NASA High Lift Common Research Model (CRM-HL) Wind Tunnel Tests at the National Transonic Facility (NTF)

05/22/2025 TTT-RCA High-Fidelity CFD Workshop

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Outline

- Introduction
- NTF high Reynolds number test of the NASA 5.2%-scale CRM-HL model
- NASA 5.2% CRM-HL model tunnel-to-tunnel comparison
- Plan for NTF high Reynolds number testing of the NASA 2.7% full-span CRM-HL model
- Future NASA CRM-HL tests
- Questions

Photo Credit: NASA

CRM-HL High Reynolds Number Wind Tunnel Tests at the NTF

Problem: Predicting $C_{L,max}$ and assessing transition, turbulence models, and Reynolds number effects in CFD requires wind tunnel data for comparison.

Objective: Expand the CFD validation database by testing multiple wind tunnel models designed using the same reference geometry in various wind tunnels around the world. The wind tunnel data and model geometry will be open source to allow for CFD validation use.

Approach: Test the NASA 5.2%-scale High Lift Common Research Model (CRM-HL) semispan model and the NASA 2.7%-scale CRM-HL semispan and full-span models at the National Transonic Facility (NTF). Test the models at chord Reynolds numbers (Re_c) between 1.6 million and 30 million and at varying Q/Es to assess Reynolds number effects and aeroelasticity affects on the model, while collecting force and moment, pressure and wing deformation data. Test the model with ice shapes installed on the leading edges.

Results: Tested eight model configurations of the NASA 5.2%-scale CRM-HL model in NTF, including four landing, two landing with ice shapes installed, and two takeoff configurations. The test was conducted in air (120°F) and nitrogen operations (-50°F, -180°F and -250°F) at 7 different chord Reynolds numbers. The data compare well with previous tests of the same model at the Germany Aerospace Center (DLR) and the LaRC 14- by 22-Foot Subsonic Tunnel (14x22).
Designed and fabricated the NASA 2.7%-scale CRM-HL full-span and semispan models for testing in the NTF.

Significance:

- Provided valuable high Reynolds number data on a relevant modern transport high lift configuration to the worldwide research community.
- Provided icing data at flight Reynolds number to the research community.

Testing of the NASA 5.2%-Scale CRM-HL at the NTF

- Jan 3, 2024 to May 23, 2024
- 85 data runs
  - 32 within-test repeats
  - 4 repeats with 14x22
  - 4 repeats with DLR/NWB
- Eight model configurations
  - Four landing configurations
  - Two takeoff configurations
  - Two configurations with ice shapes on the wing
- Air and Cryogenic (Nitrogen) runs
- Temperature: 120°F to -250°F
- Chord Reynolds Number: 1.6 million to 30 million
- Mach: 0.2 to 0.35
- Alpha: -4° to 22°

Photo Credit: NASA

Configuration	Mach	Re_c, million	Nacelle	Landing Gear	Horizontal Tail
Landing	0,2, 0.26, 0.3, 0.35	1.6, 3.33, 5.32, 5.49, 5.9, 16, 30	on/off	on/off	on/off
Landing with ice shapes	0.2	5.32, 5.49, 5.9, 16, 30	on	off	on/off
Takeoff	0.23, 0.26	1.8, 1.97, 4.08	on/off	off	off

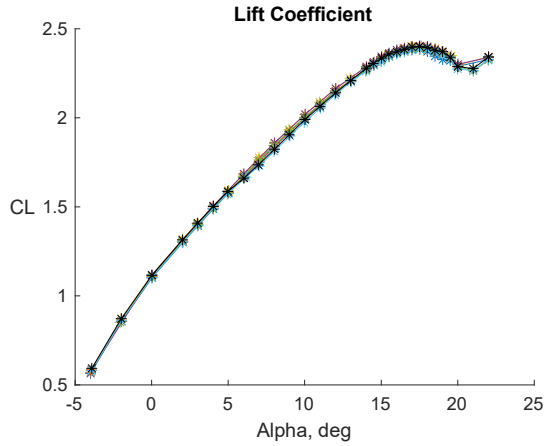
All data shown is landing unless otherwise noted

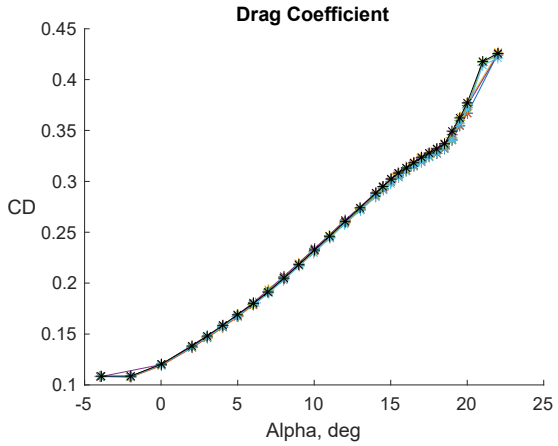
Short- and Long-Term Repeats in NTF

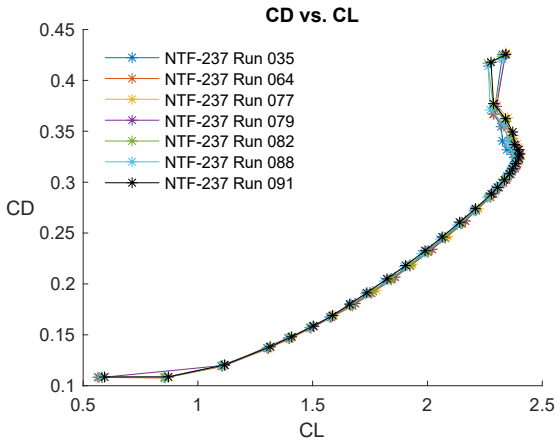
Short- and long-term repeatability look good

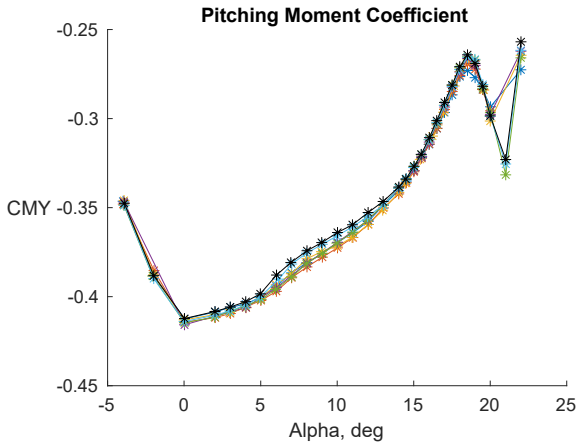
- Short-term is same day
- Long-term is one week to almost two months later

