Implementation and Validation of 3-D Ice Accretion Measurement Methodology

Sam Lee
Vantage Partners, LLC

Andy Broeren

Richard Kreeger

Mark Potapczuk
NASA Glenn Research Center

Lloyd Utt
University of Akron

Outline

- Introduction
- Scan Data Acquisition/Processing Procedure
- Straight Wing Results
- Swept Wing Results
- Conclusion

Introduction

- NASA currently undertaking multi-year research program to answer “How good is good enough” for swept wing icing.
- Documentation of the ice accretion key piece of data in icing-wind-tunnel tests.
- Currently used options for documenting ice accretion
  - Photography
  - Pencil tracings
  - Mold and casting
- Current methods have limitation that affect usability.

Introduction (cont'd)

- NASA incorporated development of three-dimensional ice accretion digitization methods into its current research plans.
- Phase 1
  - Romer Absolute SI scanner and Geomagic Studio software selected for further development.
- Phase 2
  - The selected scanner system used to implement and validate the use of this technology through a series of icing and aerodynamic tunnel tests.

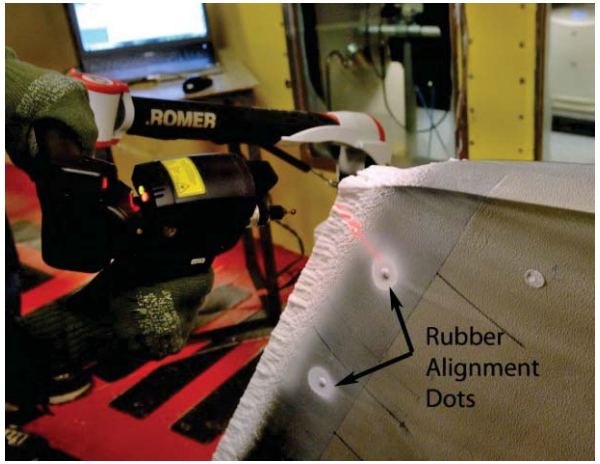
Introduction (cont'd)

- Benchmark measurements were performed on a metal "roughness sample" block.
- Geometric and aerodynamic assessment on a straight wing airfoil geometry.
  - Comparison of scanned ice shapes to castings of the same ice shape.
  - Scan data were also used to create Rapid Prototype Manufacturing (RPM) artificial shapes that were scanned and compared to the original ice accretion.
  - An aerodynamic evaluation was also conducted
  - Four basic categories of ice accretion: glaze horn, roughness, rime and runback.
- Geometric validation performed on a swept-wing geometry.
  - Quantified the limitations of capturing very complicated scallop geometries.
  - Did not contain an aerodynamic assessment.

Data Acquisition Procedure

The IRT scanner data acquisition procedure consisted of the following six steps:

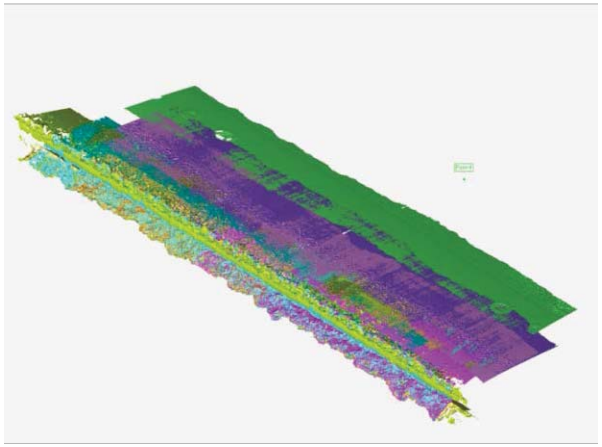
1. Accrete ice on the test article
2. Photograph the ice
3. Spray the ice with white paint
4. Install and set up the scanner
5. Scan the ice shape
6. Make mold of ice shape

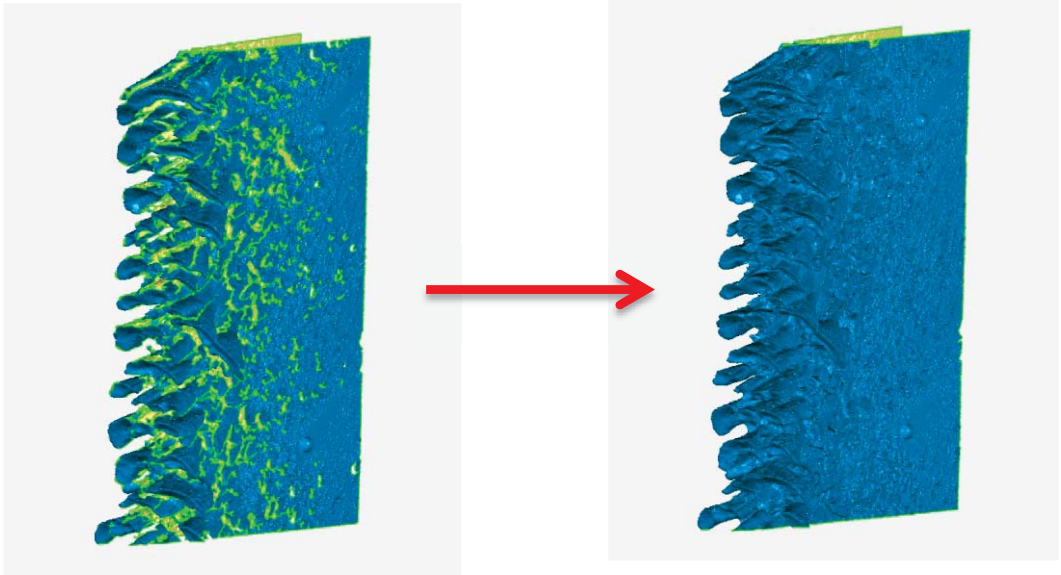


Data Processing Procedure

The IRT scanner data processing procedure consisted of the following five steps:

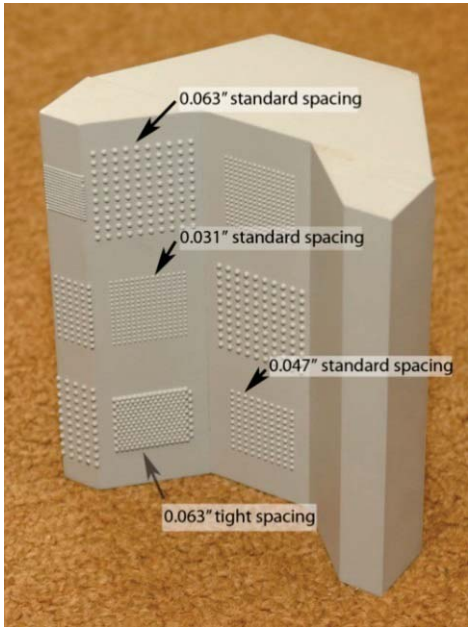
1. Align/combine scan passes
2. Reduce data set
3. Wrap surface
4. Repair mesh/fill holes
5. Coordinate transformation

