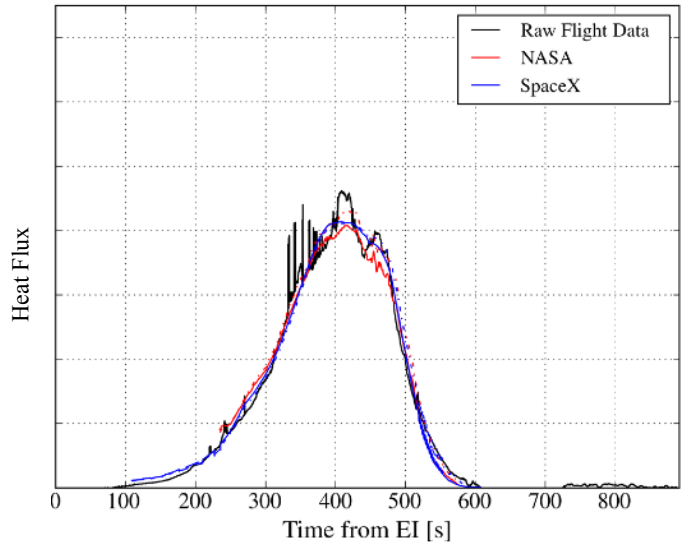
- Perform analysis specific to vehicle features, physics, and/or flight regimes not covered in the independent database
- Provides an assessment of environments in high-risk configurations without resources required for development of database models

Independent Assessment of Commercial Providers

Independent Database Development

- **Independent database developed for each commercial provider to assess design environments**
  - Use NASA best-practices for database development
  - Databases built from CFD, engineering models, wind tunnel testing, and flight tests, where available
    - DPLR, LAURA, and Loci-CHEM are used primarily for independent CFD analysis
    - Wind tunnel and flight test data from provider vehicle-specific tests as well as data from other similar, applicable vehicle wind tunnel tests
  - Database does not cover all flight regimes or vehicle features, but provides sufficient data in critical areas for assessment of partner approach
- **Comparisons between NASA independent database environments and partner environments provide confidence in provider approach**
  - Good agreement provides confidence in partner assumptions and practices leading to a robust TPS design
  - Poor agreement provides opportunities for partnered approach with commercial providers to understand differences in design approach and assumptions to ensure critical design elements are not overlooked



