

# Validation Process for LEWICE by Use of a Navier-Stokes Solver

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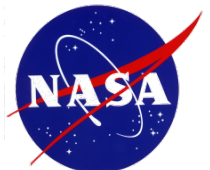
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Icing Branch

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at Lewis Field



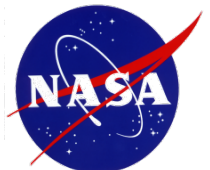
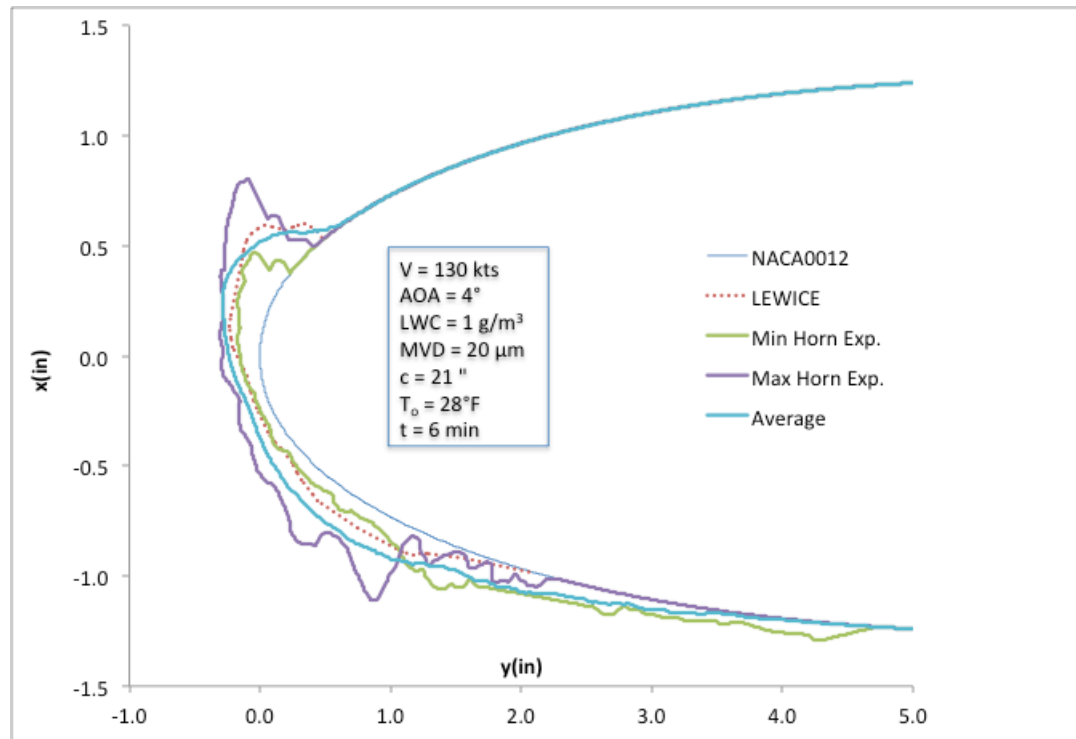
# Outline

- **Validation History**
- **LEWICE-Pointwise-FUN3D Script**
- **Validation Process**
- **Results**



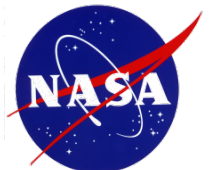
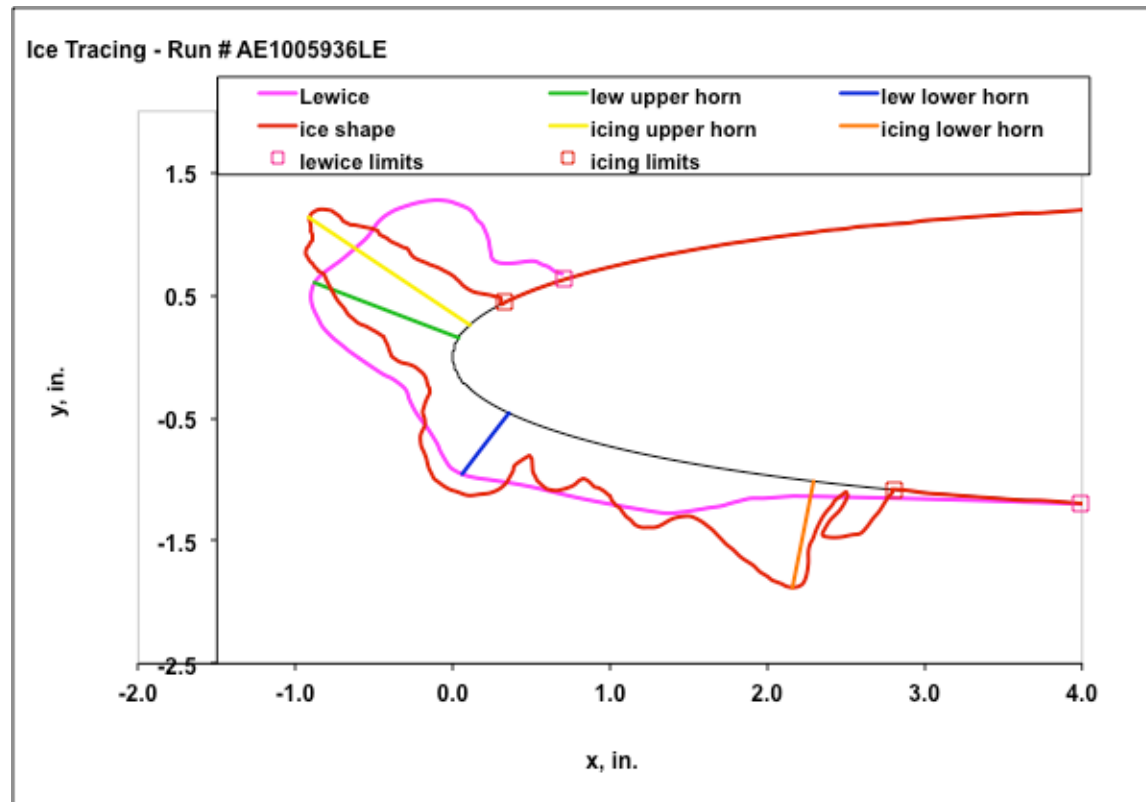
# Validation History

- Many icing Codes Use a Small Set of Cases for Validation
- Typical Shape (below) from Tunnel Calibration Test
- 46 tracings available
  - Warm Glaze Shows Wide Variation in Experiment Shapes



# Geometric Validation

- Previous LEWICE Validations Were Limited to Geometry Comparison (THICK Utility)



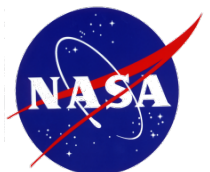
# Revised Validation

- **Perform Geometric Comparisons as Before**
- **Perform Navier-Stokes Calculations On Tracings from Experiment and LEWICE Predictions**
  - 12 conditions (all large glaze ice shapes)
  - Compare lift and drag (AOA from  $-6^{\circ}$  to  $8^{\circ}$  )
- **Three Conditions have Experimental Aero Data**
  - Compare CFD to experiment
  - Show variation in aero performance
    - Repeat shapes
    - Variation of shape along span
    - Smoothing
- **Solutions performed with NASA FUN3D**
  - Wilcox 2006 turbulence model