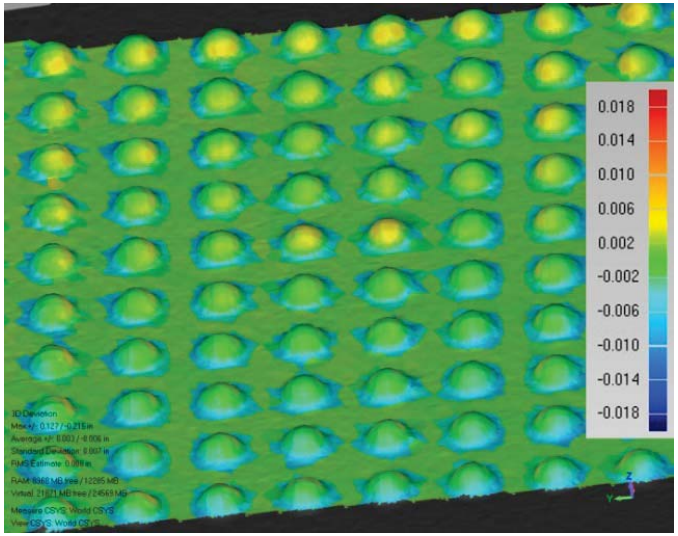


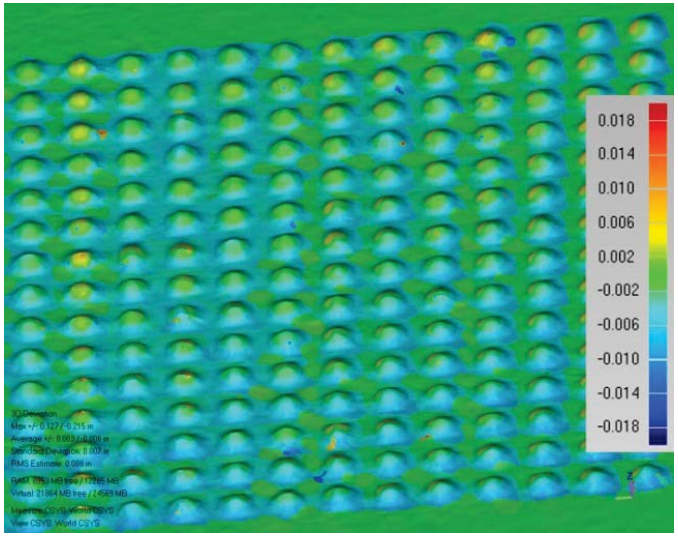


Benchmark Measurement Results

- Benchmark results on “roughness” block:
  - Used to simulate roughness on horn shape
  - 3 roughness sizes
  - 2 roughness patterns



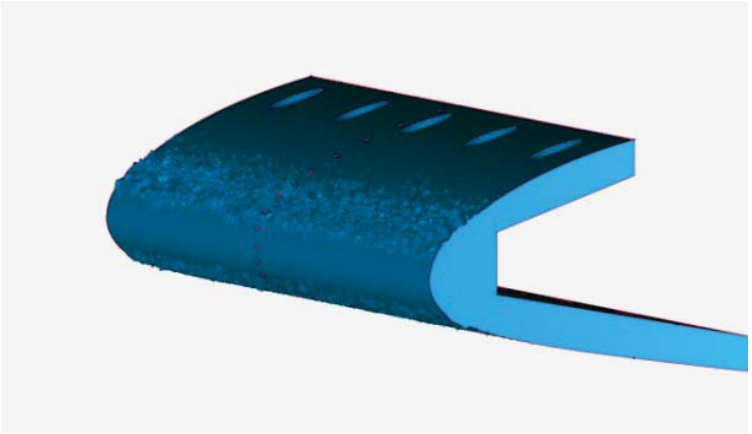




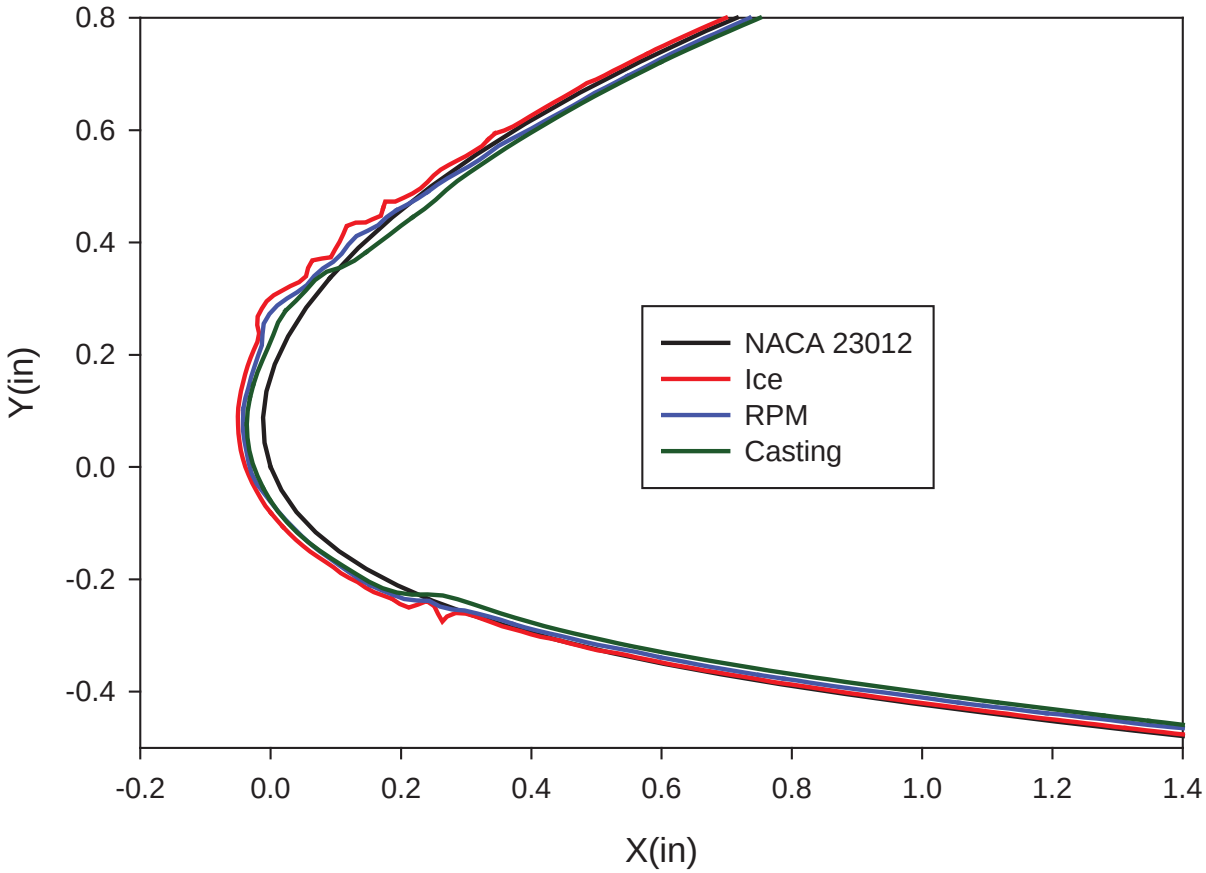
0.063” diam. hemisphere 0.031” diam. hemisphere

