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NASA 5.2%-Scale Semispan High Lift Common Research Model High Reynolds Number Wind Tunnel Test in the National Transonic Facility

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Outline



- Introduction
- National Transonic Facility
- NASA 5.2%-Scale CRM-HL Model
- High Reynolds Number Test
- Test Results
- Questions





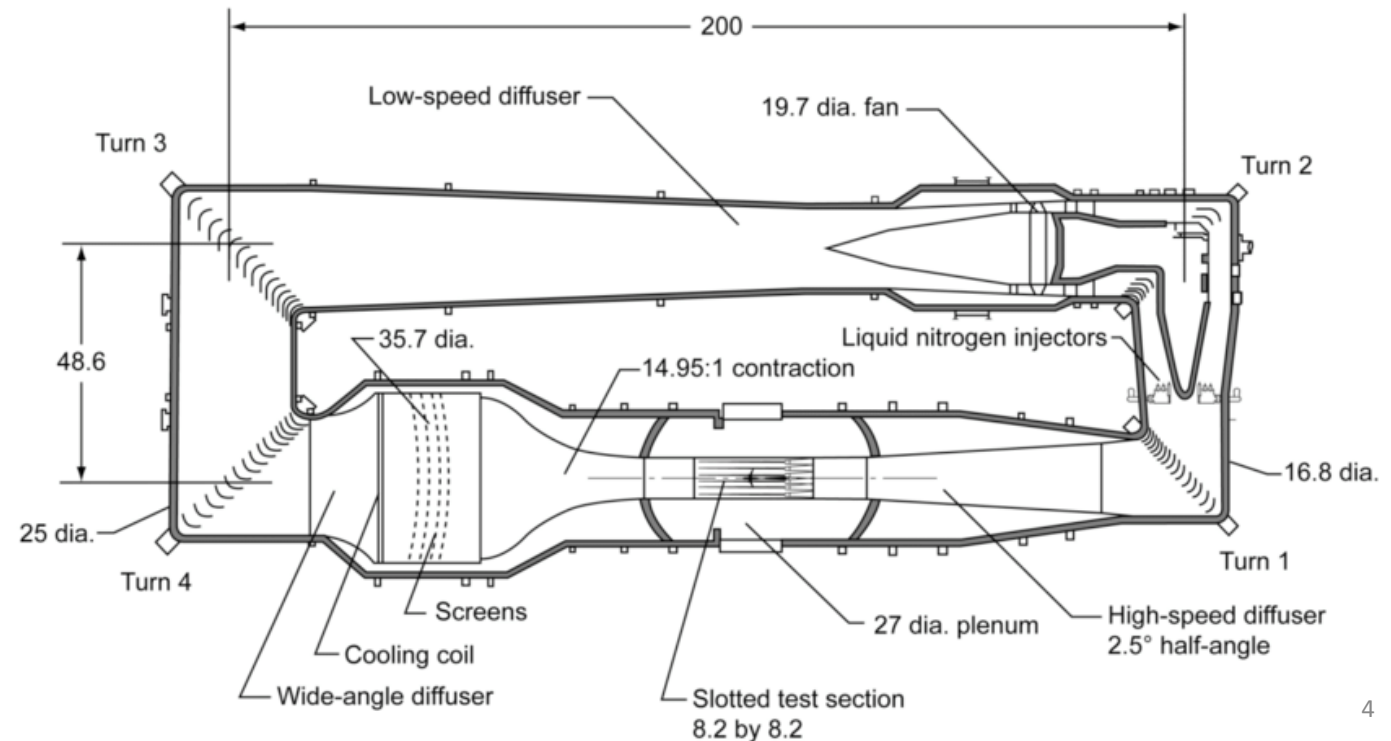
Introduction

- Validation of $C_{L,max}$ predictions and assessing transition, turbulence models, and Reynolds number effects in CFD requires wind tunnel data for comparison
- High Lift Common Research Model (CRM-HL)
 - Ecosystem of models designed using the same reference geometry
 - The wind tunnel data and model geometry will be open source to allow for CFD validation use
 - High Lift Prediction Workshop (HLPW)
- NASA 5.2%-scale CRM-HL semispan model
 - Designed for high Reynolds number testing at the National Transonic Facility (NTF)
 - Chord Reynolds numbers (Re_c) between 1.6 million and 30 million to assess Reynolds number effects
 - Collecting force and moment, pressure and wing deformation data
 - Test the model with ice shapes installed on the leading edges.
- 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

