

Validation Process for LEWICE by Use of a Naviér-Stokes Solver

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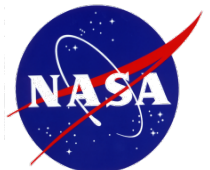
June 6, 2017

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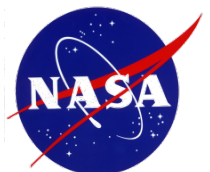
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at Lewis Field



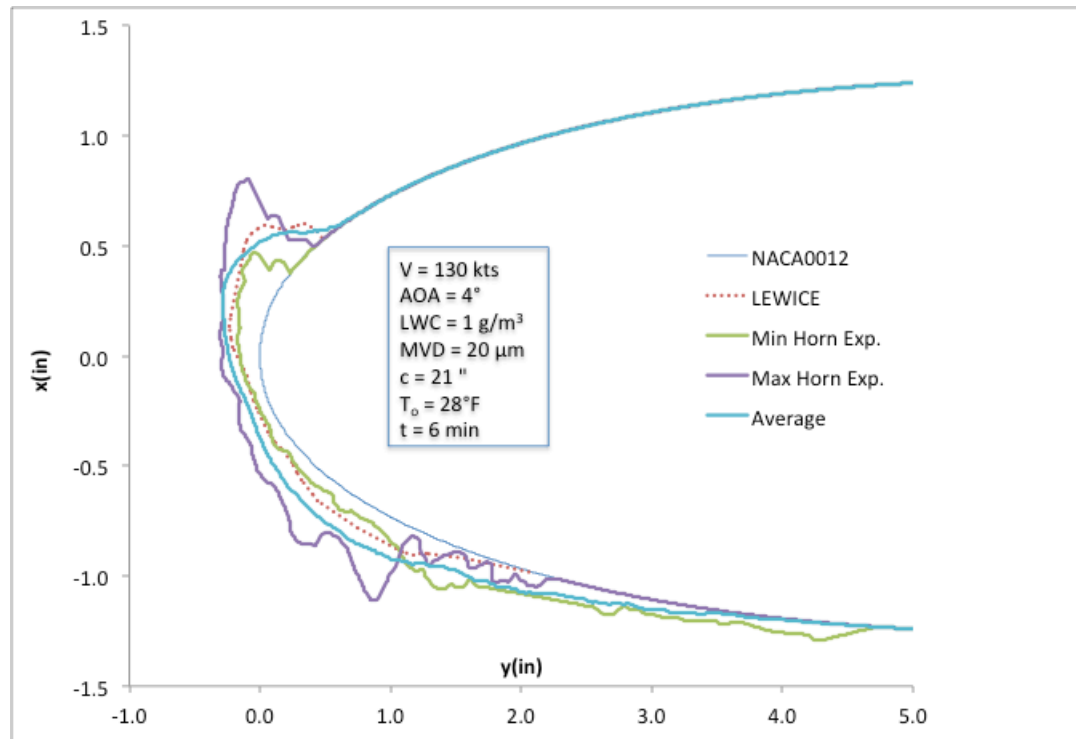
Outline

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



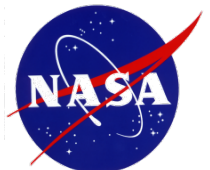
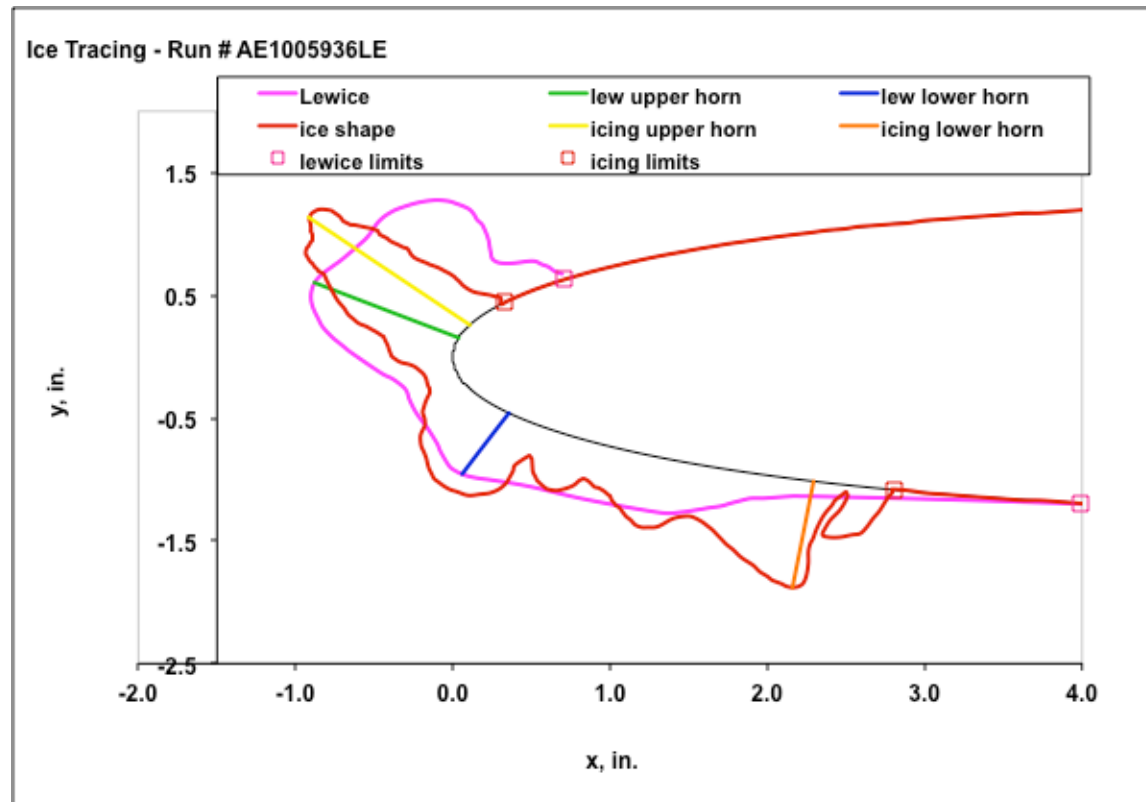
Validation History

- 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)



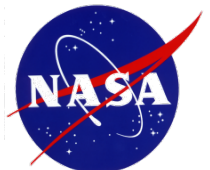
Revised Validation

- **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° to 8°)
- **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