Scan vs. CAD model

Straight Wing Results
Roughness Shape



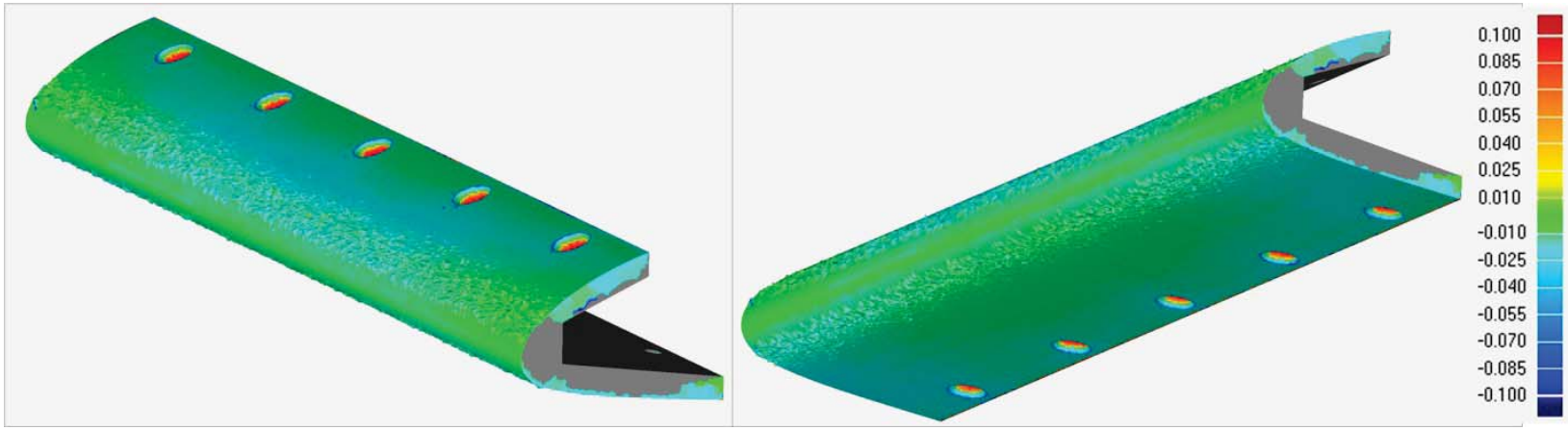
Water-tight model



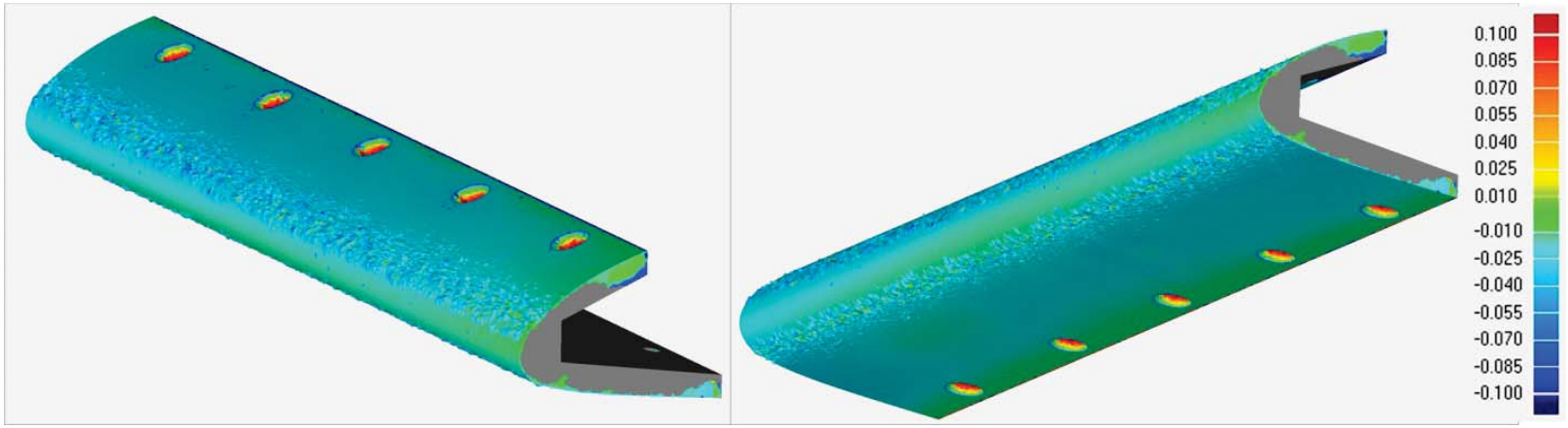
Cross section cut

Straight Wing Results

Roughness Shape



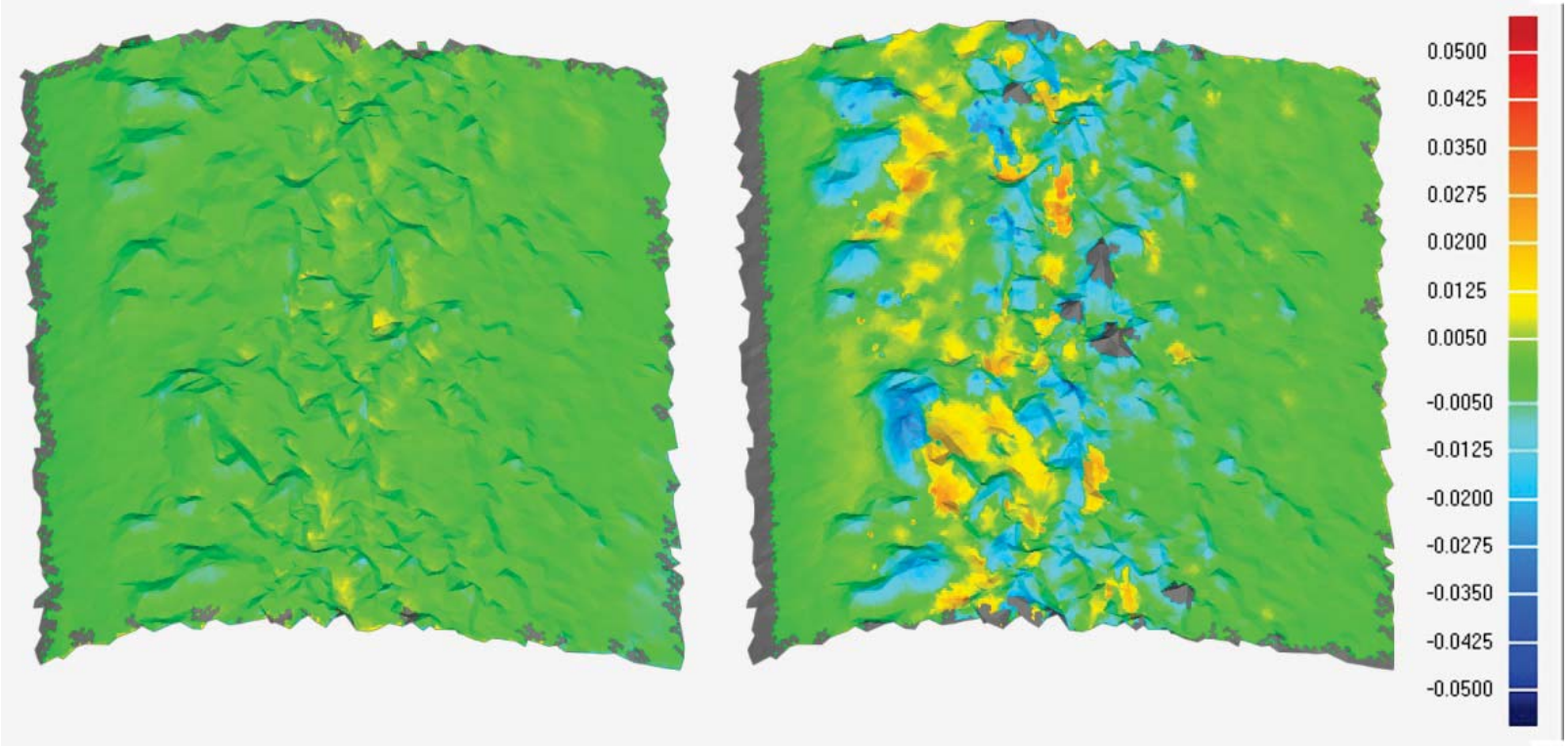
