

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

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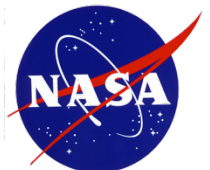
June 17, 2016

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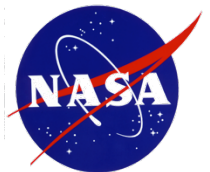
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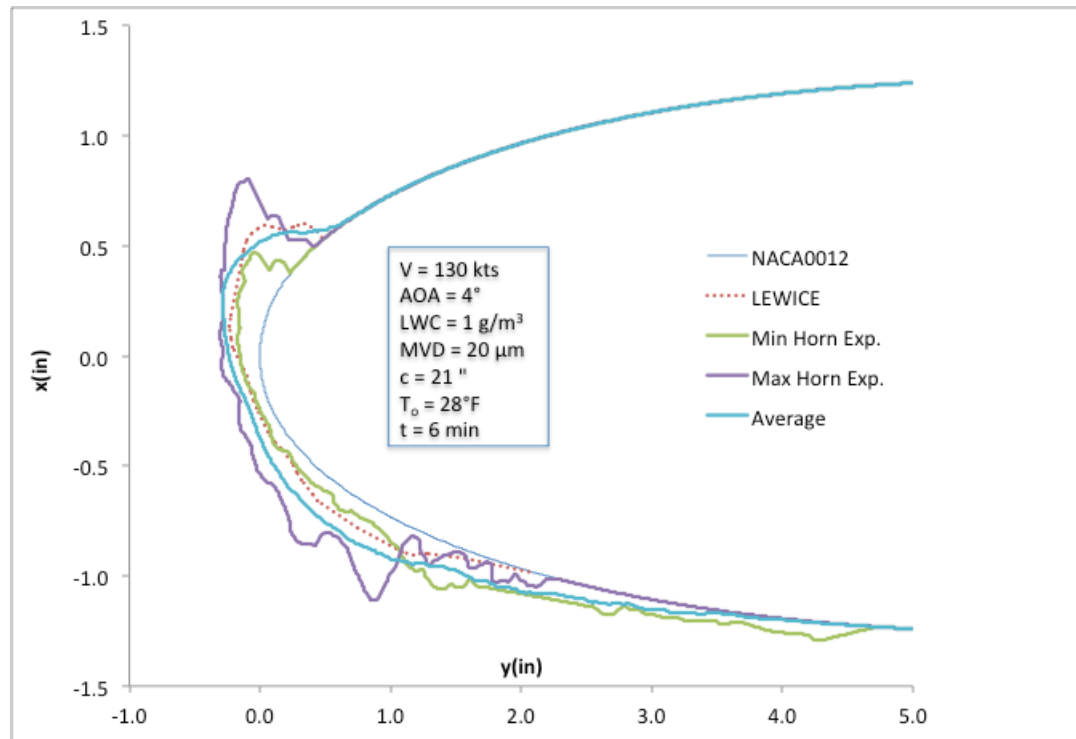
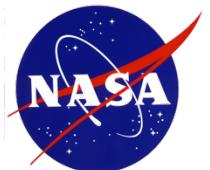
Outline

- **Validation History**
- **LEWICE-Pointwise-SU2 Script**
- **Validation Process**
- **Results**
- **Future Work**



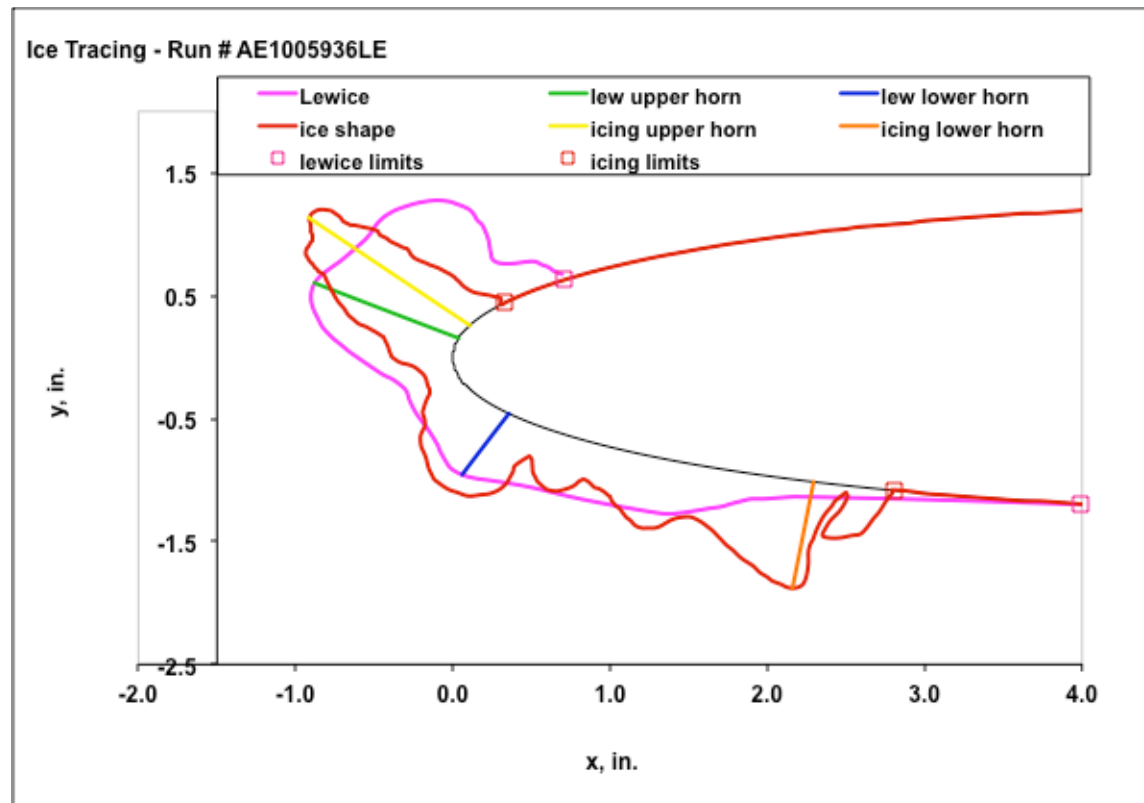
Validation History

- 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)

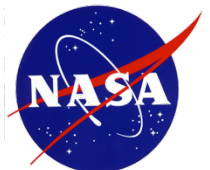


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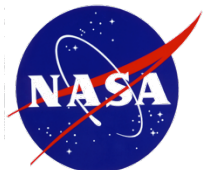
Revised Validation

- **Perform Geometric Comparisons as Before**
- **Perform Navier-Stokes Calculations on Shapes from Experiment and Shapes from LEWICE**
 - Compare Lift and Drag
 - Requires Reduced Data Set (Performing CFD calculations on thousands of ice shapes takes too long)
- **Reduced Validation Test Set Based on Large Glaze Shapes**
 - Accumulation Parameter based on Leading Edge Diameter > 3
 - Stagnation Freezing Fraction < 0.6
 - 108 Icing Conditions Meet These Criteria
 - 171 Total Shapes from Experiment
- **Flow Comparisons Performed at 6° AOA**
 - Insufficient Time for Other Flow Conditions