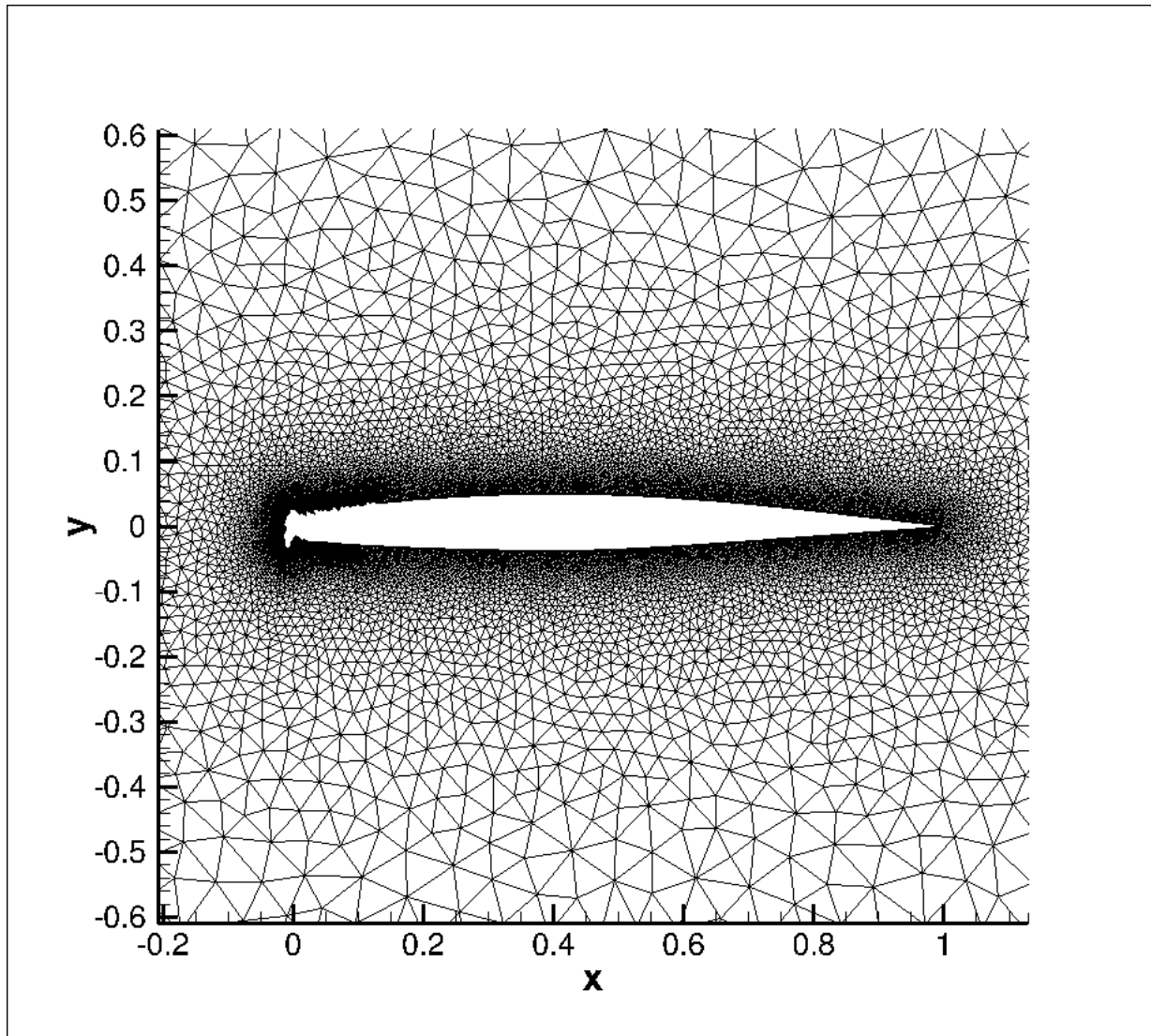


Conditions

Airfoil	Chord (m)	Air Speed (m/s)	AOA (deg)	Total Temp (° C)	LWC (g/m ³)	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
NACA23012	0.46	102.9	2	-2.2	0.75	15.4	300	0.31	3.68
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
BizJet	0.91	90.0	6	-0.8	0.54	20	1350	0.27	6.32
NLF0414	0.91	66.9	2	-3.1	0.54	20	1350	0.20	4.71
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

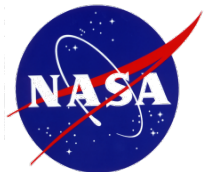


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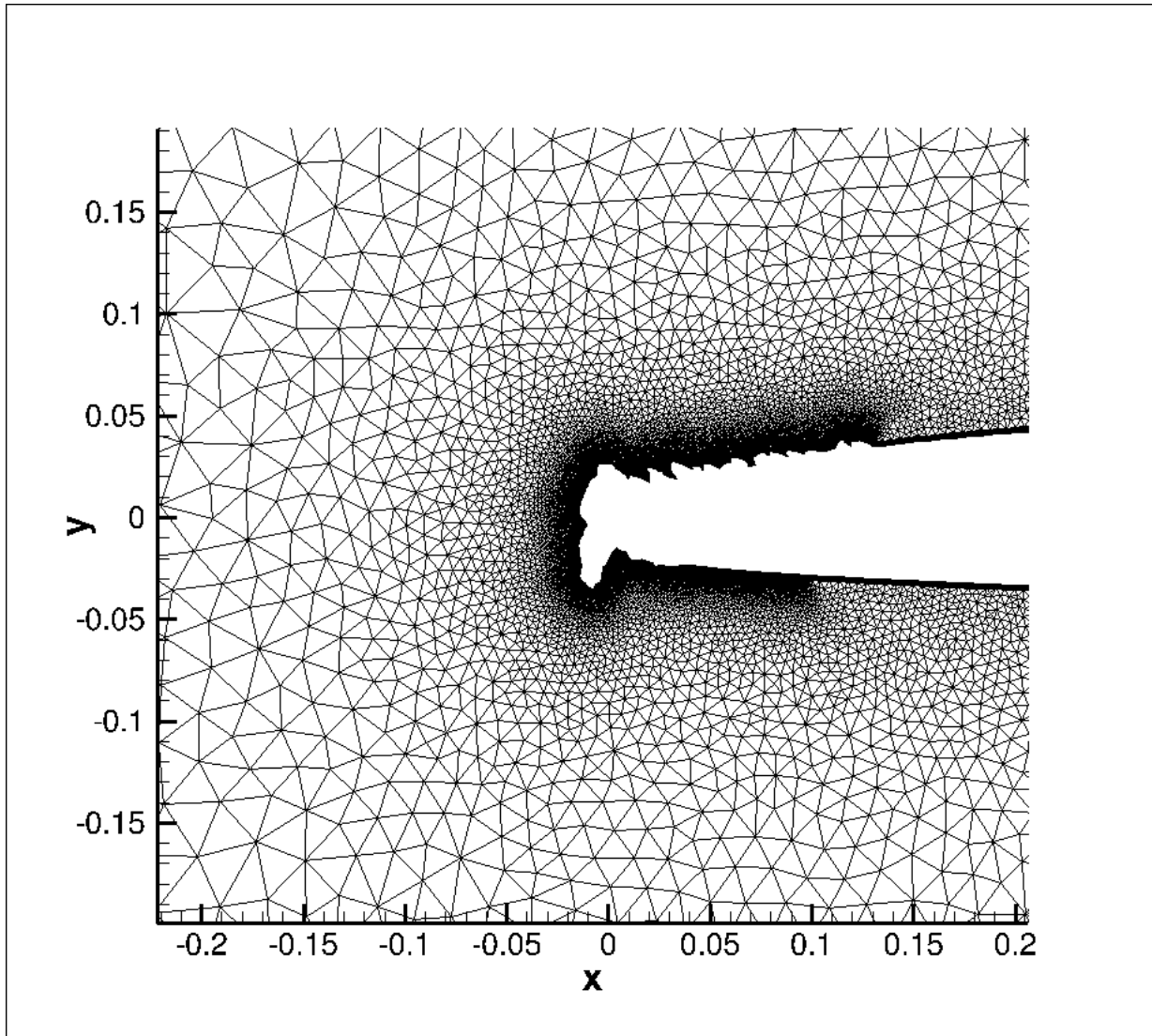
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Sample Grid

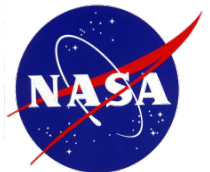


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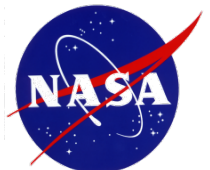
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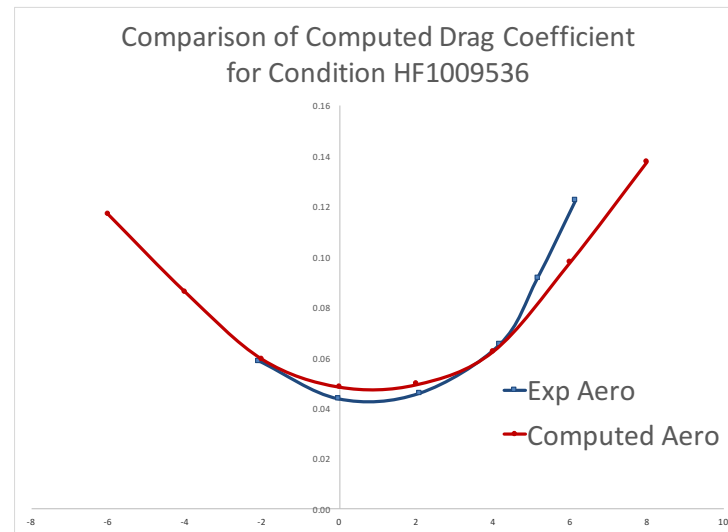
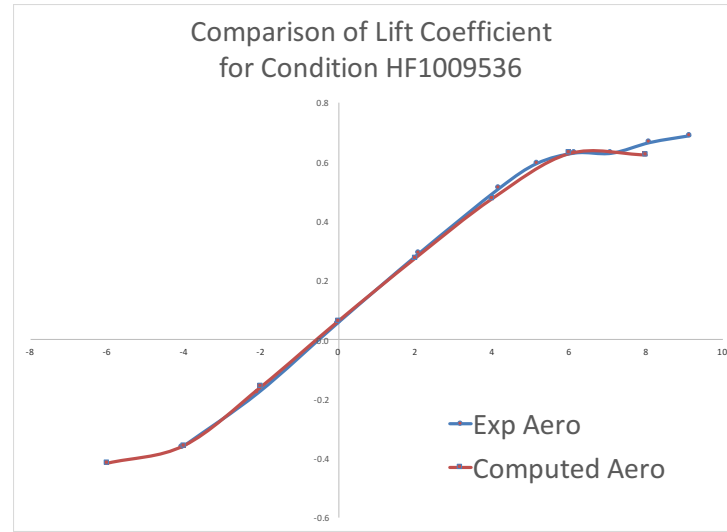
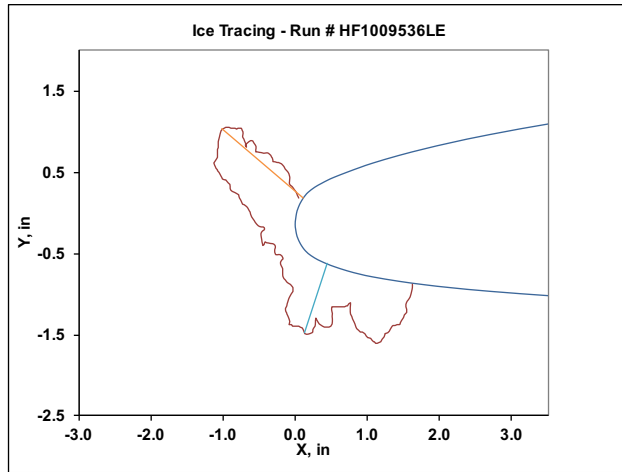