National Transonic Facility



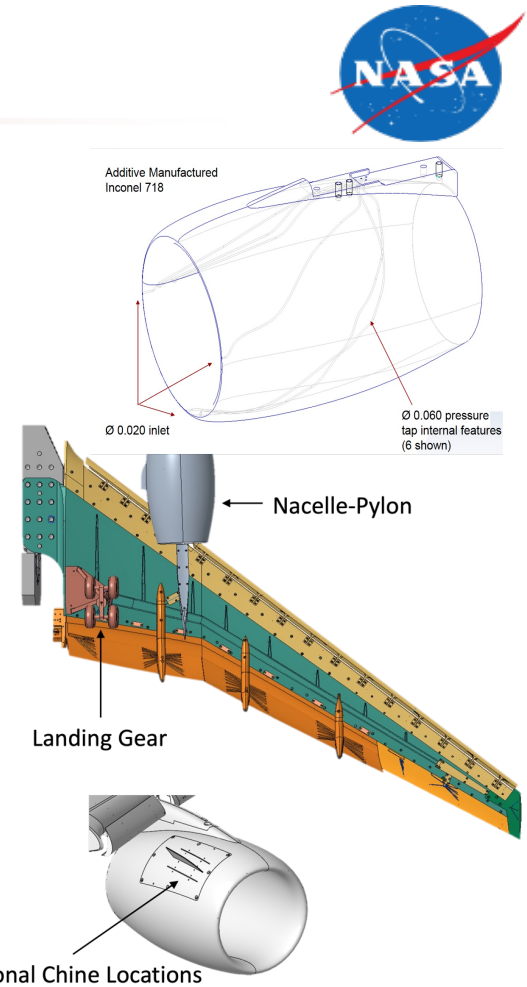
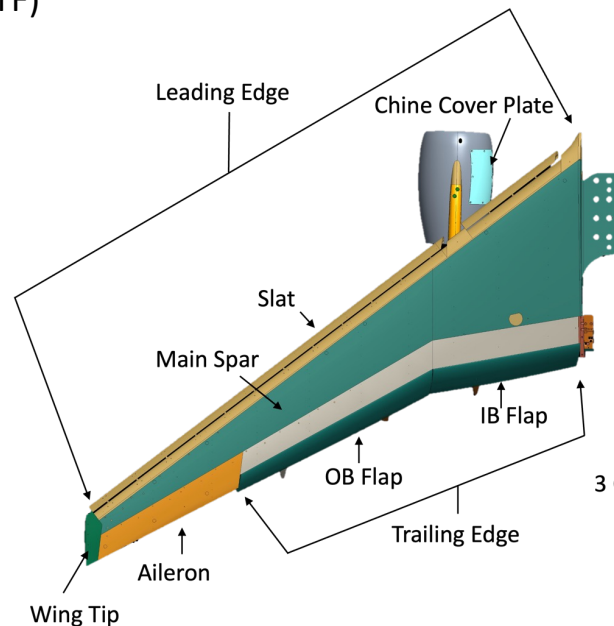
- NASA Langley Research Center, Hampton VA
- High Reynolds number testing
 - Cryogenic
- Closed-circuit, continuous flow
- Pressurized
- 8.2 ft x 8.2 ft x 25 ft long
- Slotted ceiling and floor



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
 - 14- by 22-Foot Subsonic Tunnel (14x22) checkout test
 - Low-Speed Wind Tunnel at Braunschweig (NWB)
 - NTF high Reynolds number test
 - 14x22 flow visualization test



