

NASA Contributions to the High Lift Common Research Model Ecosystem

Melissa Rivers, Courtney Winski, and Sarah Langston
NASA

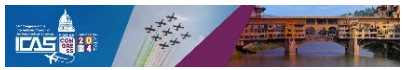


Outline



Outline

- Background
- Model Design and Fabrication
- Testing of the NASA 5.2% Scale Semi-Span Model
- Comparison to Partner Data

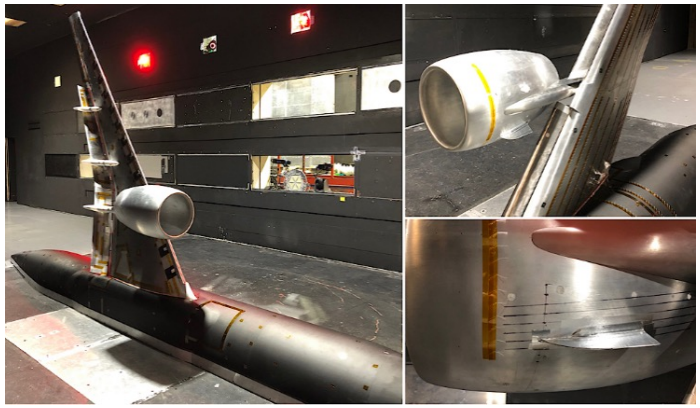


Background



Ecosystem Background

- Design and build of 10% scale High-Lift Common Research Model (CRM-HL)
- Test in 2018 in 14 x 22 Ft subsonic wind tunnel at NASA Langley Research Center
  - Focus on Active Flow Control
  - Minimal baseline high lift test points

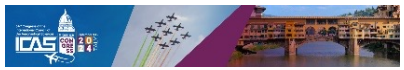


- Test in 2019 at QinetiQ 5-metre wind tunnel in the United Kingdom
  - Refined device positioning
  - Official reference configuration standard



NASA's Part in the Ecosystem

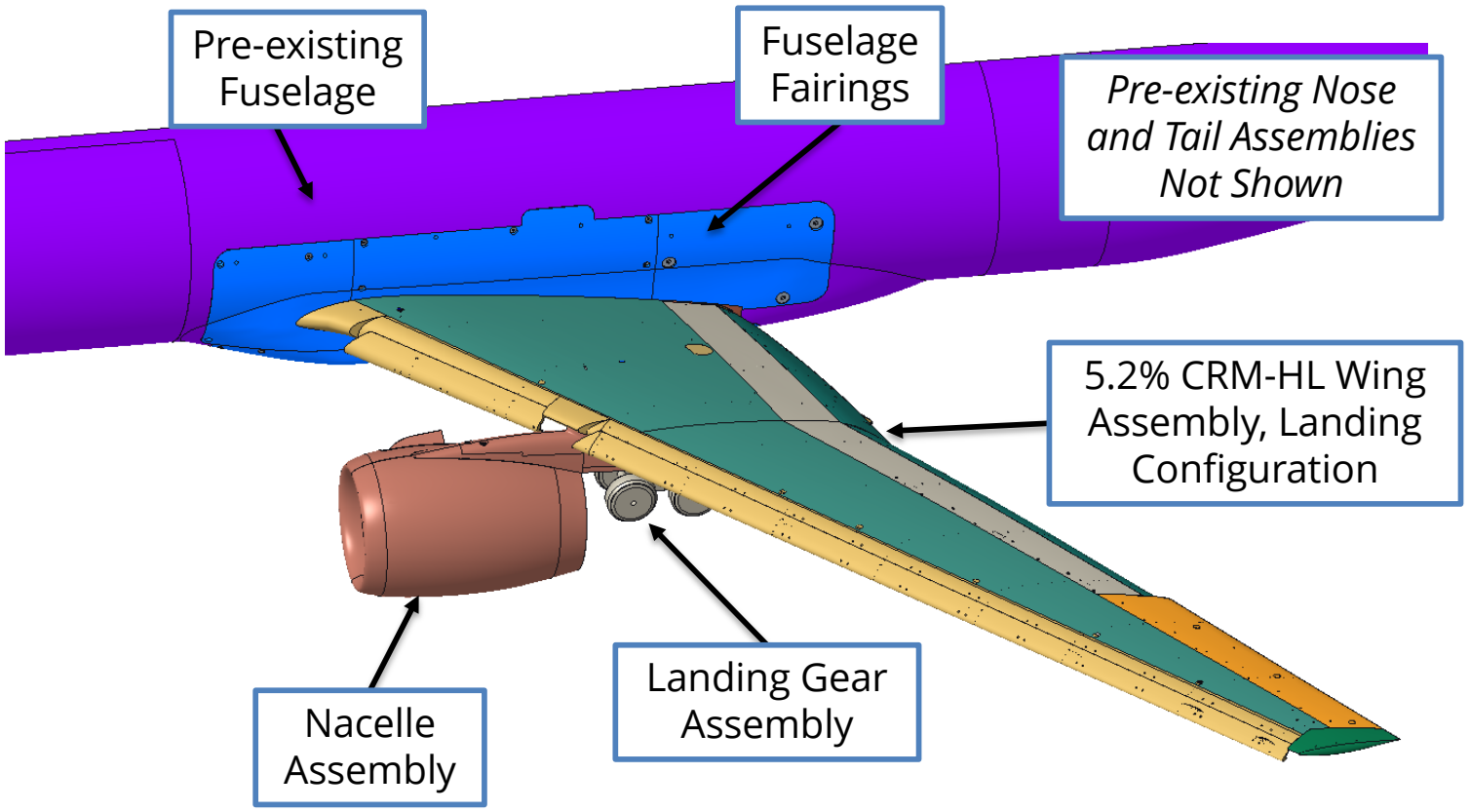
- Design and build two additional CRM-HL models
- Test at NASA Langley's National Transonic Facility (NTF)
  - Cryogenic facility
  - Up to flight Reynolds numbers
- First model – 5.2% scale semi-span model
  - Modular landing, takeoff and cruise configurations
- Second model – 2.7% scale full span model
  - Modular landing and takeoff configurations



Model Design and Fabrication

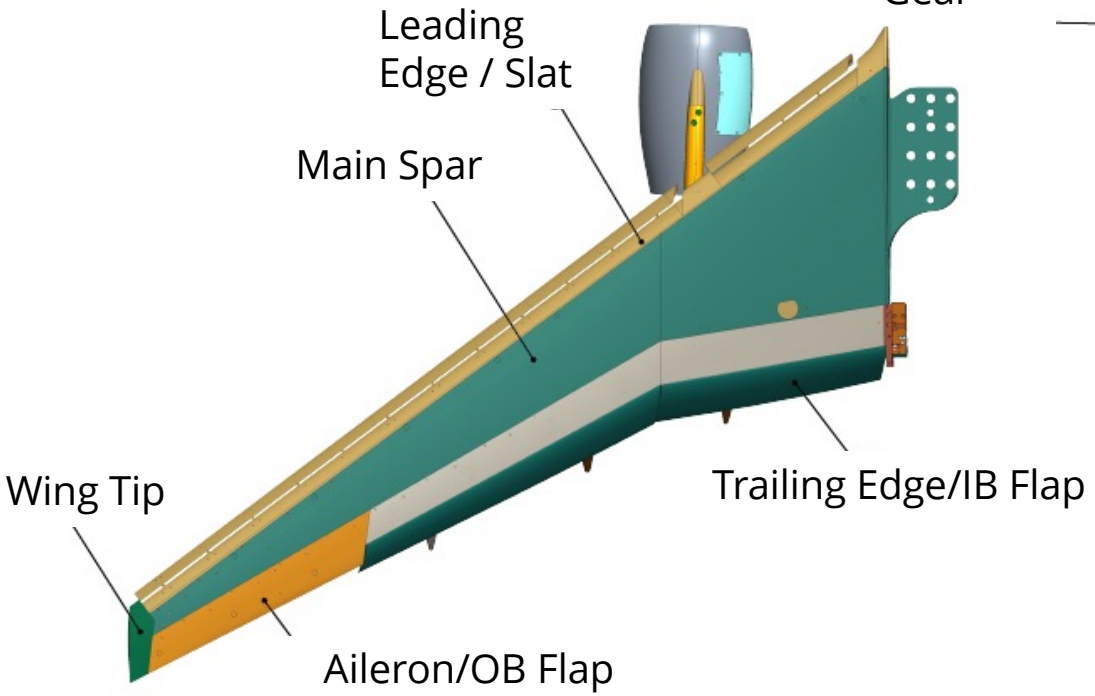


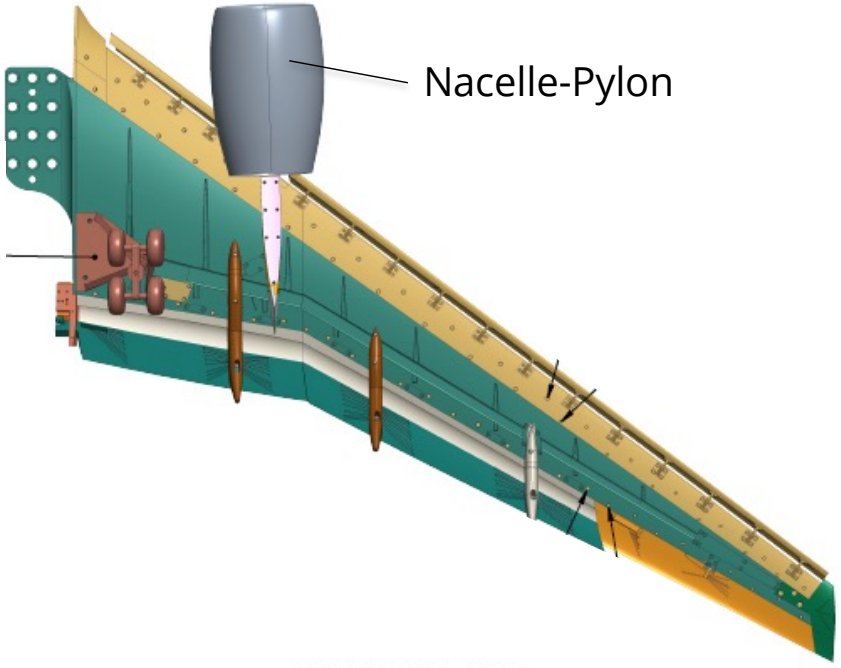
5.2% Scale CRM-HL Semi-Span Model Assembly



5.2% Scale CRM-HL Semi-Span Model Assembly (cont.)