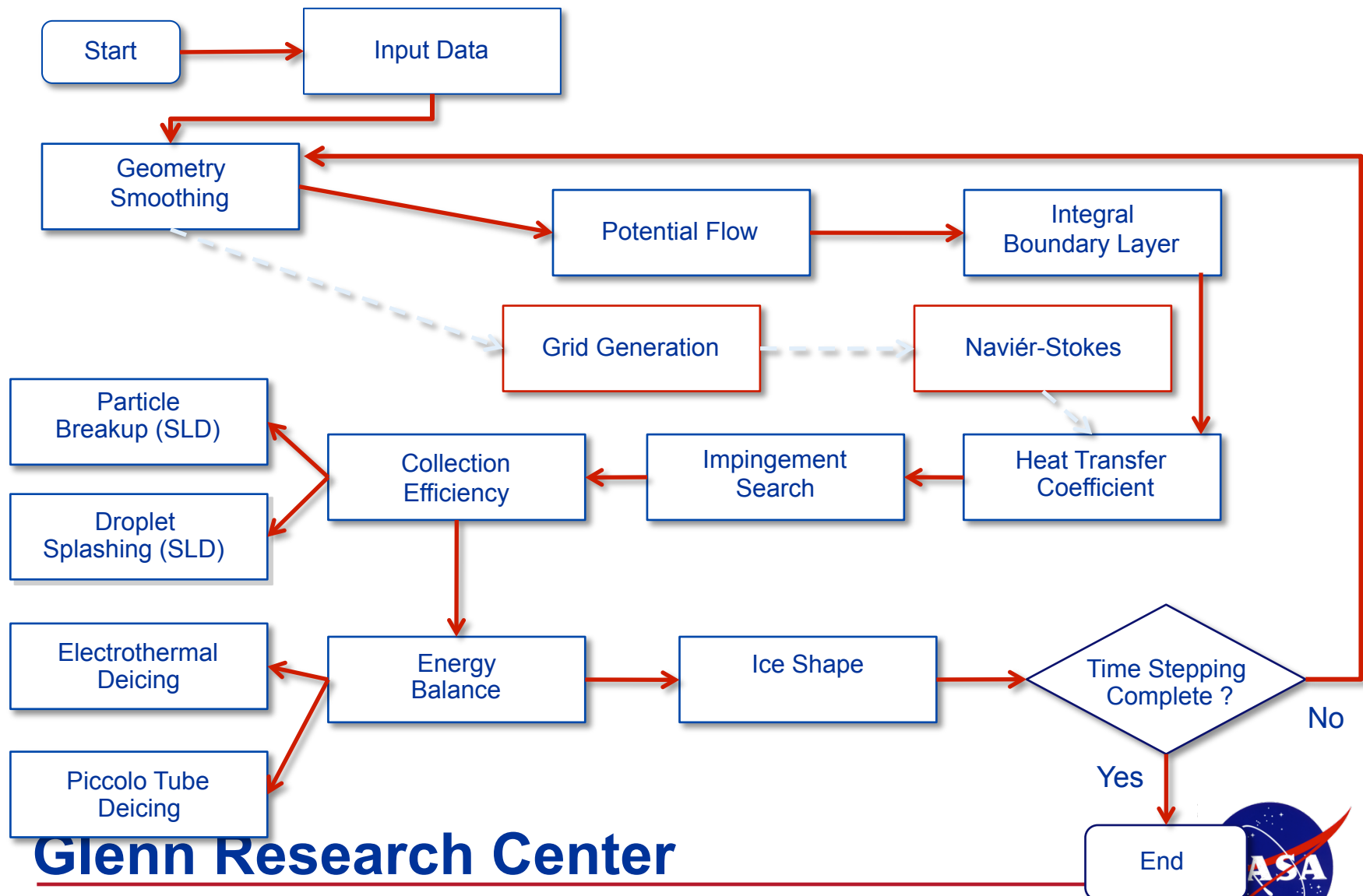


LEWICE

- **Expanded Grid Options**
 - Multi-block
 - Structured
 - Unstructured
 - Cartesian
 - Chimera (overlap)
- **Automated Python Script**
 - Performing Multiple Runs With or Without Grids
- **Multiphase (Ice Crystal) Icing**
 - Presented previously
 - Wright, W., Struk, P., Bartkus, T., and Addy, G., "Recent Advances in the LEWICE Icing Model," SAE Technical Paper 2015-01-2094, 2015, doi:10.4271/2015-01-2094.



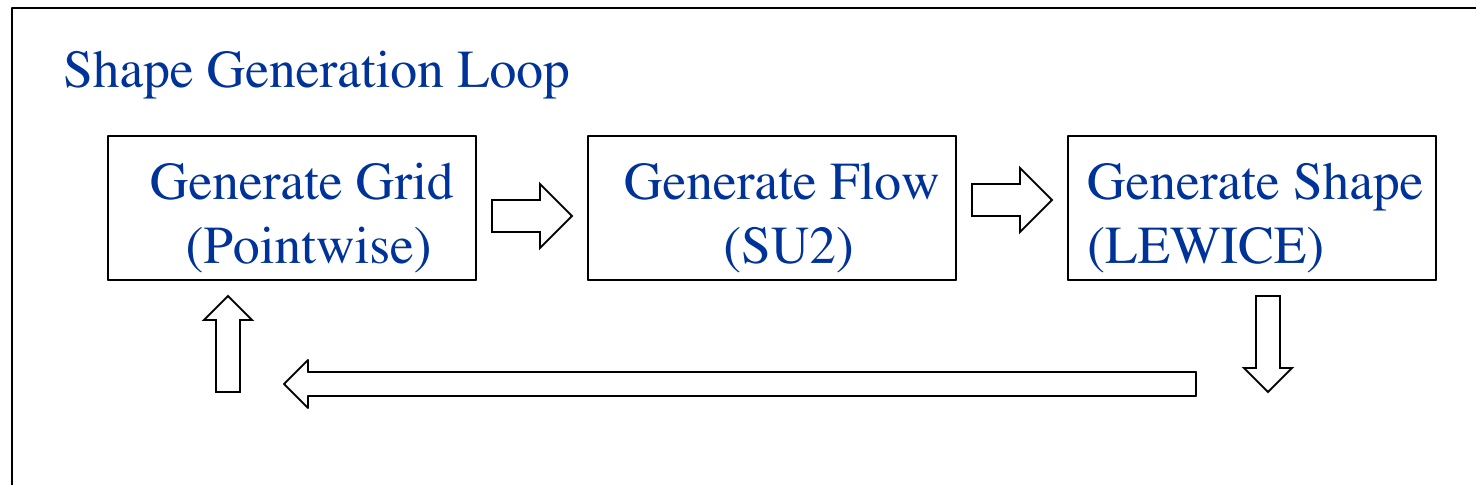
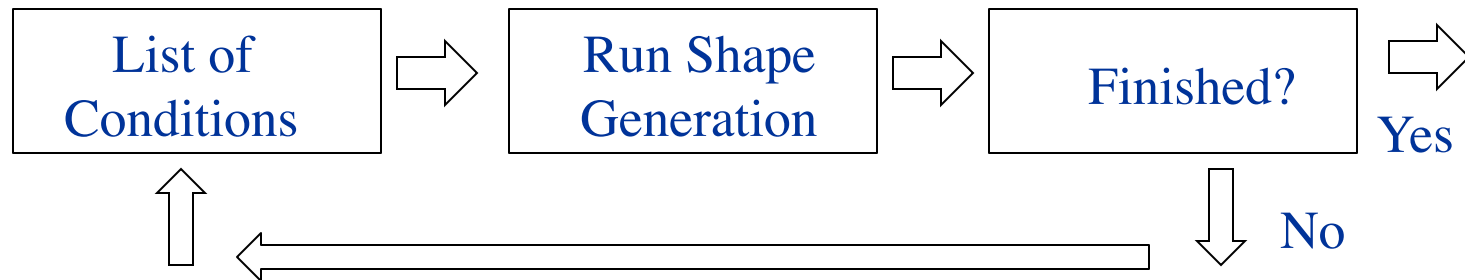
LEWICE Flow Diagram