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°

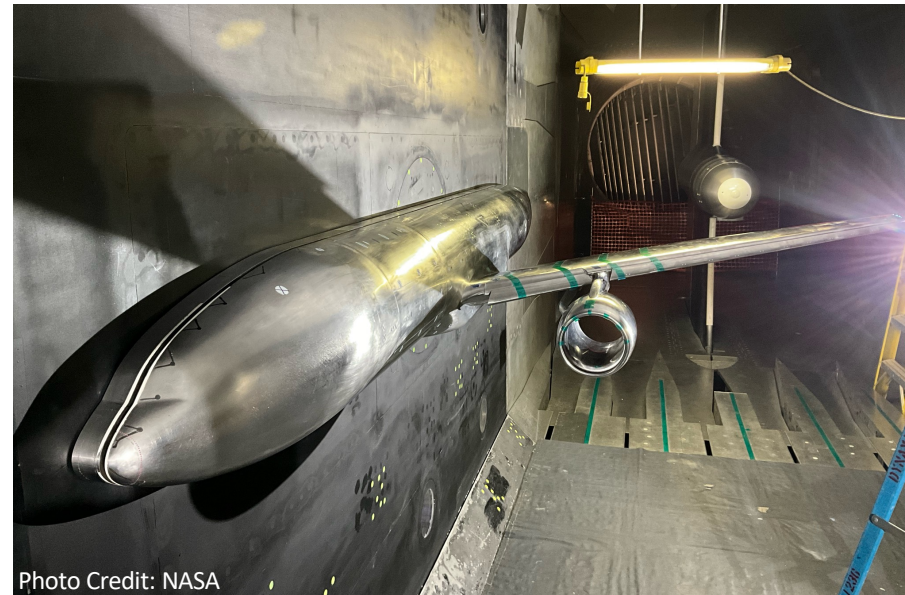


Photo Credit: NASA

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

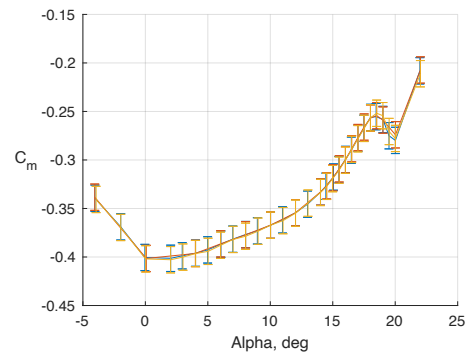
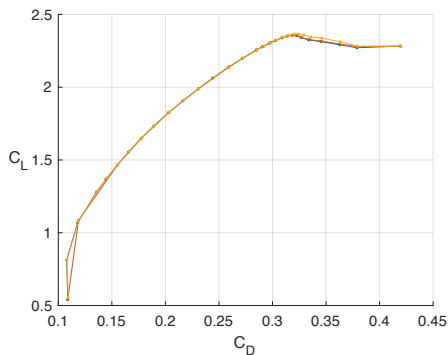
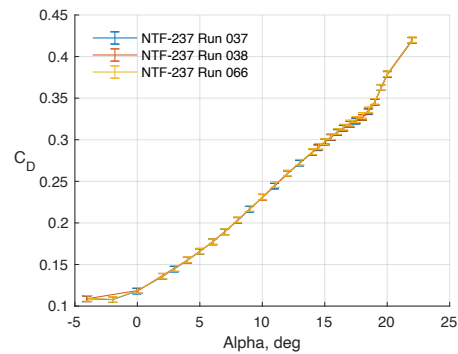
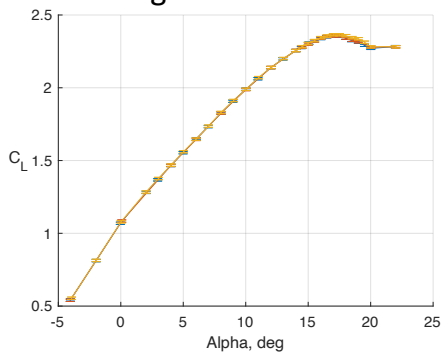
Short- and Long-Term Repeats, Re_c 3.33 Million