Validation Results

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



HF1009536 Aero Comparison

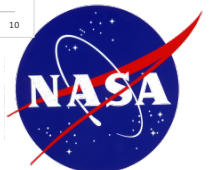


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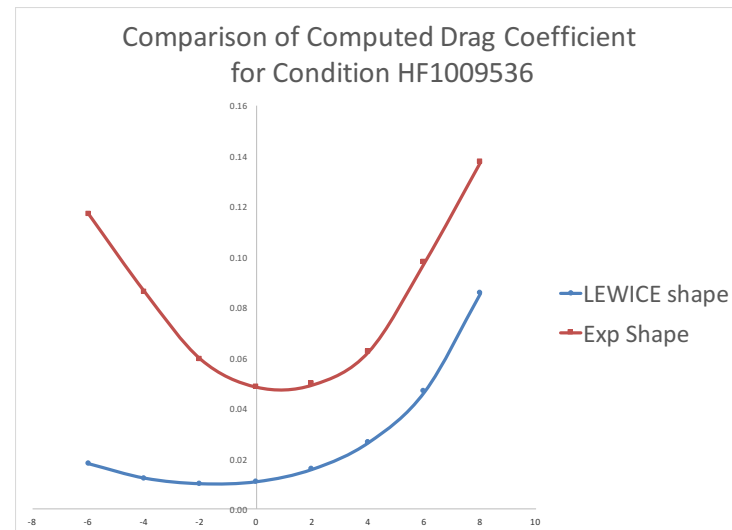
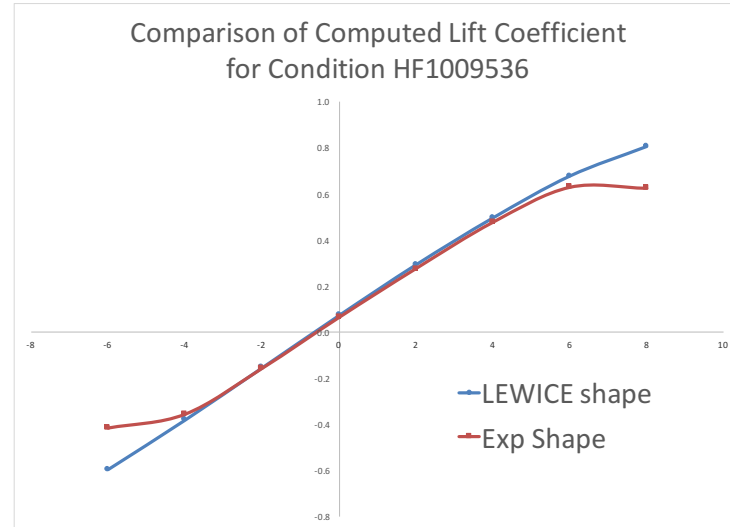
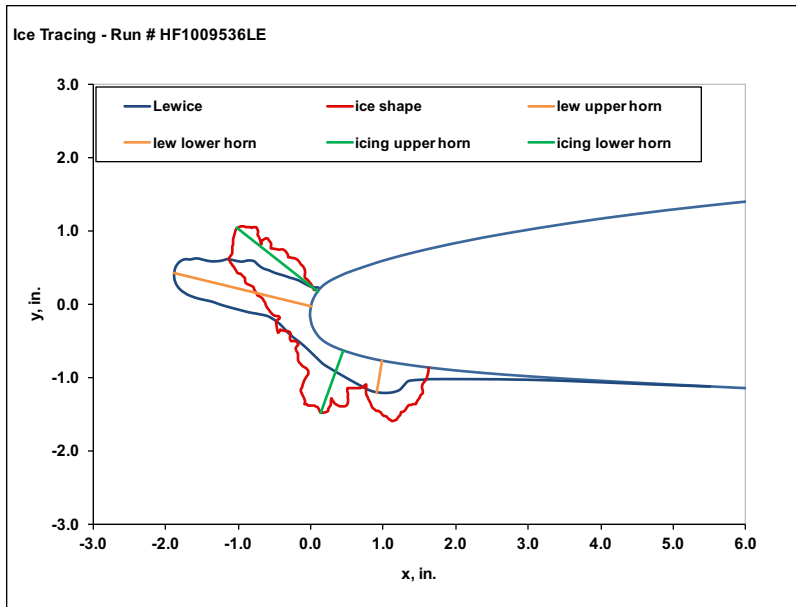
Icing Branch