Landing Configuration:
Inboard (IB) Flap angles 37°, 40°, and 43°
Outboard (OB) Flap angles 34°, 37°, and 40°
IB & OB Slat angles 30°

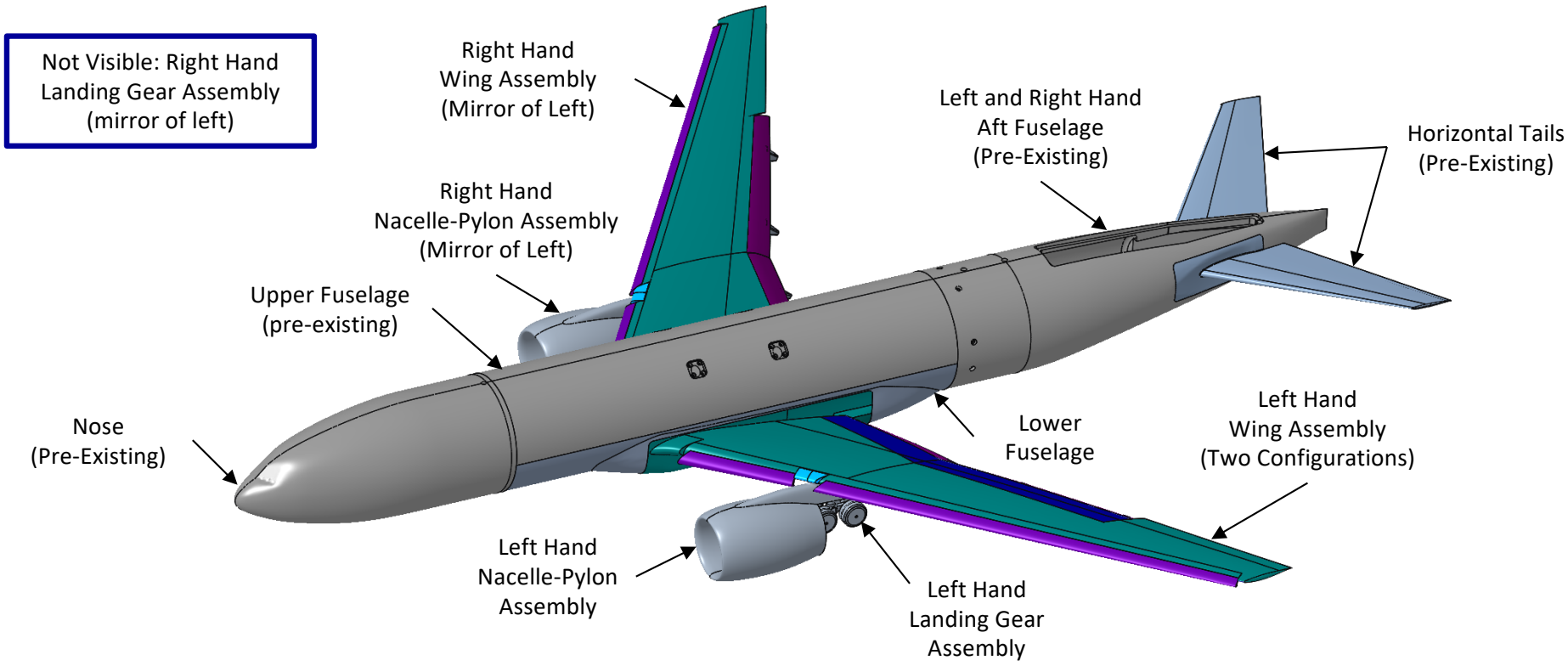




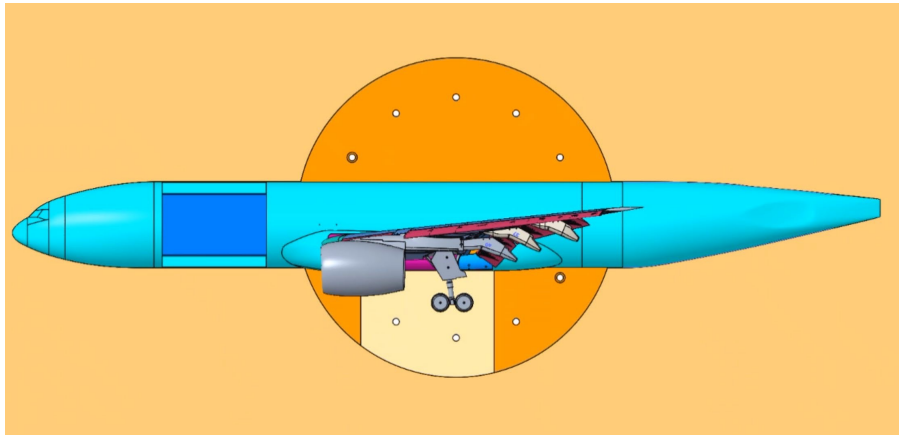
Takeoff Configuration:
IB & OB Flap angles 25°
IB & OB Slat angles 22°

Cruise Configuration

2.7% Scale CRM-HL Full Span Model Assembly



2.7% Scale CRM-HL Semi-Span Model Assembly



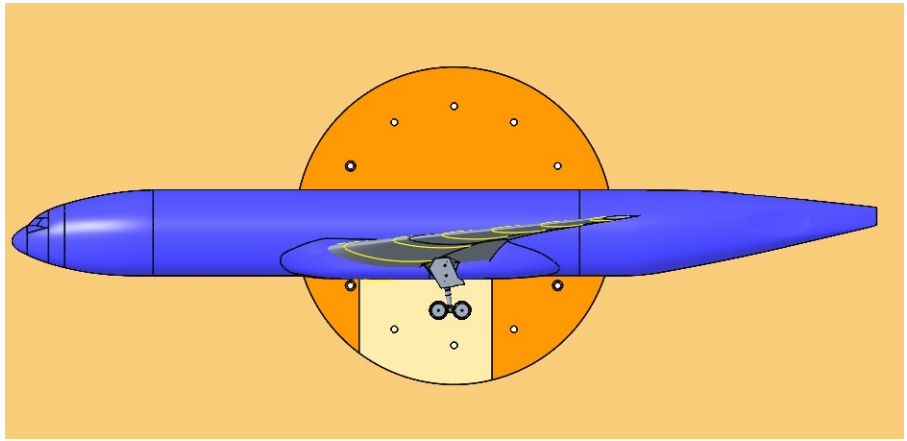
Left Hand Wing: *Wing scaled from 5.2% CRM-HL*

Takeoff Configuration: *25°IB Flap, 25°OB Flap, 22°IB & OB Slat*

Landing Configuration: *40°IB Flap, 37°OB Flap, 30°IB & OB Slat*

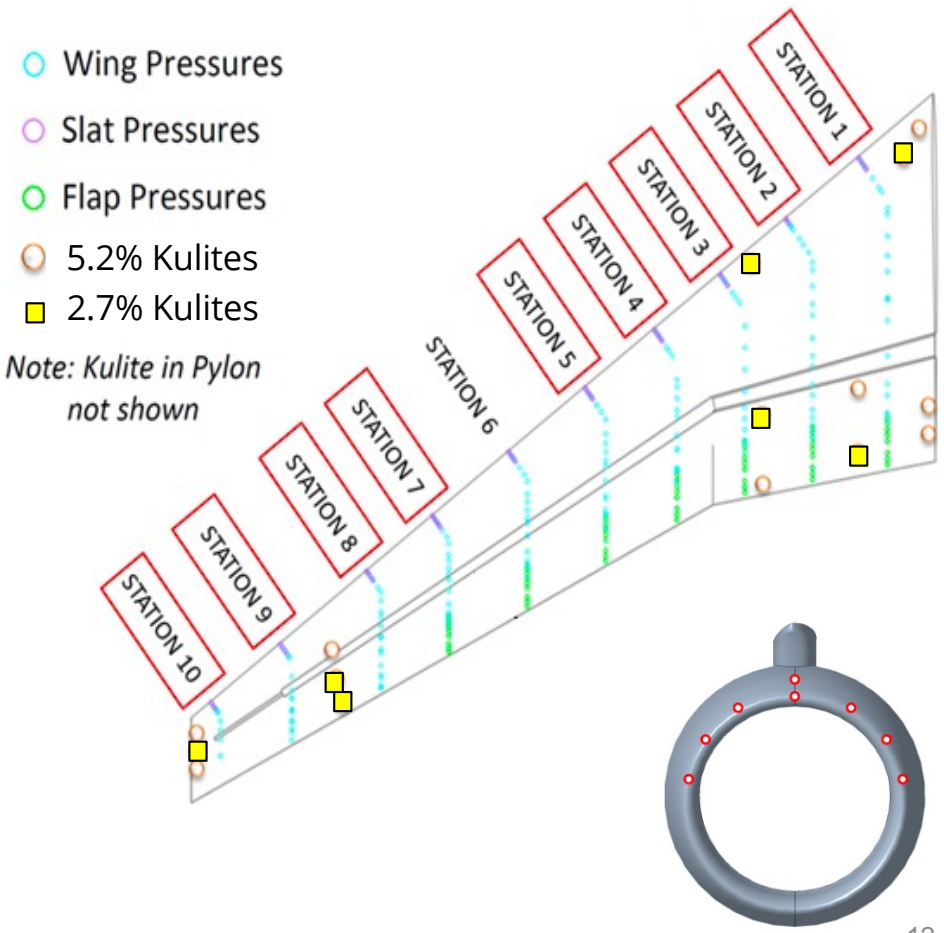
Right Hand Wing: *HLPW-4 fuselage, wing from re-lofted surfaces*