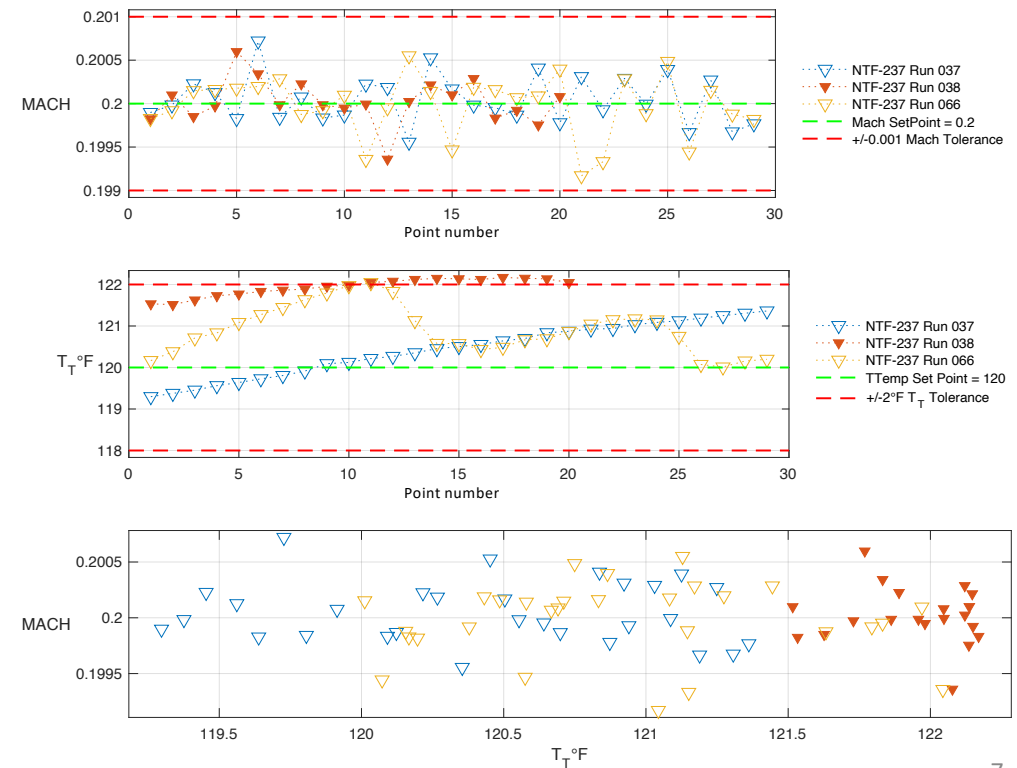
Short- and long-term repeatability look good

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

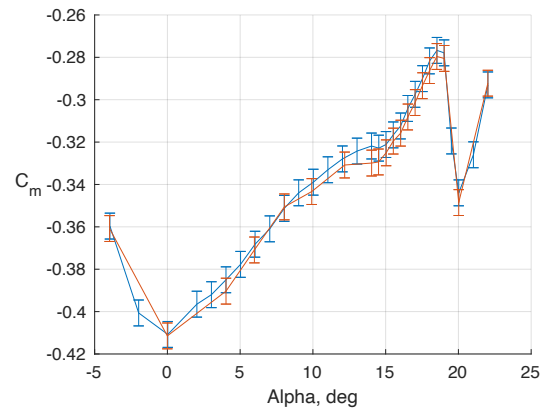
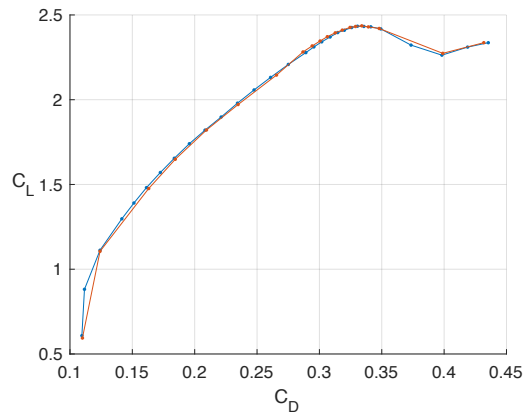
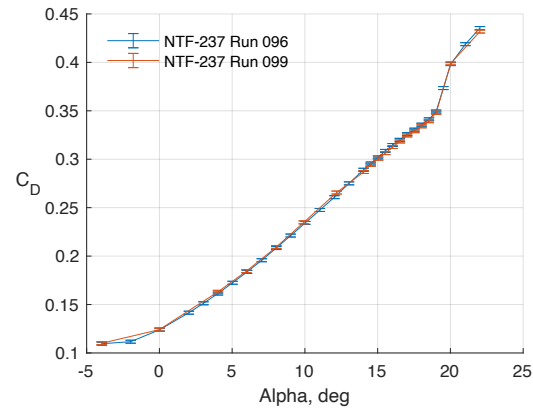
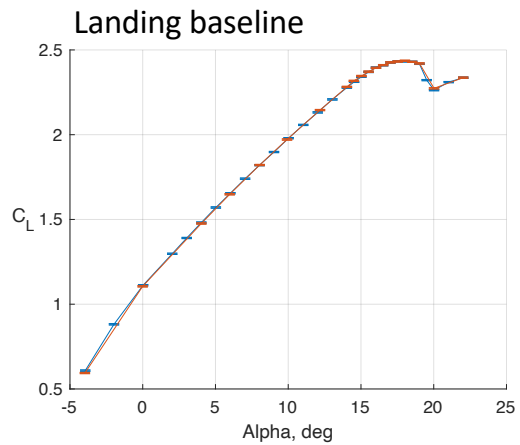
Landing baseline