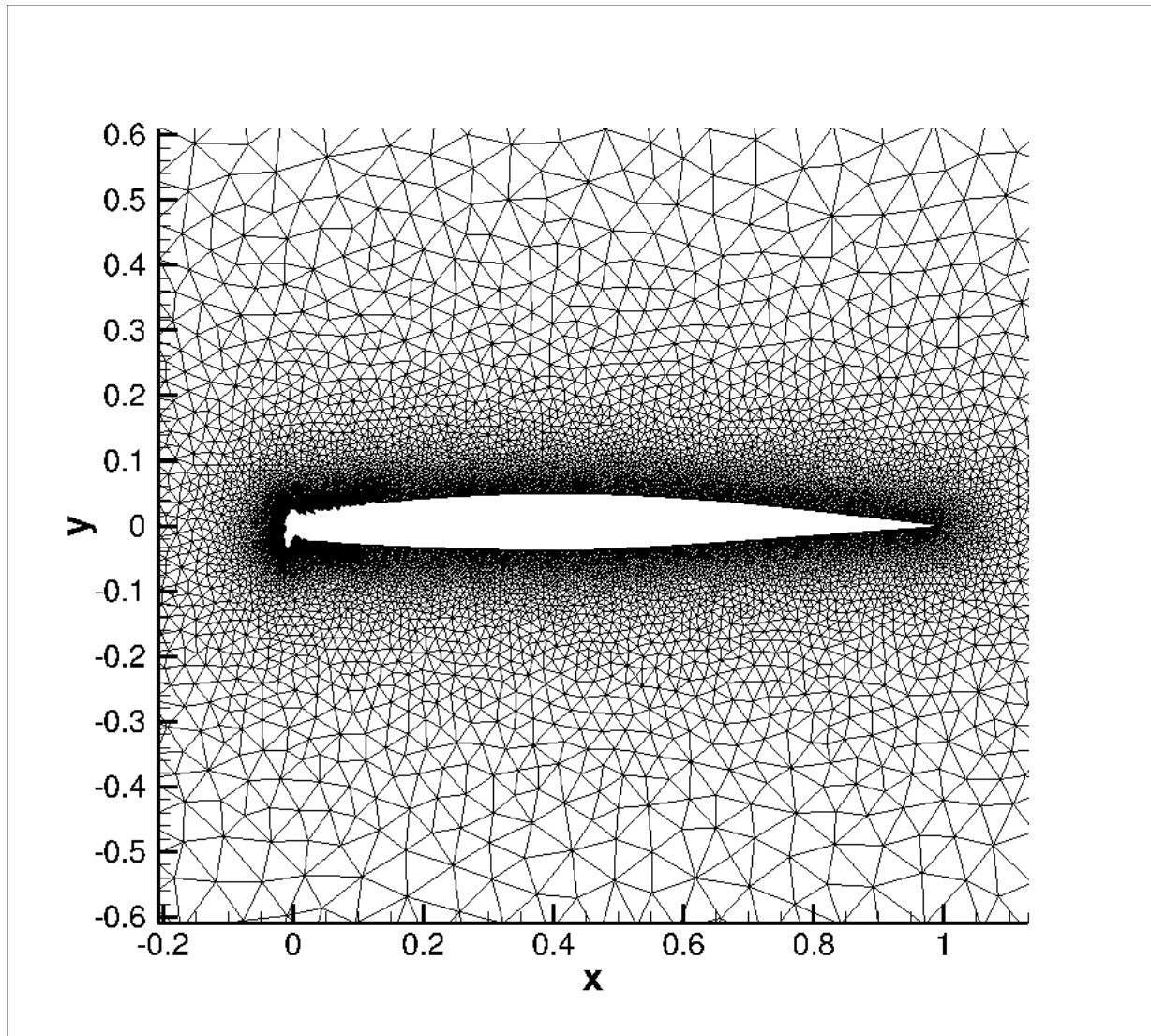
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Python Script Process



Sample Grid

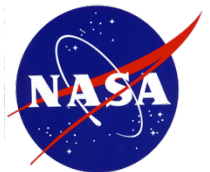


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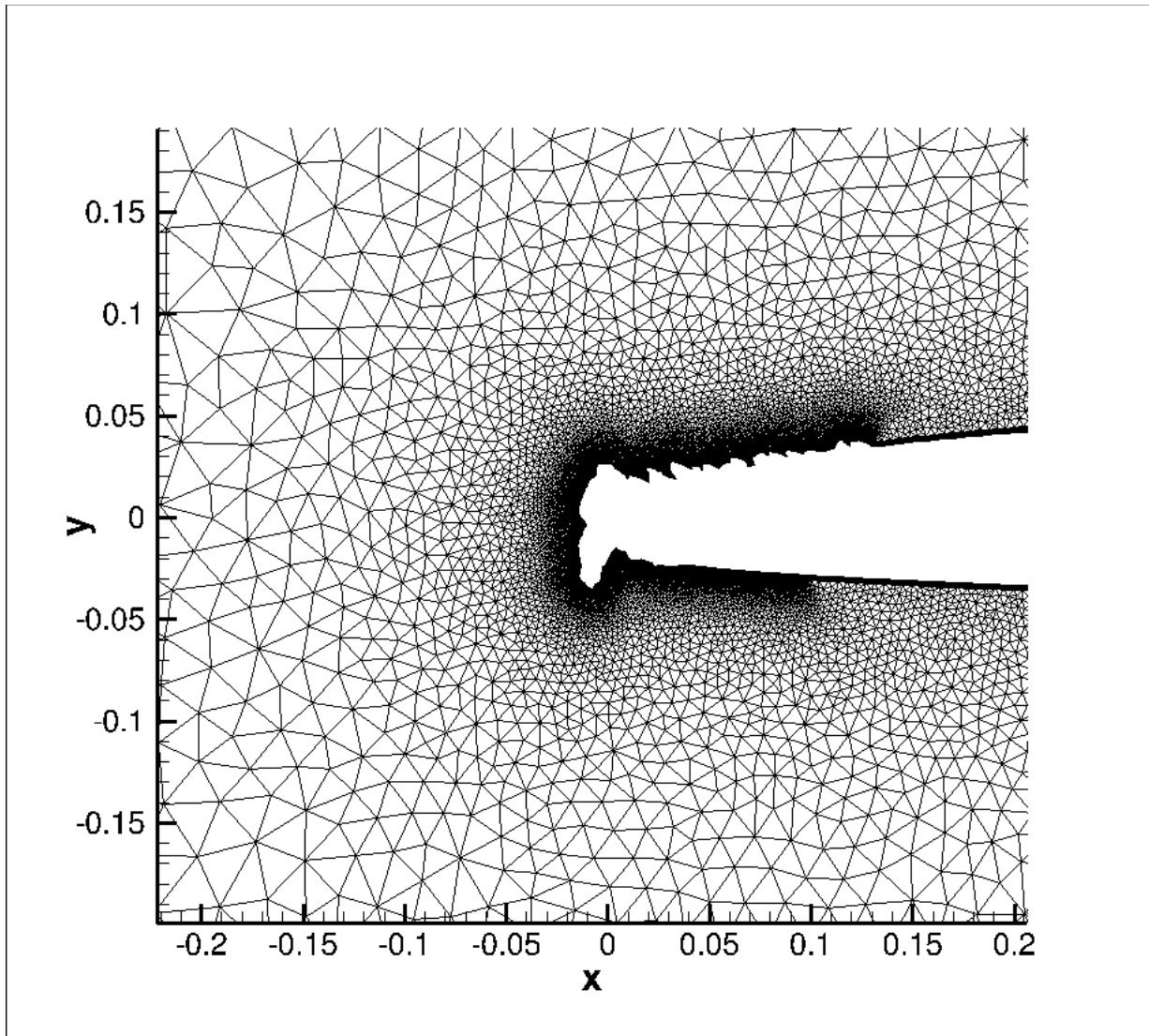
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Sample Grid