Landing baseline
5.49 million Re_c

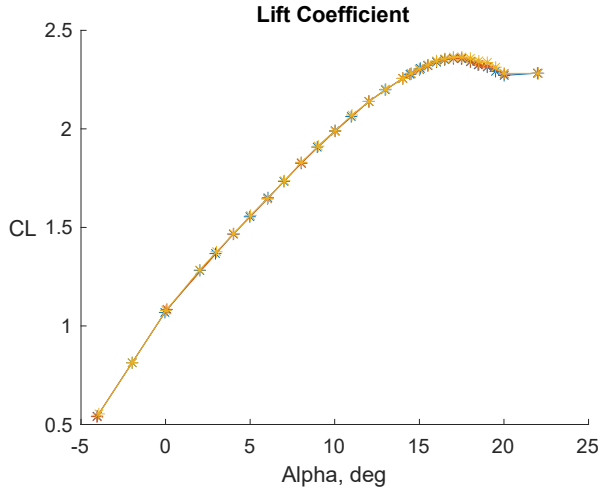


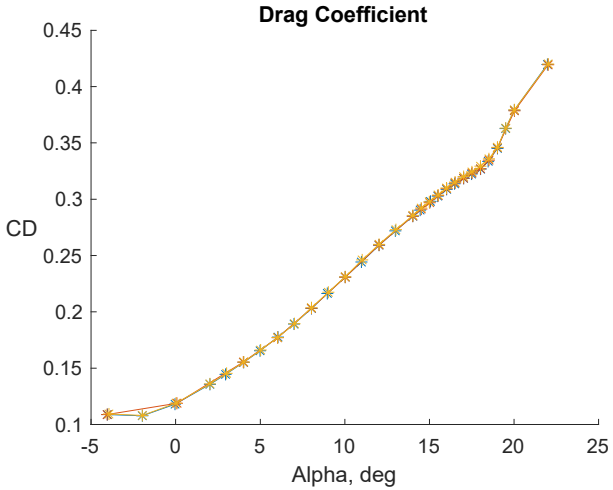


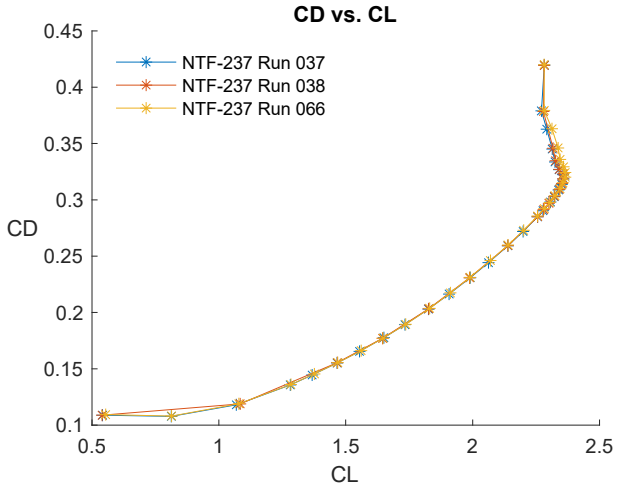


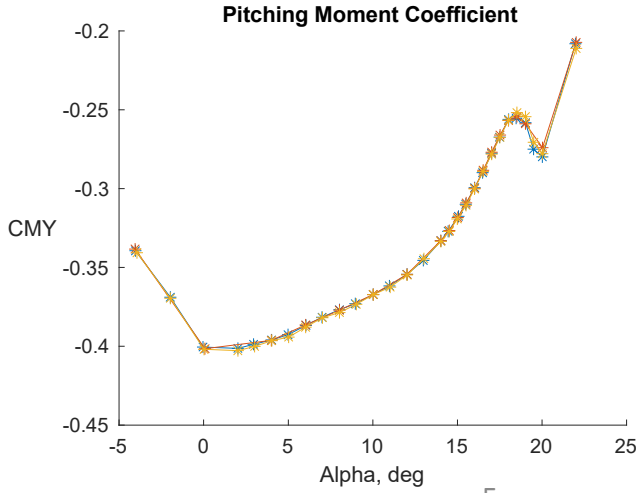


Landing baseline
3.33 million Re_c





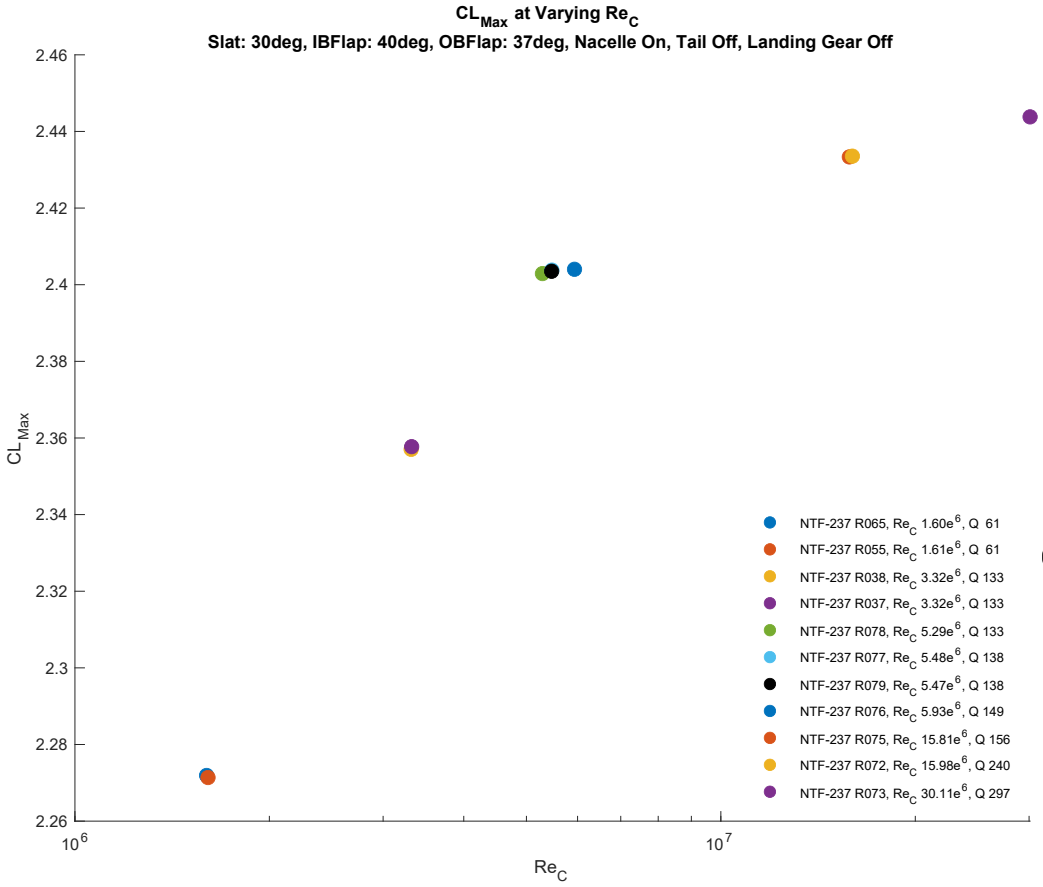


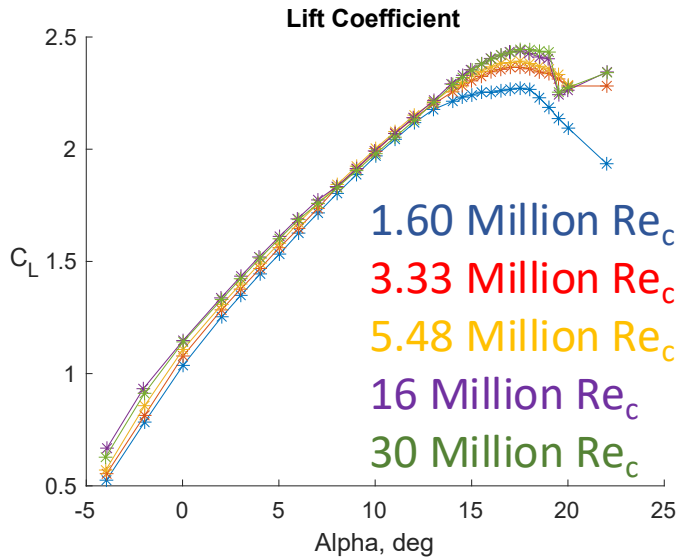


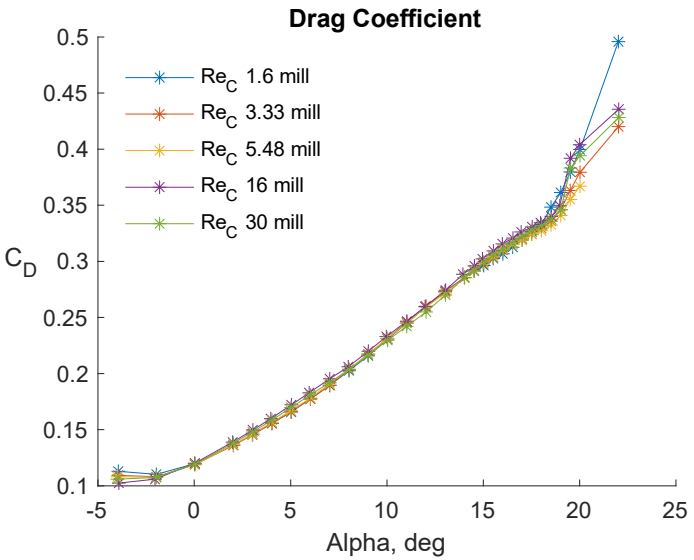
5.2%-Scale CRM-HL NTF Reynolds Number Effects