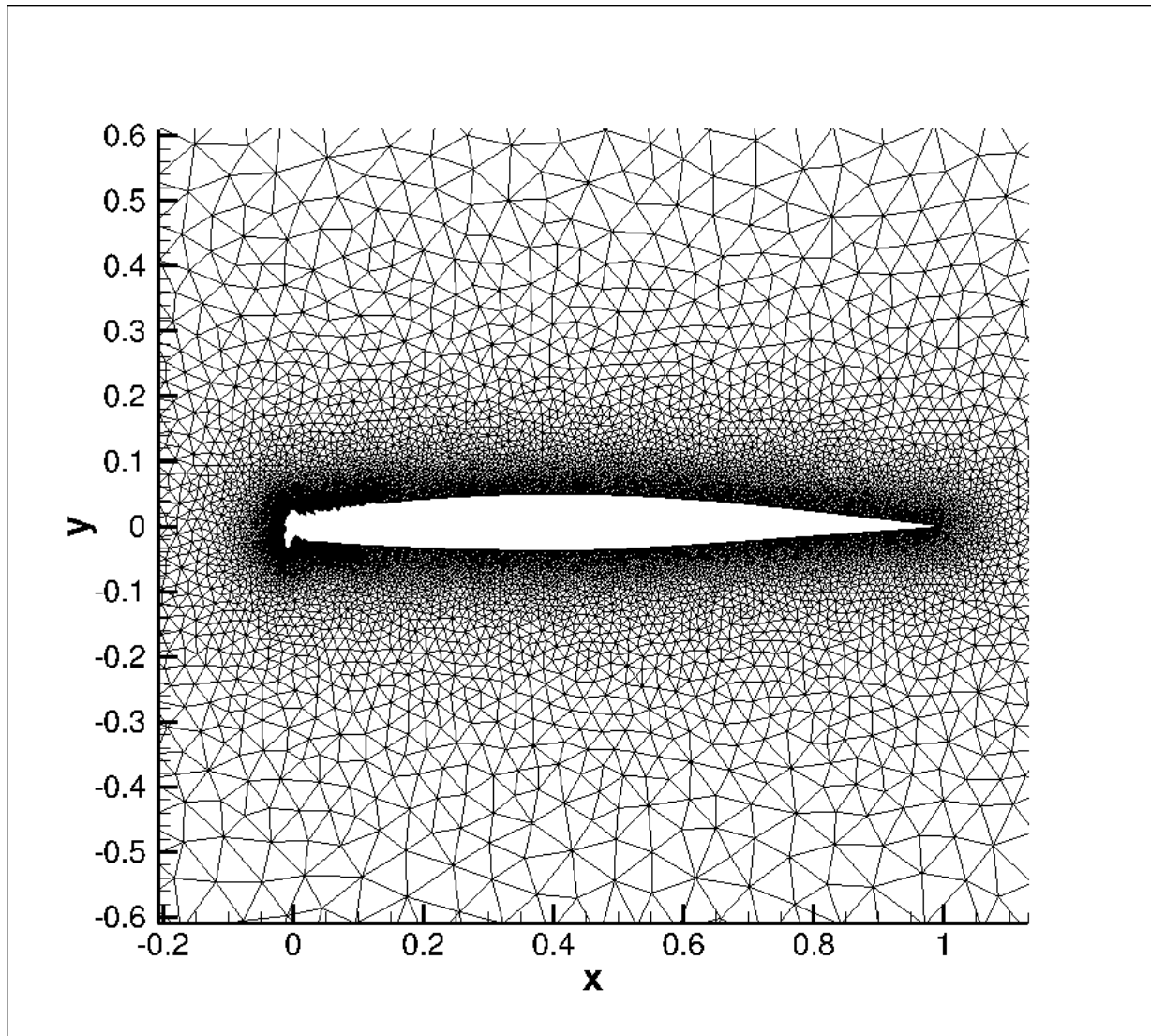


# Conditions

Airfoil	Chord (m)	Air Speed (m/s)	AOA (deg)	Total Temp (° C)	LWC (g/m <sup>3</sup> )	MVD (μm)	Time (s)	Mach	Re*10-6
NACA0012	0.53	102.9	4	-5.6	1.8	30	360	0.32	4.40
NACA0012	0.91	77.1	0	-8.3	1	15	1224	0.24	5.67
<b>NACA23012</b>	<b>0.46</b>	<b>102.9</b>	<b>2</b>	<b>-2.2</b>	<b>0.75</b>	<b>15.4</b>	<b>300</b>	<b>0.31</b>	<b>3.68</b>
NACA23012	1.83	90.0	2	-5.0	0.94	15	600	0.28	13.03
BizJet	0.30	139.4	0	-7.9	1.12	19	138	0.44	3.58
BizJet	0.46	88.4	0	-6.1	1.47	29	240	0.27	3.22
BizJet	0.61	89.4	0	-6.0	1.3	35	360	0.27	4.34
BizJet	0.61	89.4	0	-13.0	1.27	43	360	0.28	4.57
<b>BizJet</b>	<b>0.91</b>	<b>90.0</b>	<b>6</b>	<b>-0.8</b>	<b>0.54</b>	<b>20</b>	<b>1350</b>	<b>0.27</b>	<b>6.32</b>
<b>NLF0414</b>	<b>0.91</b>	<b>66.9</b>	<b>2</b>	<b>-3.1</b>	<b>0.54</b>	<b>20</b>	<b>1350</b>	<b>0.20</b>	<b>4.71</b>
LTHS	0.91	130.2	0	-1.4	0.563	21	1476	0.40	9.47
NACA0015	0.35	95.2	0	-5.5	0.75	19	600	0.29	2.68



# Sample Grid

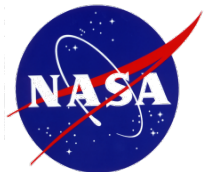


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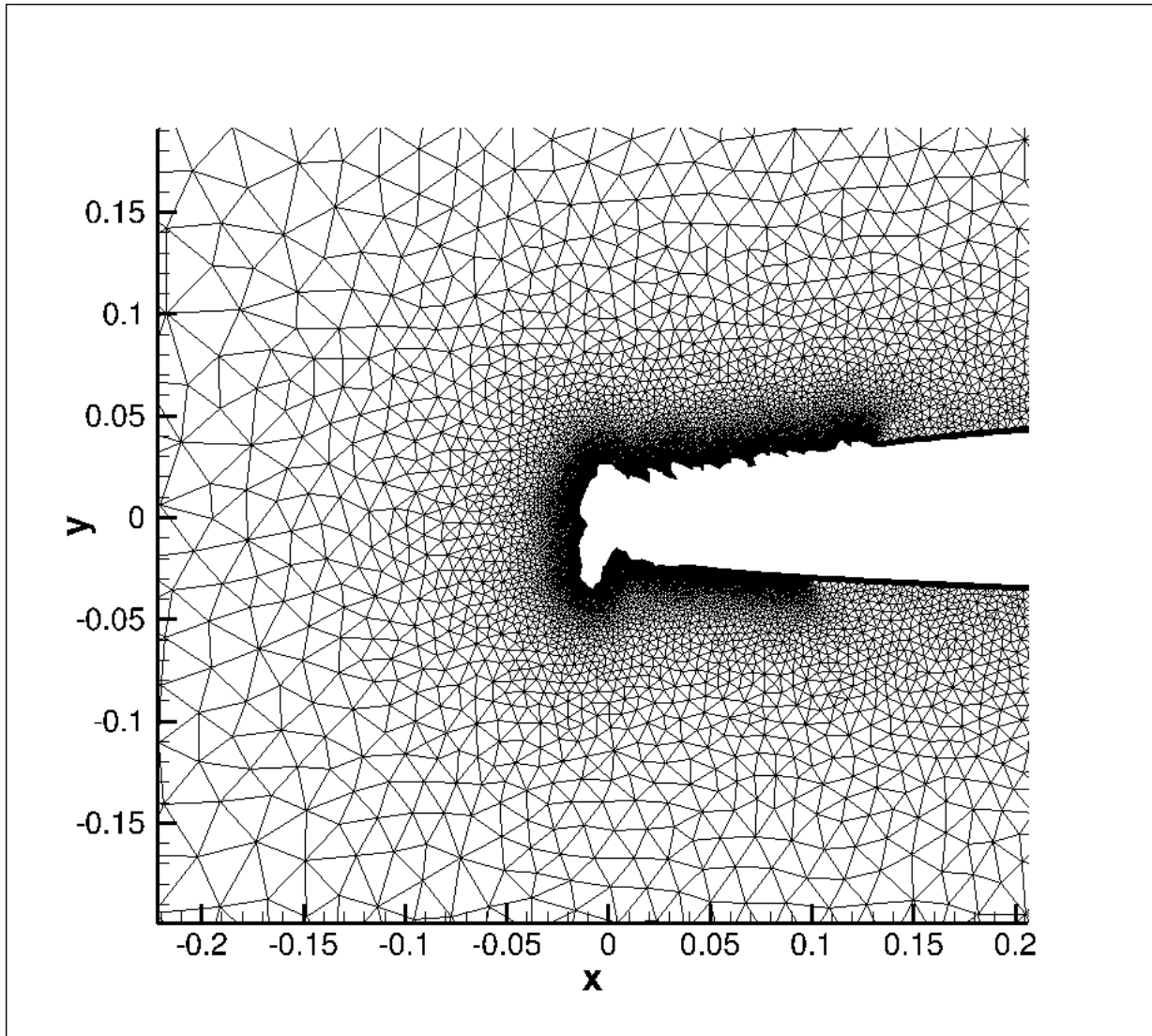
Icing Branch