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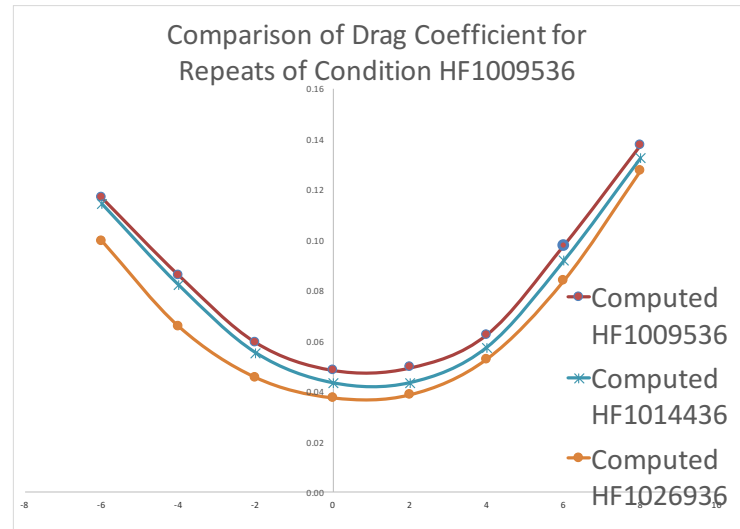
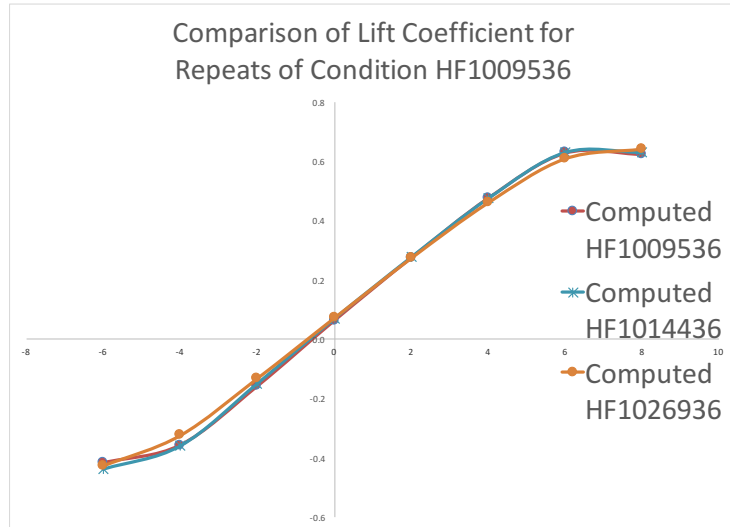
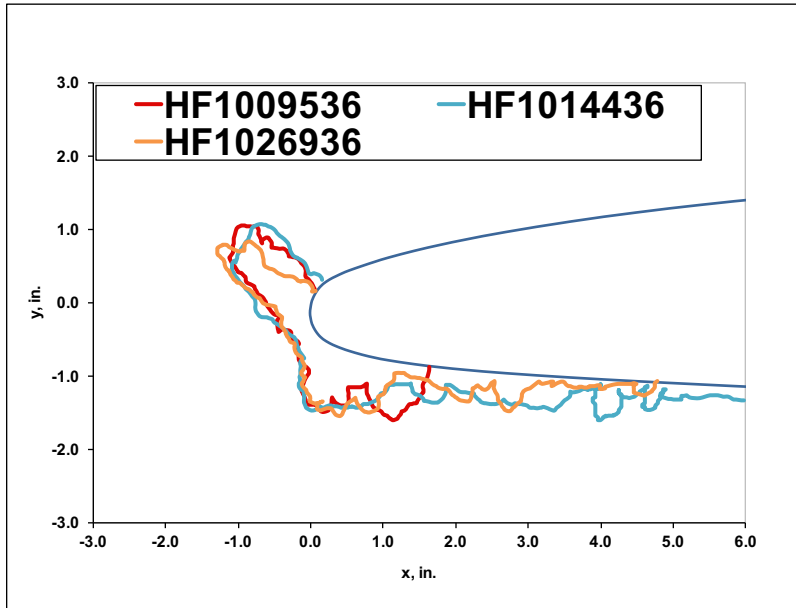
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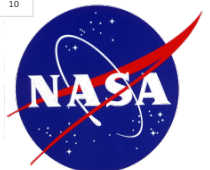
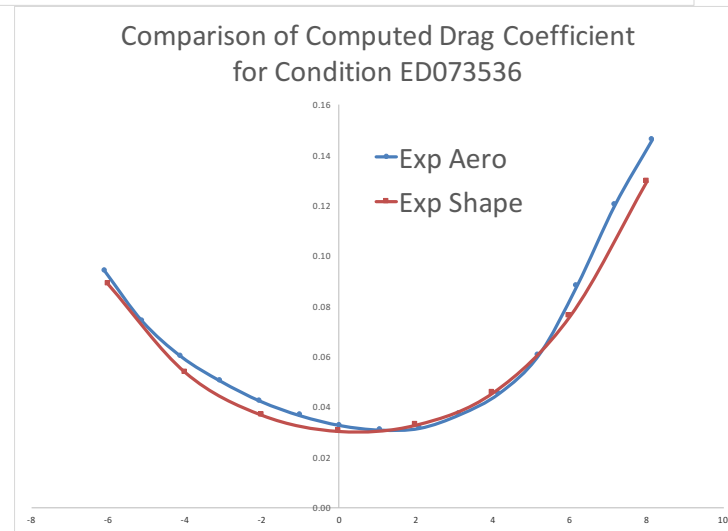
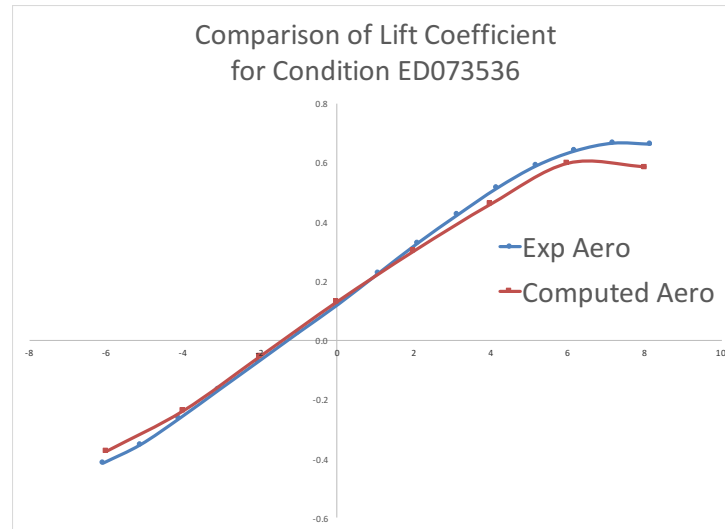
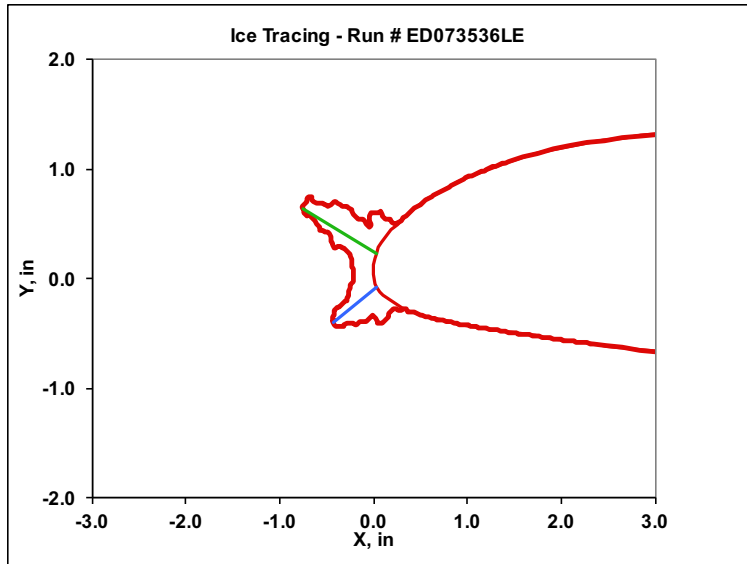
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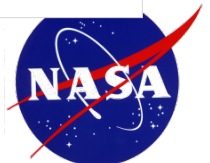
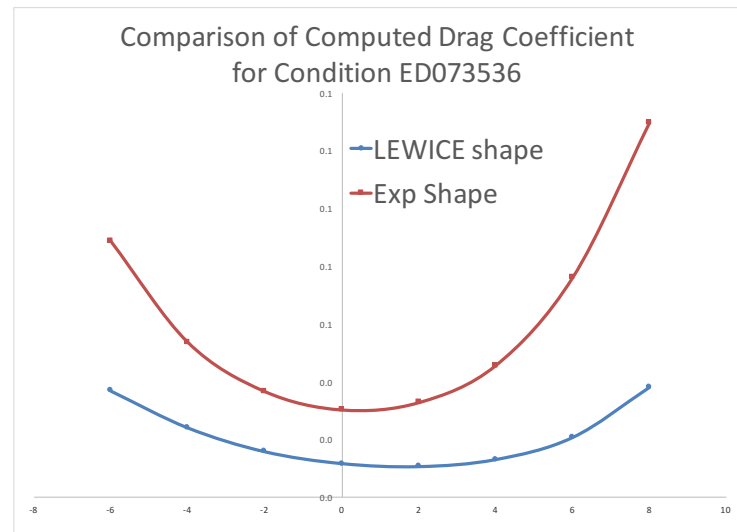
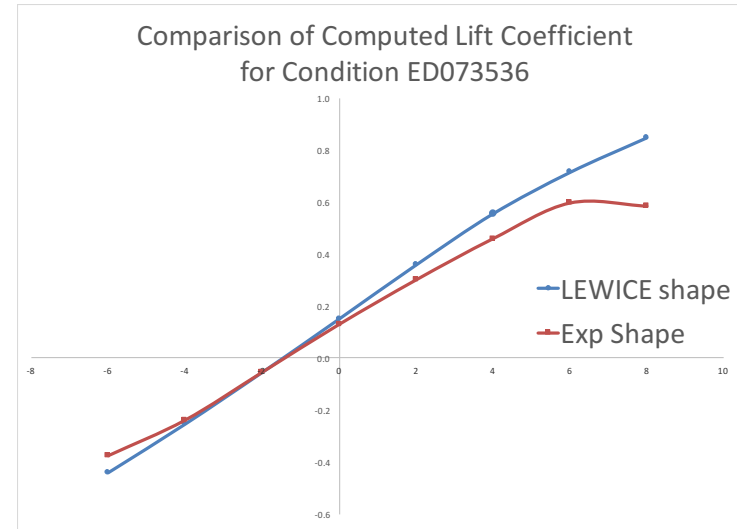
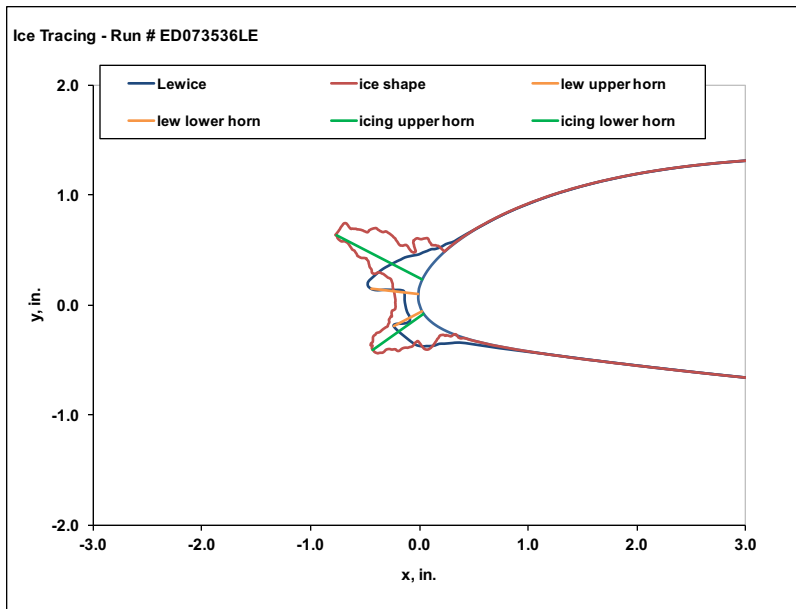
HF1009536 Repeatability