(re-lofted surfaces are unique to 2.7% scale with .40" full-scale trailing edge thickness)



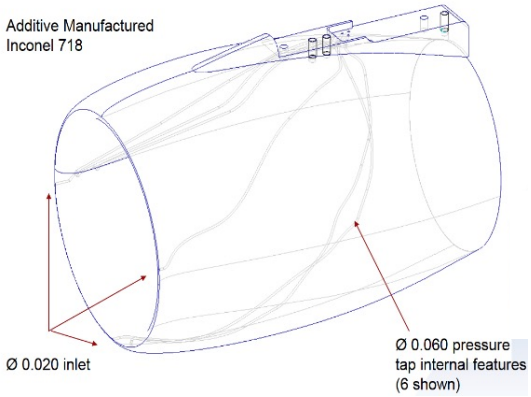
Model Pressures

- Pressure taps on the 5.2% model are pared down from the locations defined by the CRM-HL ecosystem
  - 309 pressure ports, total number vary with configuration
    - Wing – 174
    - Slat – 55
    - Flap – 63
    - Nacelle – 17
  - 12 Kulites® connected (16 installed)
- 2.7% model pressures are a subset of the 5.2% model
  - 315 pressure ports between the 2 wings
  - 189 pressure ports on the port/semi-span wing
    - 8 nacelle pressures
  - 8 Kulites ®



Nacelle & Landing Gear – 3D Printed

- Nacelle
  - 17 pressure taps built into the design
- Landing Gear
  - 1 build
  - Landing gear door and wheels fabricated separately and attached







Testing of the NASA 5.2% Scale Semi-Span Model



Model Checkout Test in the NASA LaRC 14x22 Ft facility

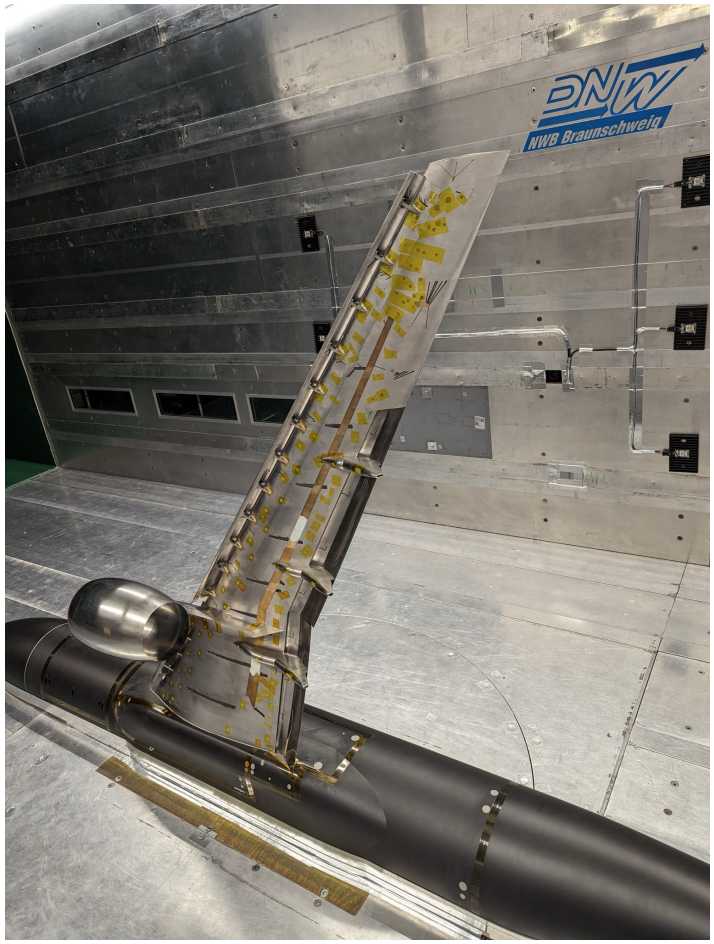
- The 5.2% scale CRM-HL semi-span model was tested in the NASA LaRC 14x22 in the fall of 2022
- 8 configurations tested
  - All model parts tested
- Mach 0.2 and 0.26
- α = -4° to 24°
- Post-test model work due to discoveries during testing
  - Updates to make model changes easier
  - Design fixes



Photo Credit: NASA

Testing in the Low-Speed Wind Tunnel at Braunschweig (NWB)

- Tested the NASA 5.2% CRM-HL wing at the German Aerospace Center (DLR) site in Braunschweig, Germany in the NWB tunnel
  - Fuselage and balance were not the same as the NASA model
- NASA takeoff, landing, and cruise configurations tested
- A DLR designed Kruger and a DLR designed nacelle were also tested
- DLR NWB data collected
  - Forces and moments
  - Model pressures
  - Particle Image Velocimetry (PIV)
  - Mini-tufts
  - Oil flow
  - Aeroacoustics



Testing in the NTF

- 5.2% scale semi-span version of the CRM-HL reference geometry

- Designed for the NTF
  - Temperature: -250°F to 120°F
  - Max dynamic pressure: 380 psf
  - Angle of attack: -4° to 22°

- Baseline Ecosystem configurations
  - Landing
  - Takeoff
  - ~~Cruise~~

- Air and Cryogenic (Nitrogen) runs
  - Reynolds number (Re_c) effects

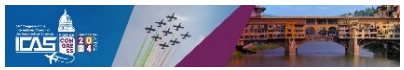


- NTF data collected
  - Forces and moments
  - Model pressures
  - Wing deformation

- Other data obtained
  - Nacelle effects
  - Landing Gear Effects
  - Tail effects

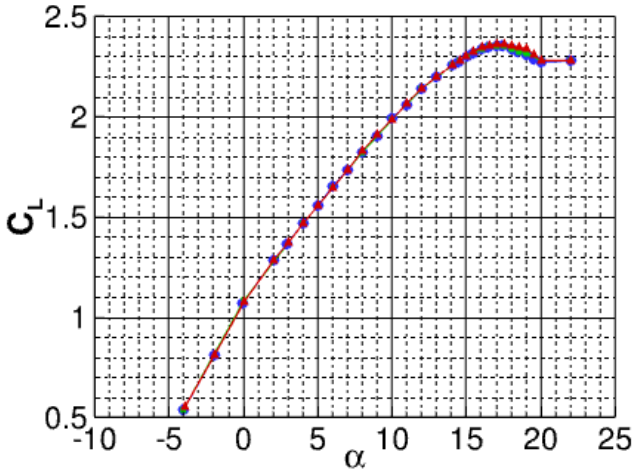
NTF Run Log

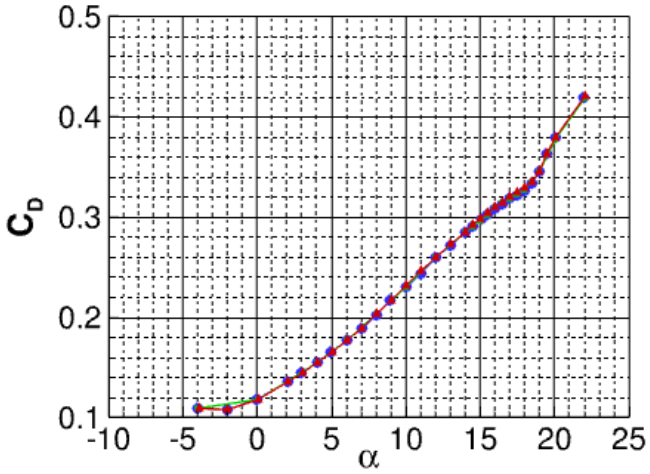
Configuration	Mach range	Re_c range, million	Nacelle	Landing Gear	Horizontal Tail
Landing	0,2, 0.26, 0.3, 0.35	1.6, 3.33, 5.32, 5.49, 5.9, 16, 30	on/off	on/off	on/off
Landing with ice shapes	0.2	5.32, 5.49, 5.9, 16, 30	on	off	on/off
Takeoff	0.23, 0.26	1.8, 1.97, 4.08	on/off	off	off