RPM vs original ice scan deviation map



Cast vs original ice scan deviation map

Straight Wing Results
Roughness Shape

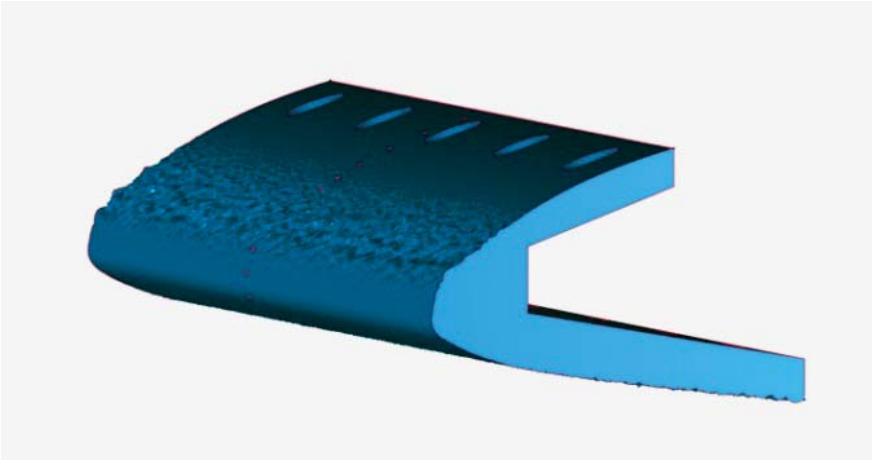
Local Deviation Map



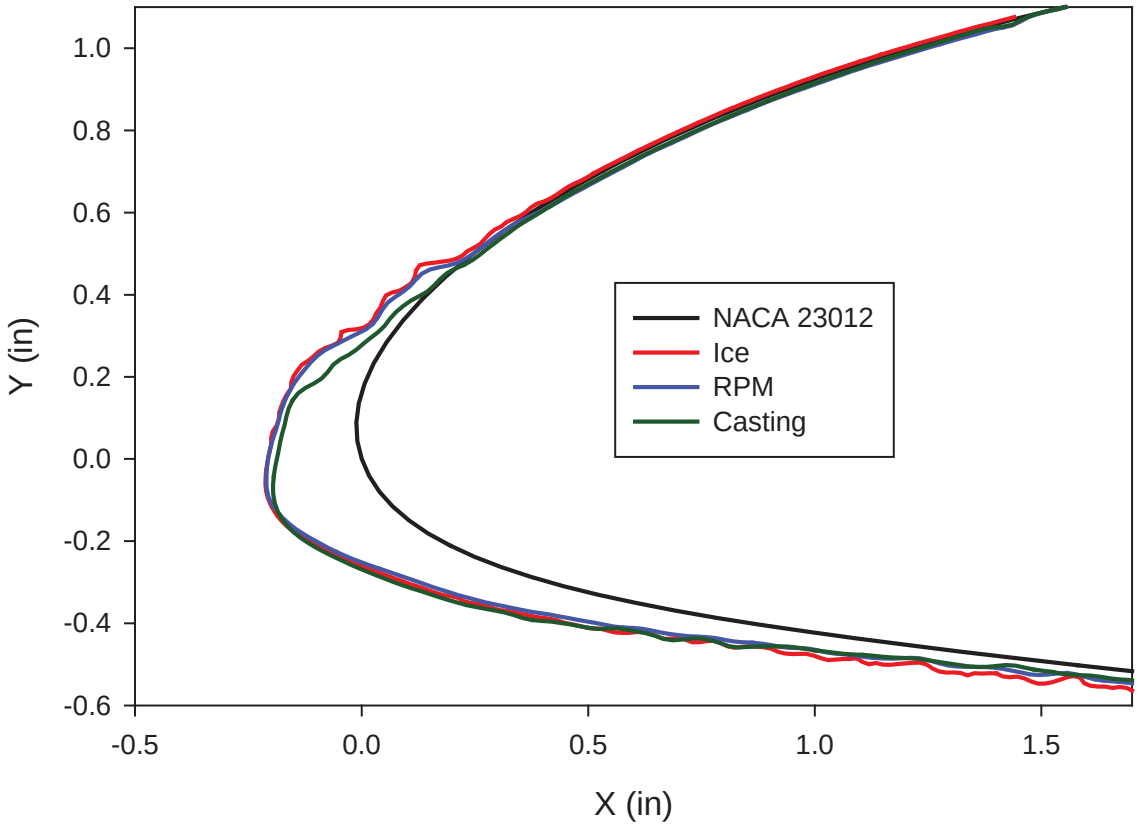
RPM Shape