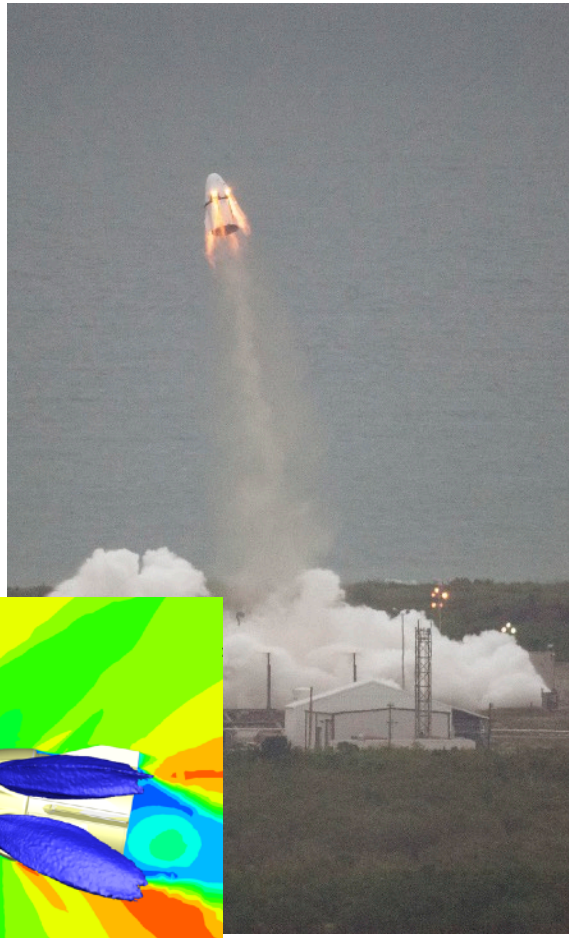


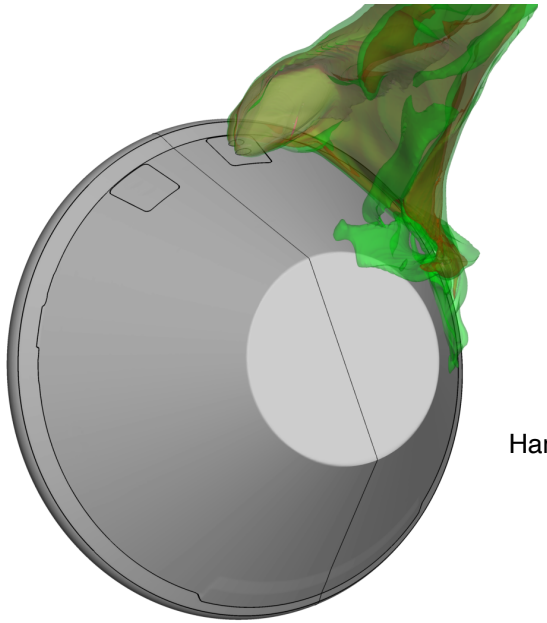
CFD comparisons to wind tunnel and flight test data for uncertainties development and database validation

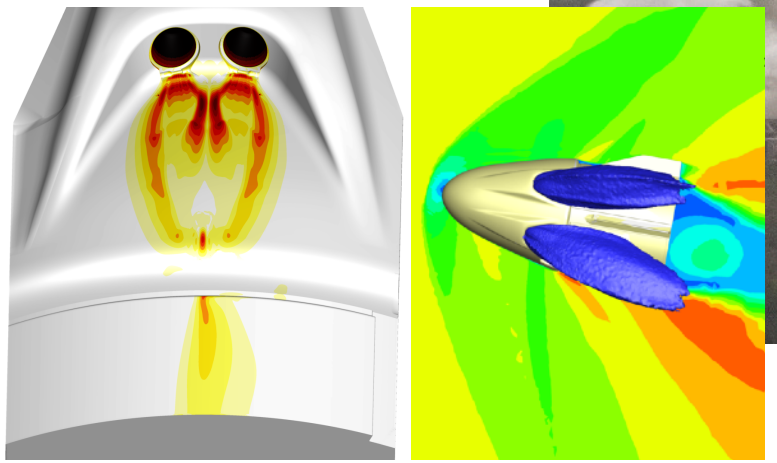
Independent Assessment of Commercial Providers

Targeted, Risk-based Analysis

- **Analysis is performed to understand vehicle and TPS performance for high-risk flight regimes or vehicle configurations**
  - Not all aspects of flight or vehicle features are captured in the independent databases
  - Targeted analysis allows for quickly quantifying aerothermal and TPS risk
  - Analyses focus on cavity/protuberance modeling and plume interactions for specific flight regimes