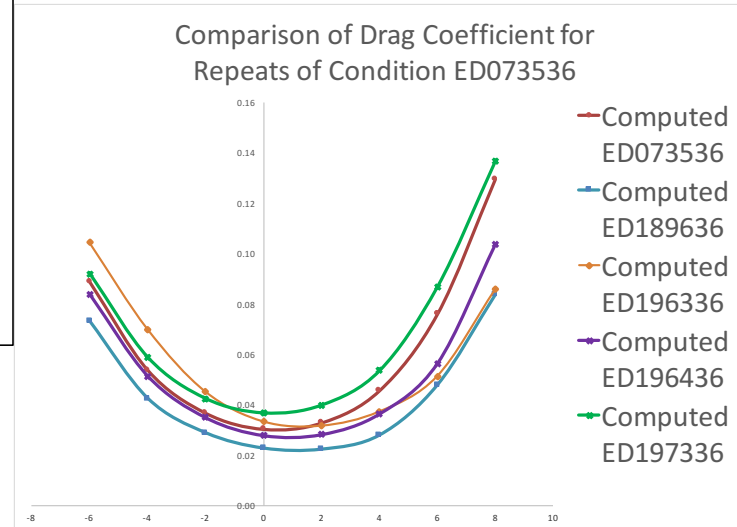
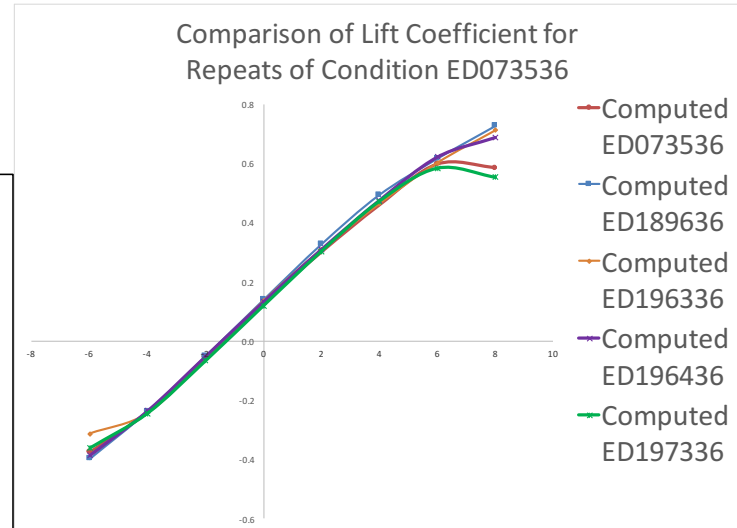
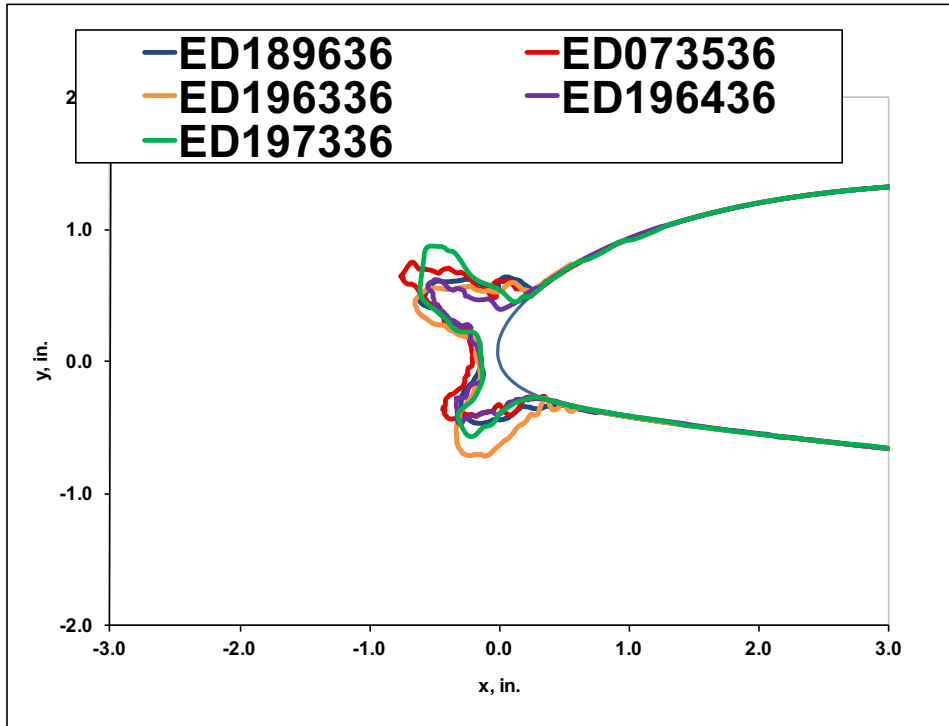
ED073536 Aero Comparison