Cast Shape

Straight Wing Results
Rime Shape



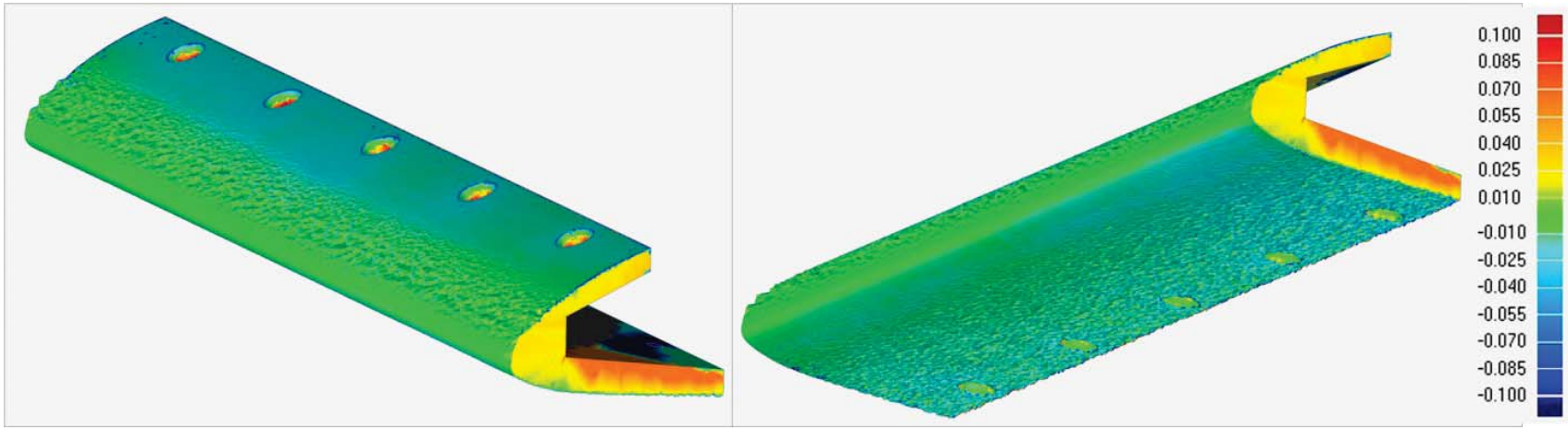
Water-tight model



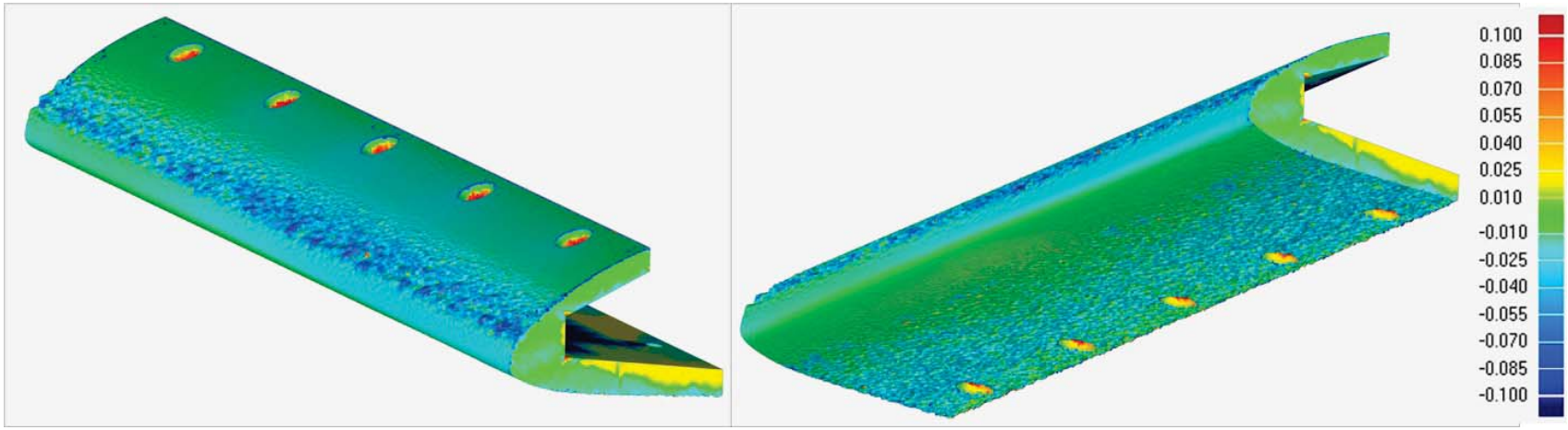
Cross section cut

Straight Wing Results

Rime Shape



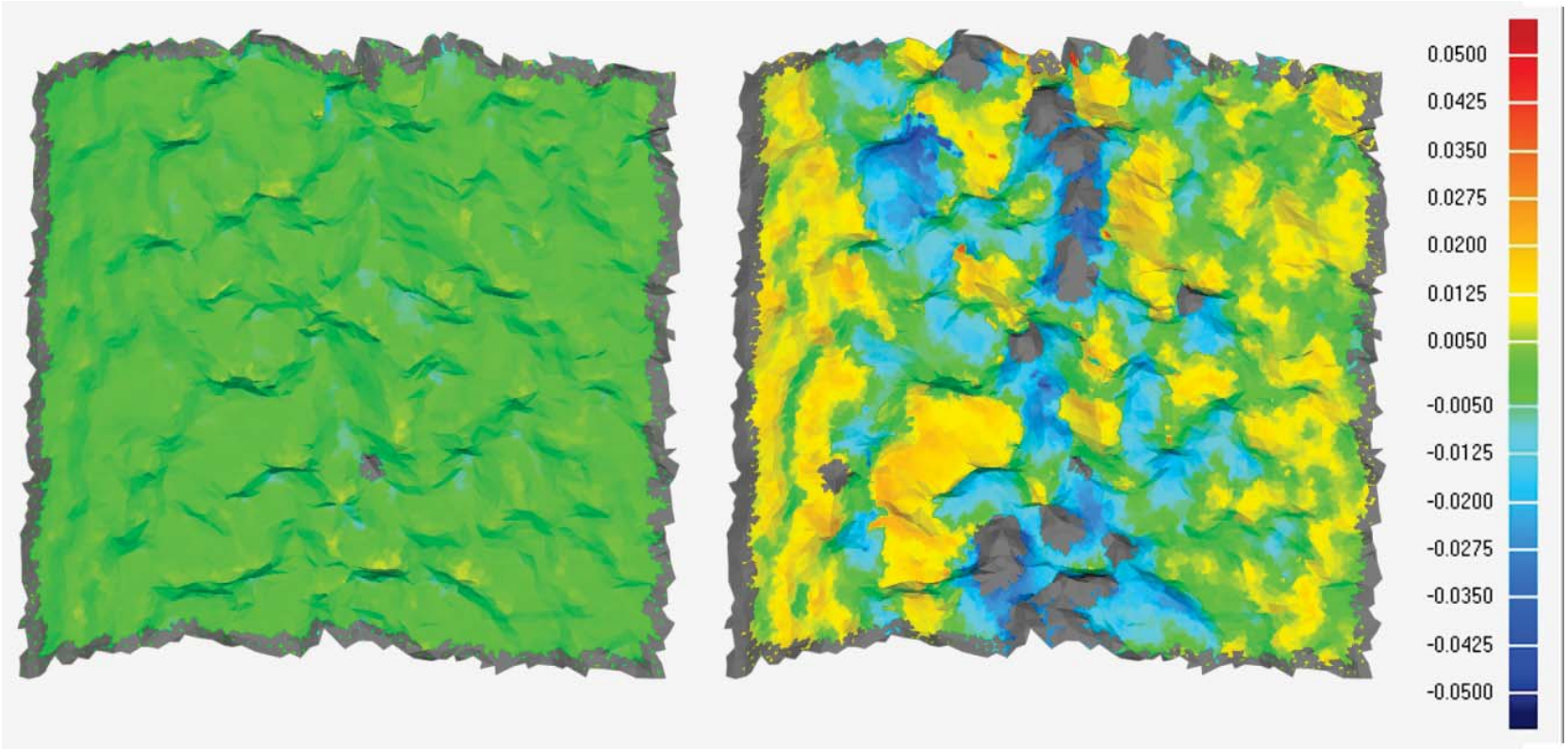