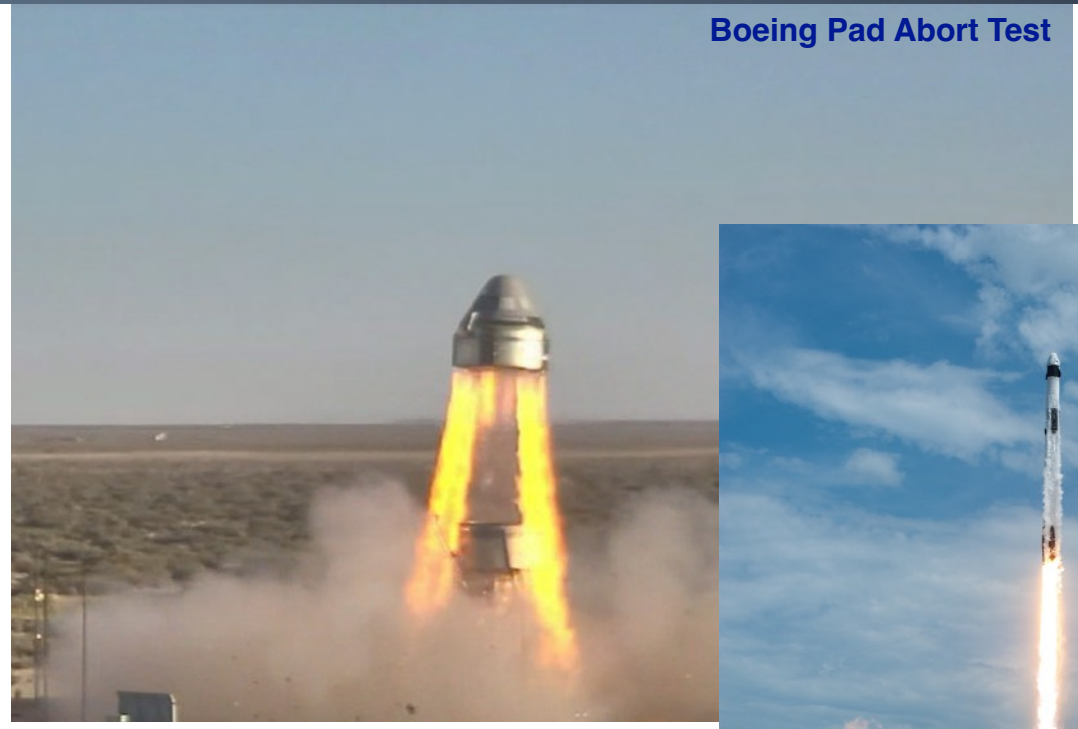




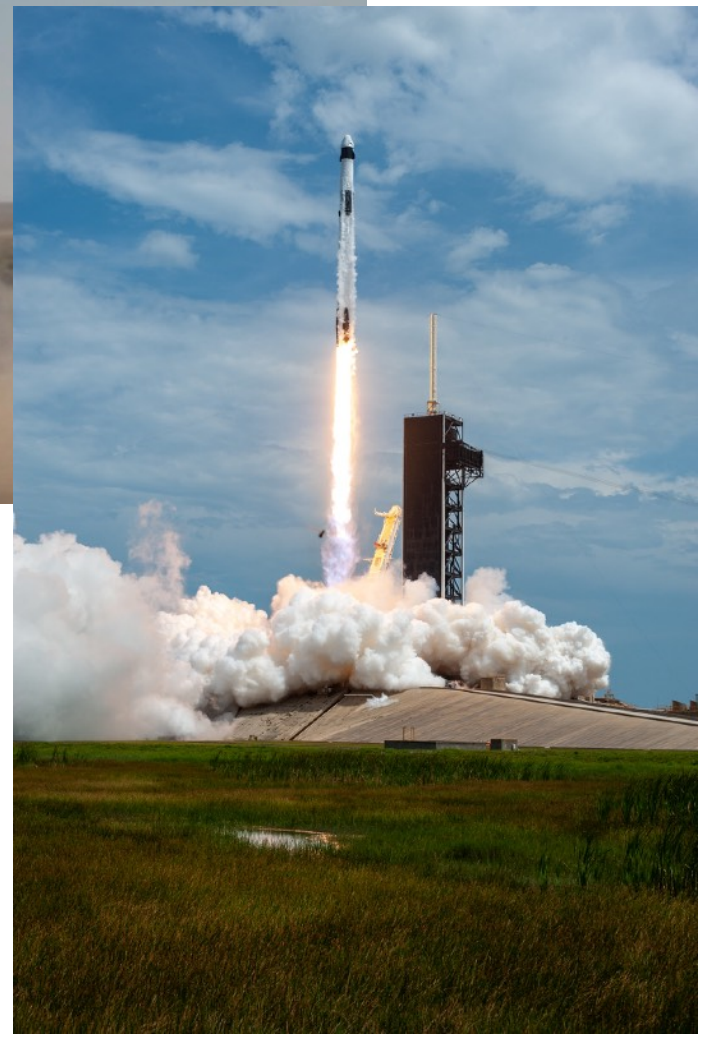
Check out this cool video of the SpaceX SuperDraco abort engines!!