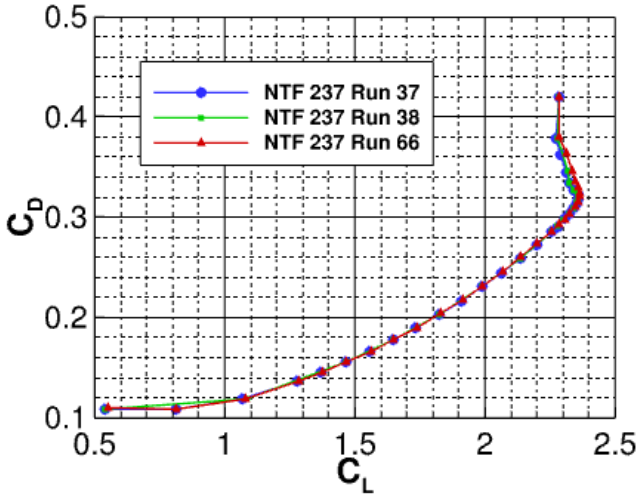


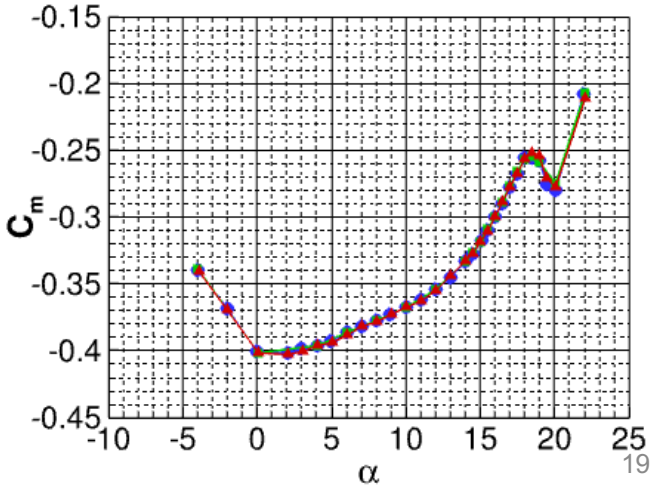
Short- and Long-Term Repeats, Re_c=3.33 million

- Short- and long-term repeatability look good
  - Short-term is same day
  - Long-term is almost two months later



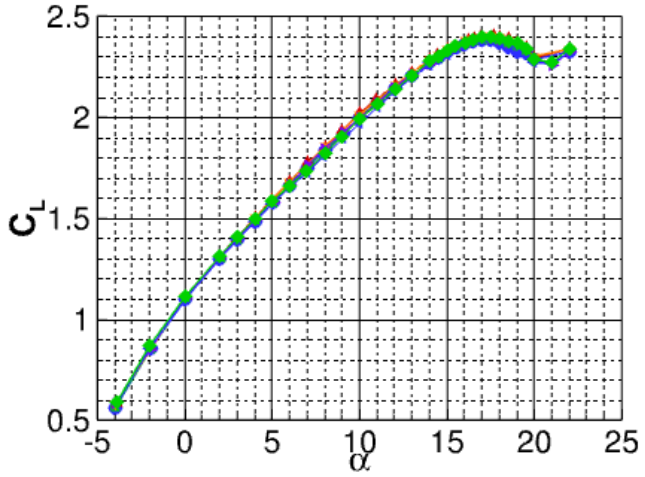


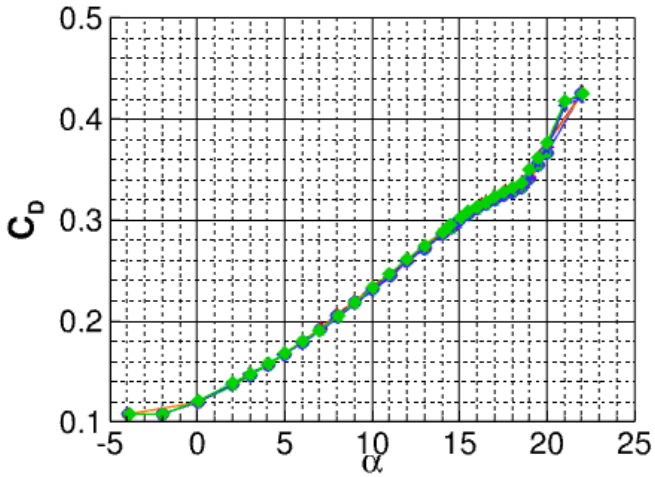


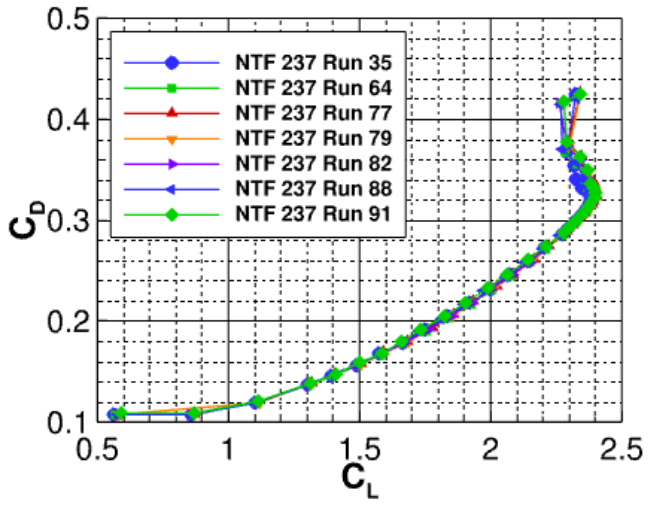


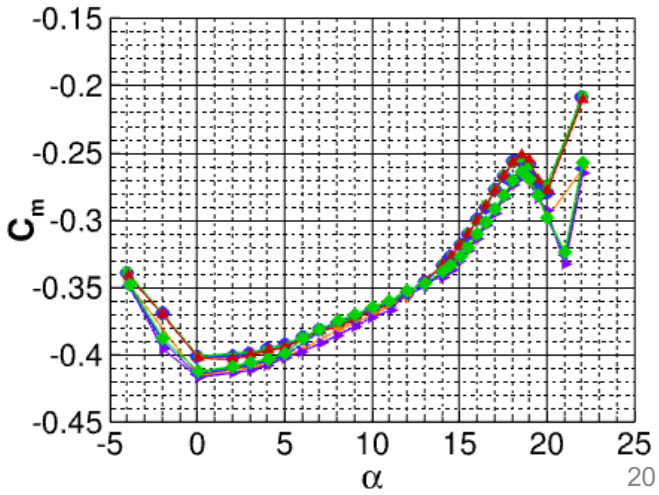
Short- and Long-Term Repeats, Re_c=5.49 million

- Short- and long-term repeatability look good
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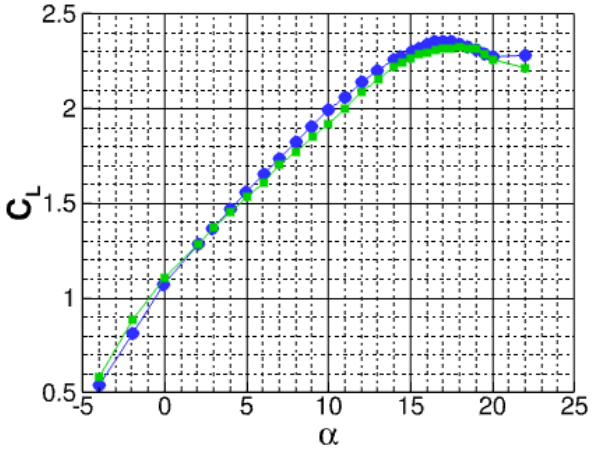