RPM vs original ice scan deviation map



Cast vs original ice scan deviation map

Straight Wing Results
Rime Shape

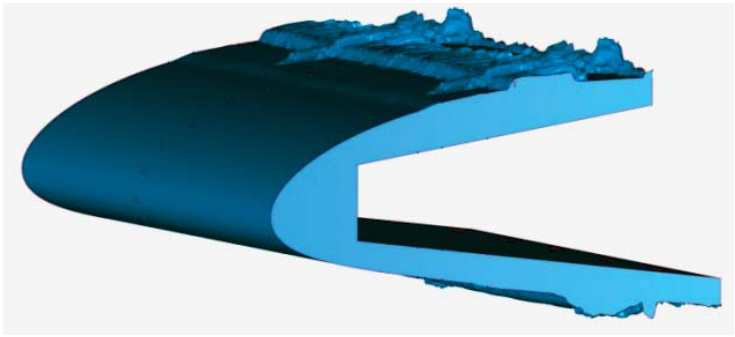
Local Deviation Map



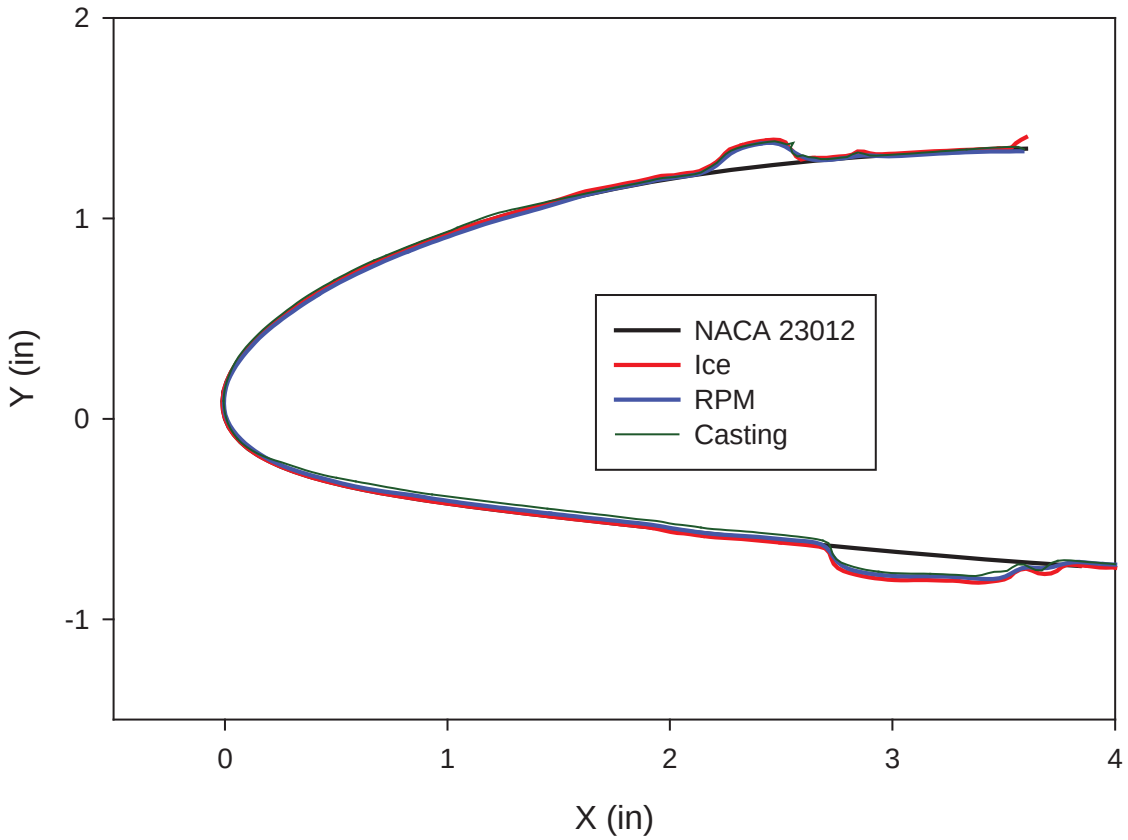
RPM Shape

Cast Shape

Straight Wing Results