Flight Tests and Operational Missions

- **Flight tests used to demonstrate integrated vehicle operations**
  - Abort flight tests
  - Orbital mission flight tests to the ISS
  - Uncrewed and crewed missions
    - Allow for initial demonstration of vehicle performance without risk to onboard crew
    - Manual piloting demonstrations occur after uncrewed flight tests but prior to final vehicle certification
- **Operational missions allow for access to the ISS using commercial services**
  - Allow NASA to put resources towards exploration missions
  - Develops commercial space economy and increases access to space



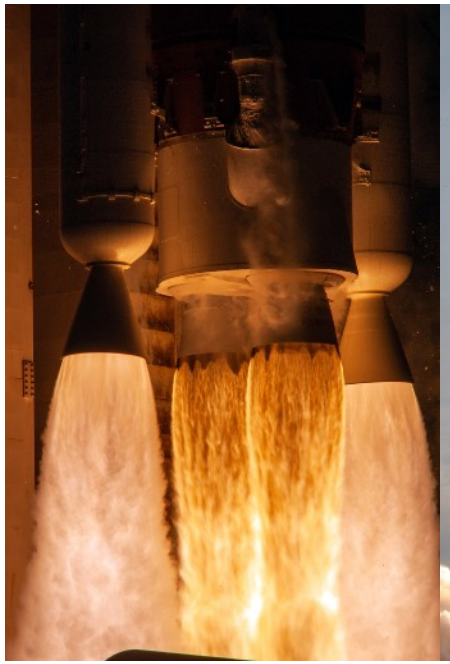
Boeing Pad Abort Test

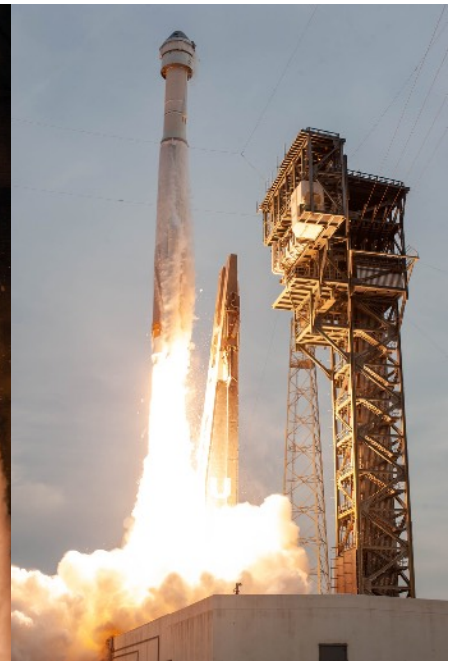


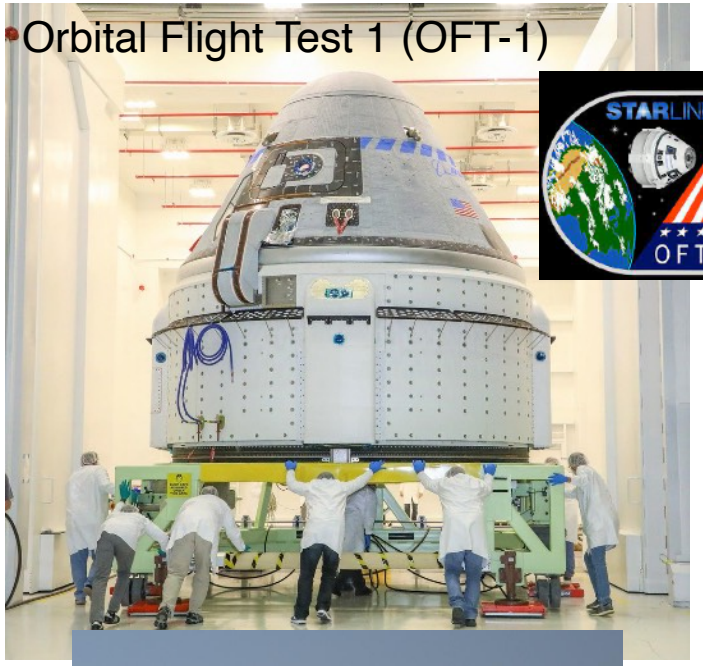
SpaceX Demonstration Mission 2 (DM-2):
First Crewed Flight to ISS on a Commercial Vehicle