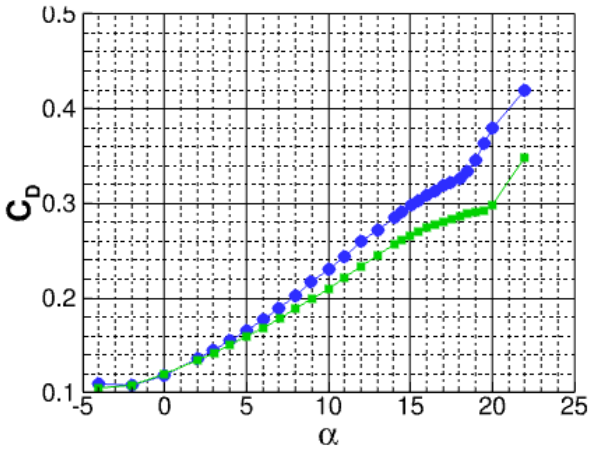


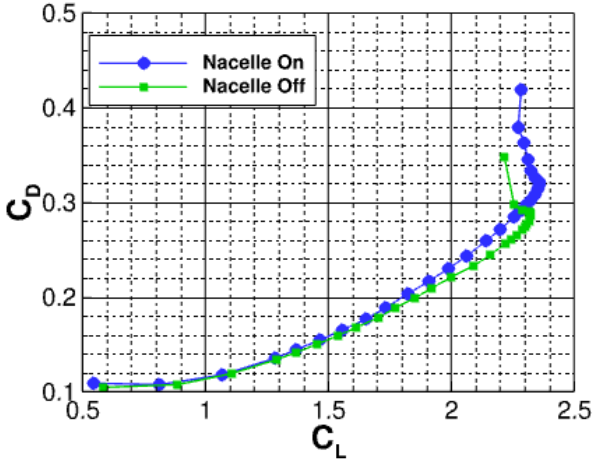


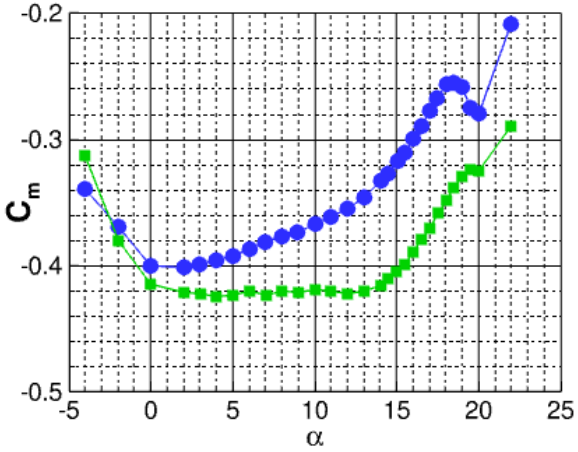


Nacelle Effects - Re_c=3.33 million







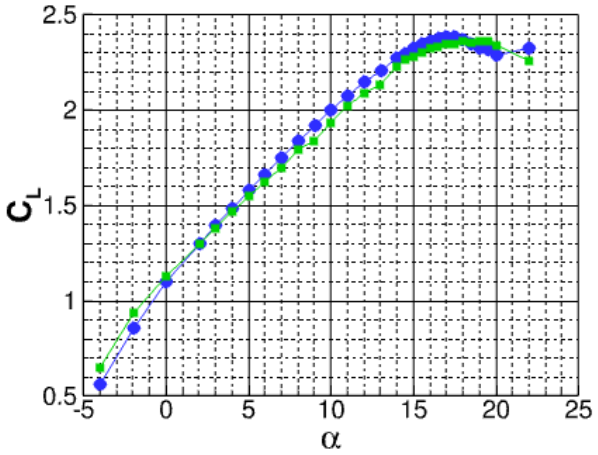


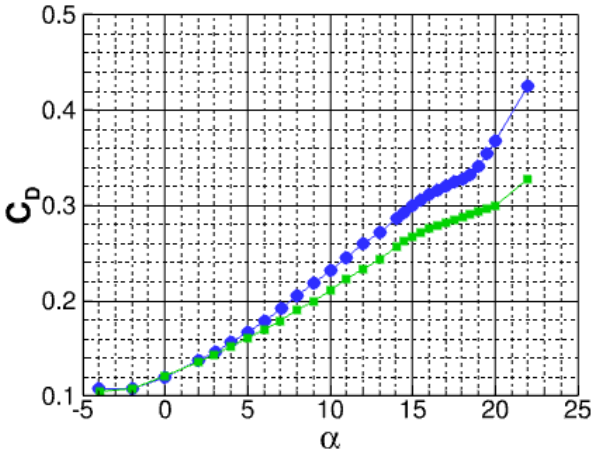


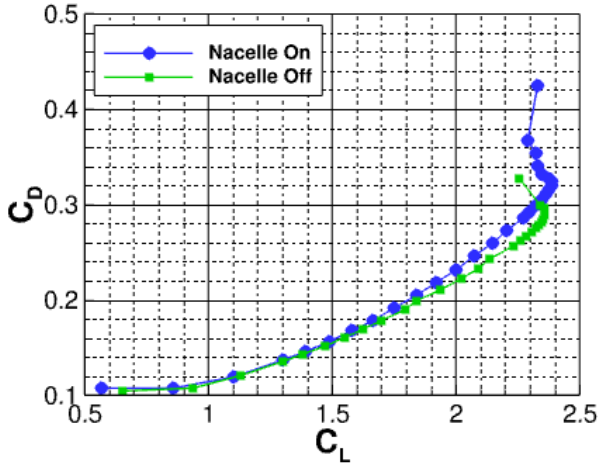
- Nacelle on
- Nacelle off

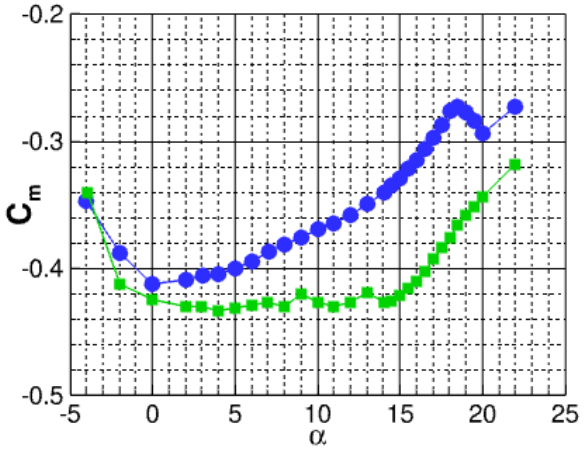
Nacelle effects are as expected

Nacelle Effects - Re_c=5.49 million







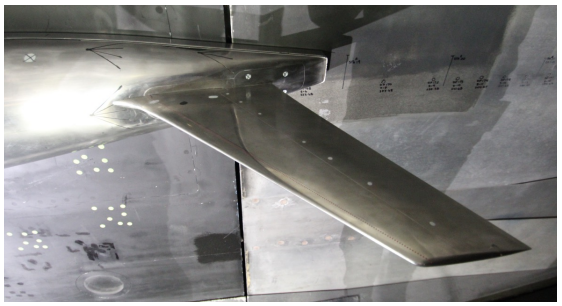




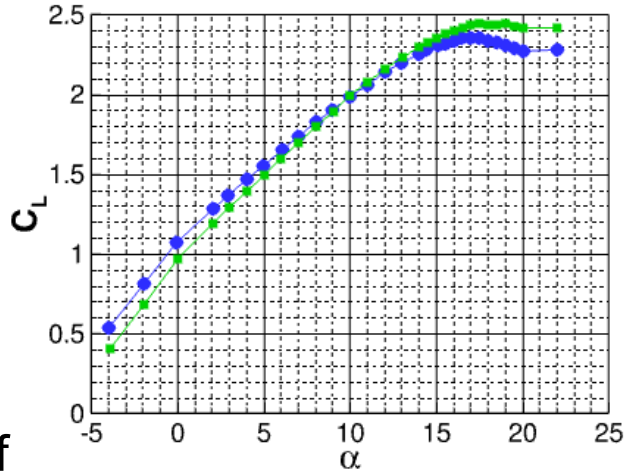
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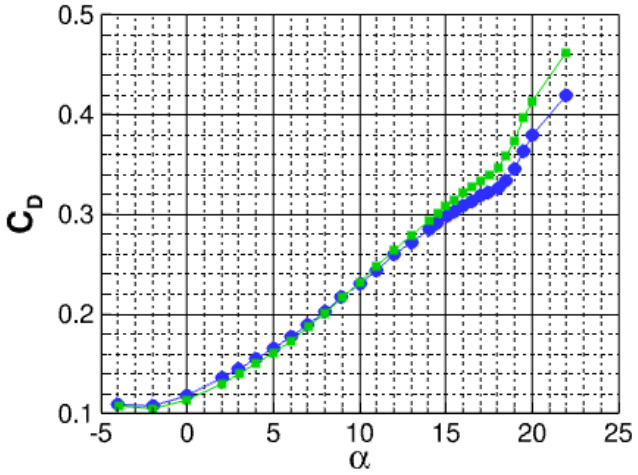
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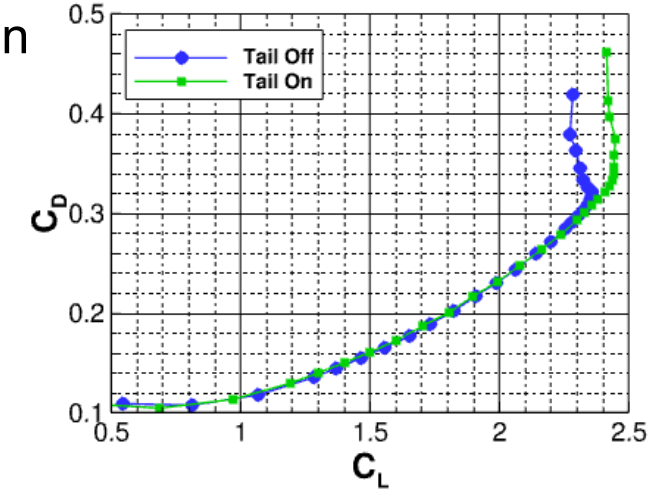
Horizontal Tail Effects - Re_c=3.33 million