Tunnel Conditions



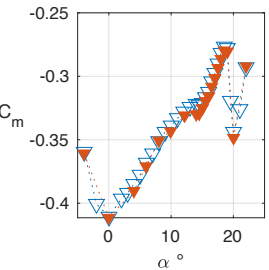
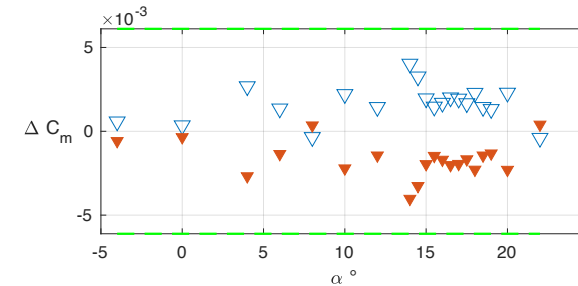
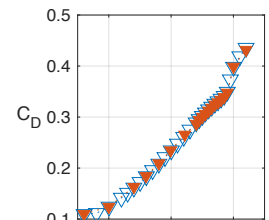
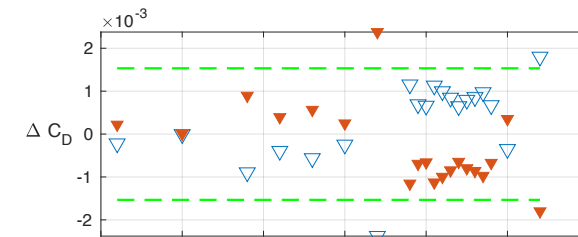
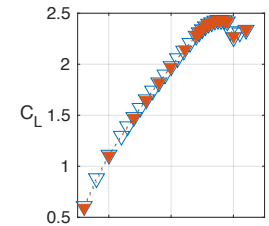
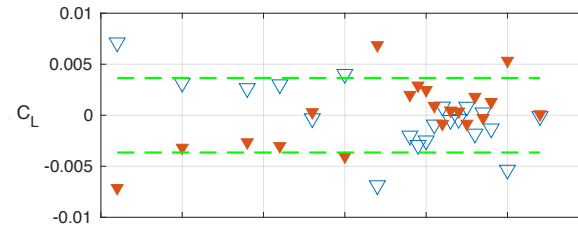
Short-Term Repeats, Re_c 30 Million



Residuals

Test	Run	Mach	Rec	Q	
				$\times 10^6$ (PSF)	
∇	237	96	0.20	30.0	294
$\blacktriangledown$	237	99	0.20	30.1	295