Boeing Flight Tests

- **Orbital Flight Test 1 (OFT-1) mission did not dock to ISS due to several anomalies during the mission, so OFT-2 was flown to complete all test flight objectives**







- **Crew Flight Test (CFT) will carry two crew members to the ISS**
- **Currently scheduled for late 2022, pending review of OFT-2 flight data and vehicle performance**

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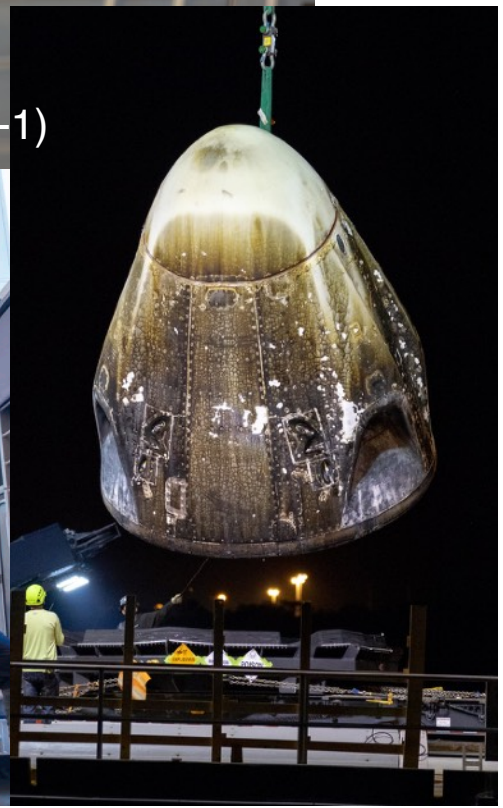
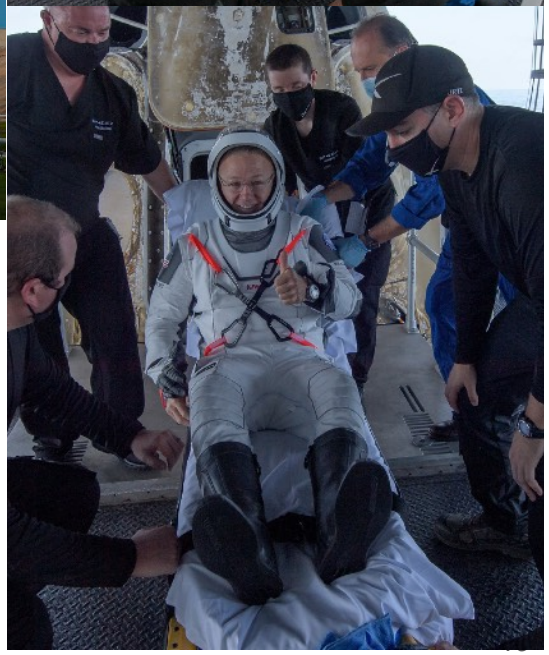
SpaceX Flight Tests

Demonstration Mission 1 (DM-1)



Demonstration Mission 2 (DM-2)