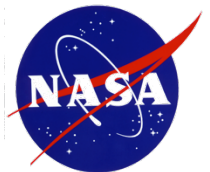


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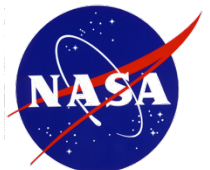
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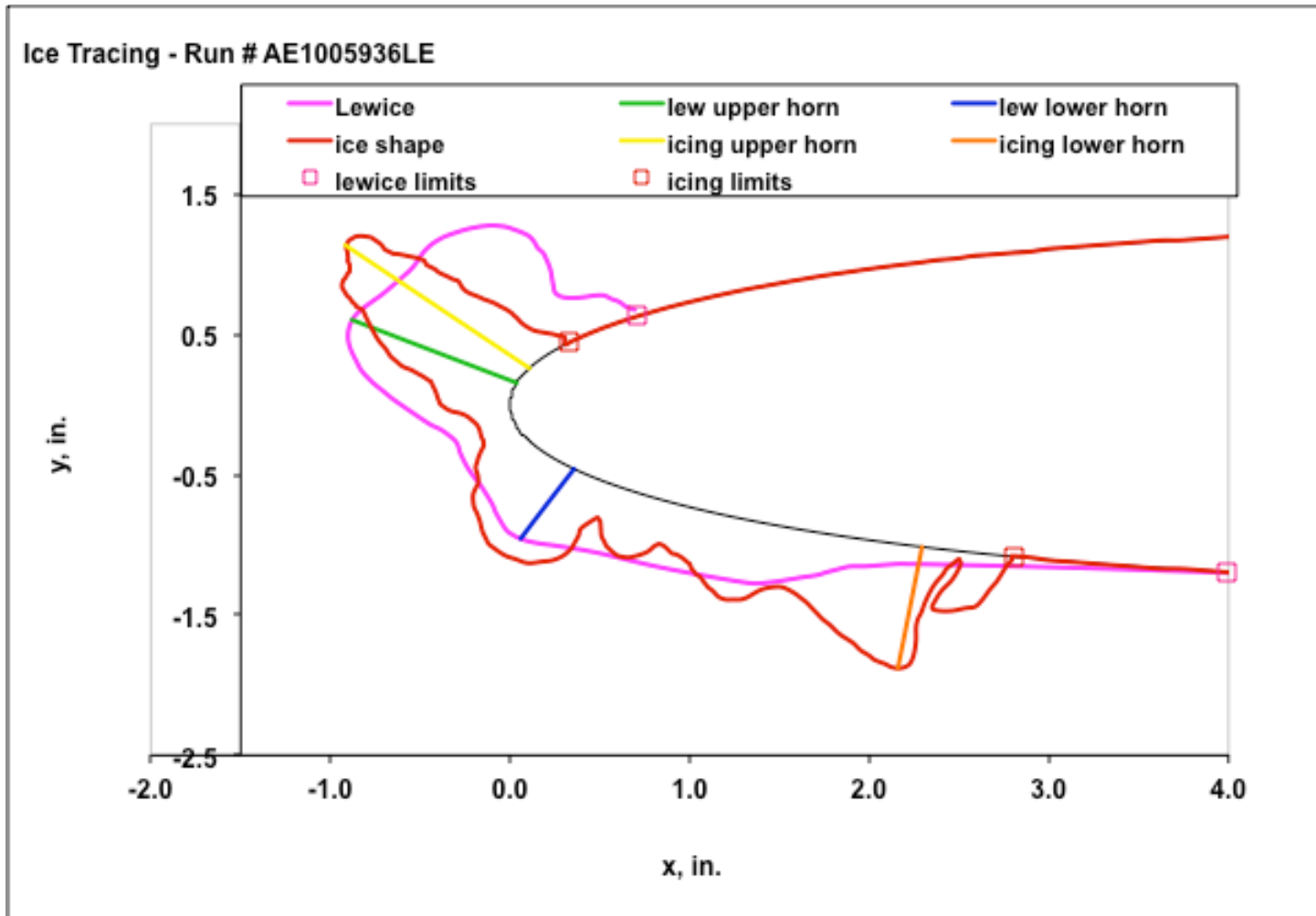


Validation Results

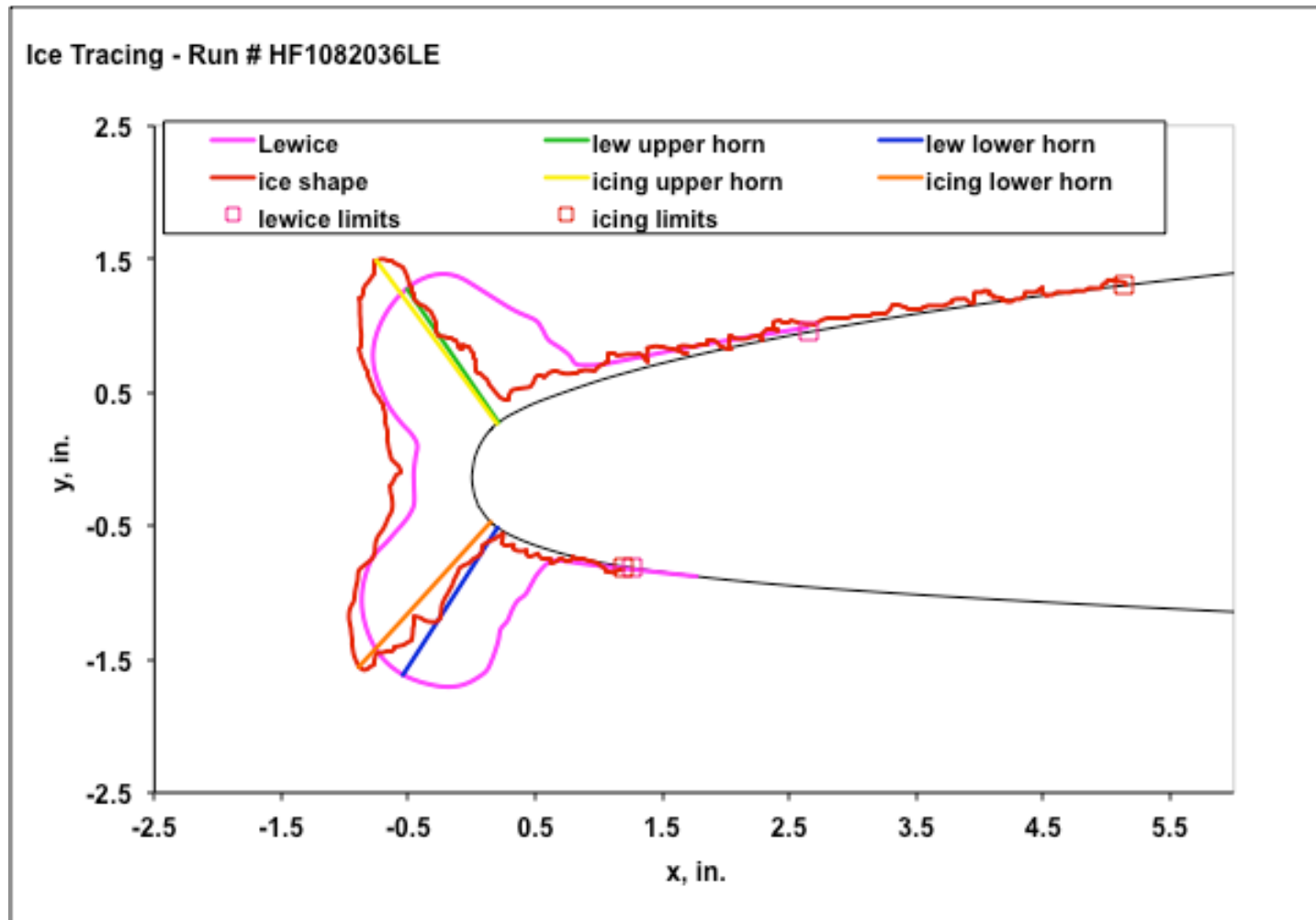
- **Due to Time Constraints, Shapes were Generated Using Potential Flow**
 - Final Shape Was Run with Navier-Stokes
- **Geometric Differences between LEWICE and Experiment Less Than Experimental Variability of Full Database**
- **Geometric Differences of Experimental Shapes Chosen Relatively Small**
- **Only 96 of 171 Experimental Shapes had Converged Flow Solutions**
 - 52 of 107 LEWICE shapes have converged flow solutions