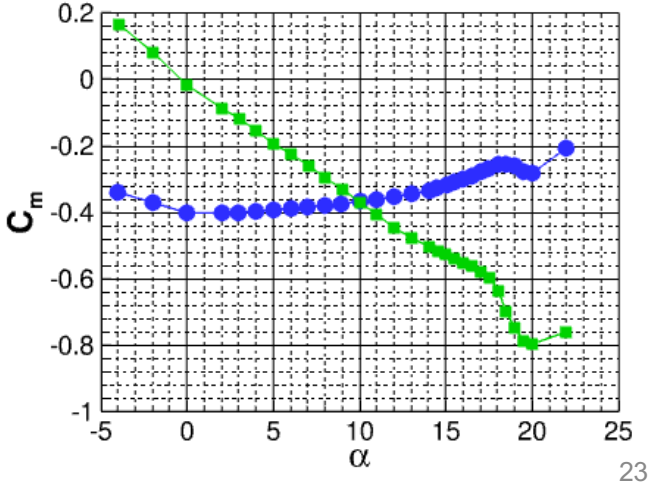


Tail Off
Tail On



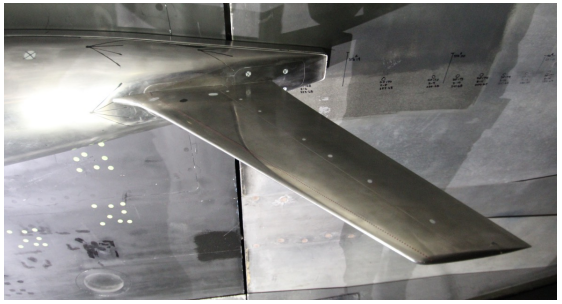




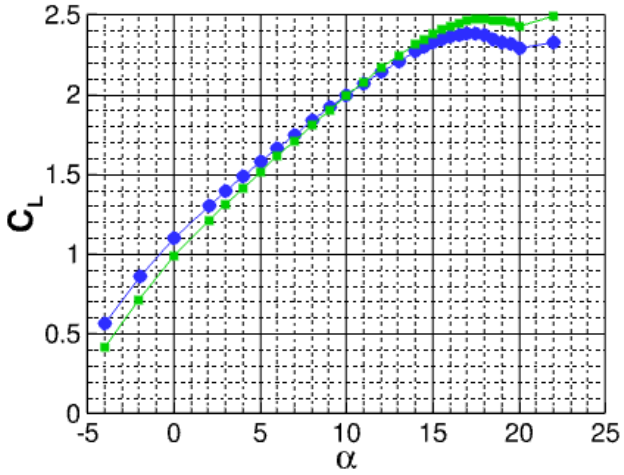


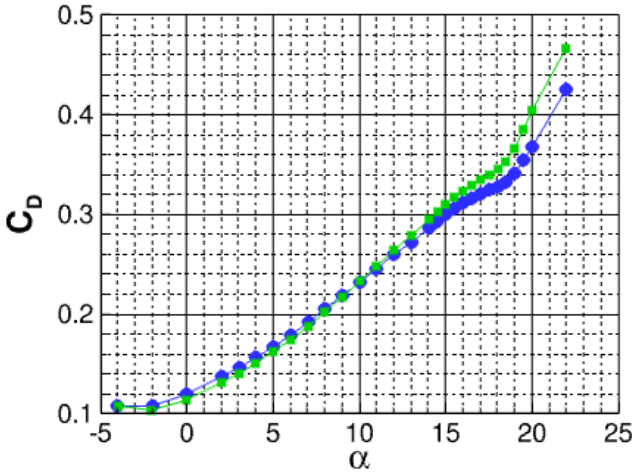
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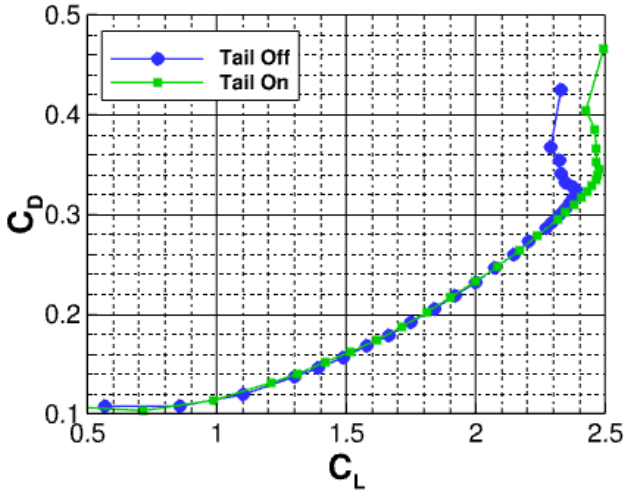
Horizontal Tail Effects - Re_c=5.49 million

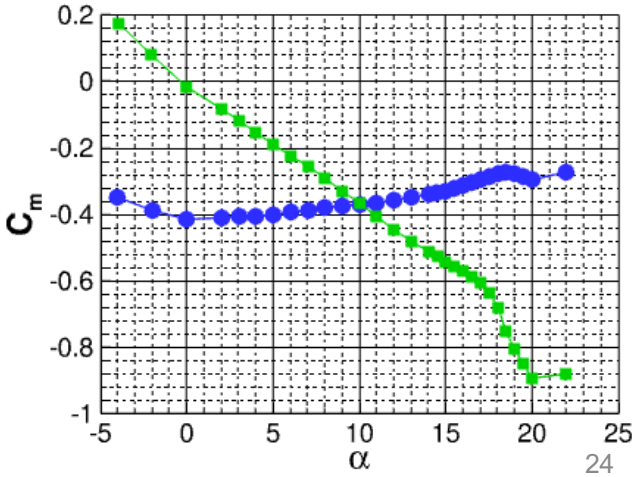


Tail Off
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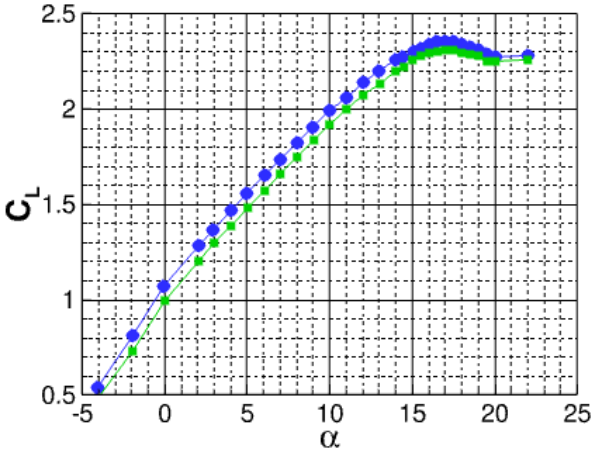