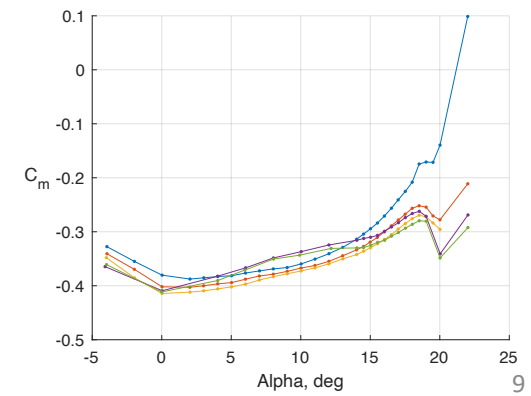
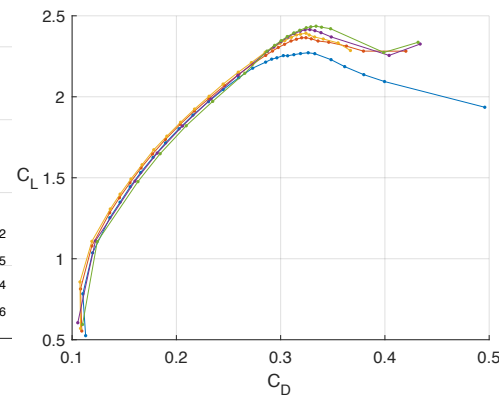
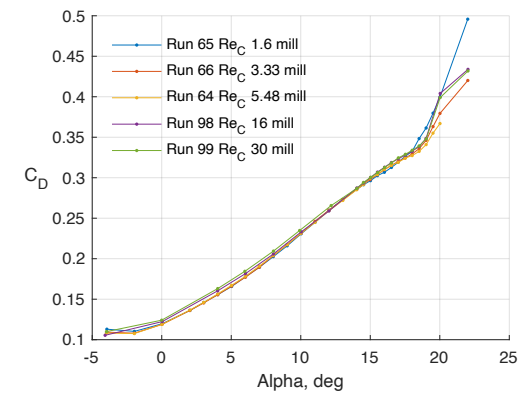
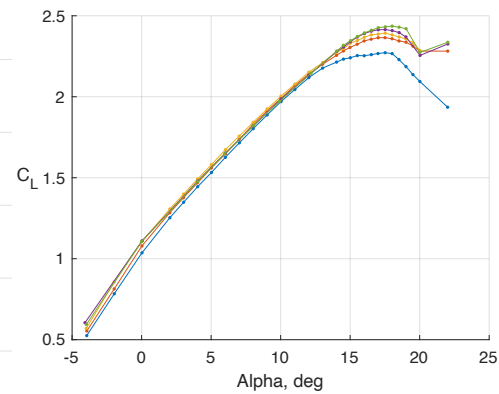
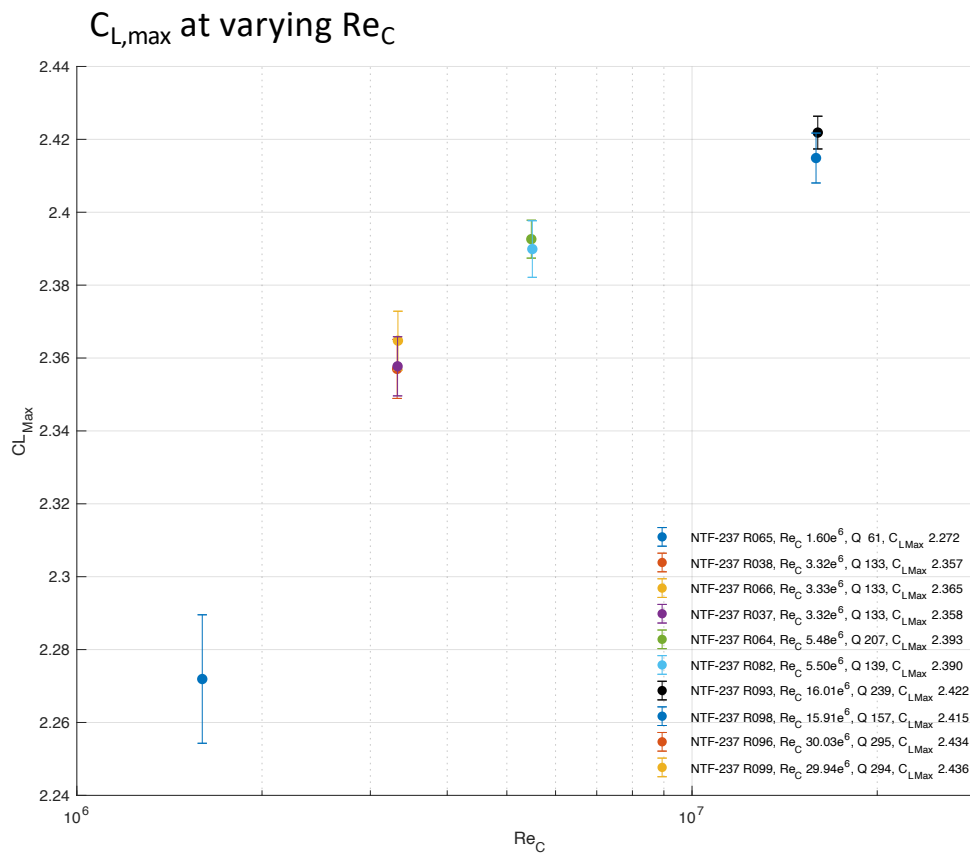
— 95% Bal Accuracy