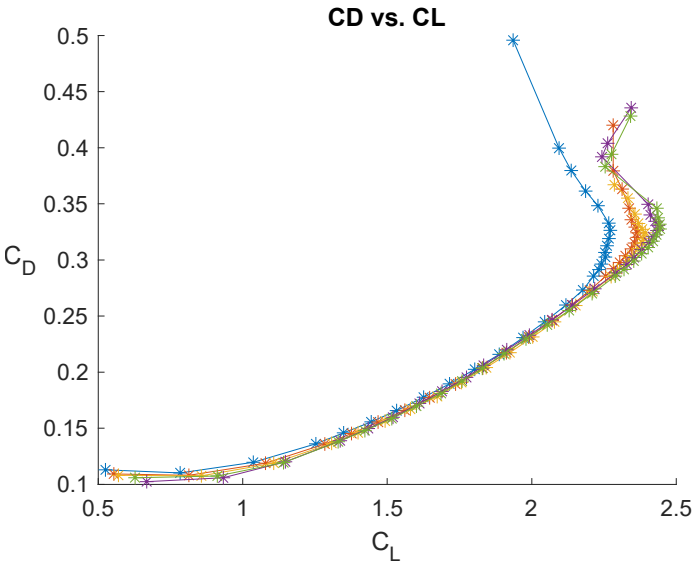
Reynolds number effects are as expected

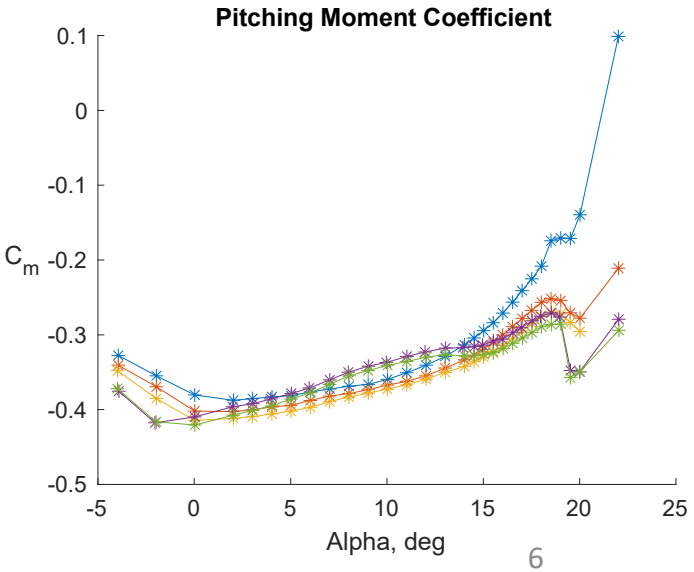
Landing baseline









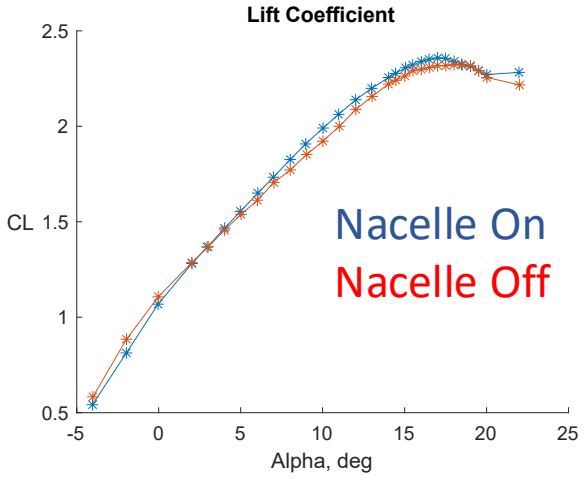


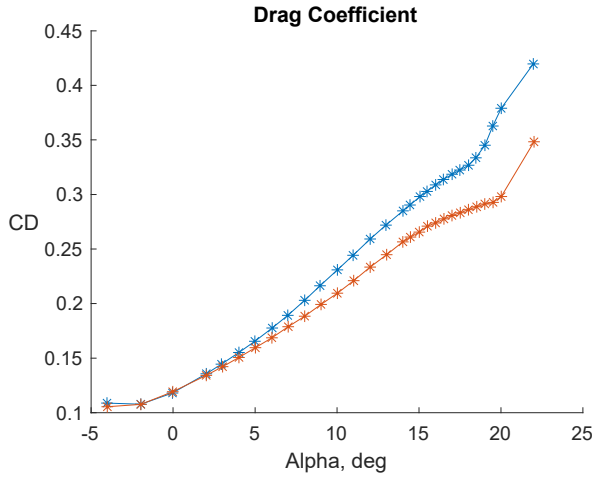
Nacelle On vs. Nacelle Off

Nacelle effects are as expected

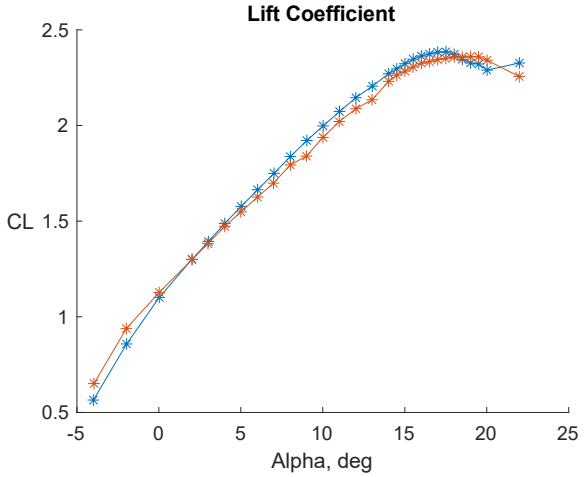
Photo Credit: NASA

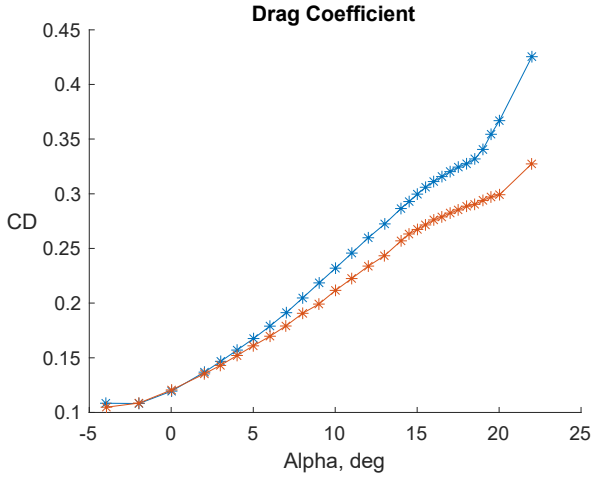
Re_c 3.33 million

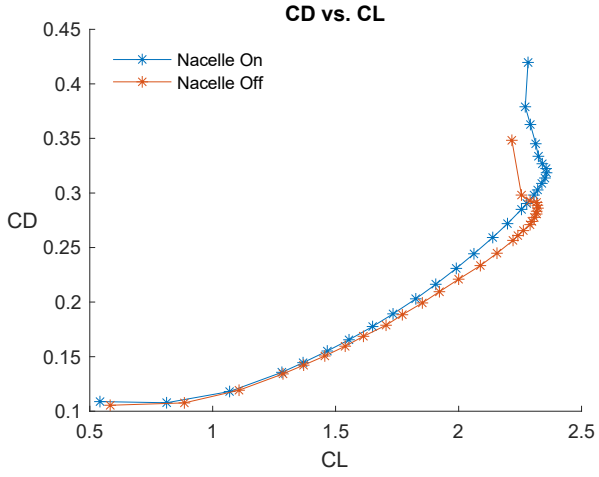


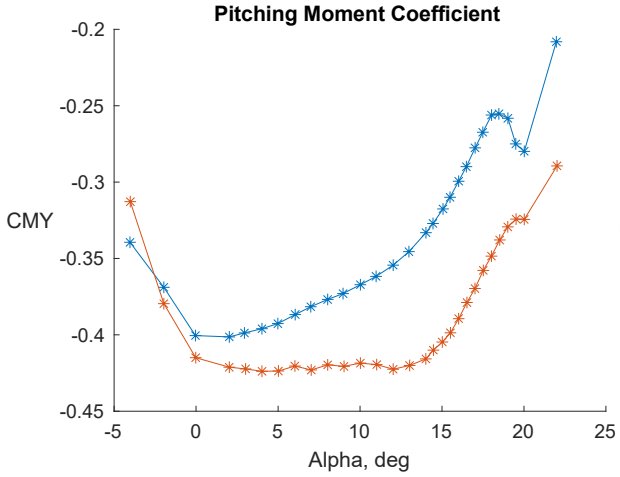


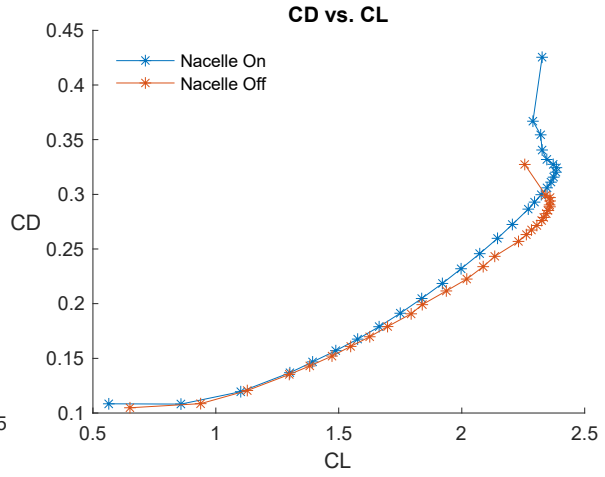
Re_c 5.49 million

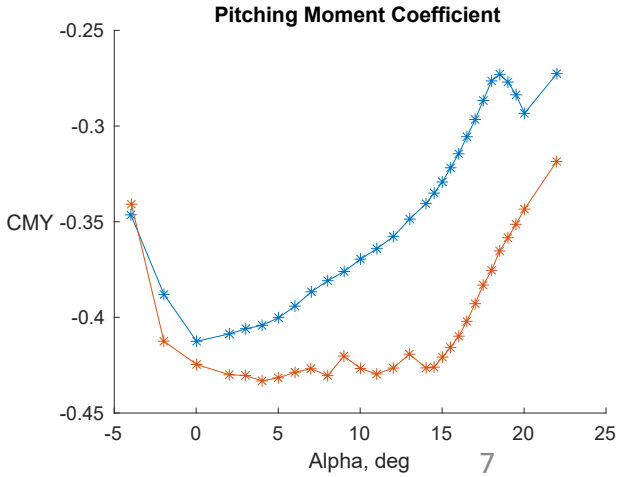










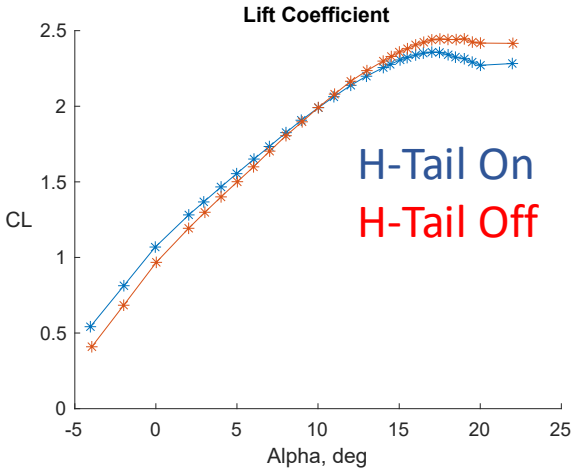


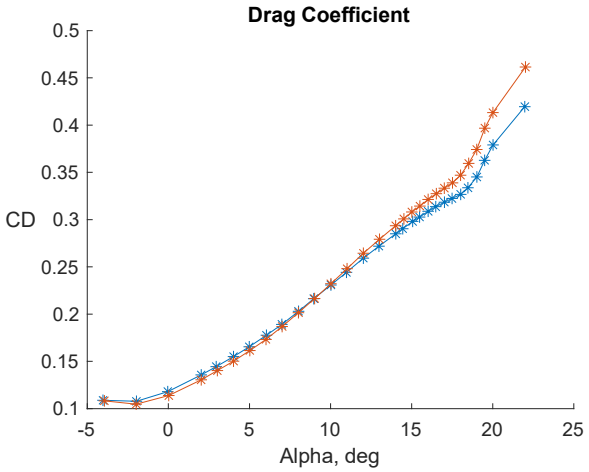
Horizontal Tail Off vs. Horizontal Tail On