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at Lewis Field



# Sample Grid

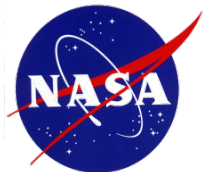


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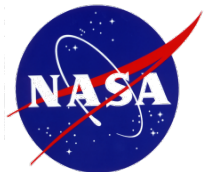
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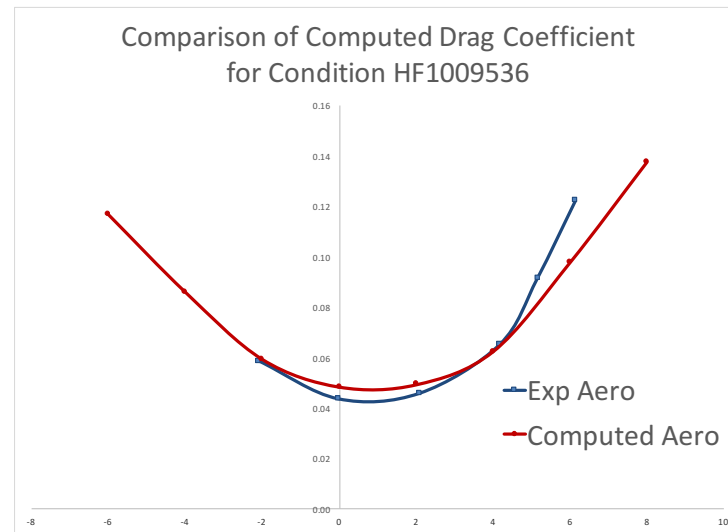
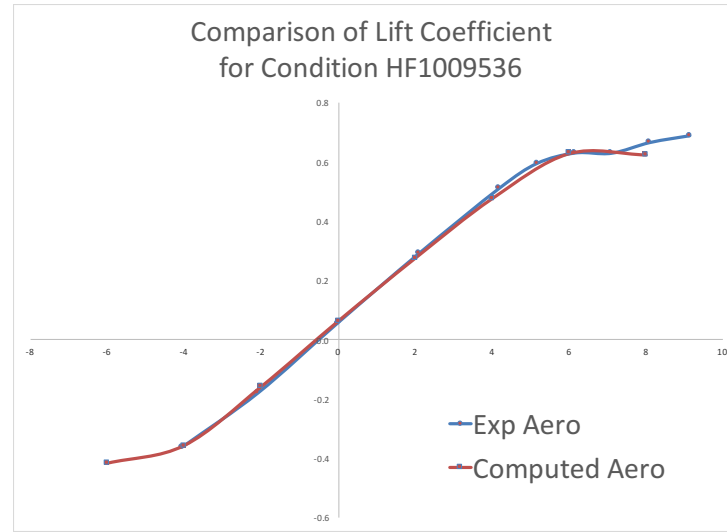
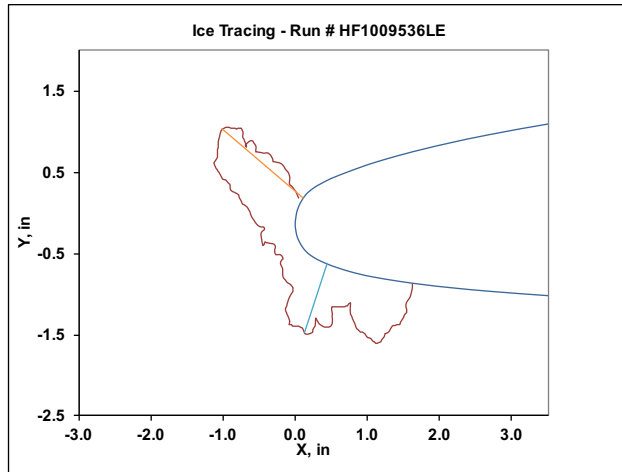


# Validation Results

- **Geometric Differences between LEWICE and Experiment Less Than Experimental Variability of Full Database**
- **Geometric Differences of Experimental Shapes Chosen Relatively Small**



# HF1009536 Aero Comparison

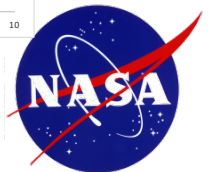


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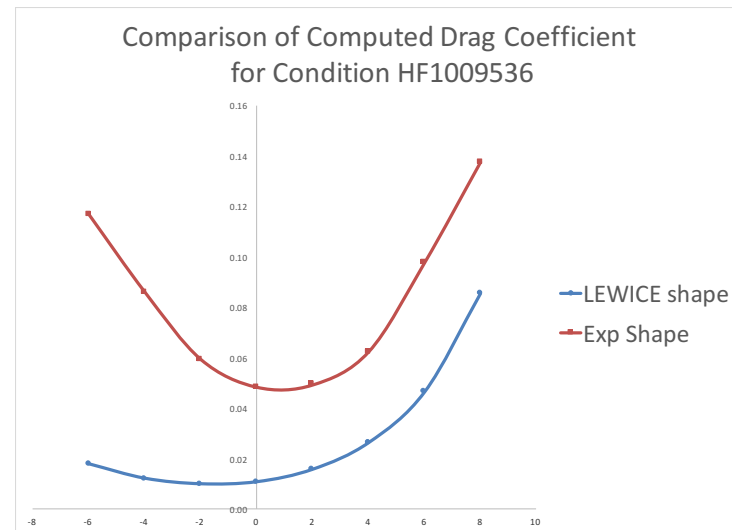
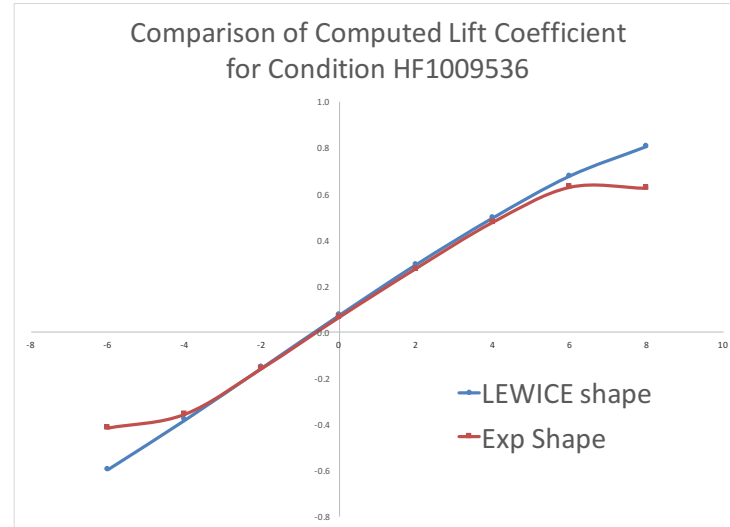
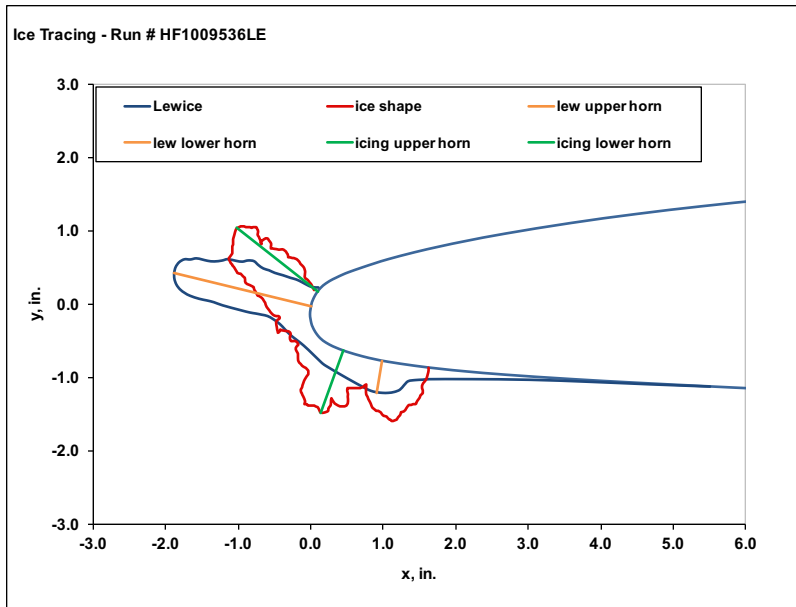
Icing Branch