5.2%-Scale CRM-HL NTF Reynolds Number Effects



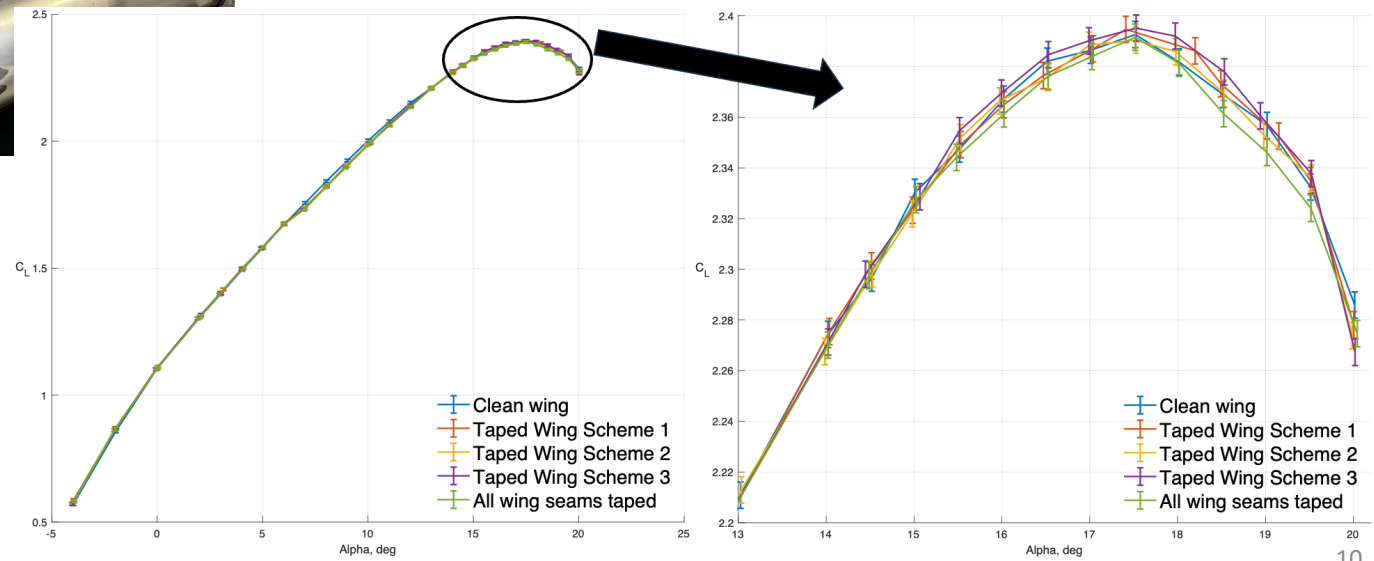
$C_{L,max}$ increases with Reynolds number



Leak Path Checks



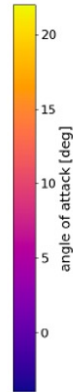
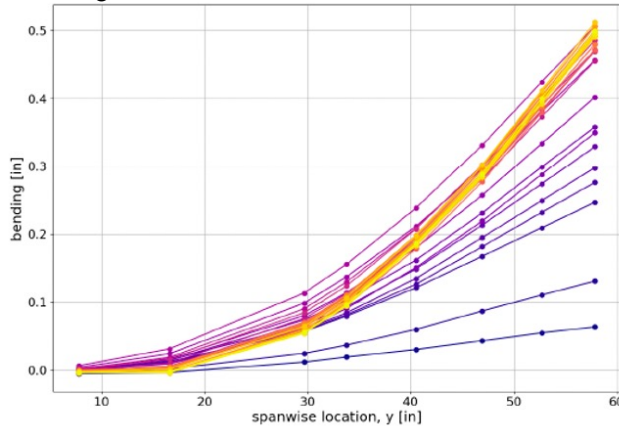
- 5 leak path check runs
 - Clean wing
 - Increasing amount of tape on the wing
 - All wing seams taped
- No increase in C_L
 - Within balance accuracy
- No leak paths in the wing