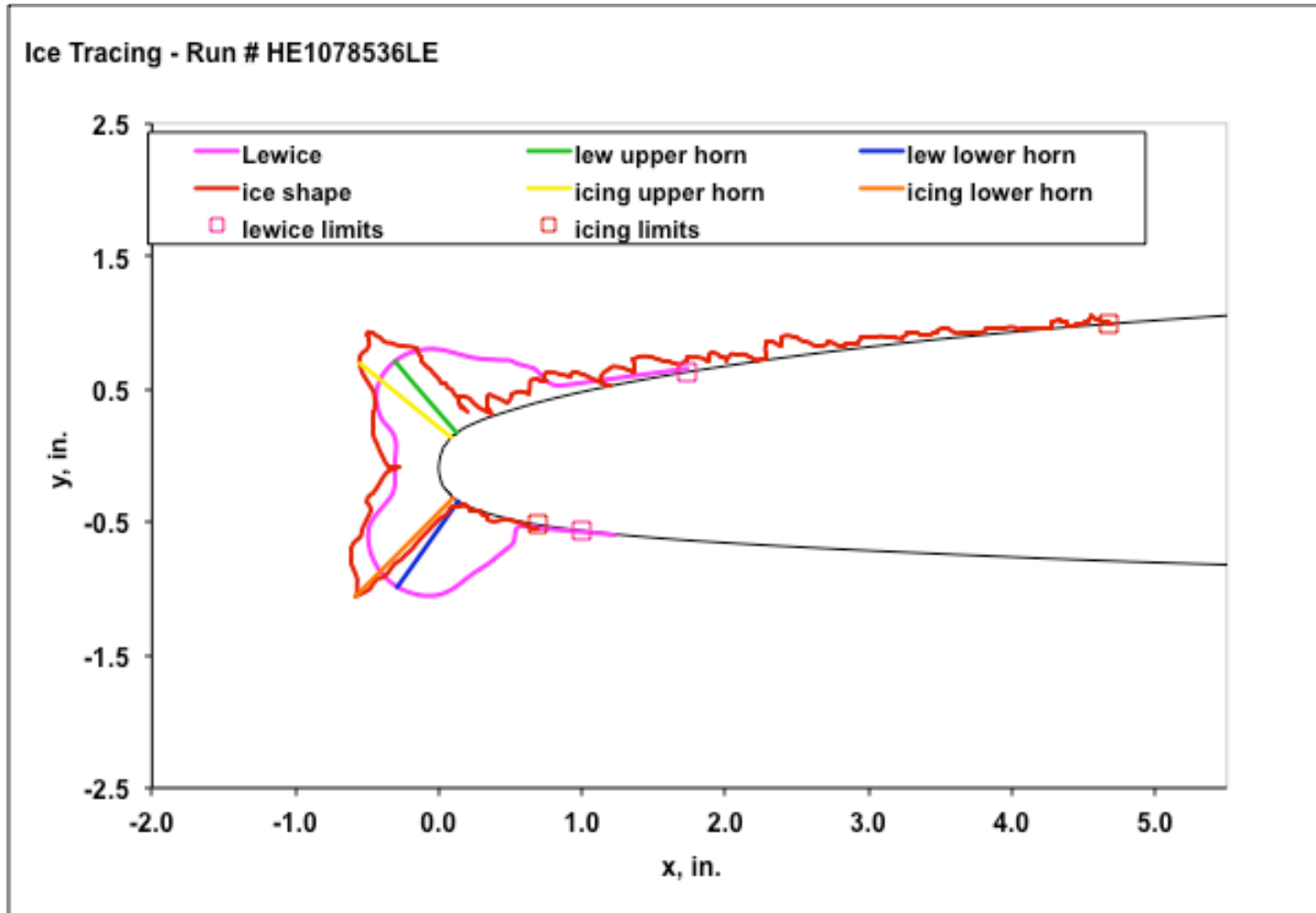
Average Difference in Icing Limit Case



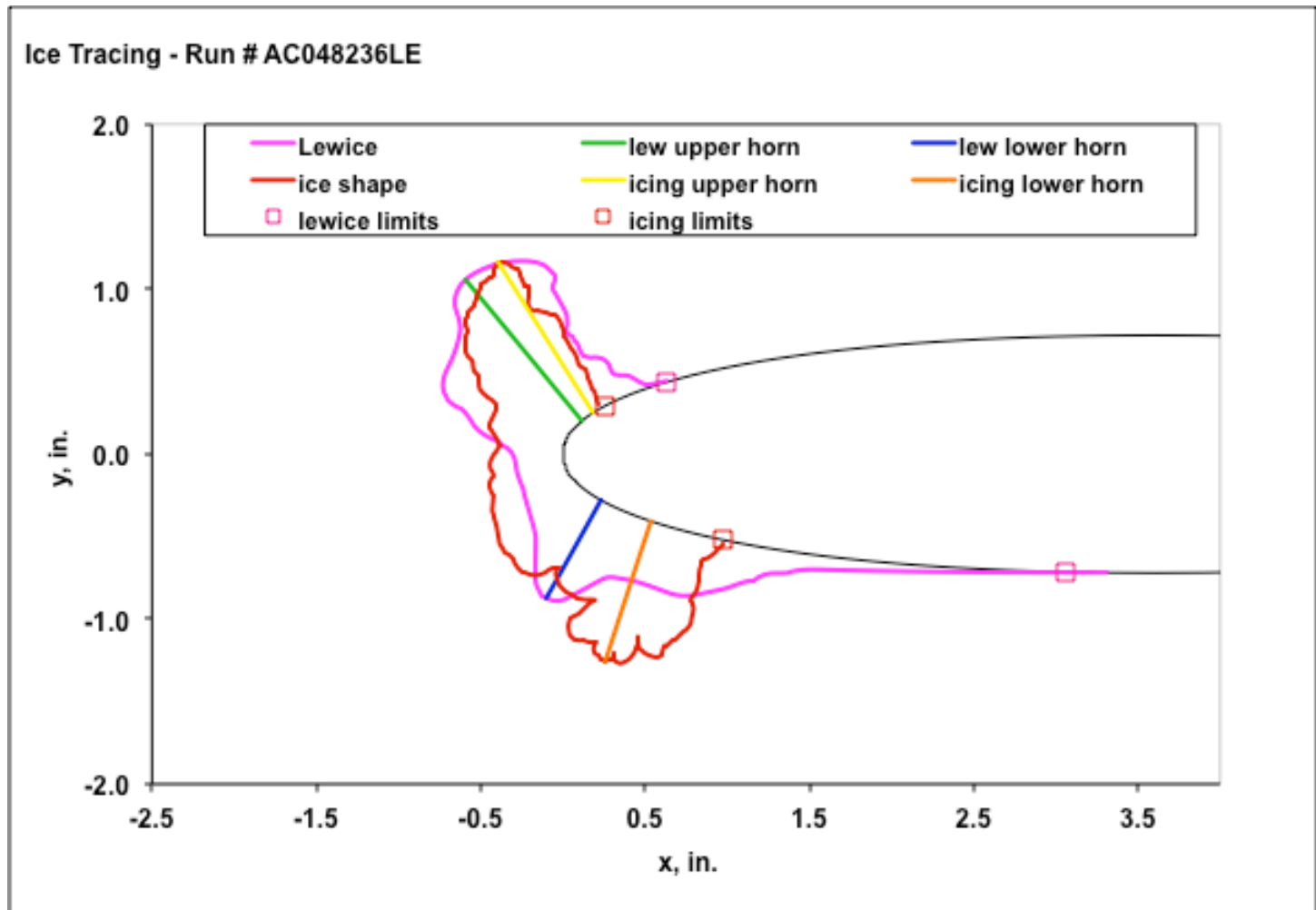
Average Difference in Leading Edge Minimum and Area