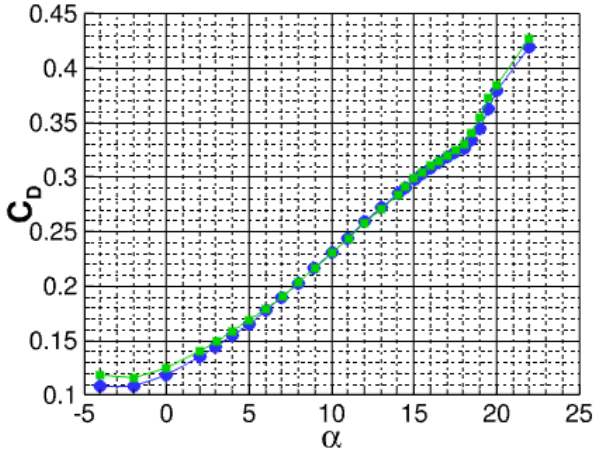


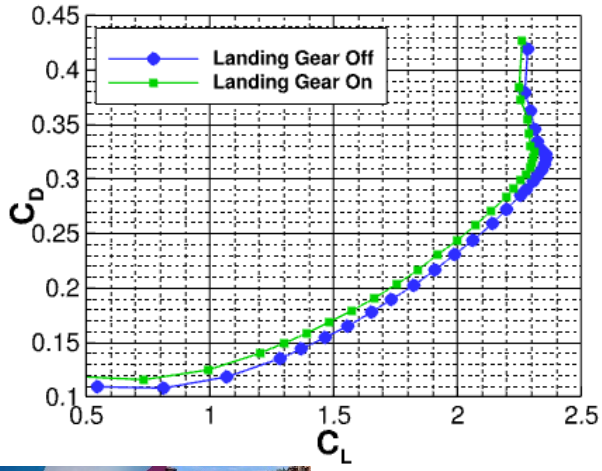


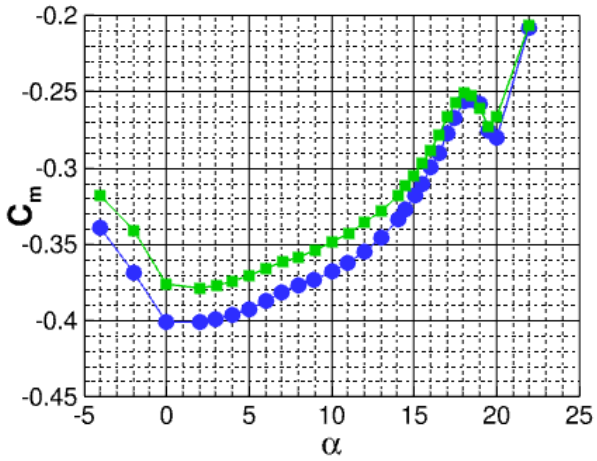
Tail effects are as expected

Landing Gear Effects - Re_c=3.33 million







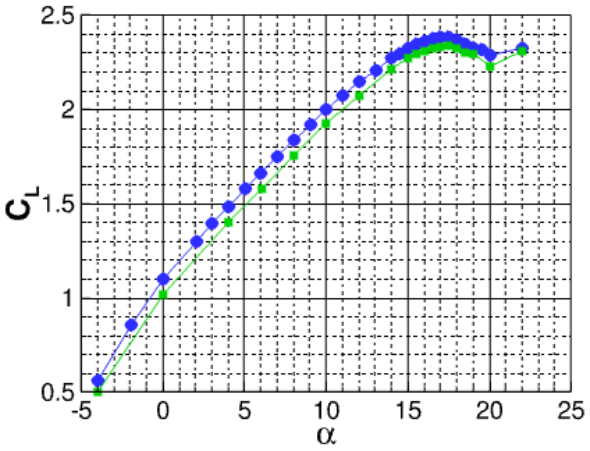


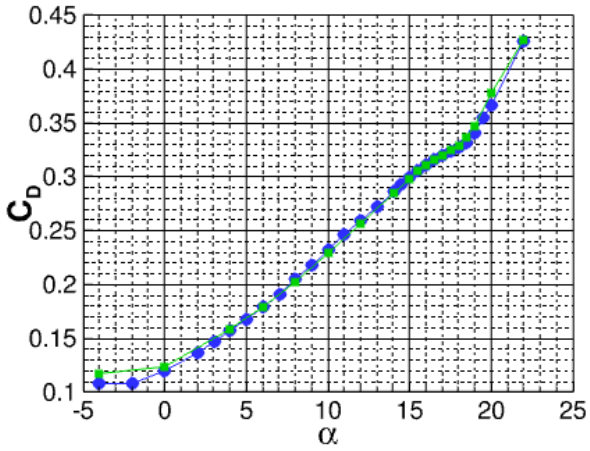


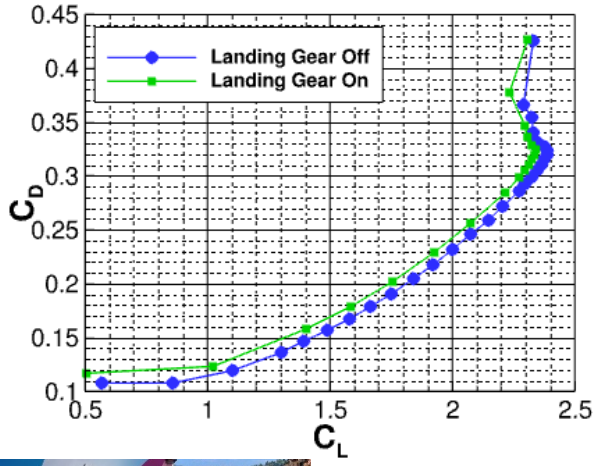
- Landing Gear Off
- Landing Gear On

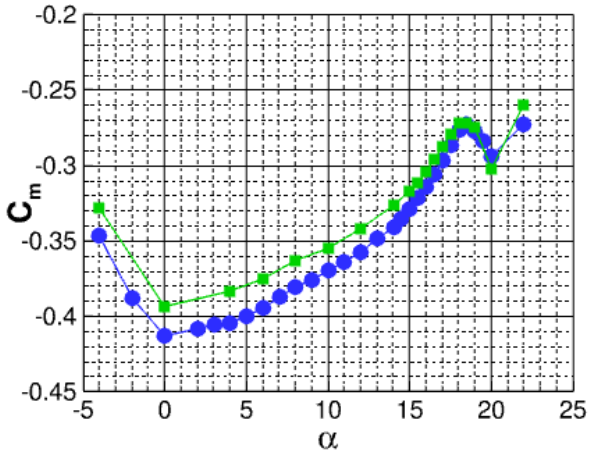
Landing Gear effects are as expected

Landing Gear Effects - Re_c=5.49 million









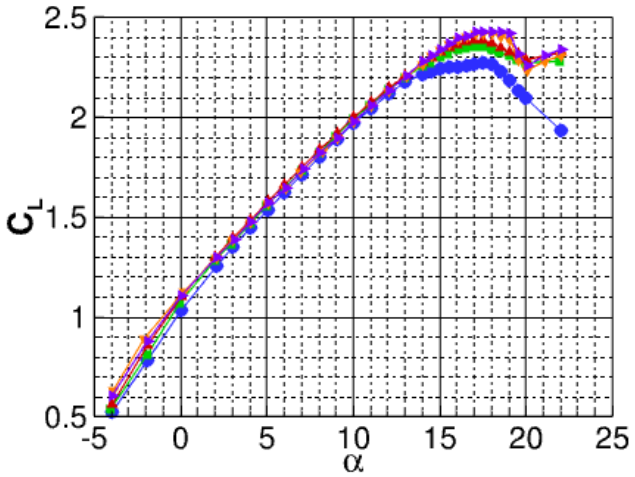


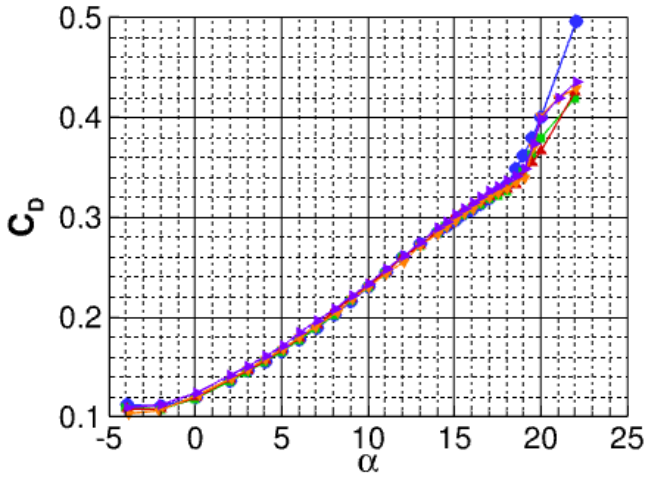
- Landing Gear Off
- Landing Gear On

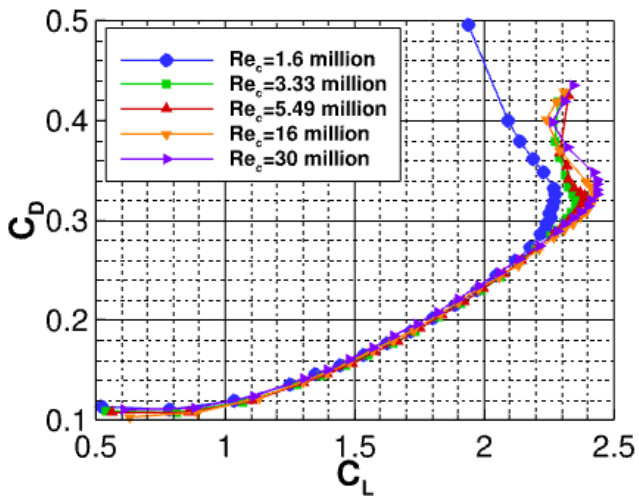
Landing Gear effects are as expected

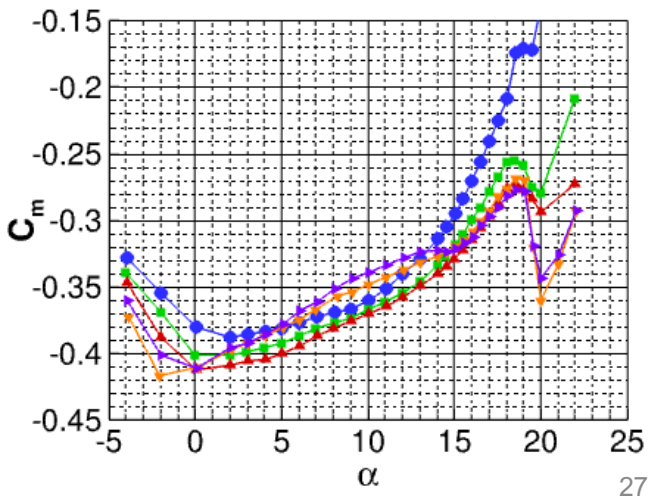
Reynolds Number Effects

Reynolds number effects are as expected







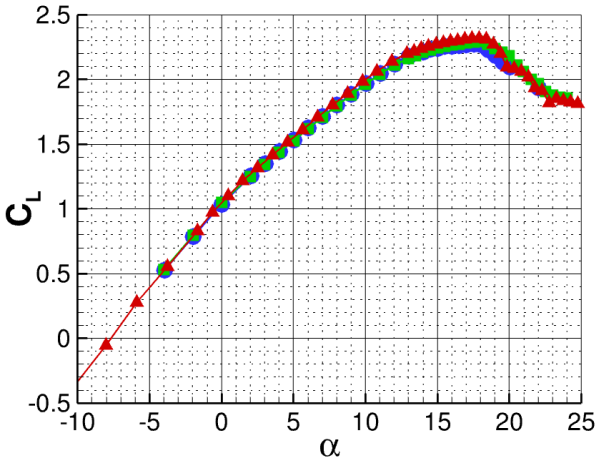


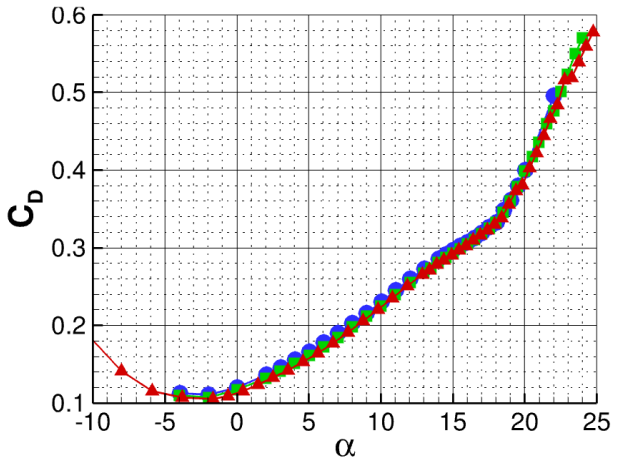
Comparison to Partner Data

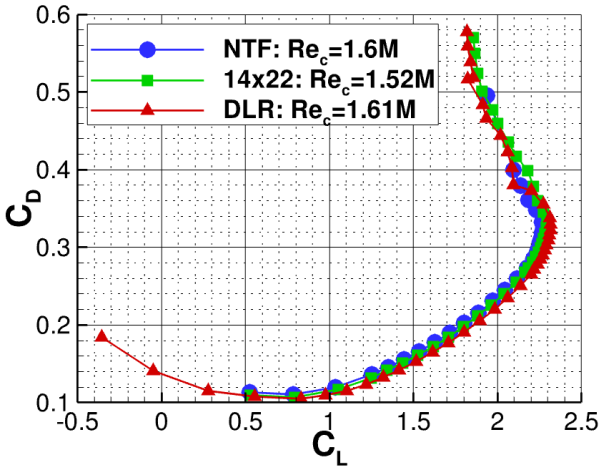


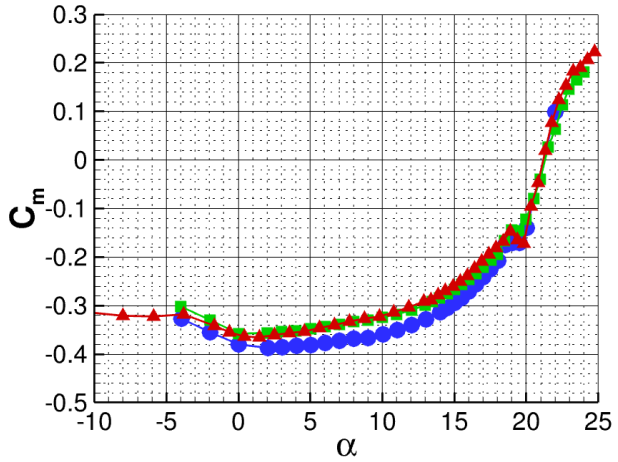
NASA 5.2% Model in NTF, 14x22 and NWB, Re_c=1.6 million