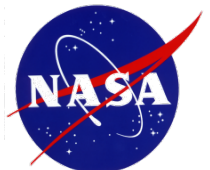
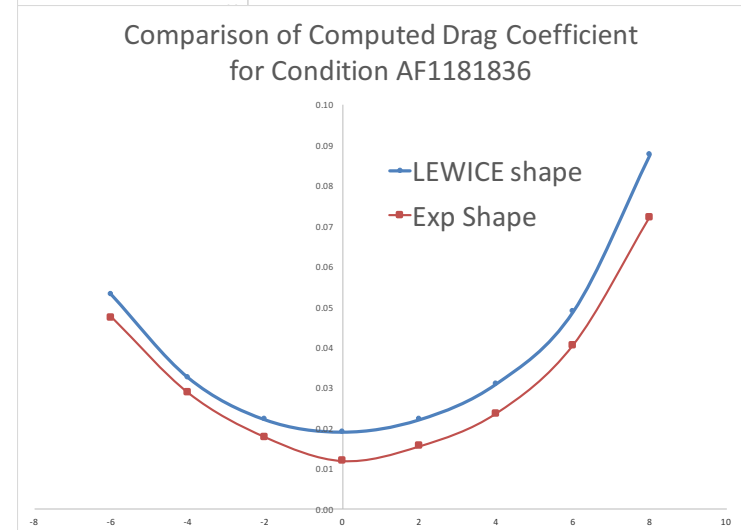
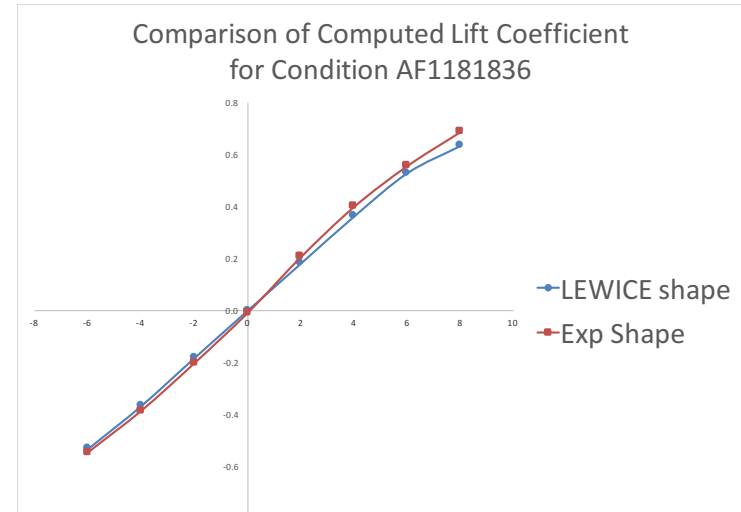
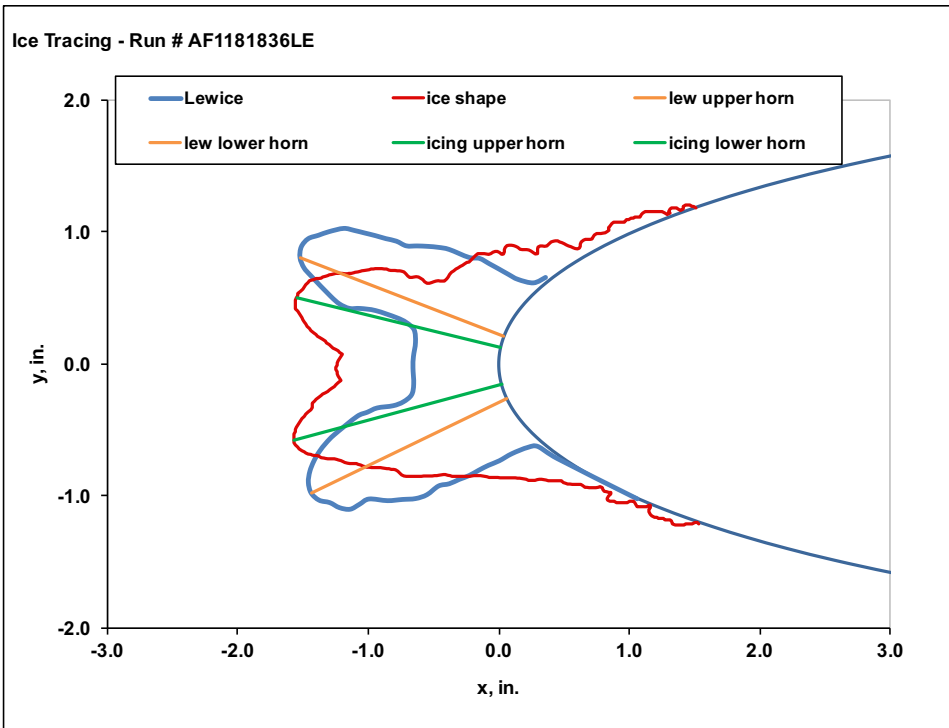
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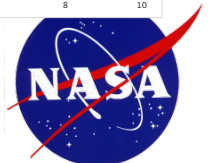
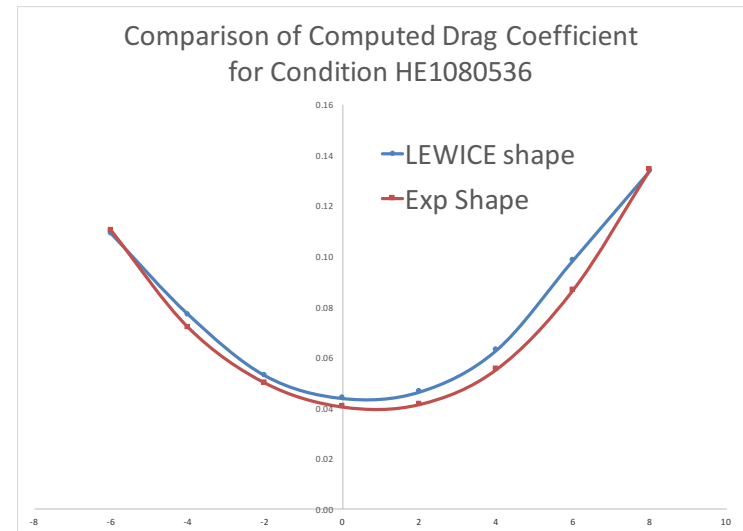
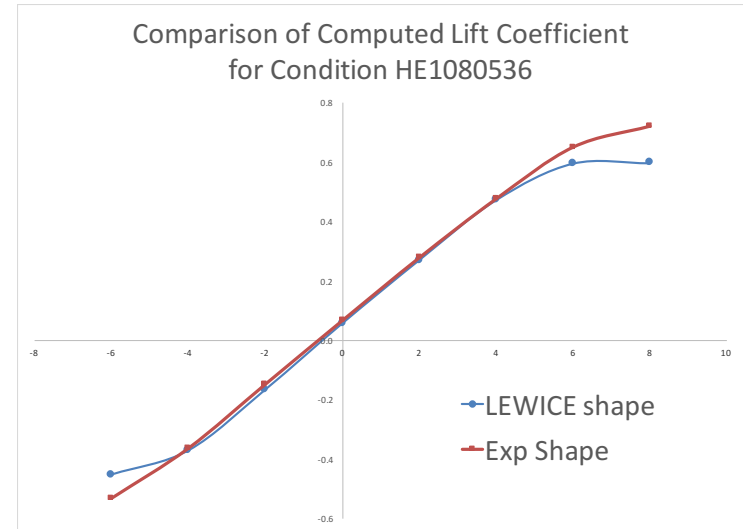
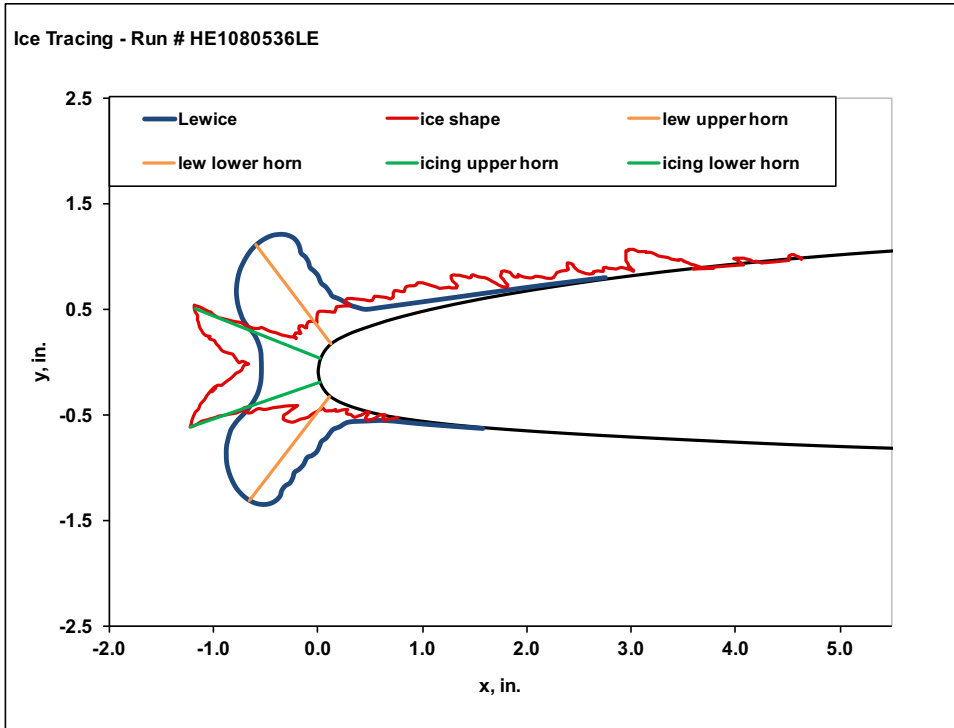
ED073536 Repeatability