Runback Shape

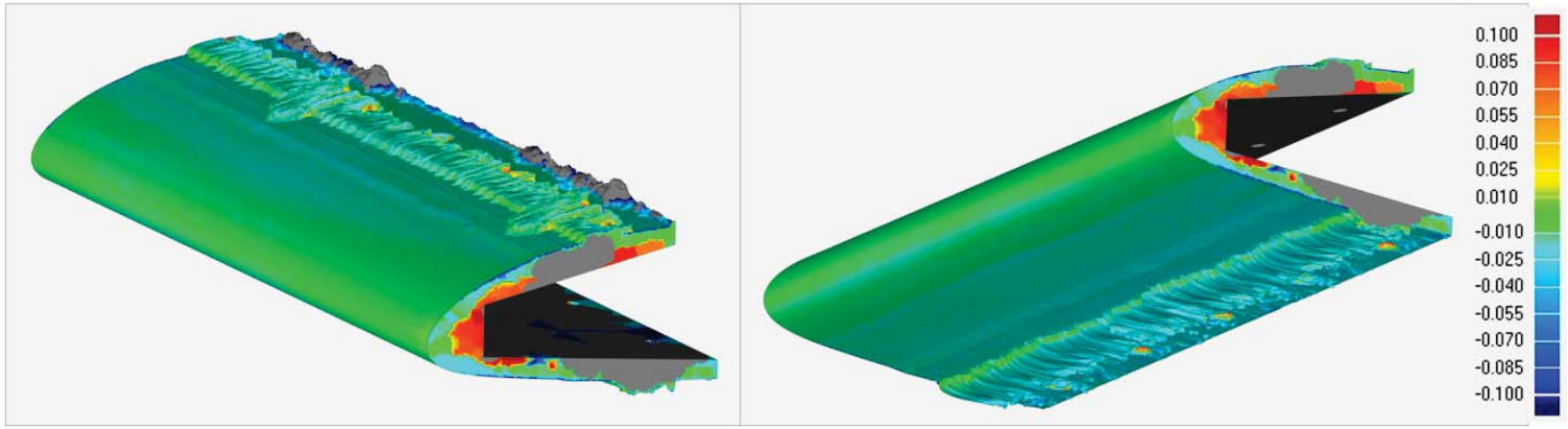


Water-tight model

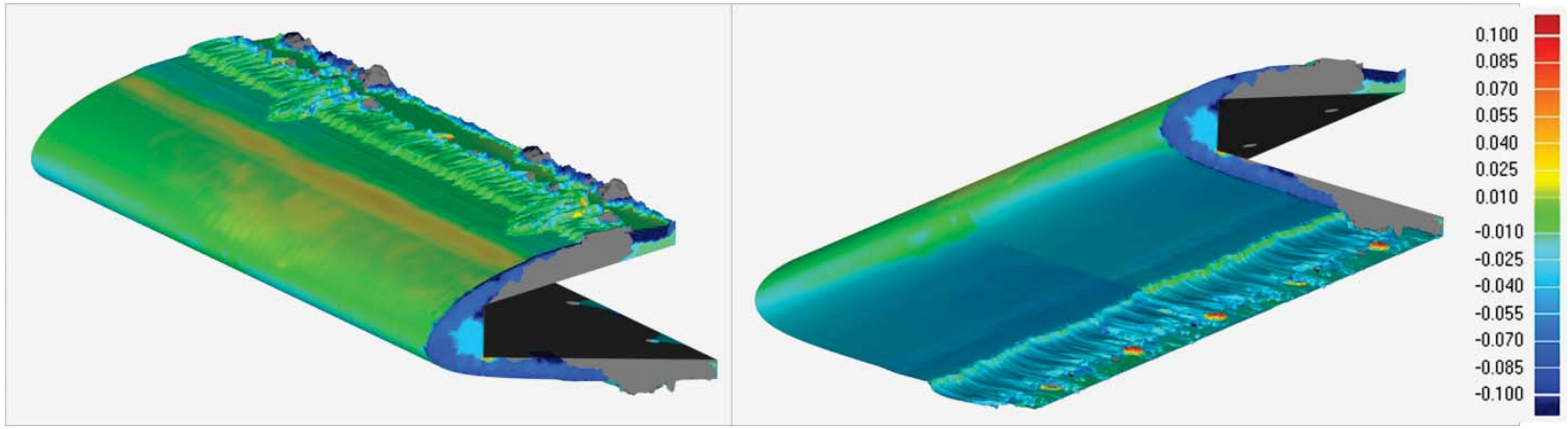


Cross section cut

Straight Wing Results
Runback Shape



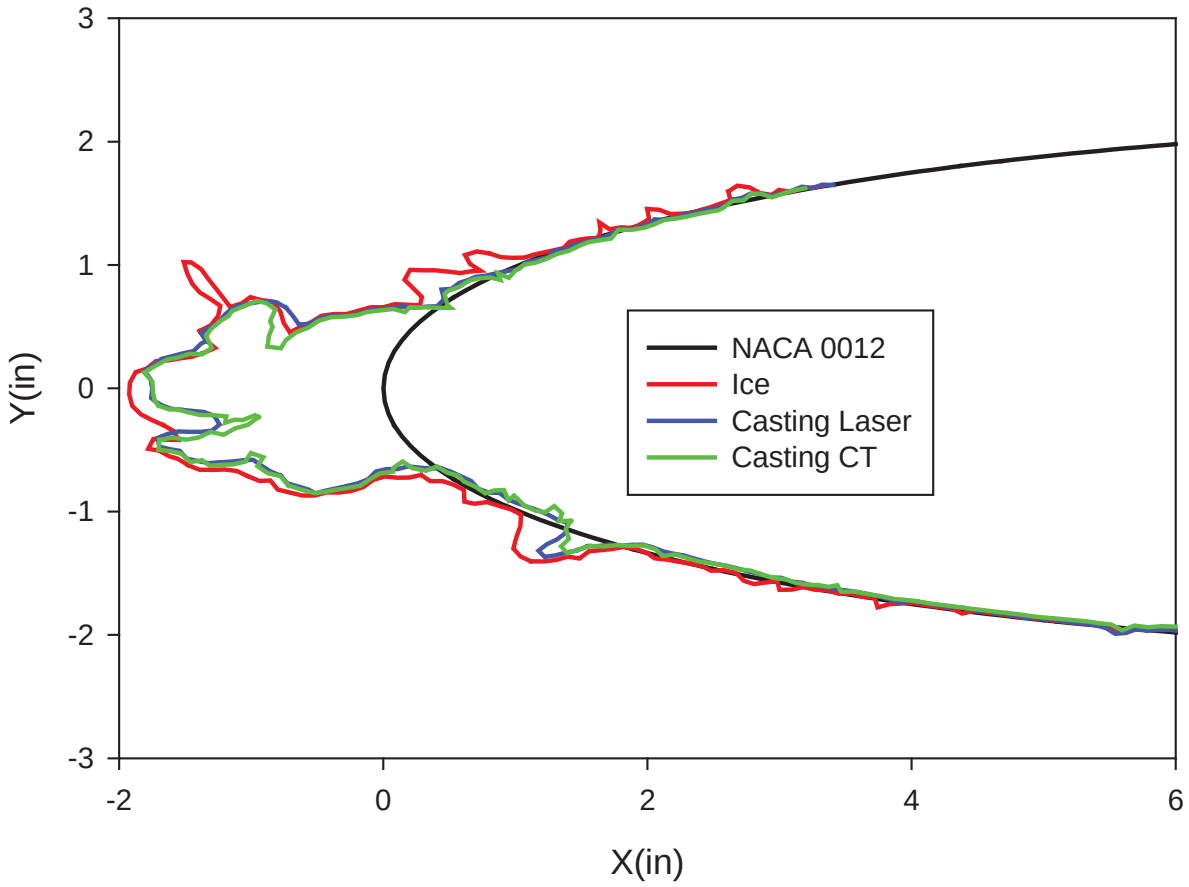
RPM vs original ice scan deviation map