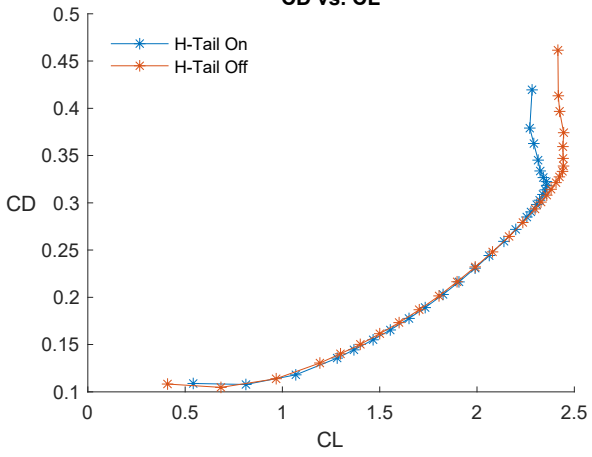
Tail effects are as expected

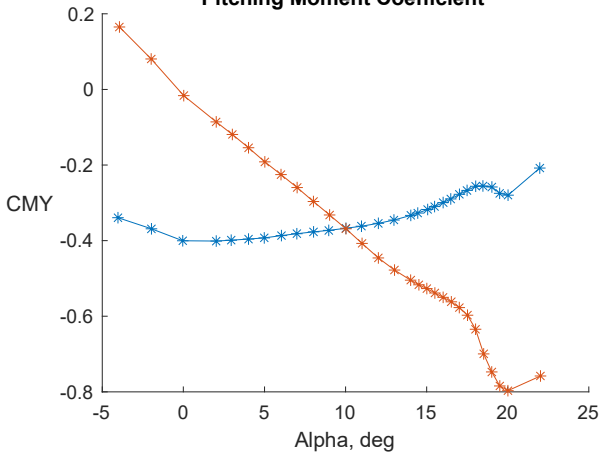
Photo Credit: NASA

Re_c 3.33 million

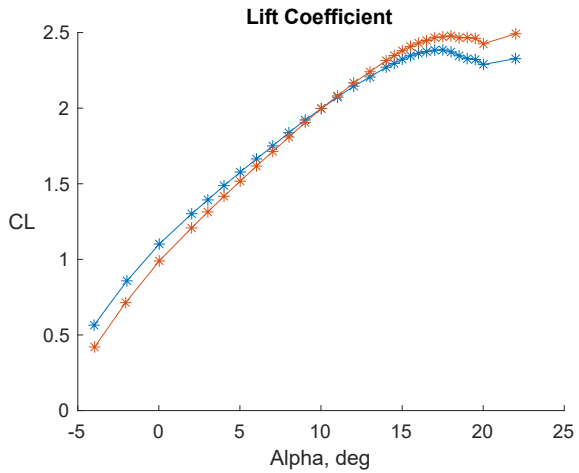


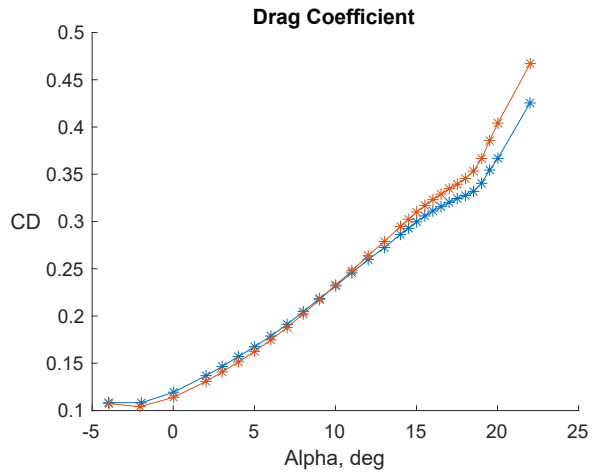


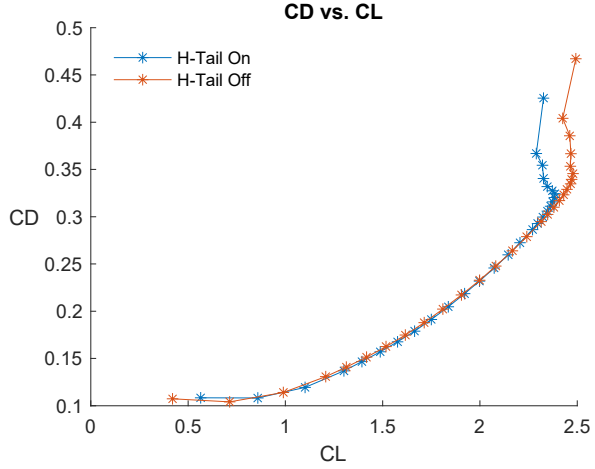


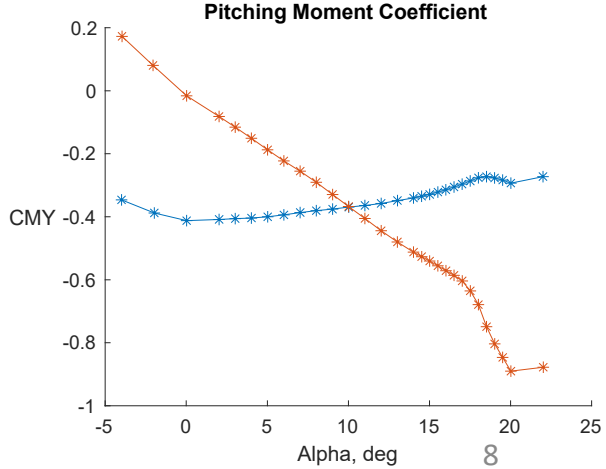


Re_c 5.49 million







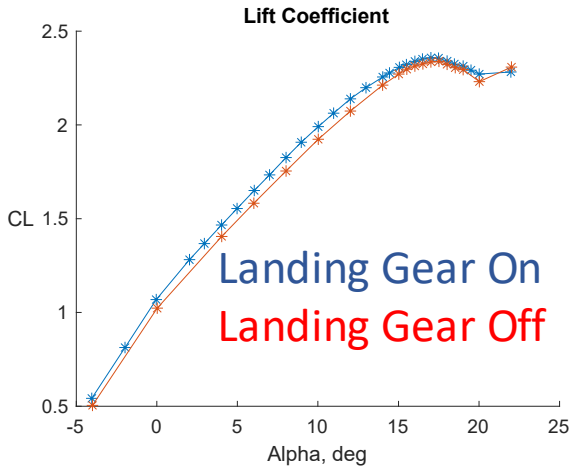


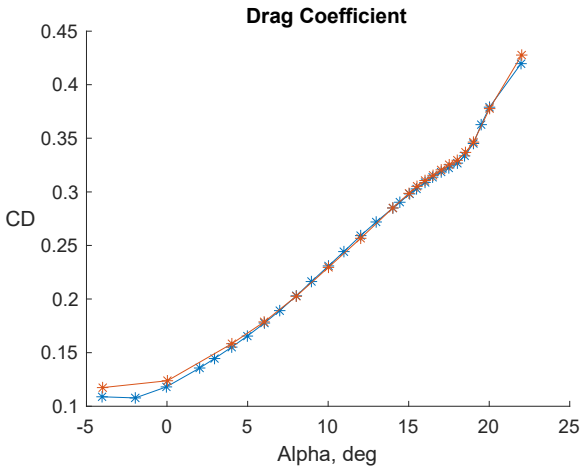
Landing Gear Off vs. Landing Gear On

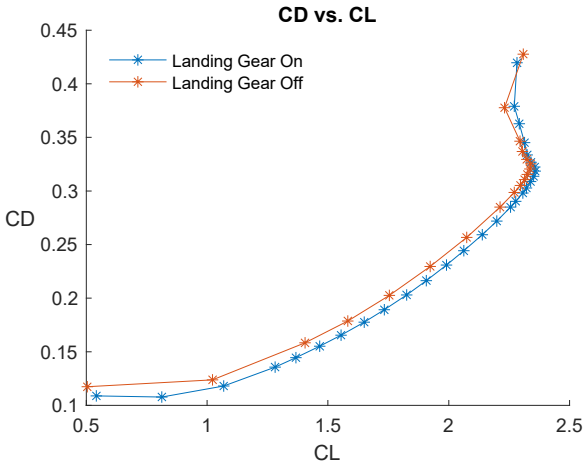
Landing gear effects are as expected

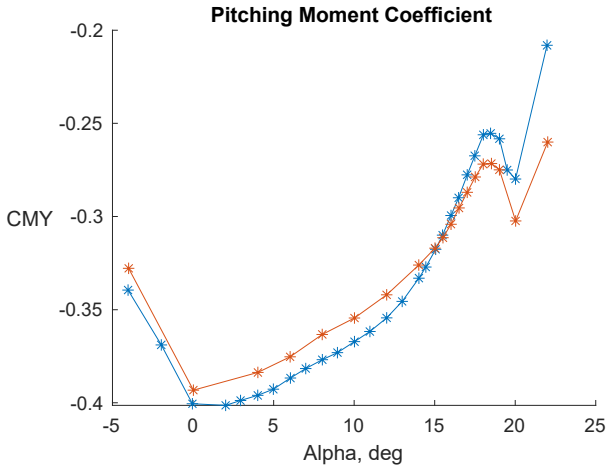
Photo Credit: NASA

Re_c 3.33 million

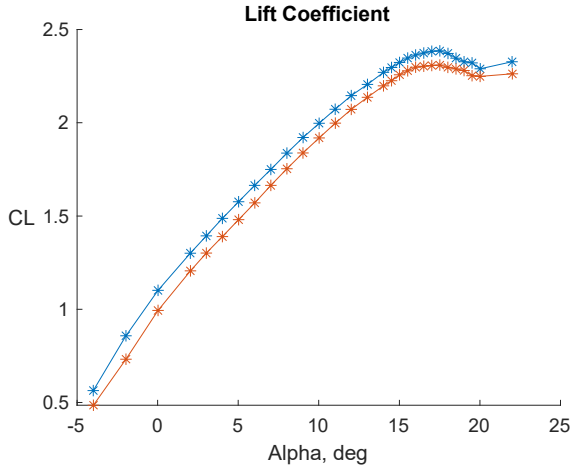


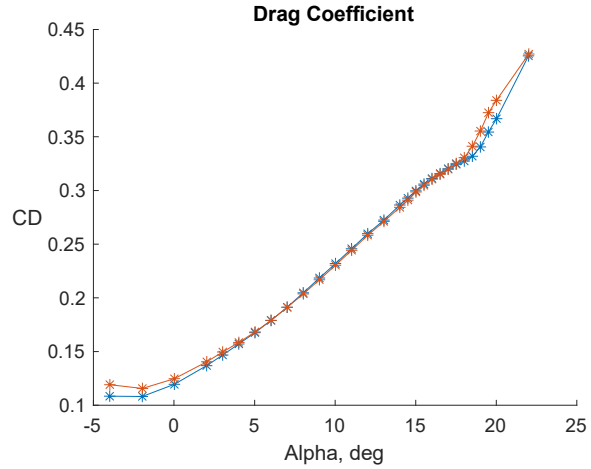


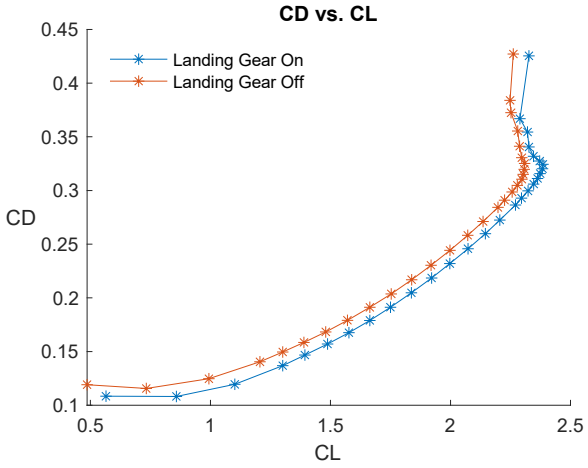


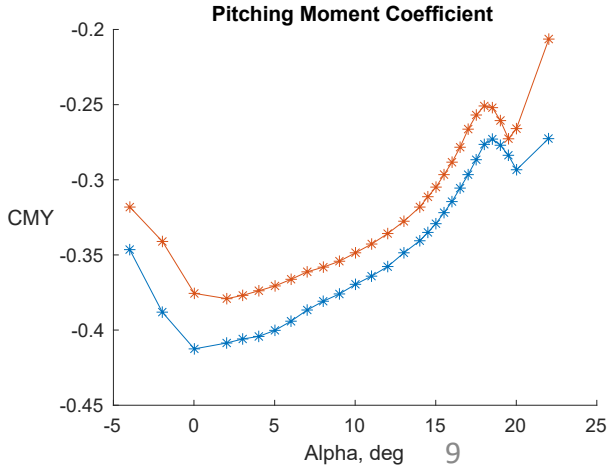


Re_c 5.49 million



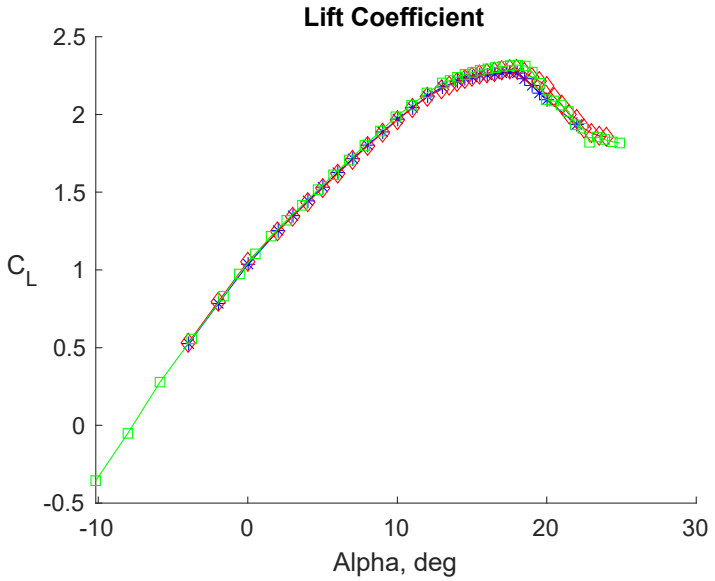


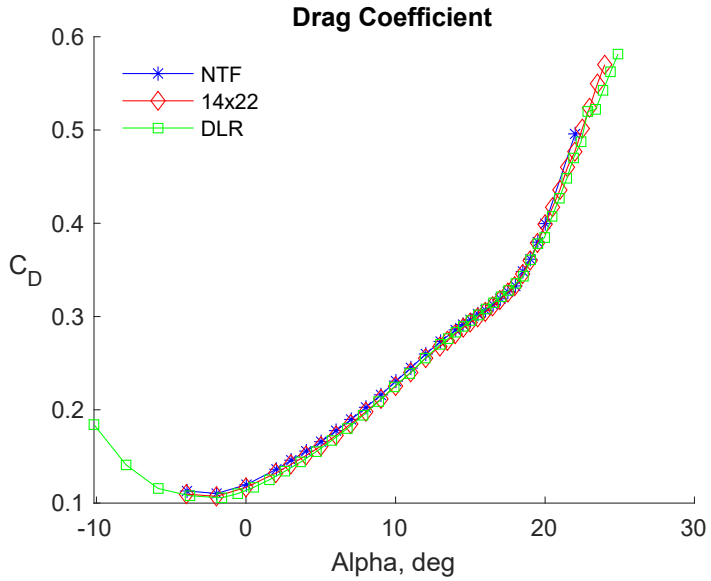


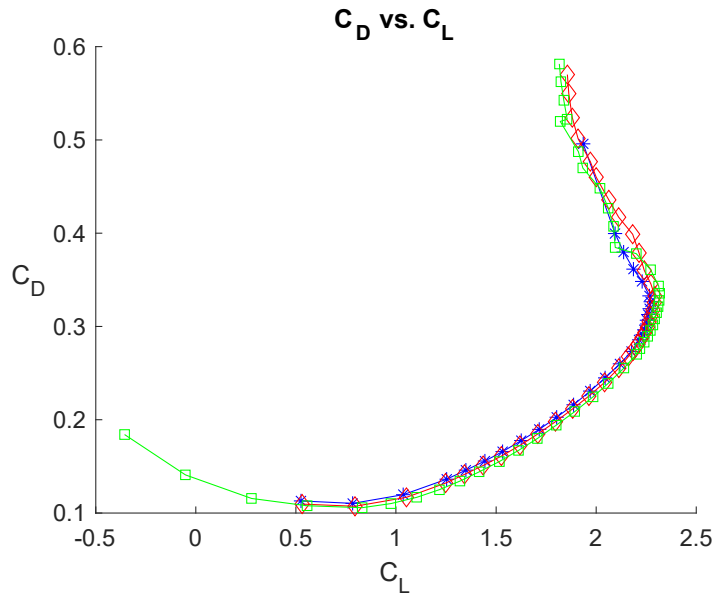


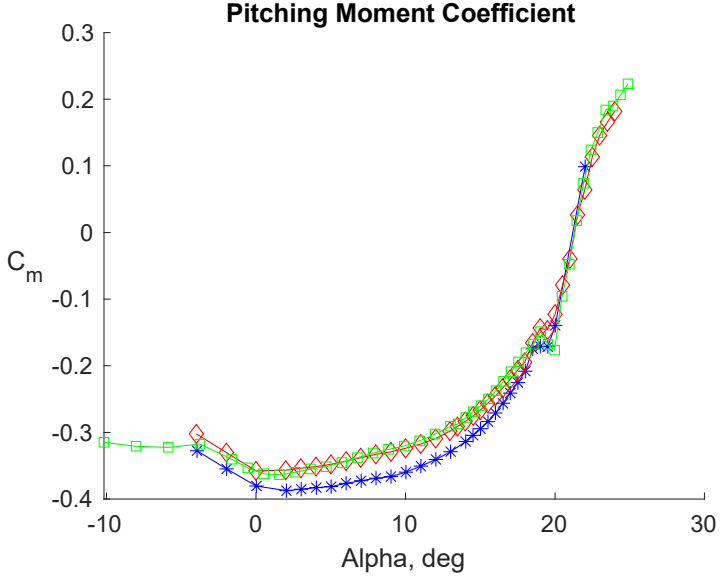
NASA 5.2%-Scale Model in NTF, NWB, and 14x22

- Landing baseline repeat
  - Mach 0.2
  - 1.6 million Re_C
- Data from the 3 tests compare well in lift and drag
- Pitching moment in NTF varies from the other two wind tunnel









NASA 2.7%-Scale CRM-HL Full-Span NTF Tests

- Data collection on the model
  - Forces and moments
  - Wing static pressures
  - Wing dynamic pressures
  - Wing deformation
  - Flow transition with pressure taps
- Comparison runs with previous tests
- Two separate entries
  - July 2025 – Air only
    - Landing
  - Jan 2026 – Air and Cryo
    - Takeoff and Landing