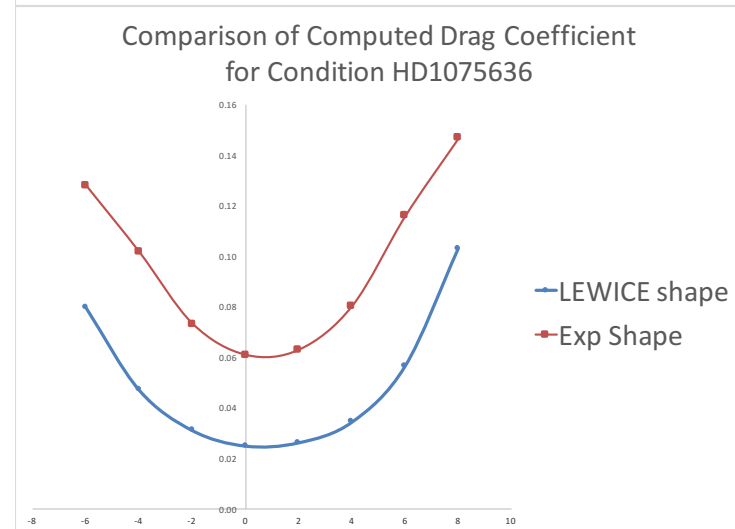
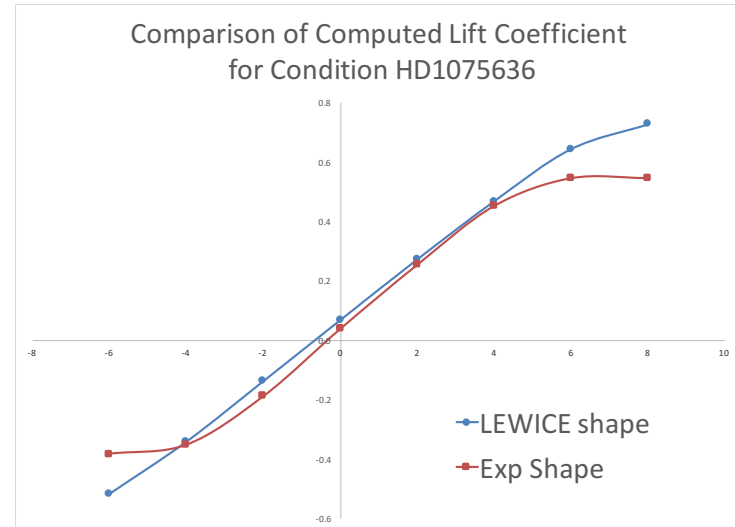
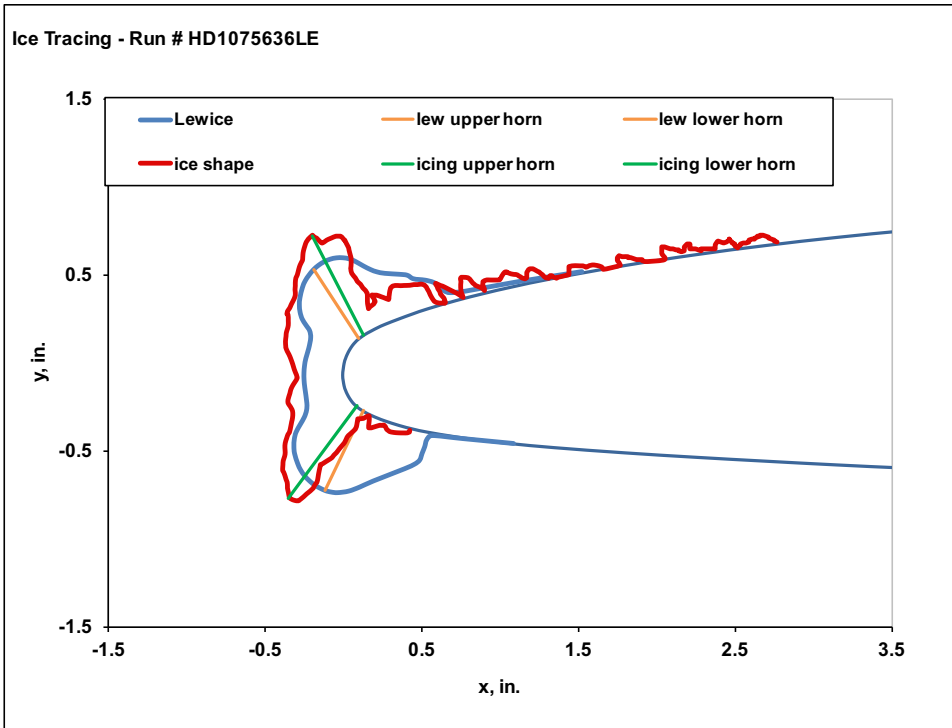
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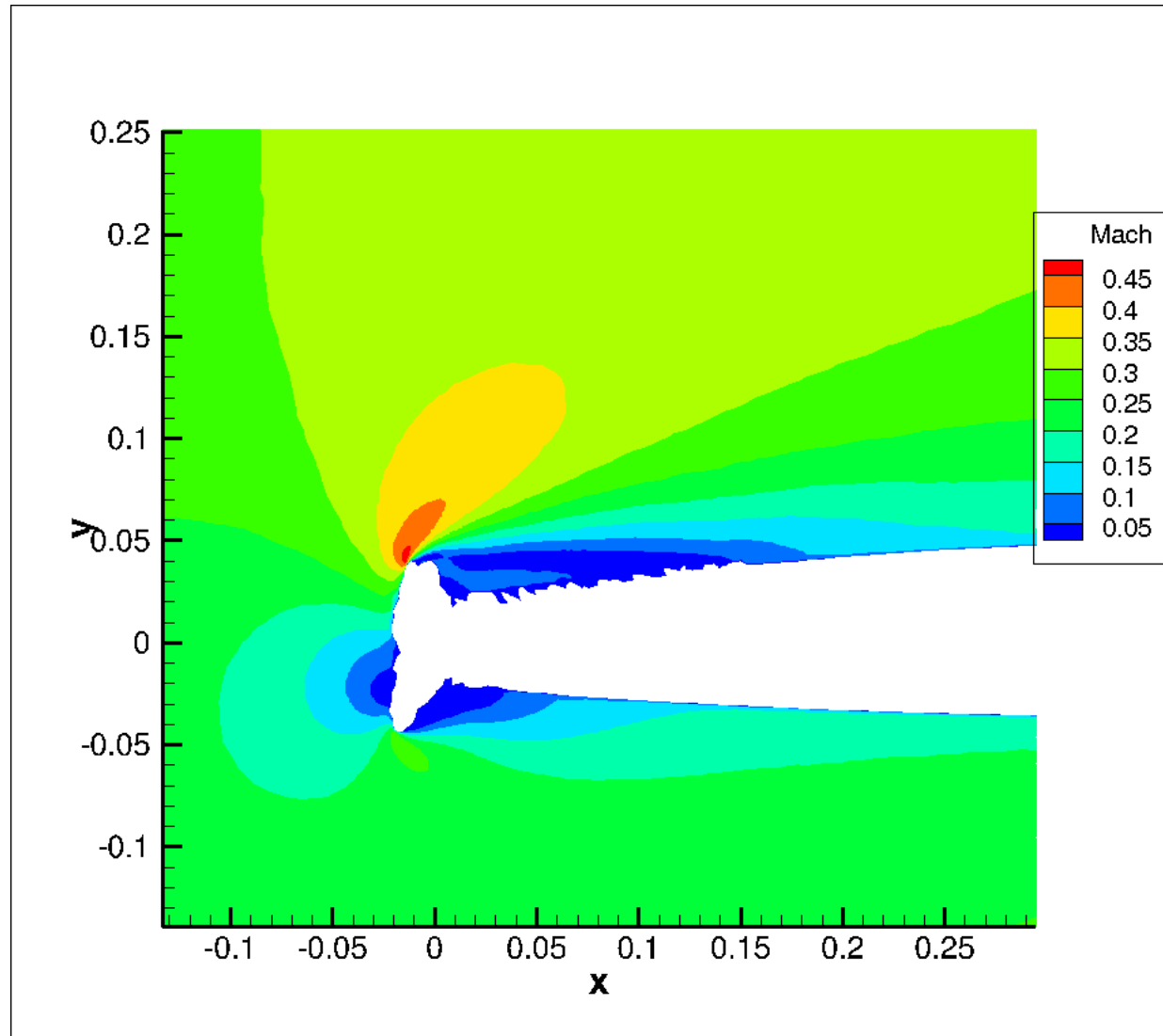
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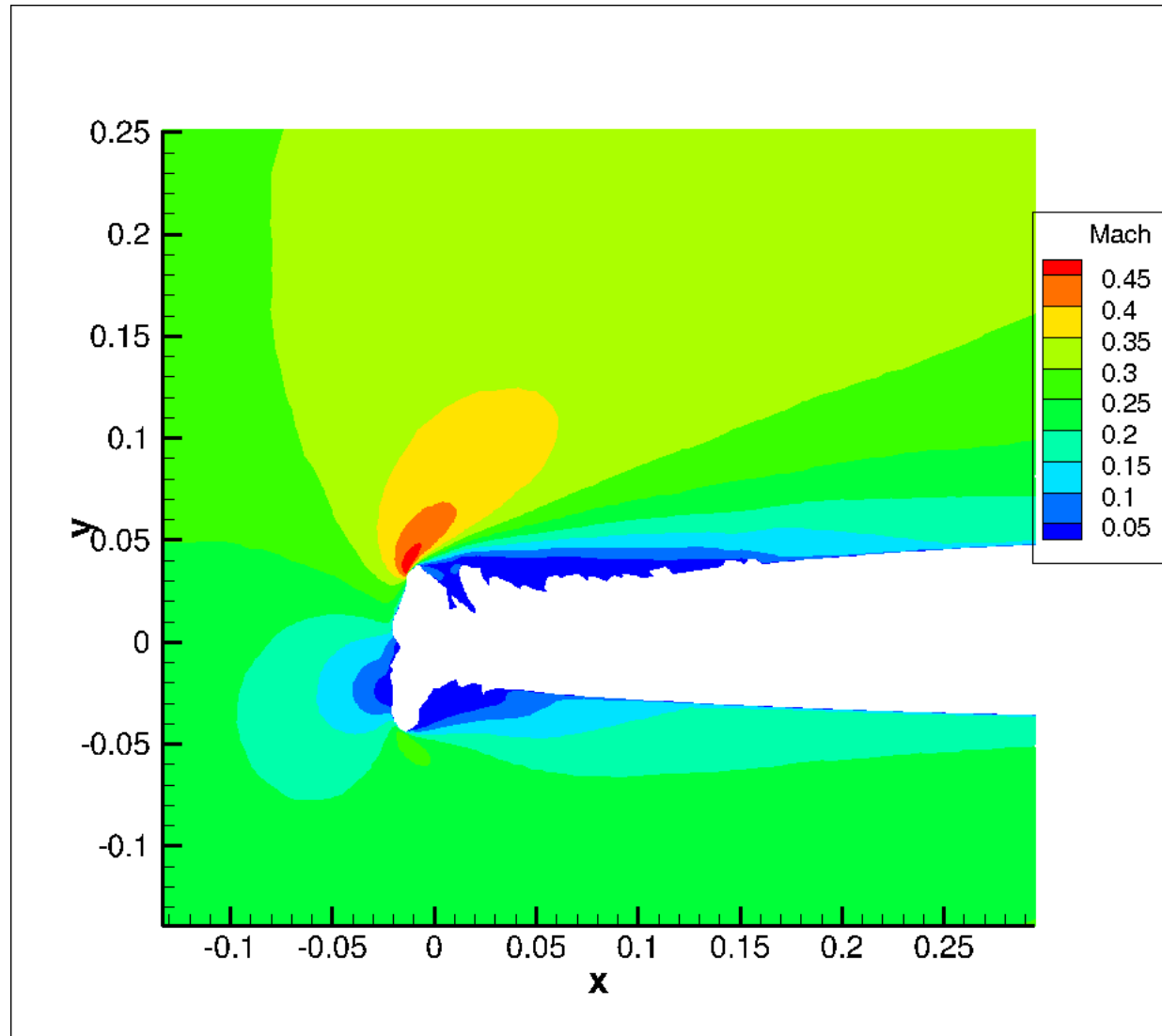
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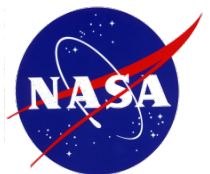
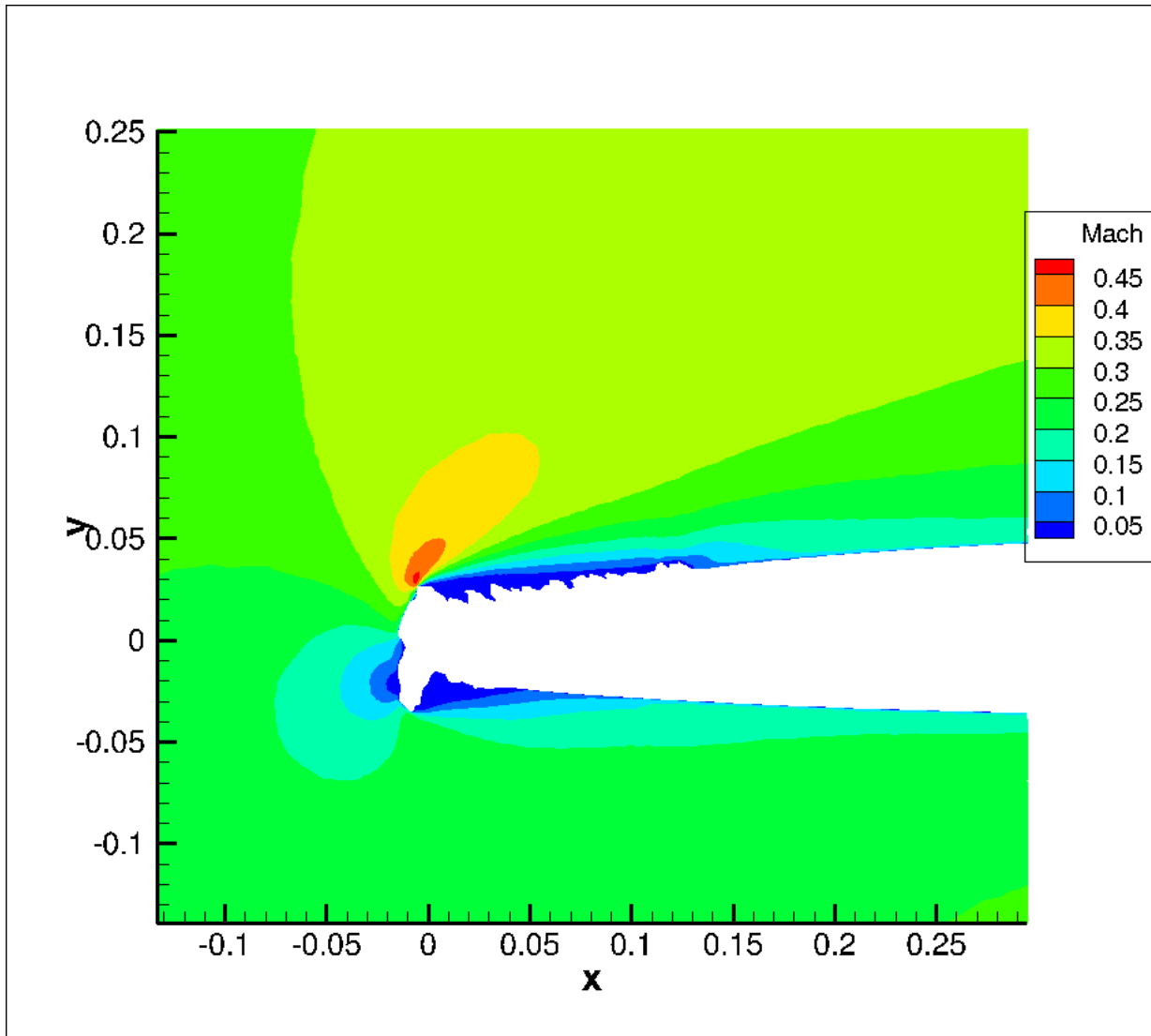
Mach Contours for HD1075636