- Data from these three tests compare well in lift and drag
- Pitching moment in NTF varies from other two wind tunnels



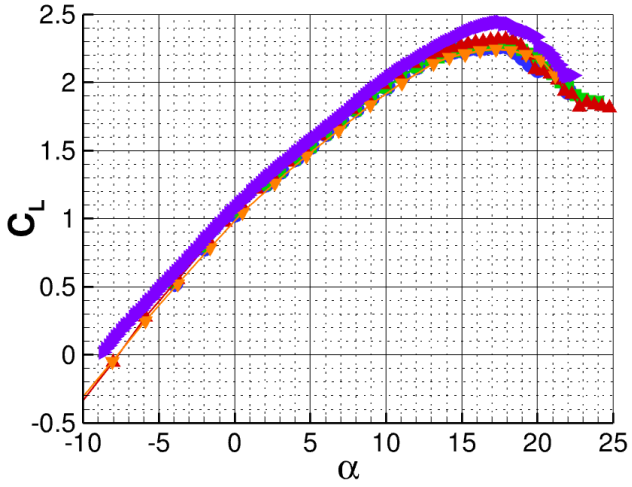


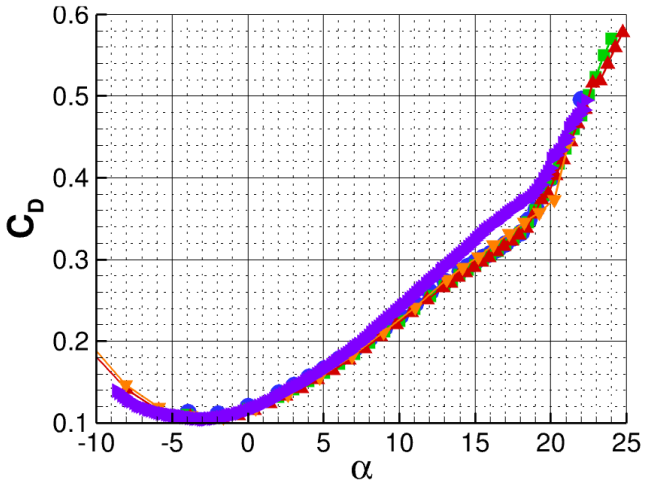


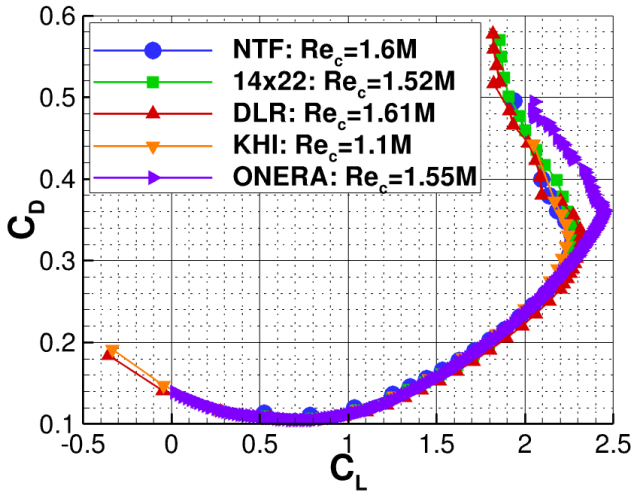


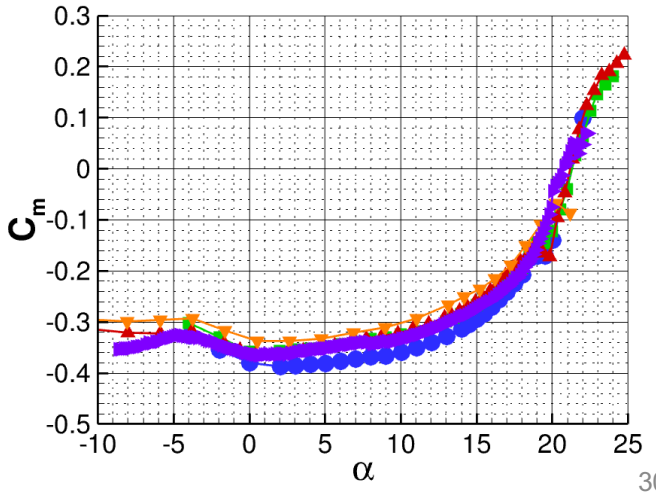
Add KHI and ONERA to Comparison, Re_c~1.6 million

- When adding data from KHI and ONERA tests, KHI compares well
- ONERA has a higher lift
- ONERA has a higher drag in the middle of the polar
- Pitching moment in ONERA is between the other tunnels and NTF



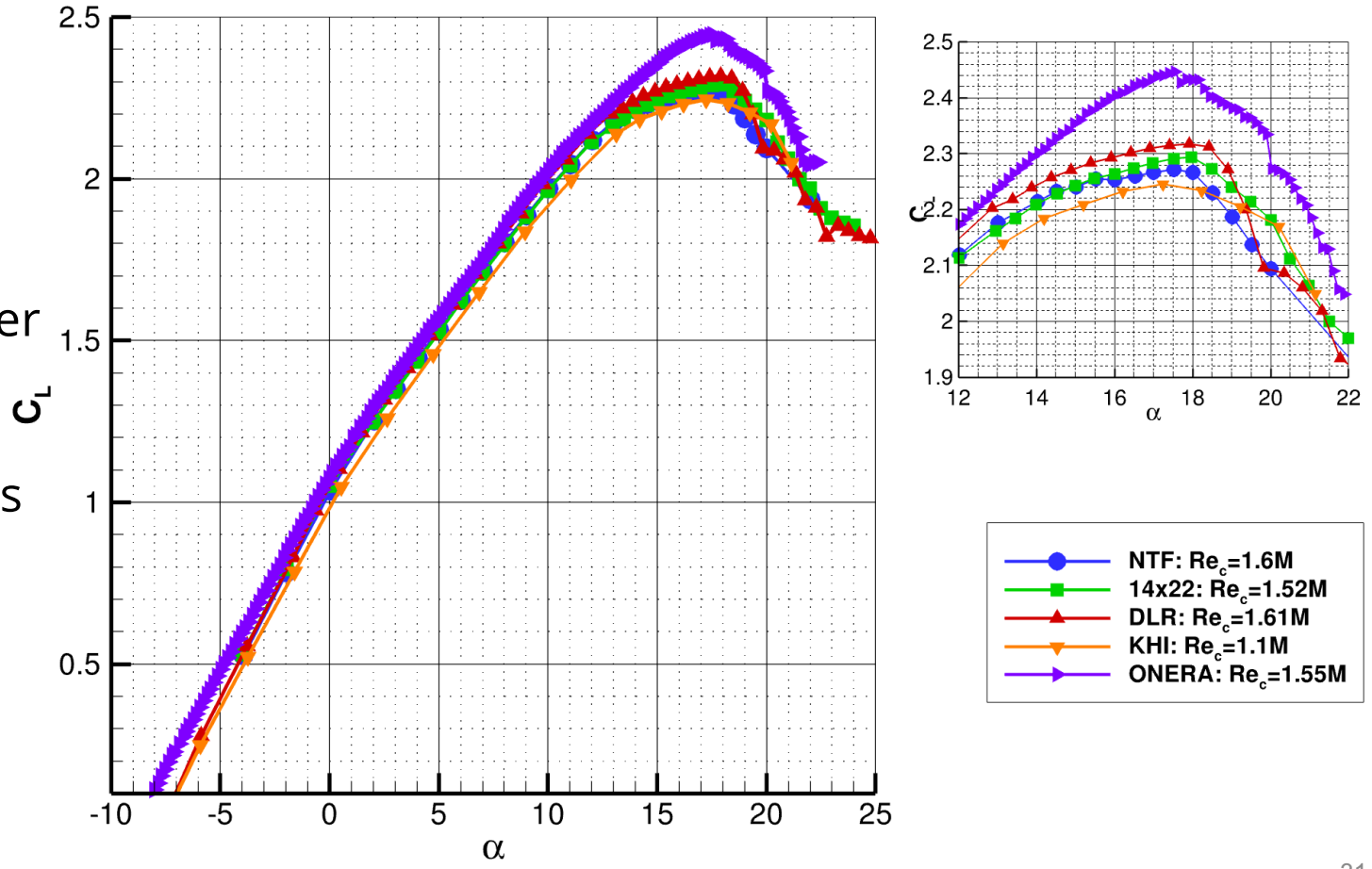






Closer Look at C_L

- Closer look at C_L shows a 0.2 difference between ONERA and the other wind tunnels
- A possible cause has been thoroughly investigated but to no avail yet



Future NTF testing

- NASA 2.7% Scale Full Span Model
  - Entry scheduled for December 2024 – January 2025
    - Forces and moments
    - Model pressures
    - Wing deformation
- NASA 5.2% Scale Semi-Span Model
  - Second NTF test scheduled for July - September 2025
    - Focus will be surface and off body flow field measurements
- NASA 2.7% Scale Semi-span Model
  - Entry scheduled for October – December 2025
    - Forces and moments
    - Model pressures
    - Wing deformation



QUESTIONS?