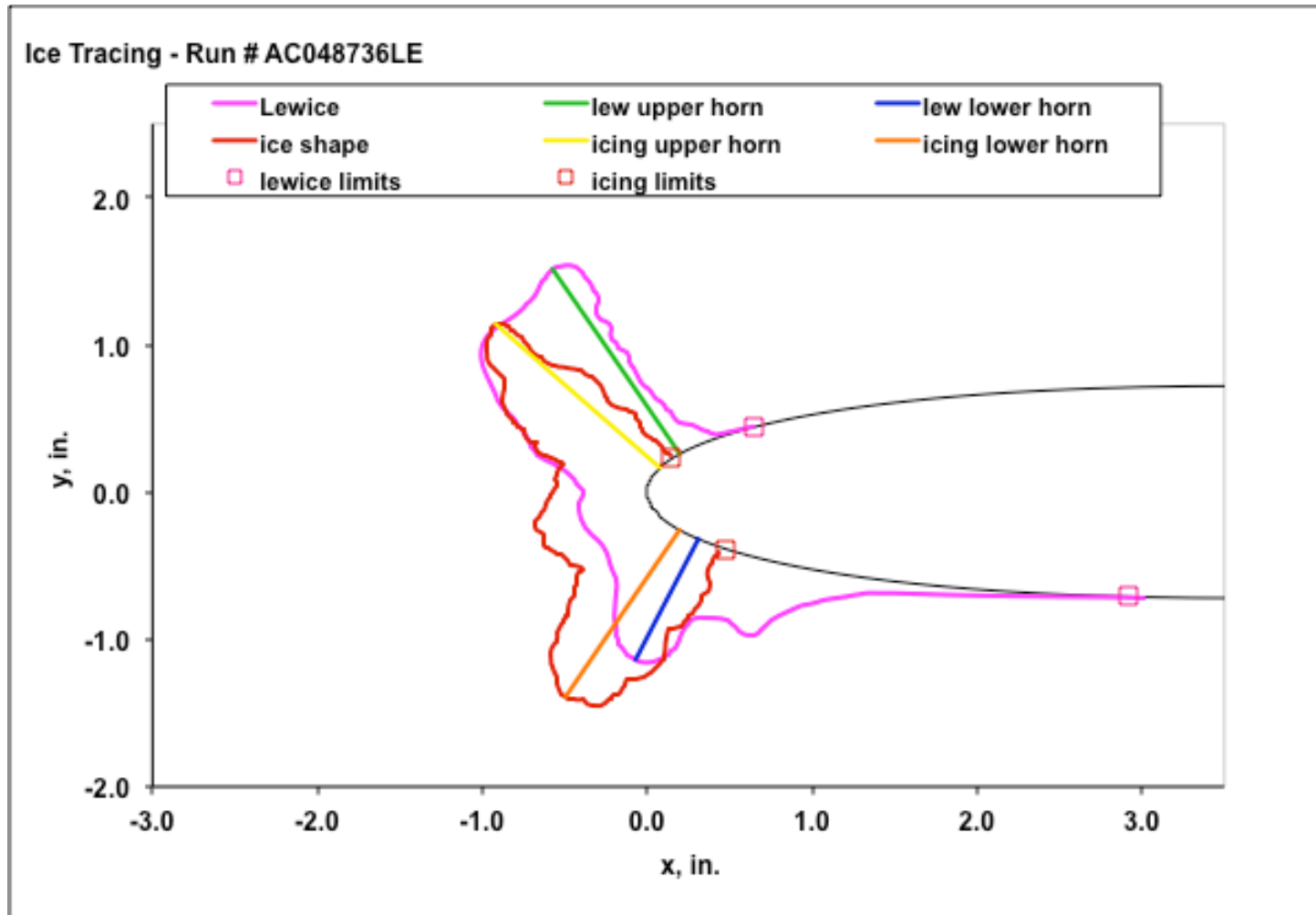
Average Difference in Horn Heights



Average Difference in Lower Horn Angle

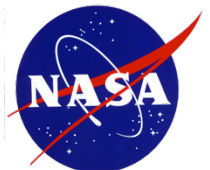


Average Difference in Upper Horn Angle

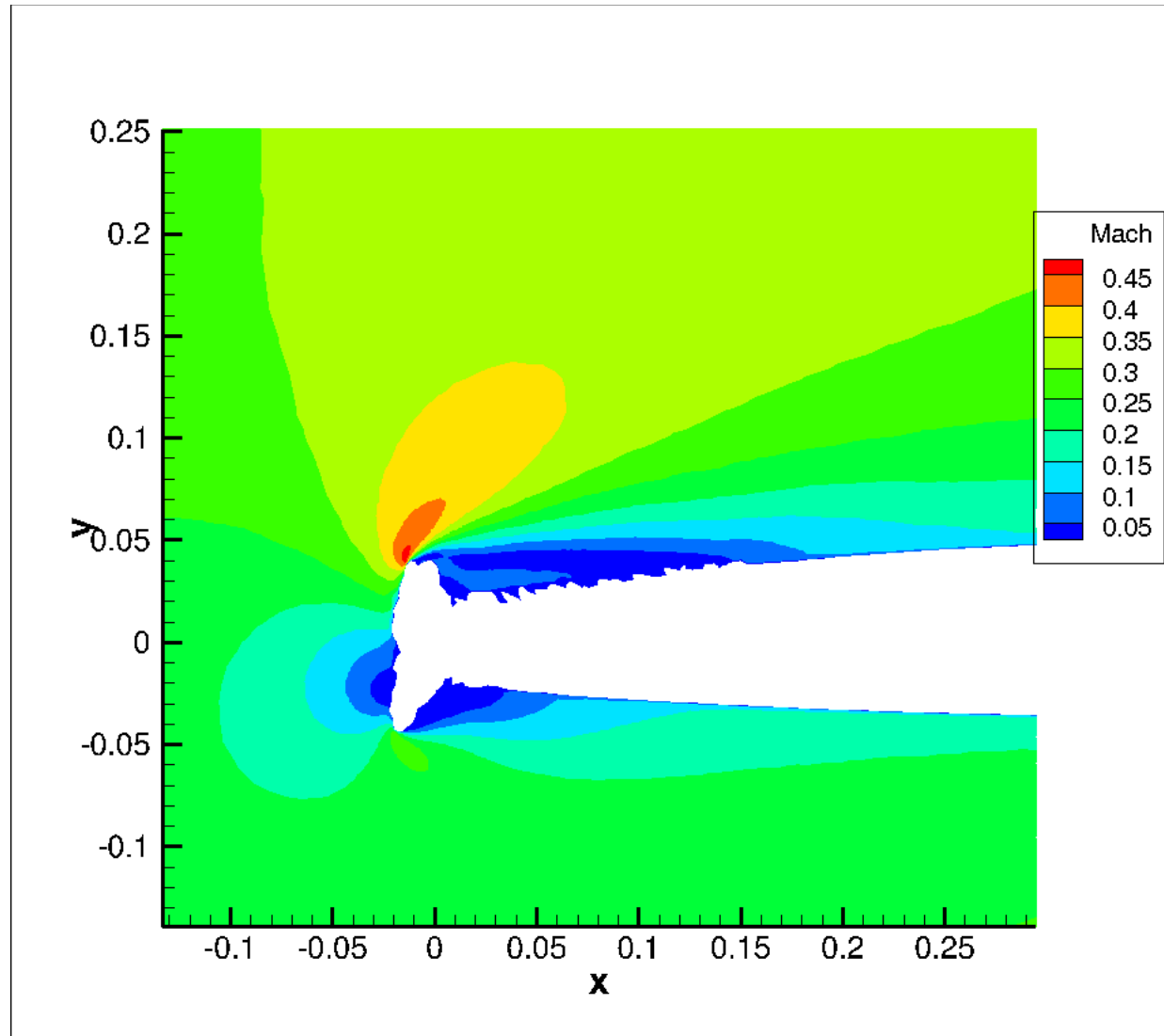


Average Difference in Lift and Drag

Case Name	Lift Coefficient	Lift Difference	Drag Coefficient	Drag Difference
HD1075736	0.5996	-0.0098	0.1280	0.0221
HD1075636	0.6205	0.0111	0.0824	-0.0235
HD1075936	0.6082	-0.0012	0.1074	0.0015
Average for this Condition	0.6094		0.1059	
LEWICE shape	0.6024	0.0070	0.1172	0.0113