- Ice shapes

Configurations
Landing Baseline – Nacelle on, H-Tail off, Landing Gear off
Landing Icing
Landing – Nacelle on and off
Landing – H-tail on and off
Landing – Landing gear on and off
Takeoff – Nacelle on and off
Takeoff – H-tail on and off

Configuration	Mach	ReC $*10^6$	Gas	q psf	Notes
Landing					
	0.2	1.1			Match KHI
	0.2	1.6			Match DLR, 14x22 T668
	0.2	3.33			
	0.2	5.32			Icing, Match Q5
	0.2	5.33			
	0.2	5.49	Air		
	0.2	5.49	Cryo		
	0.2	5.9			Match ONERA
	0.2	8			
	0.2	10		high q	
	0.2	10		low q	
	0.2	12			
	0.2	14			
	0.2	16		high q	
	0.2	16		low q	
	0.26	16			Icing
	0.3	16			Icing
	0.35	16			Icing
Takeoff					
	0.23	1.8			Match DLR
	0.26	1.97			Match 14x22
	0.26	4.08			
	0.26	5.6			
	0.26	10			
	0.26	16			

Future NASA CRM-HL Tests

- NASA 2.7%-scale full-span model
  - July 2025 **NTF**, air only
    - Forces and moments
    - Model pressures
    - Wing deformation
    - Flow transition
  - September 2025 European Transonic Windtunnel (ETW) Cologne, Germany
    - Ice testing
  - January 2026 **NTF**, air and cryo
    - Forces and moments
    - Model pressures
    - Wing deformation
    - Flow transition
- NASA 5.2%-scale semispan model
  - Second **NTF** entry, FY26
    - Surface and off-body flow field measurements
- NASA 2.7%-scale semispan model
  - FY27, **NTF**
    - Forces and moments
    - Model pressures
    - Wing deformation

Photo Credit: NASA

Questions?

Photo Credit: NASA

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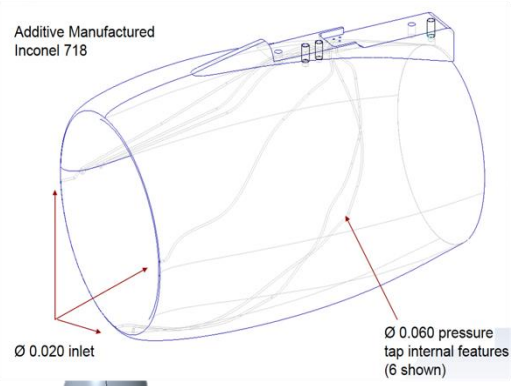
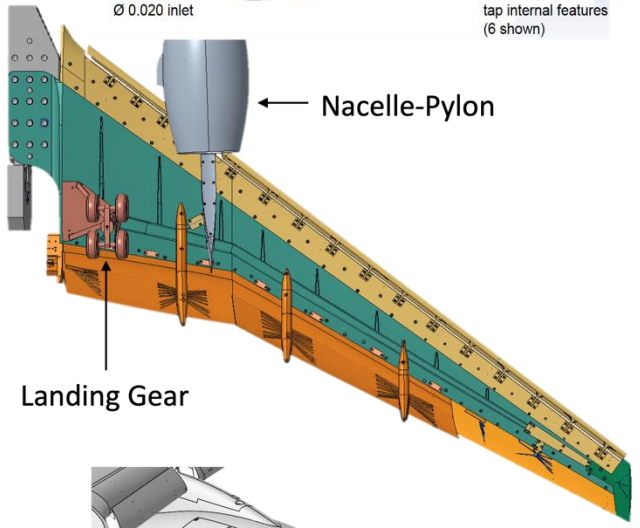
Backup