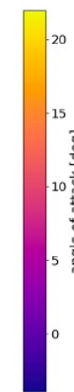
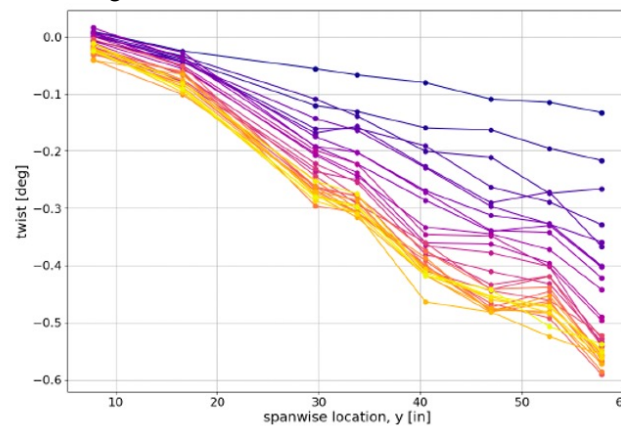
Wing Bending and Twist



Re_C 5.49 million Wing Bending

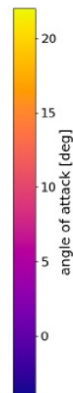
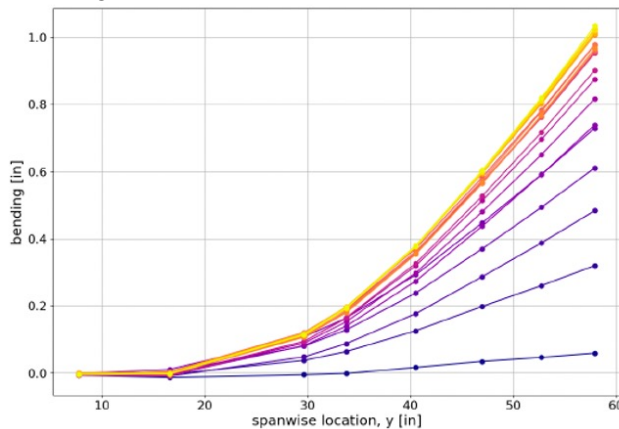


Re_C 5.49 million Wing Twist

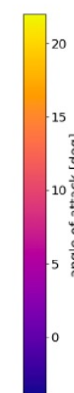
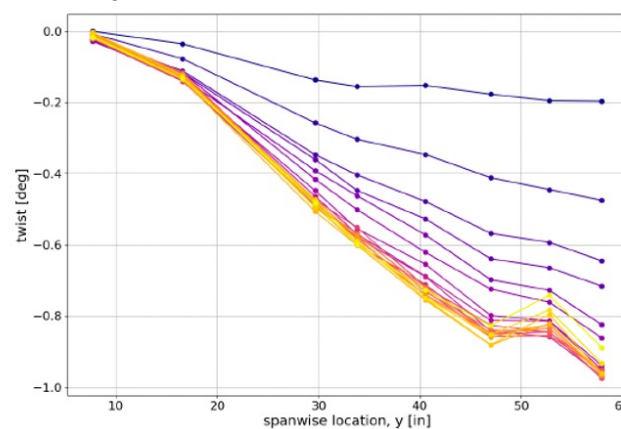


- NTF Theia system
- Deformation targets on wing
- Representative results
- Baseline Landing, Mach 0.20
- Re_C 5.49 million
- Max bending 0.51 inches at tip of the wing
 - Alpha 19.5°
- Max twist -0.59°
 - Alpha 15°

Re_C 30 million Wing Bending



Re_C 30 million Wing Twist



- Re_C 30 million
- Max bending 1.03 inches at tip of the wing
 - Alpha 22°
- Max twist -0.97°
 - Alpha 15°

Summary



- Validation of CFD $C_{L,max}$ predictions requires wind tunnel data for comparison
- Designed and built the NASA 5.2%-scale CRM-HL semispan model
- Tested model at the NTF at Re_c between 1.6 million and 30 million
- Short-term and long-term repeatability looked good
- C_{LMax} increased with increasing Reynolds number as expected
- Leak check runs were done on the wing, and no leak paths were present
- Wing bending and wing twist were recorded throughout testing
- Provided valuable high Reynolds number data on a relevant modern transport high lift configuration to the worldwide research community

Questions?



Photo Credit: NASA

Funding and support for this work was provided by the NASA Transformational Tools and Technologies (TTT) Project of the Transformative Aeronautics Concepts Program (TACP) and the NASA Aerosciences Evaluation and Test Capabilities (AETC) office, both under the Aeronautics Research Mission Directorate.

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