Mach Contours for HD1075636



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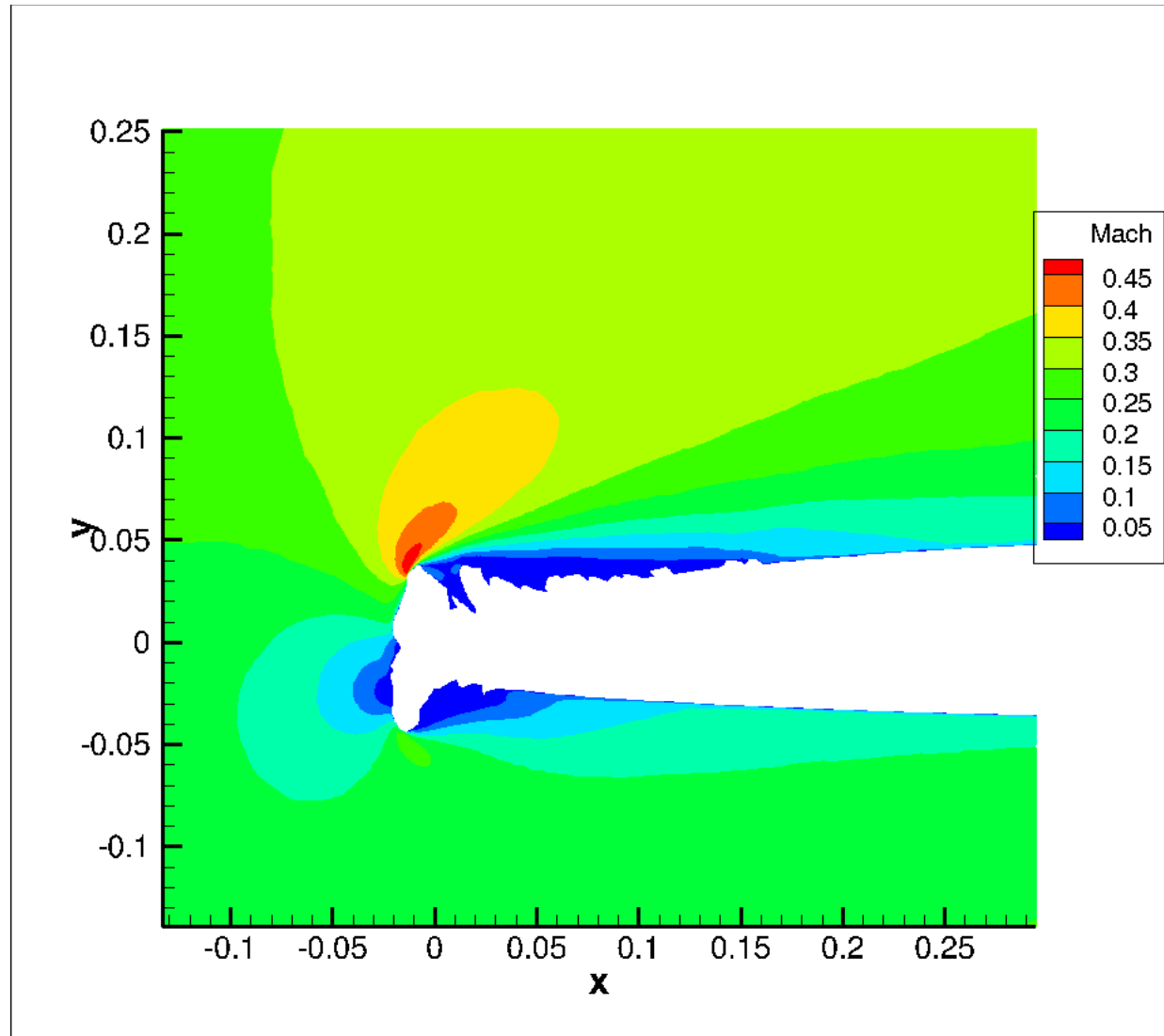
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Mach Contours for HD1075736



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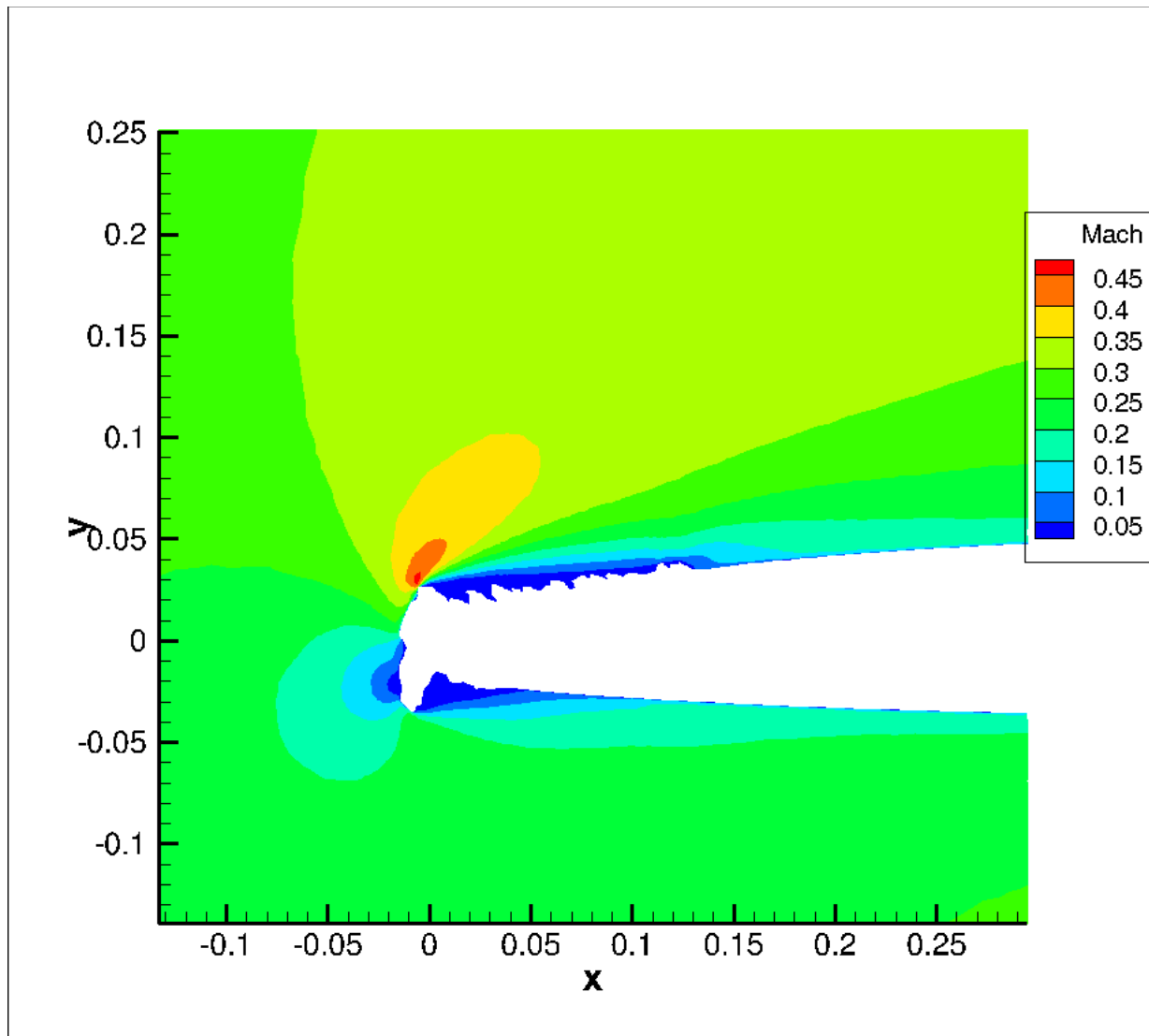
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Mach Contours for HD1075936