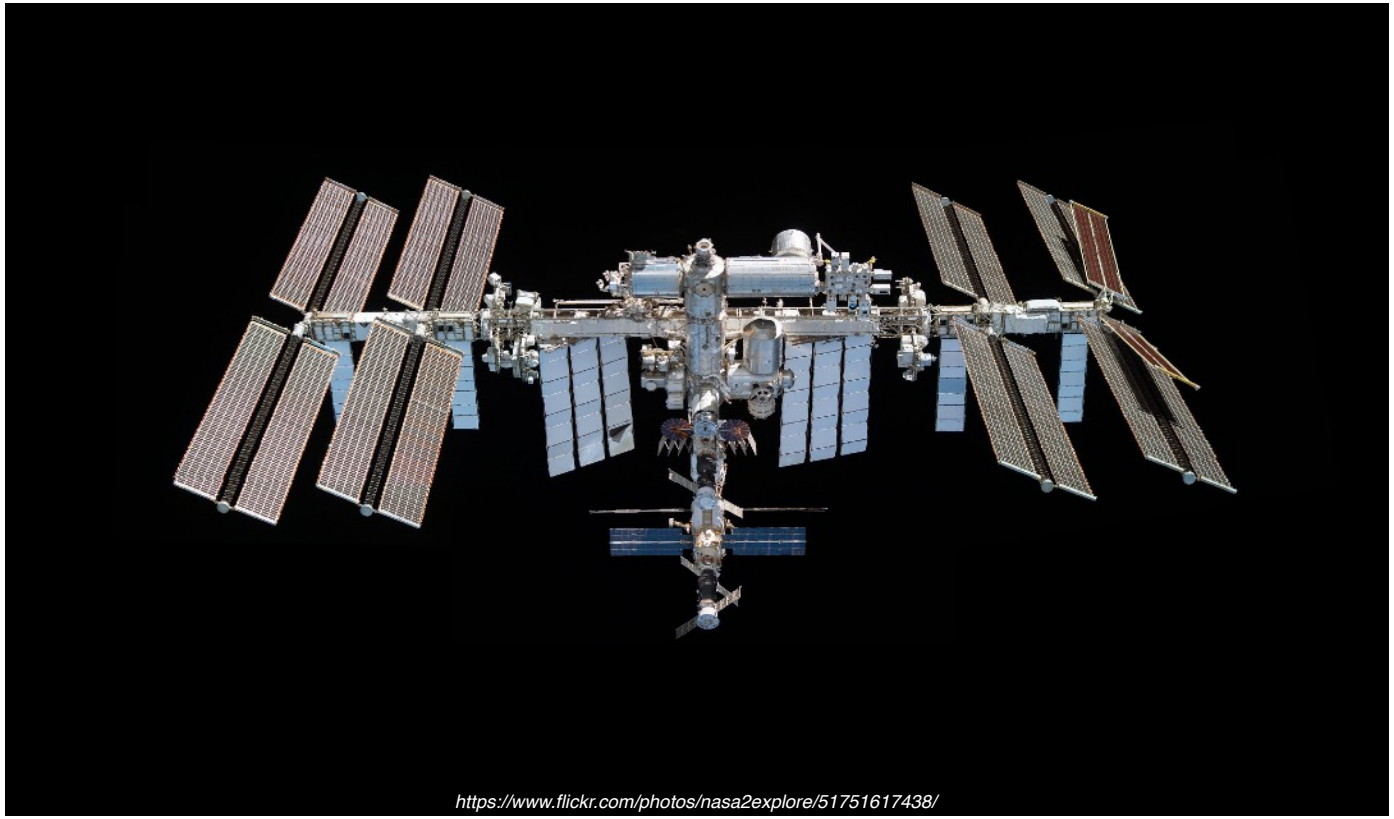


SpaceX Operational Missions

Mission	Launch Date	Return Date
Crew-1	November 16, 2020	May 2, 2021
Crew-2	April 23, 2021	November 9, 2021
Crew-3	November 11, 2021	May 6, 2022
Crew-4	April 27, 2022	October 2022
Crew-5	September 2022	March 2023

Looking to the Future

- **International Space Station will fly through 2030 on the current plan, supported by the Commercial Crew and Commercial Cargo Programs**
  - After crew certification, Boeing has six crew rotation missions on contract (PCM 1 - PCM 6)
  - SpaceX will fly up to 14 missions to the ISS to likely finish out the expected crew rotations for the life of the program (Crew-1 - Crew-14)
- **New partnerships are being pursued for development of new LEO destinations**



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