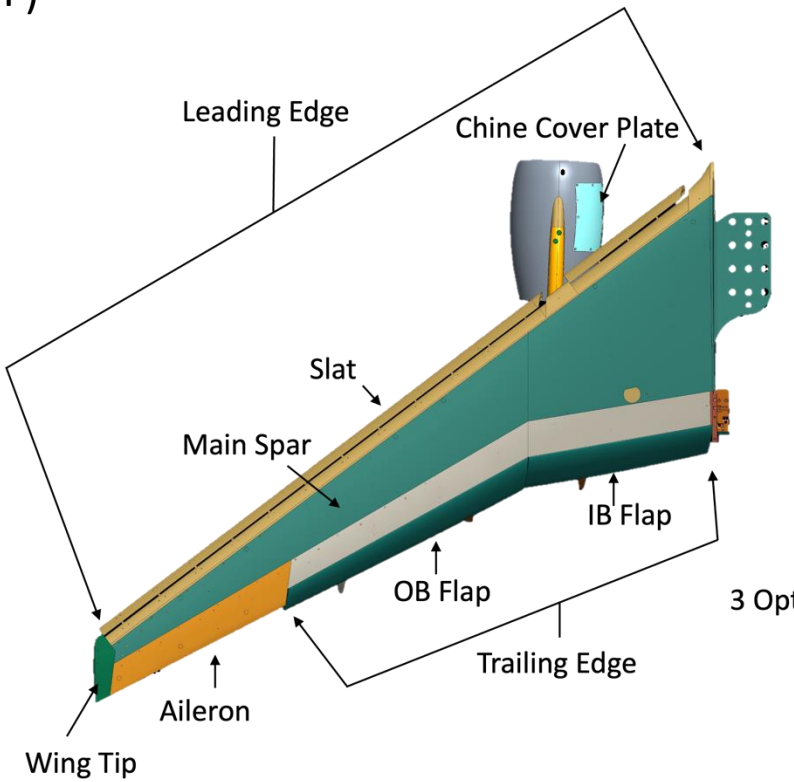
NASA 5.2%-Scale CRM-HL Geometry

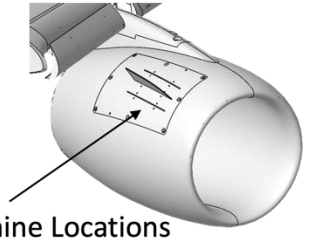
- 5.2%-scale version of the High Lift Common Research Model (CRM-HL) reference geometry
- Baseline Ecosystem configurations
  - Landing
  - Takeoff
  - Cruise
- Semispan model
- Designed for the National Transonic Facility (NTF)
  - Temperature: -250°F to 120°F
  - Max dynamic pressure: 380 psf
  - Angle of attack: -4° to 22°
- Modular design
  - Slat angle
  - Inboard and outboard flap angle
  - Nacelle
    - Chine radial location
  - Landing gear
  - Allows testing of other nonoriginal parts
- 3D-printed NASA nacelle and landing gear
  - 17 pressure taps built into the nacelle design

- Model has been tested four times
  - 14x22 checkout test
  - Low-Speed Wind Tunnel at Braunschweig (NWB)
  - NTF high Reynolds number test
  - 14x22 flow visualization test