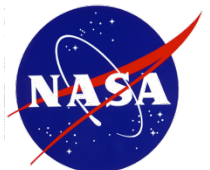


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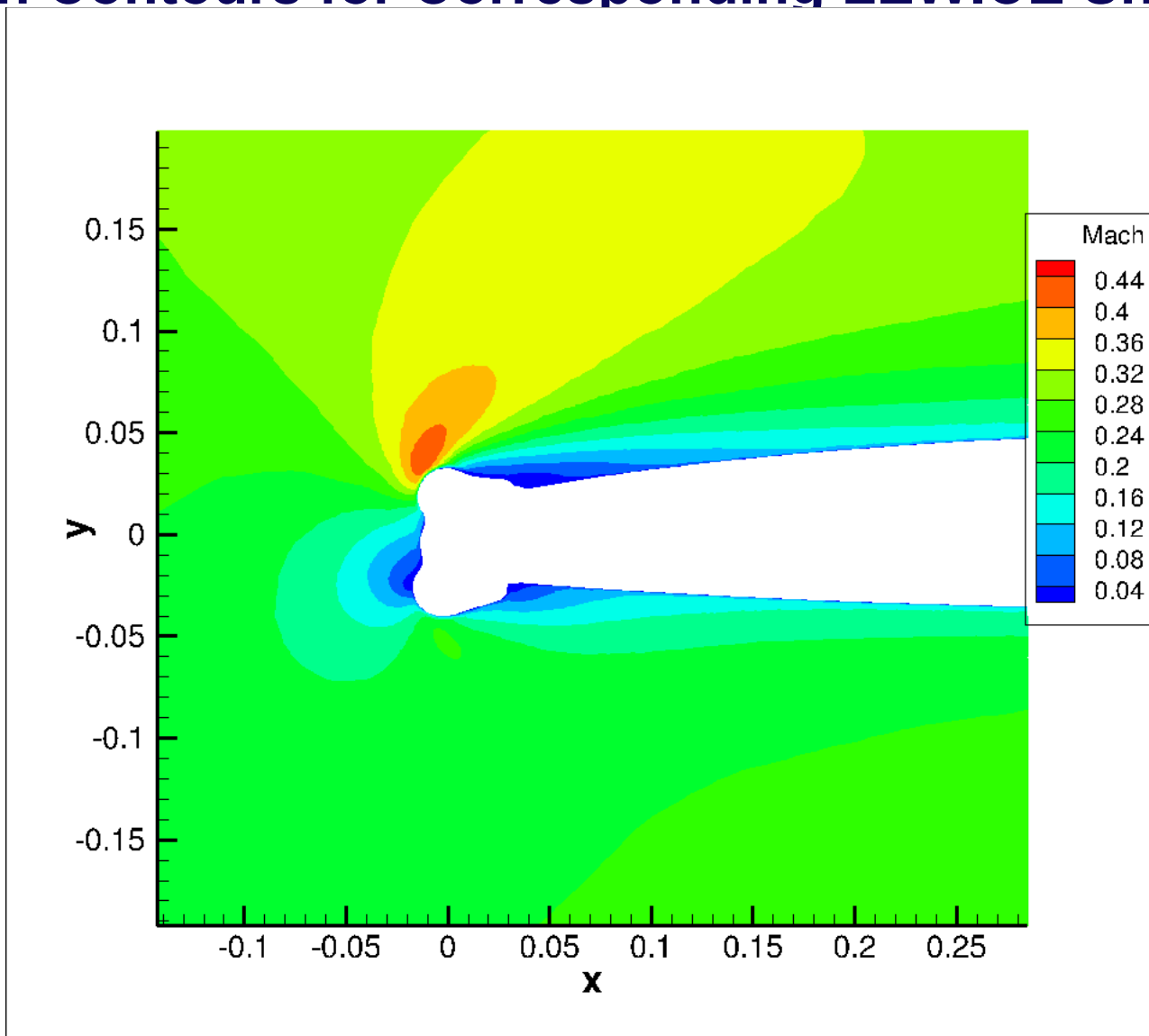
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Mach Contours for Corresponding LEWICE Shape



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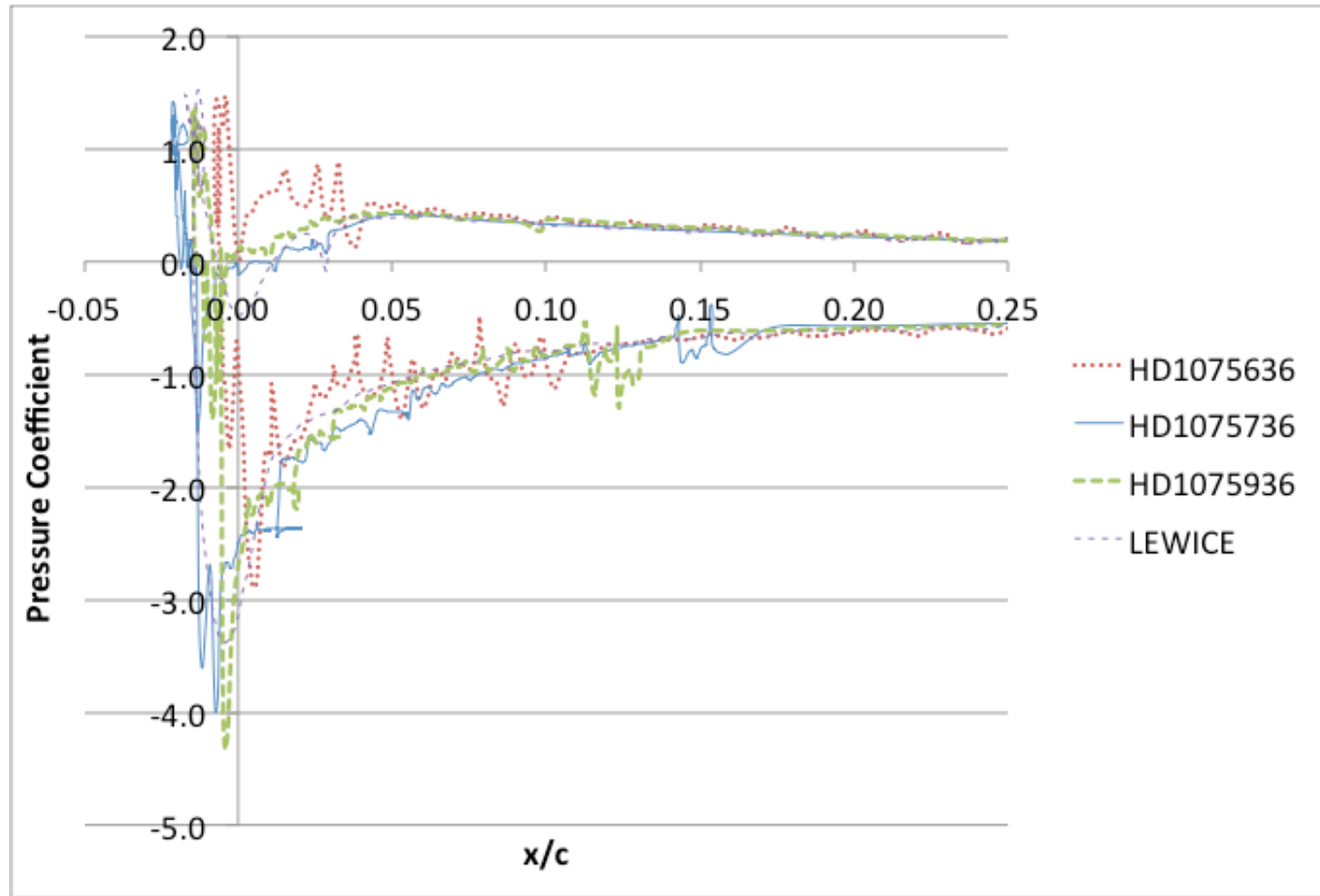
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Pressure Coefficients for HD1075636 and Repeats

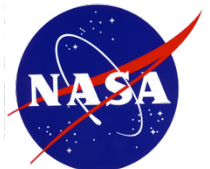


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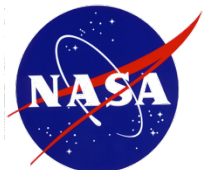
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Conclusions

- **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**
- **Lift and Drag Calculations of Ice Shapes Show Good Agreement**
 - Not All Cases Converged



Future Work

- **Further Reduction of Database Necessary to Run LEWICE with Naviér-Stokes and Ensure Convergence**
 - Selecting 1 Case for Each Airfoil/Chord Gives 13 Conditions
 - Cases with Experimental Aero Data Are Higher Priority
- **Recommend Validation Session for Next Year**
 - Everyone with an Icing Model are Invited to Participate
 - Input on Conditions To Run is Welcome