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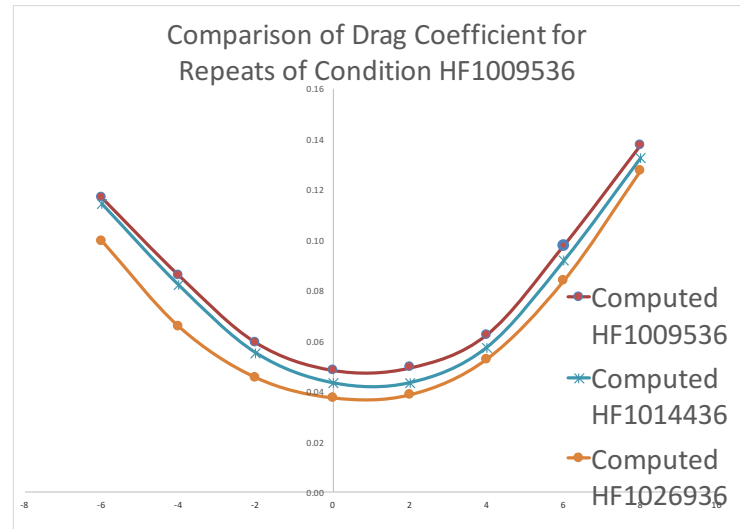
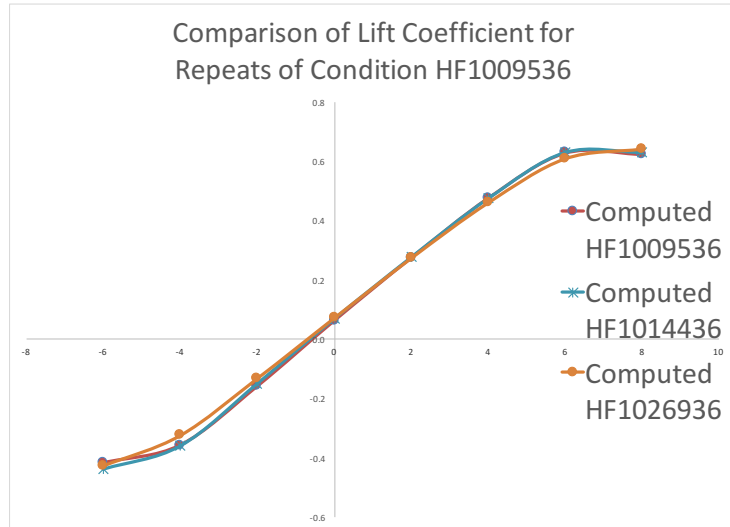
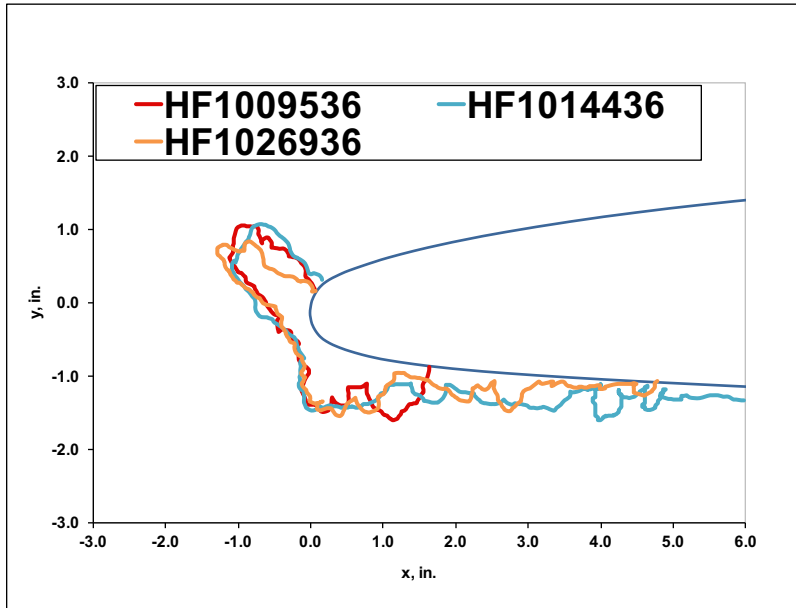
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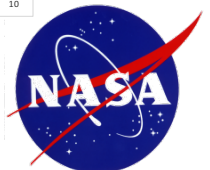
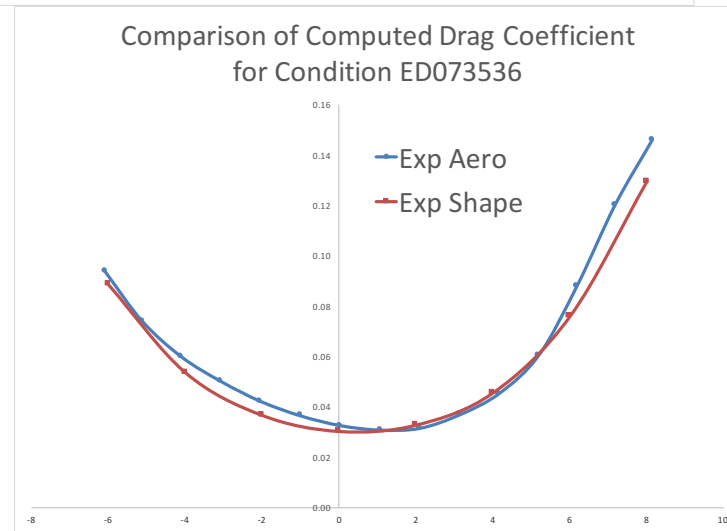
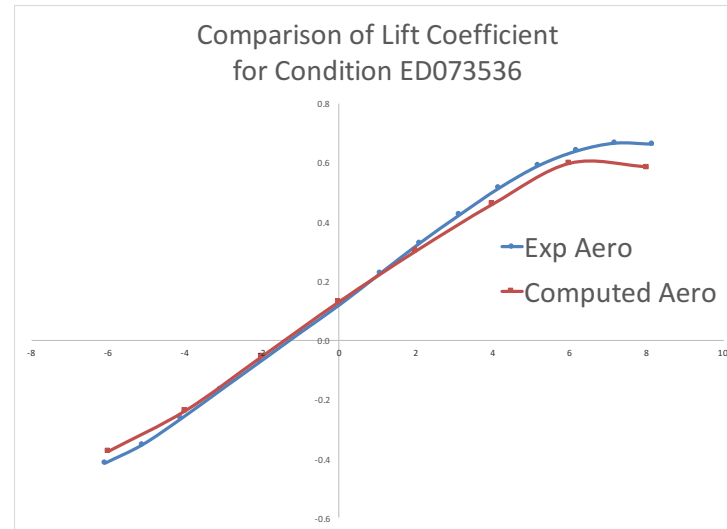
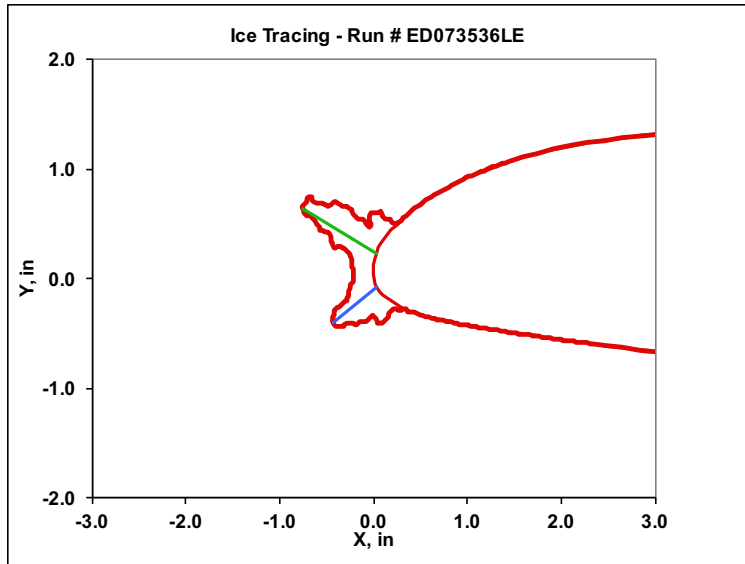
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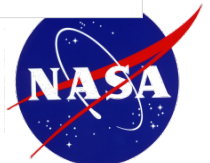
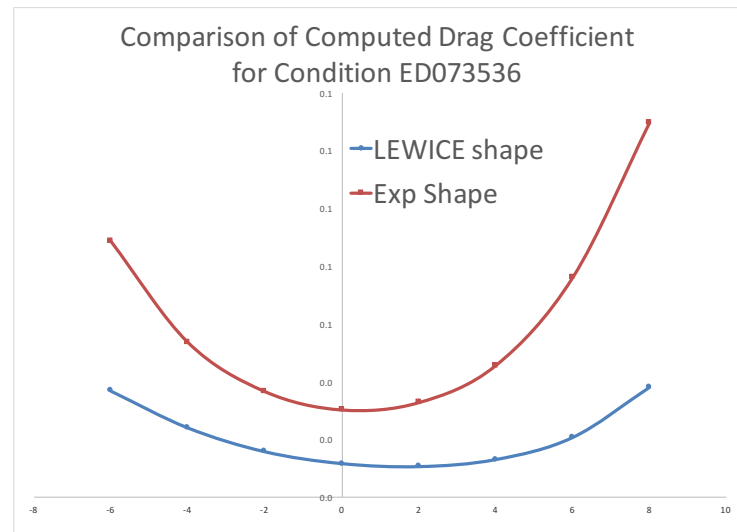
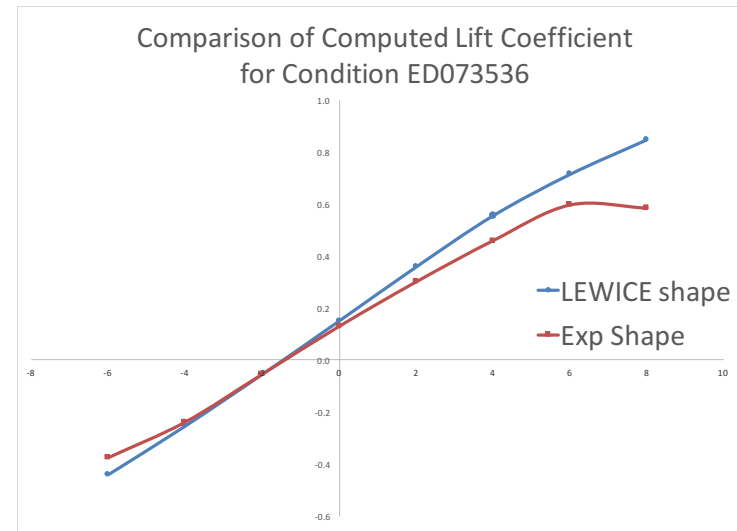
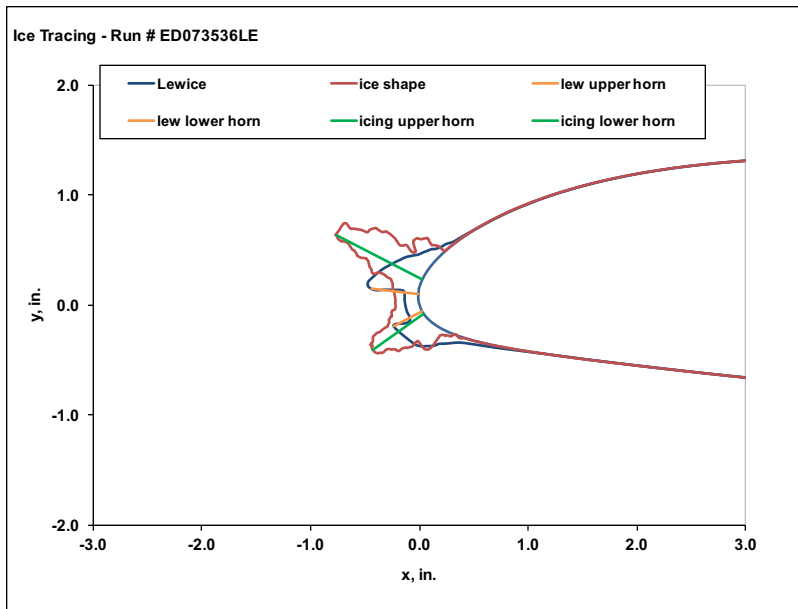
# HF1009536 Repeatability