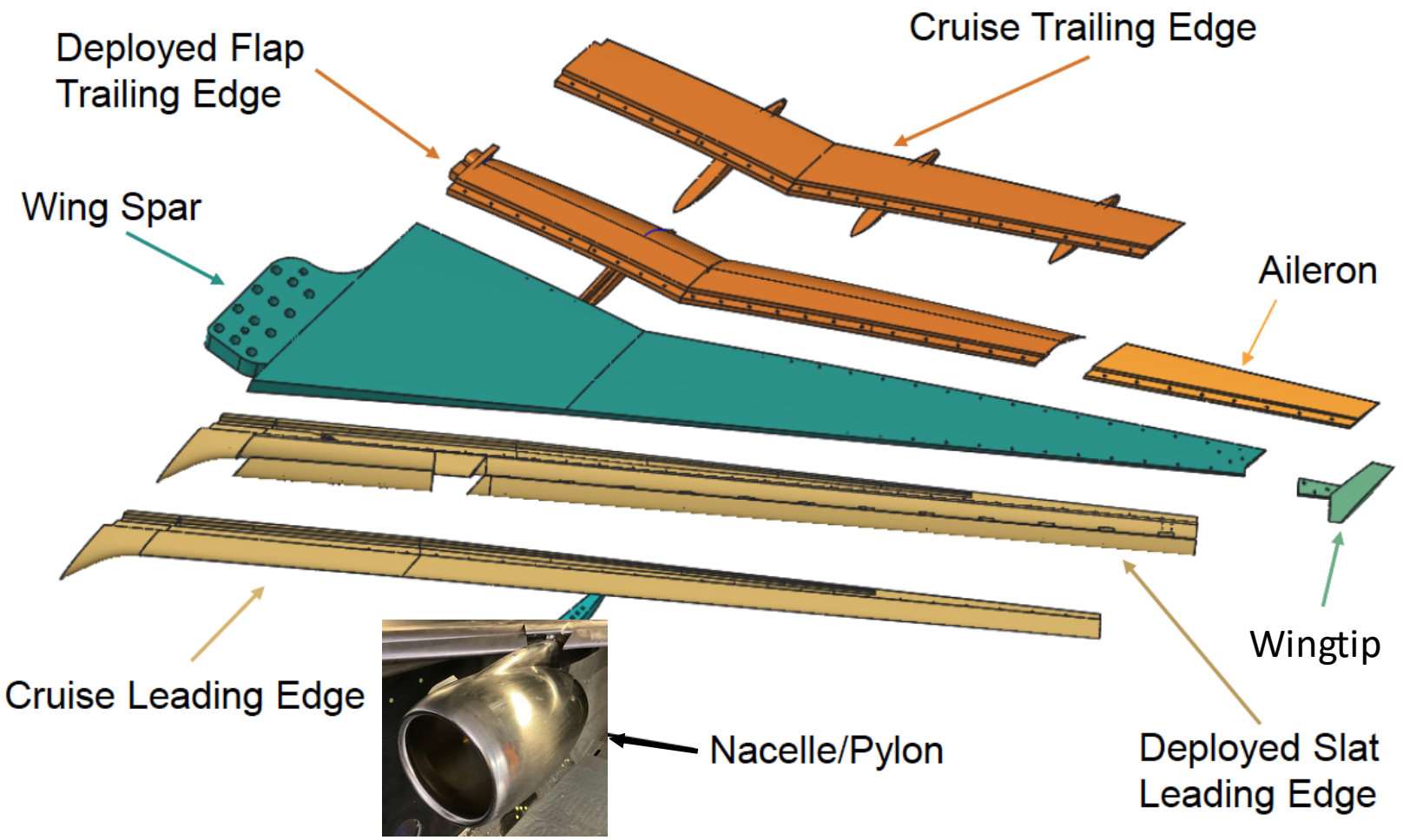


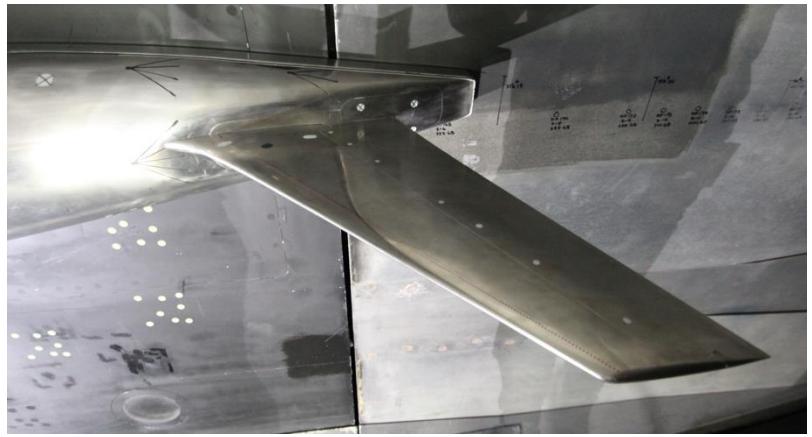




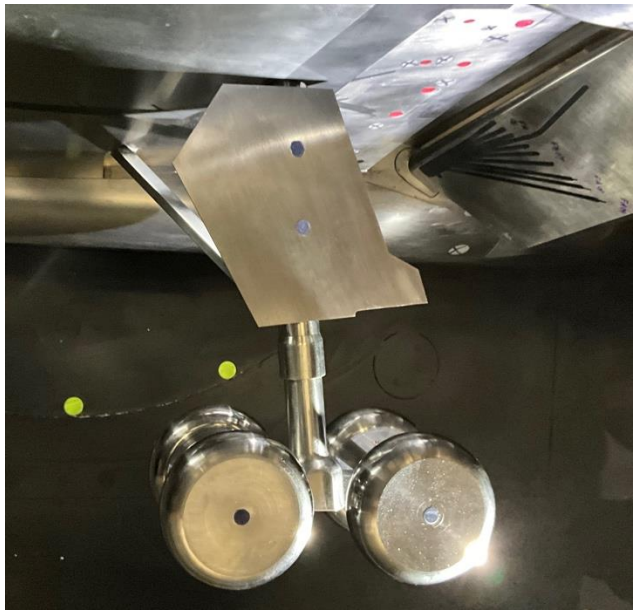


Major Model Components





Horizontal Tail

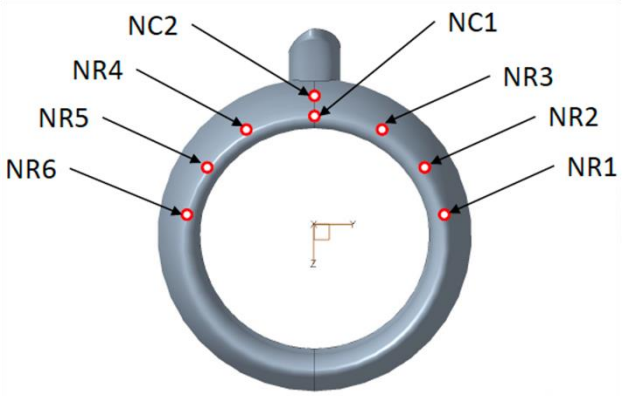


Landing Gear

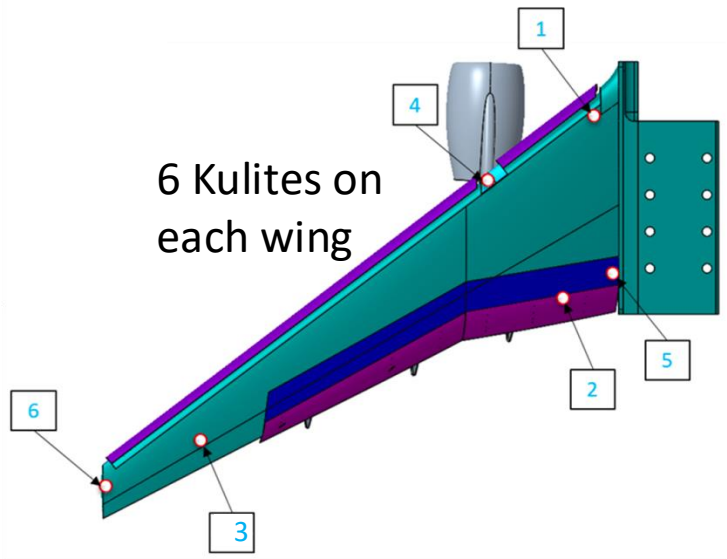
Photo Credits: NASA

NASA 2.7%-Scale CRM-HL Geometry

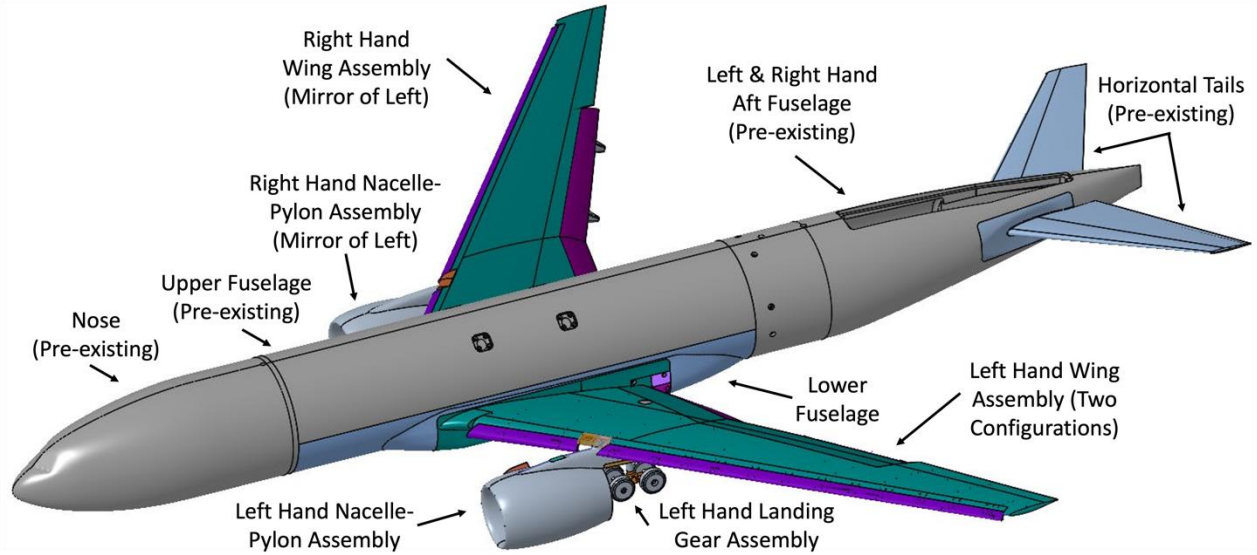
- 2.7%-scale version of the High Lift Common Research Model (CRM-HL) reference geometry
- Full-span and semispan model
- Baseline Ecosystem configurations
  - Landing
  - Takeoff
- Designed for NTF
  - Temperature: -250°F to 120°F
  - Max dynamic pressure: 380 psf
  - Angle of attack: -4° to 22°
- Modular design
  - Slat angle
  - Inboard and outboard flap angle
  - Nacelle
    - Chine radial location
  - Landing gear
  - Allows testing of other nonoriginal parts
- 3D-printed NASA nacelle and landing gear
  - 8 pressure taps built into the port nacelle design



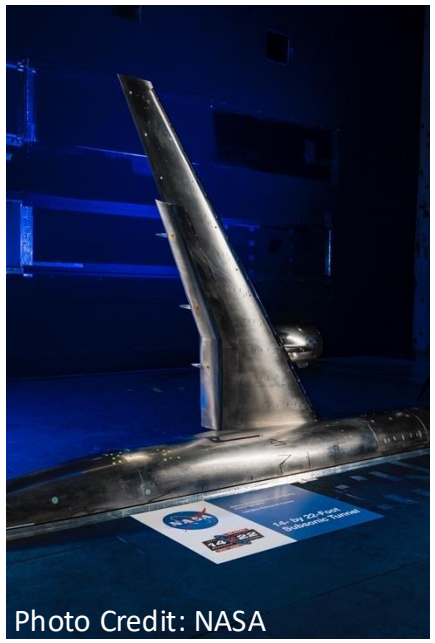
8 pressure ports on port nacelle



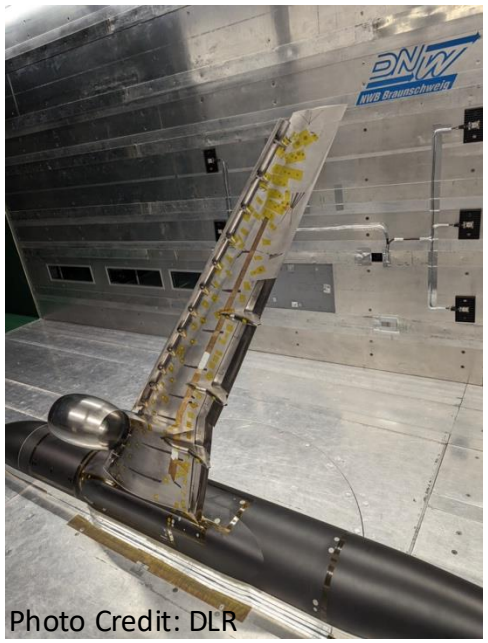
6 Kulites on each wing



NASA 5.2%-scale CRM-HL Model Tests & Publications



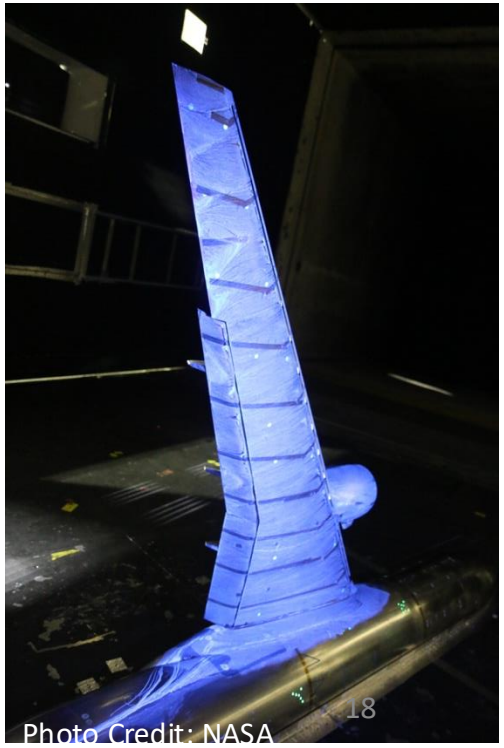