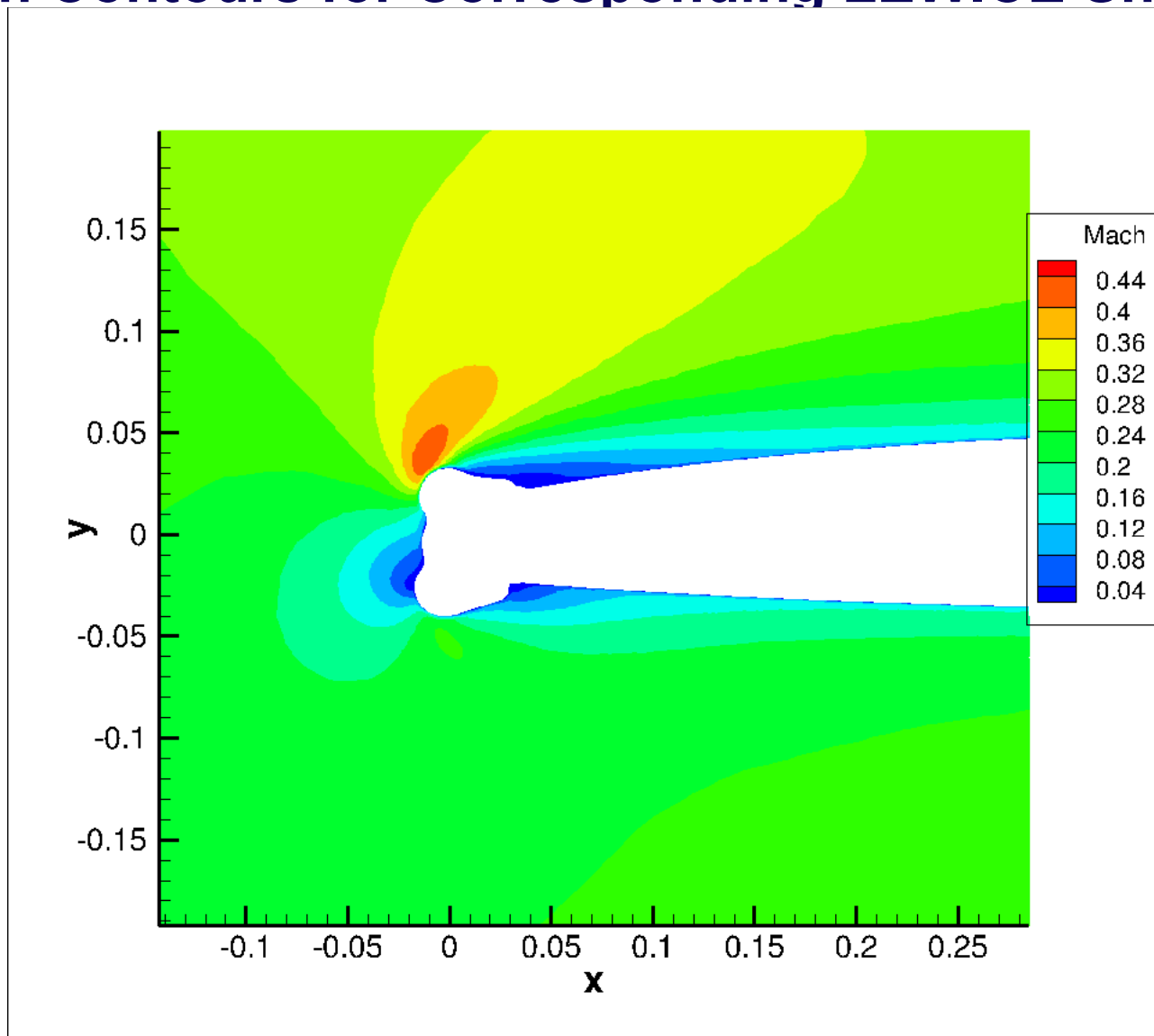
Mach Contours for HD1075736



Mach Contours for HD1075936



Mach Contours for Corresponding LEWICE Shape



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at Lewis Field



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**