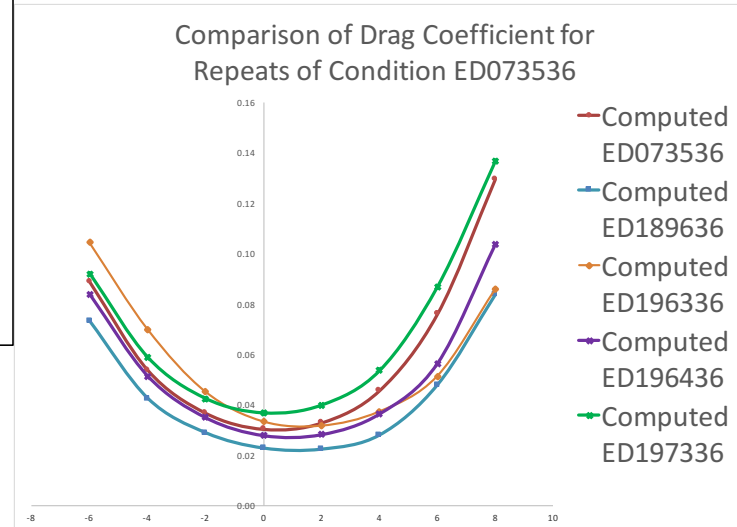
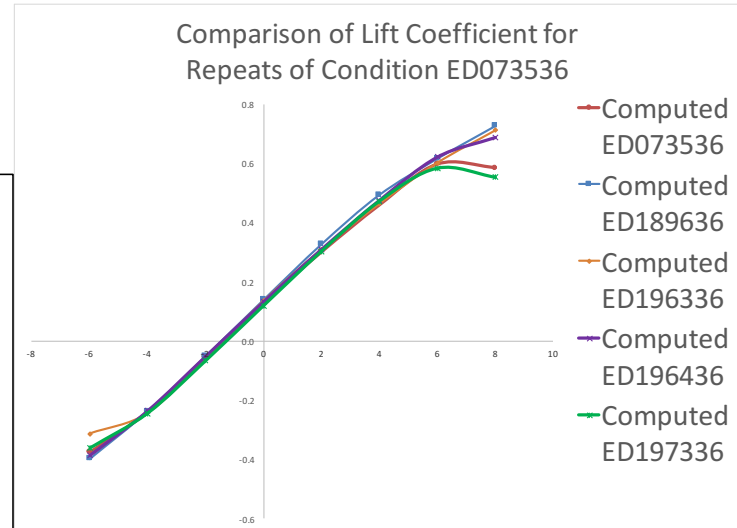
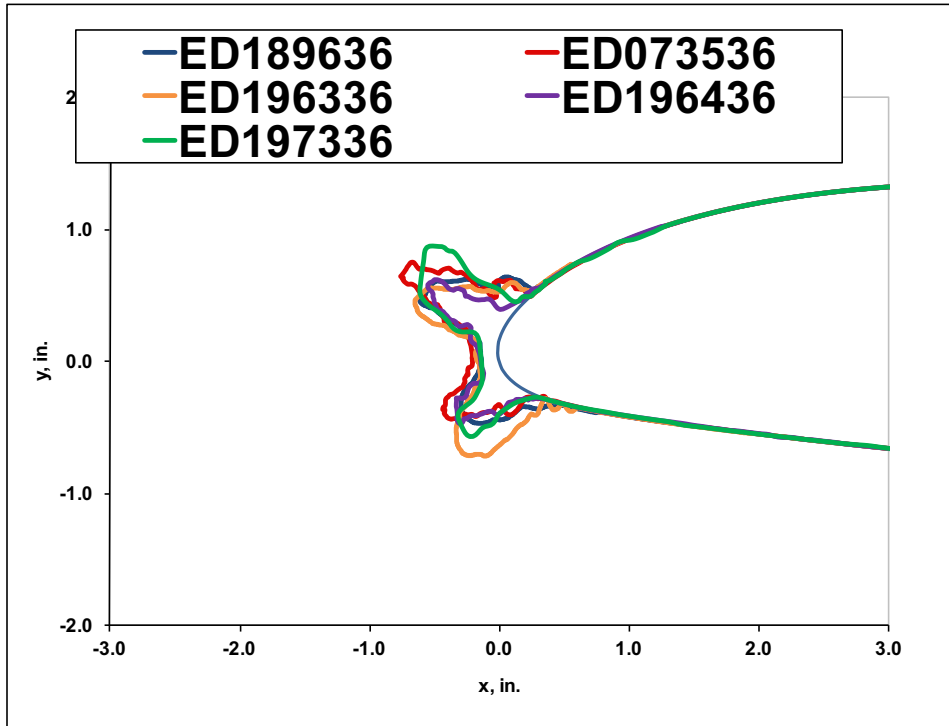
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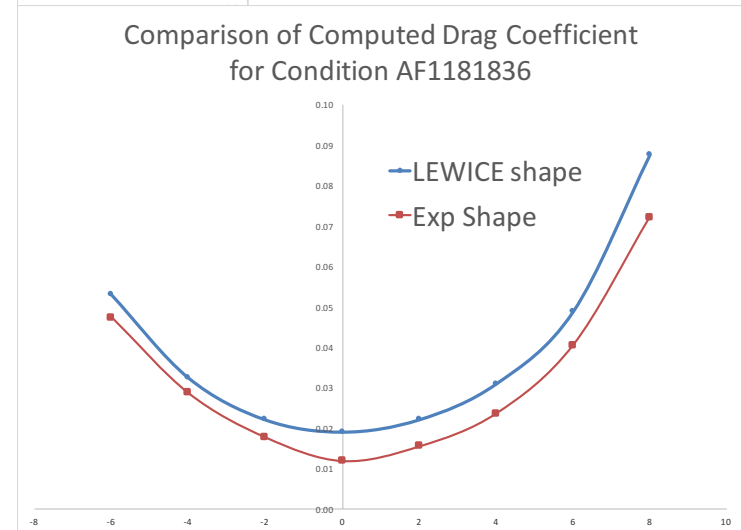
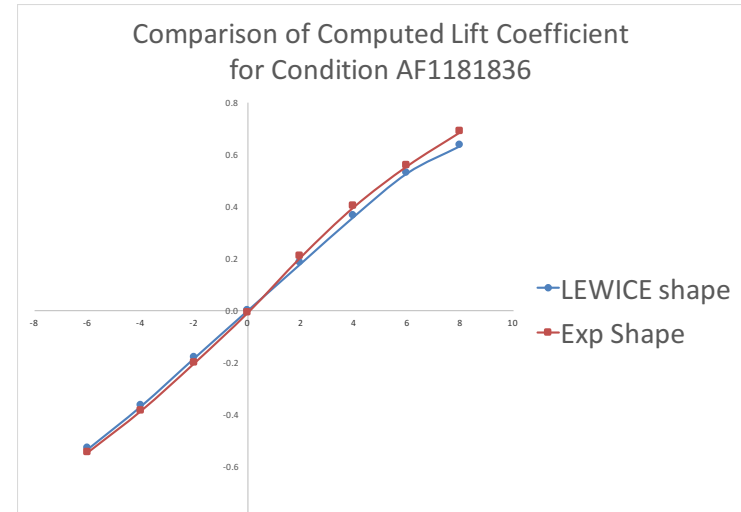
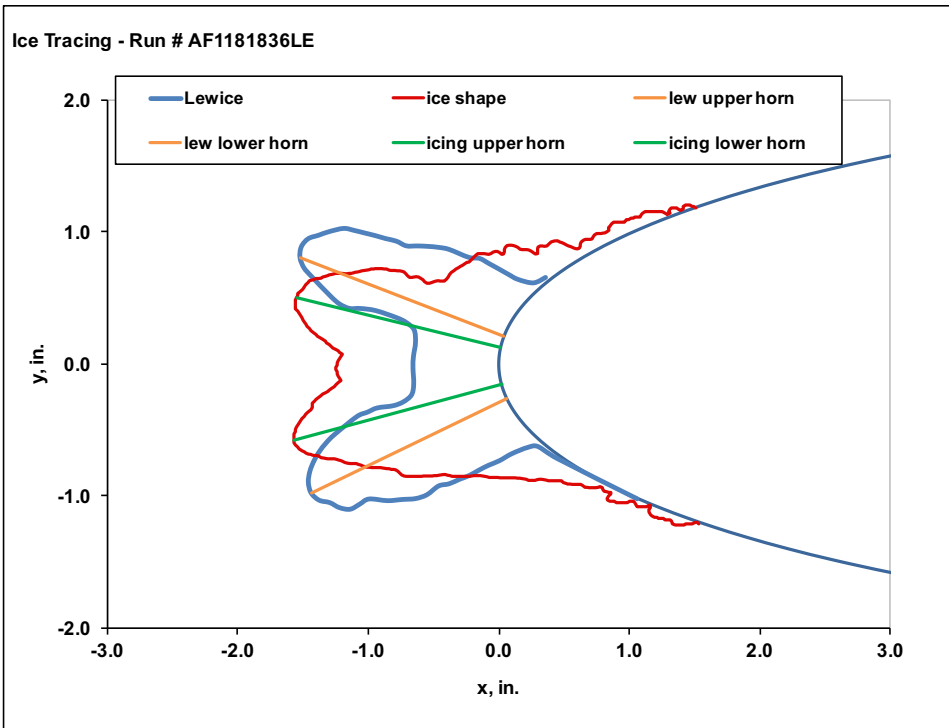
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# ED073536 Repeatability