Model checkout test at the NASA LaRC 14x22
Aug. 15 through Sep. 8, 2022



DLR test at the Low-Speed Wind Tunnel at Braunschweig (NWB)
May 9 through July 6, 2023

High Reynolds number test at the NASA LaRC NTF
Jan. 3 through May 23, 2024

Flow visualization test at the NASA LaRC 14x22
Sep. 23 through Sep. 26, 2024



SciTech 2025 Publications:
- Winski et al. - NASA 5.2% Semispan High Lift Common Research Model Wind Tunnel Test at the 14- by 22-Foot Subsonic Wind Tunnel
- Langston et al. - Reynolds Number Effects on a 5.2%-Scale High Lift Common Research Model
- Ertsgaard et al. - Development of NASA 5.2%-Scale Semispan High Lift Common Research Model

Upcoming Aviation 2025 Publications:
- Ertsgaard et al. - Additive Manufacturing for NASA High Lift Common Research Models (CRM-HL) in Cryogenic Facilities
- Ertsgaard et al. - Development of NASA 2.7% Semispan and Full Span High Lift Common Research Models (CRM-HL)
- Winski et al. - NASA 5.2%-Scale Semispan High Lift Common Research Model (CRM-HL) High Reynolds Number Wind Tunnel Test in the National Transonic Facility (NTF)
- Langston et al. - Reynolds Number Effects on the Surface Pressures on a 5.2%-Scale High Lift Common Research Model