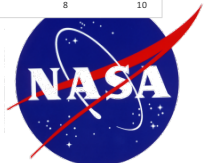
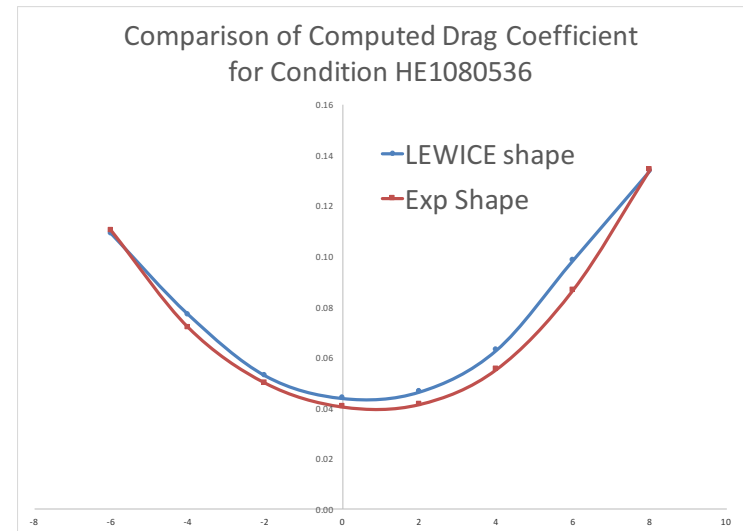
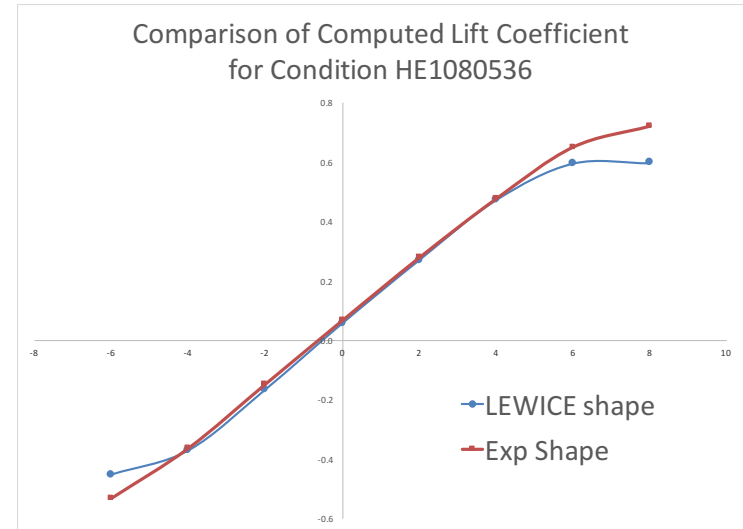
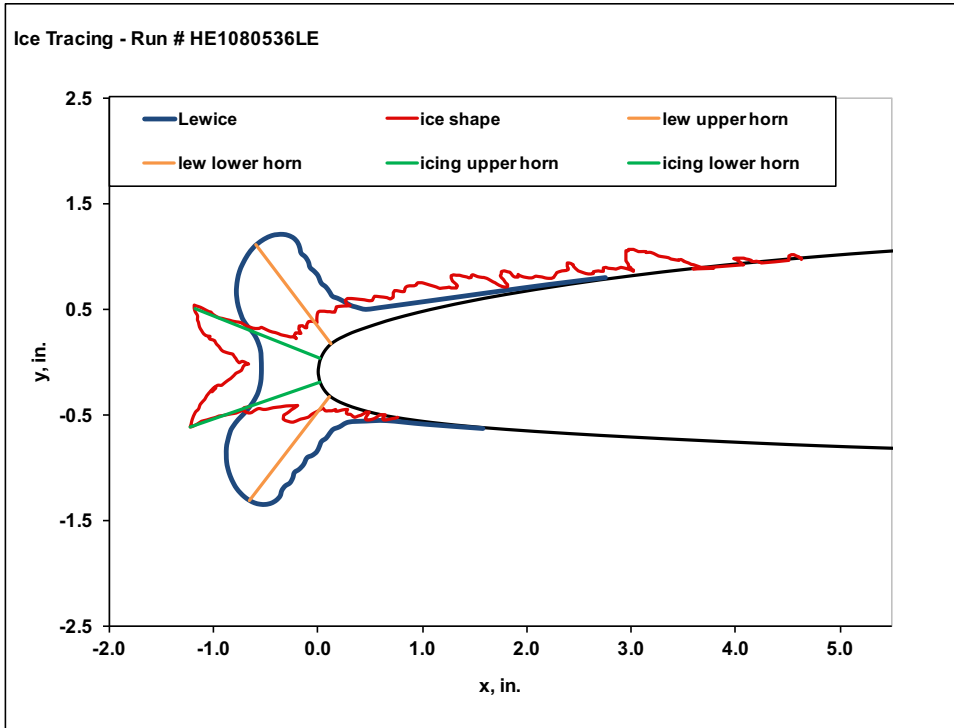


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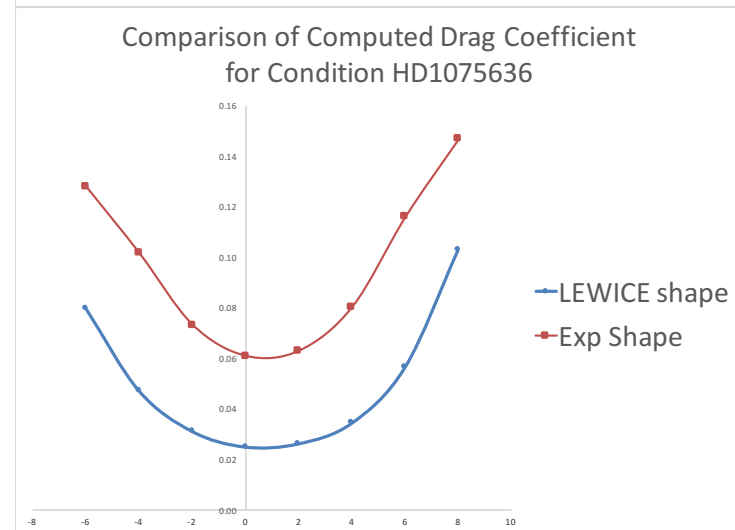
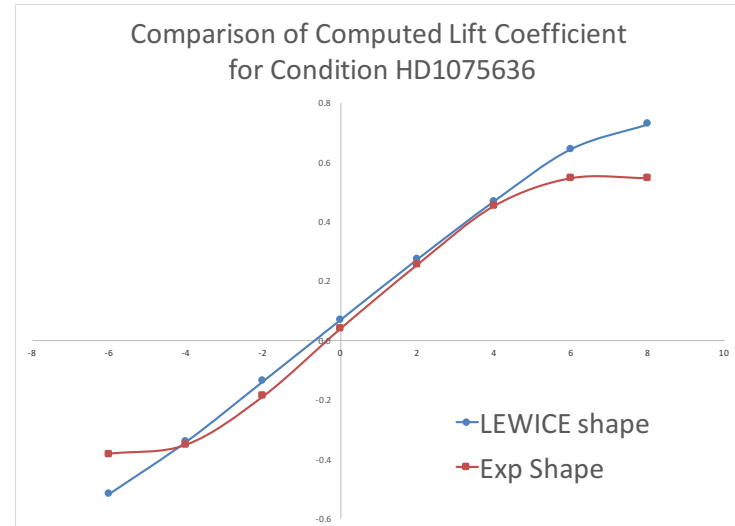
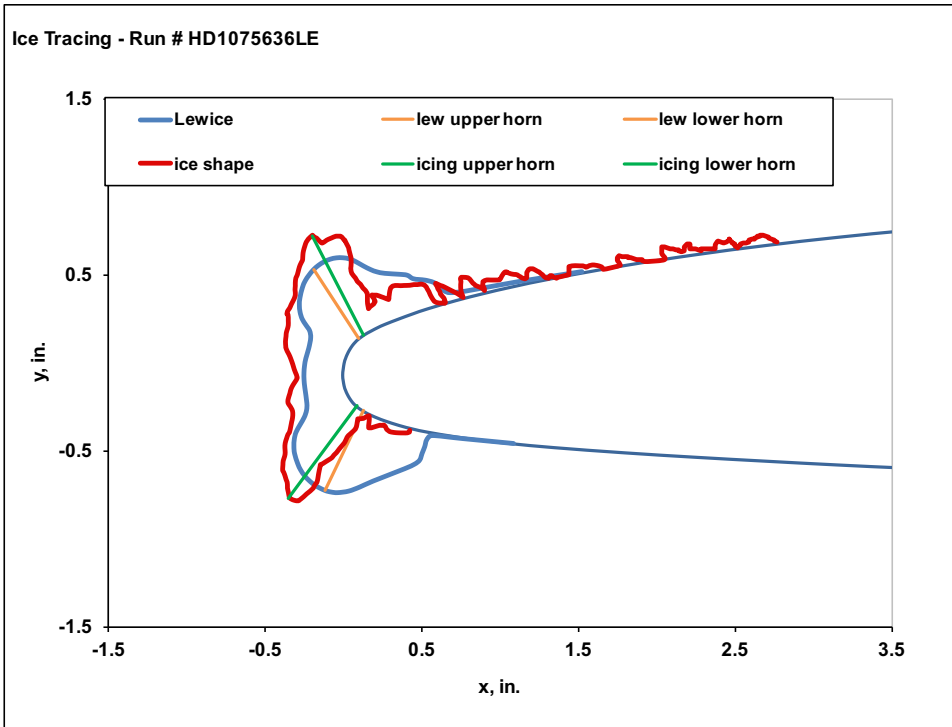




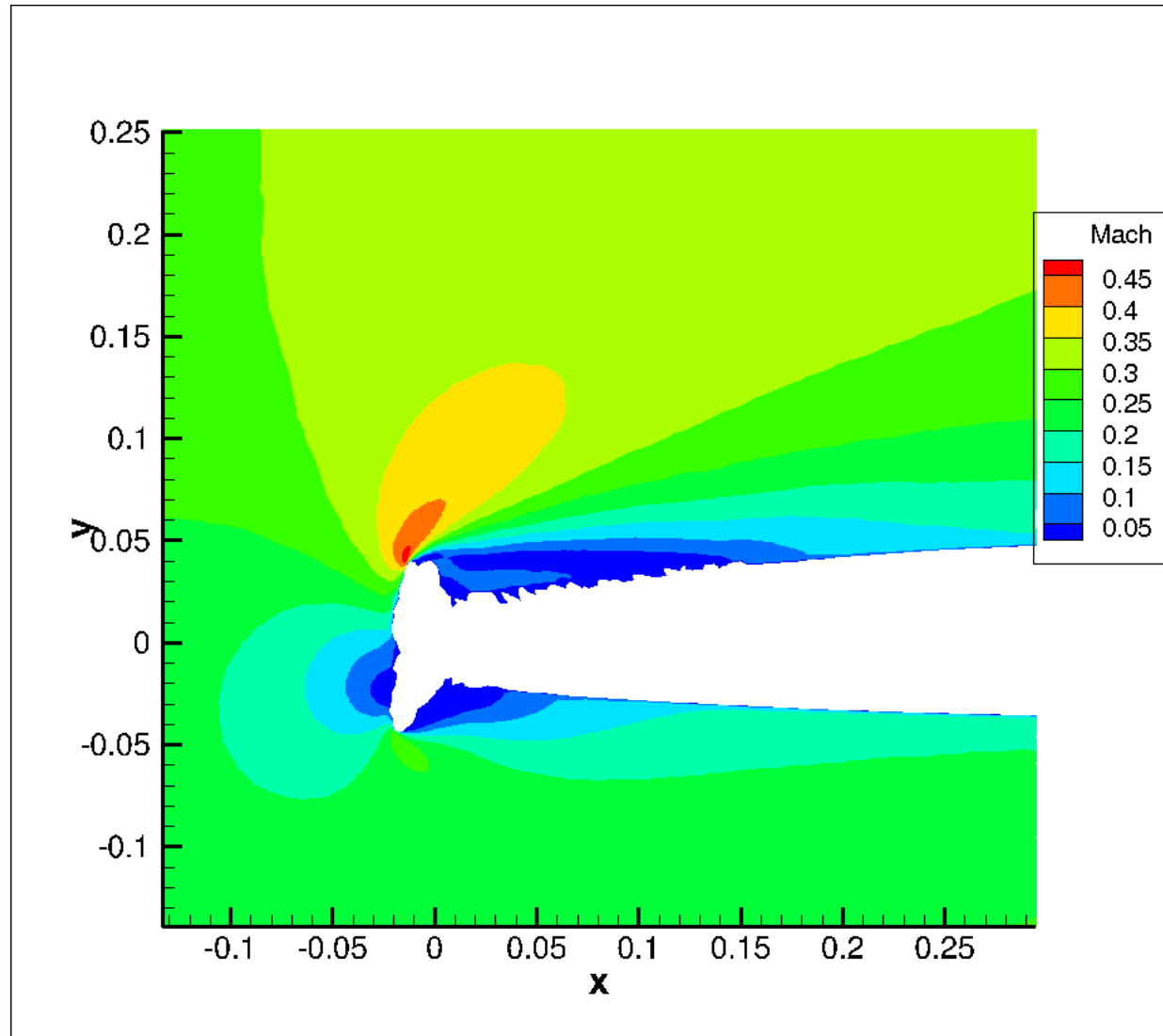
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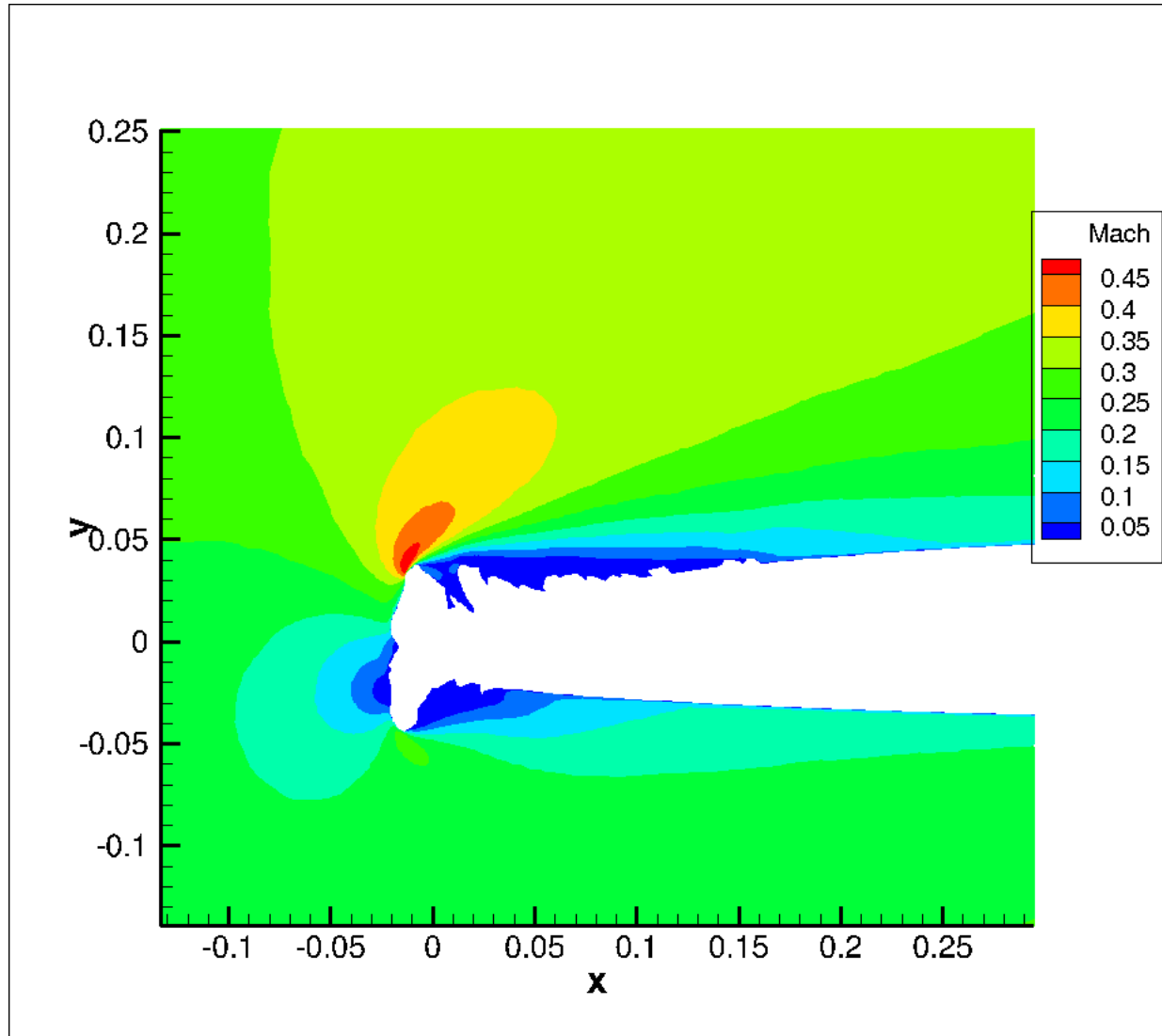
# HD1075636



# Mach Contours for HD1075636



# Mach Contours for HD1075736



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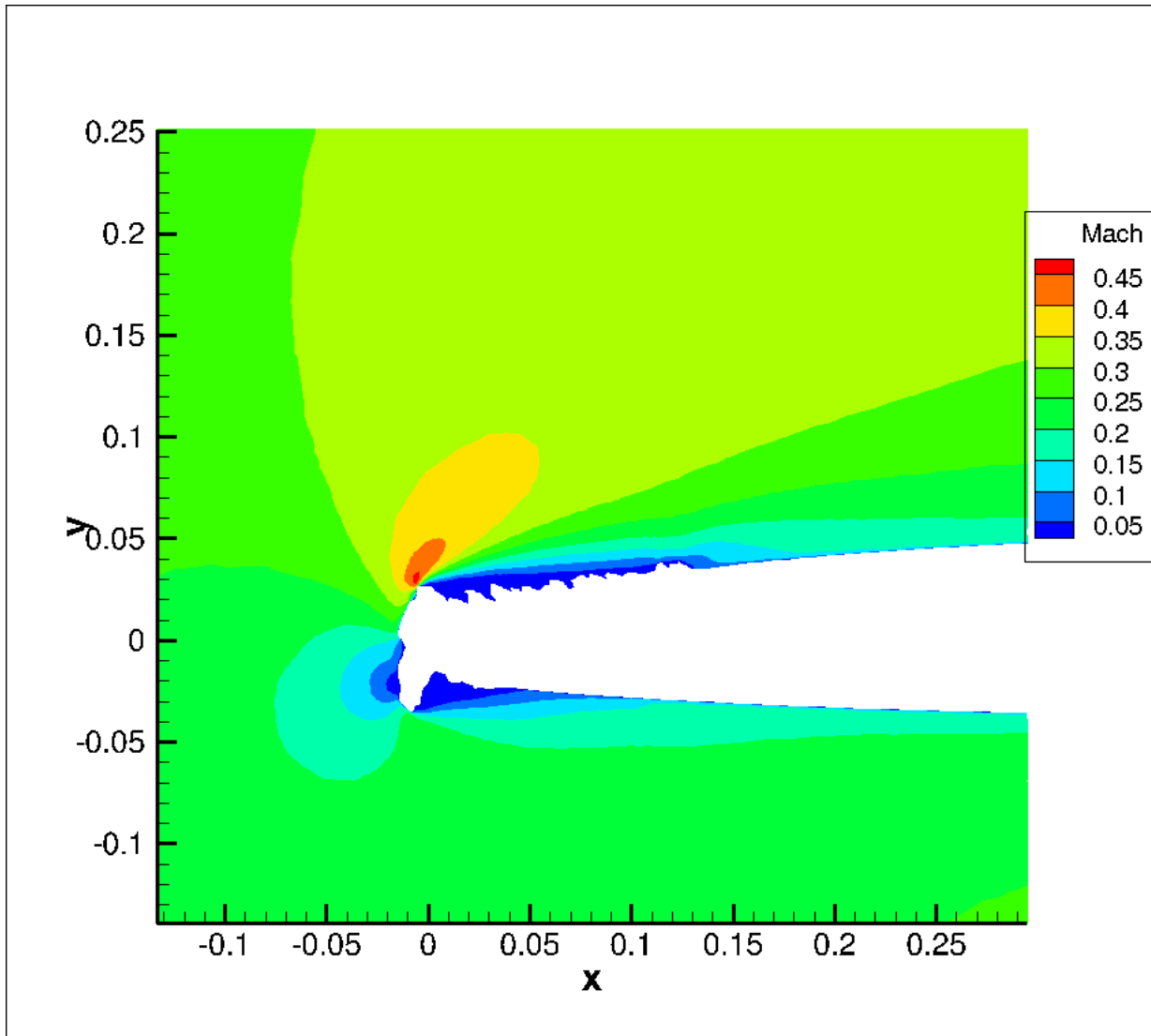
Icing Branch

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at Lewis Field



# Mach Contours for HD1075936

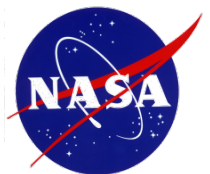


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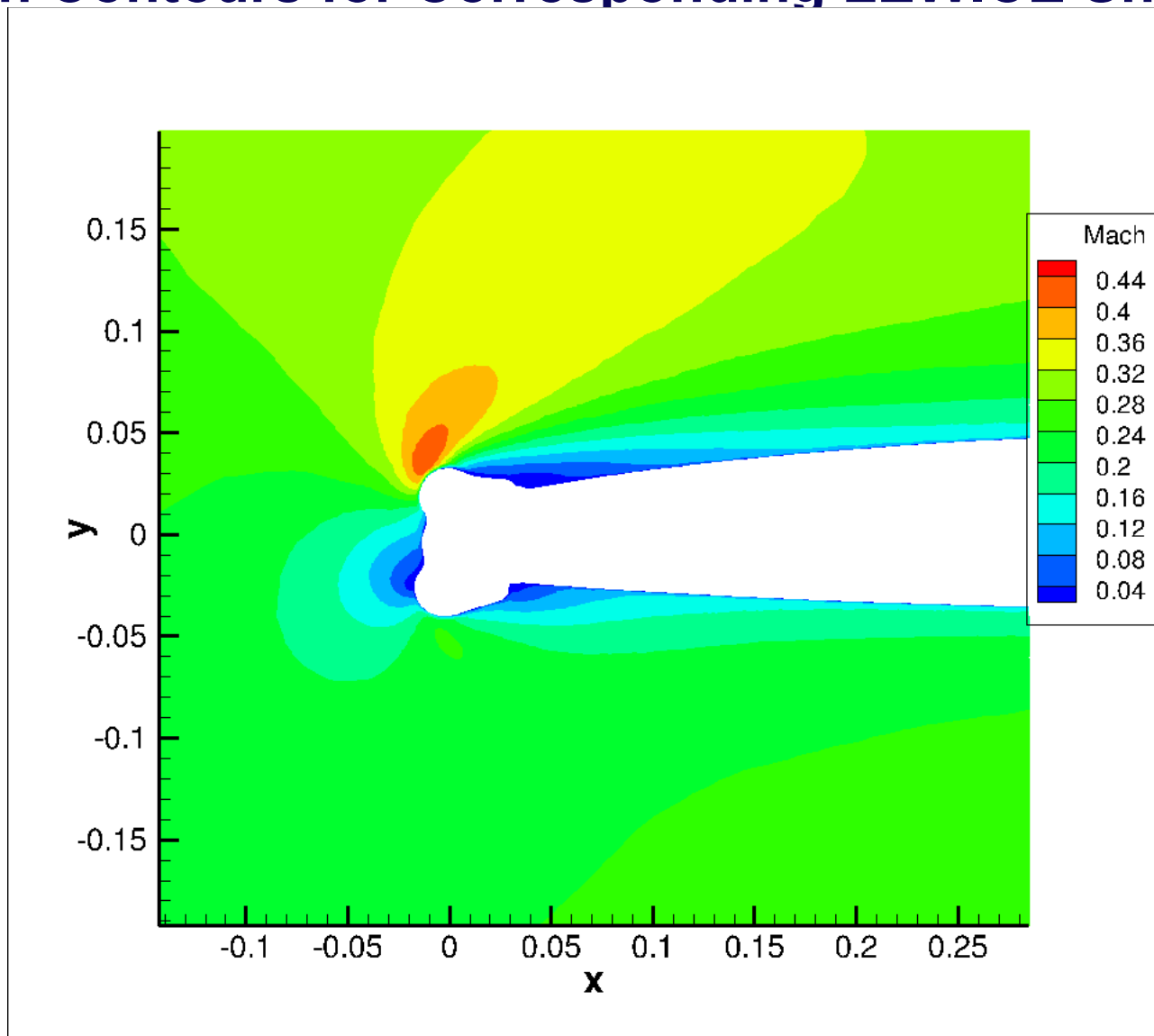
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# Mach Contours for Corresponding LEWICE Shape



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# Conclusions

- **LEWICE model updated to include additional grid options**
- **New python script allows user to run hundreds of cases with or without Naviér-Stokes**
- **Geometric comparison shows good agreement with Experiment**
- **This study suggests that geometrically similar shapes can produce different performance characteristics**
- **Lift and drag calculations of ice shapes show favorable agreement with experiment**