Cast vs original ice scan deviation map

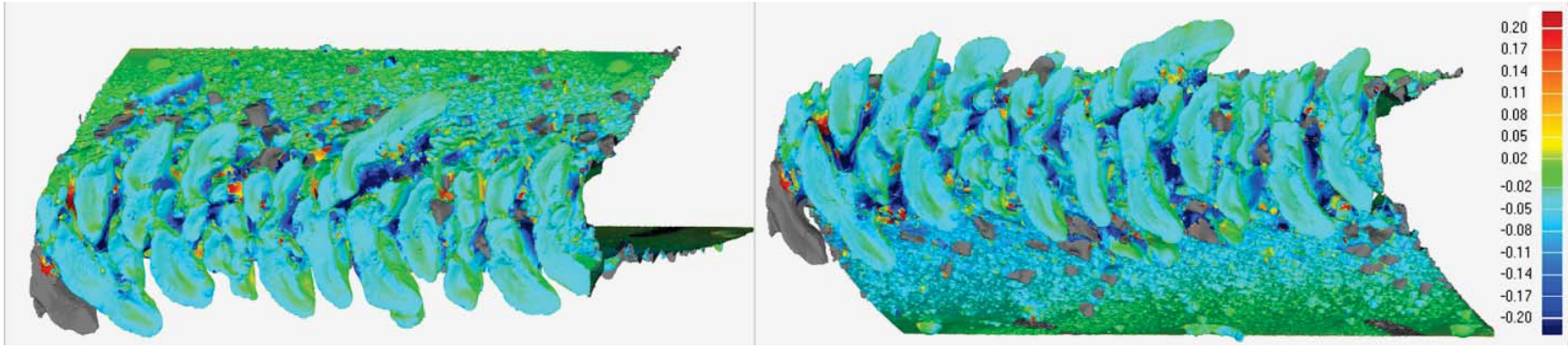
Swept Wing Results
Complete Scallop Shape

Water-tight model

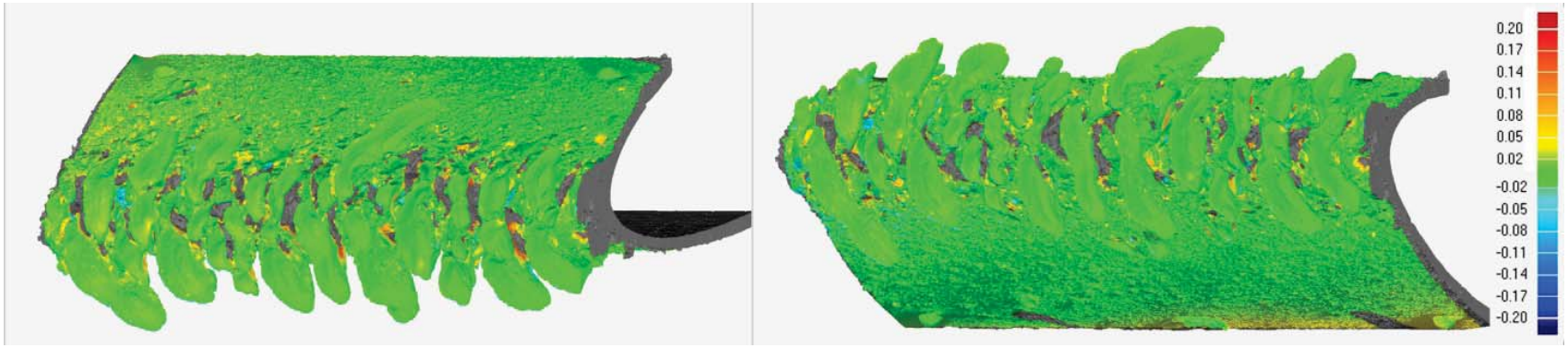


Cross section cut

Swept Wing Results
Complete Scallop Shape

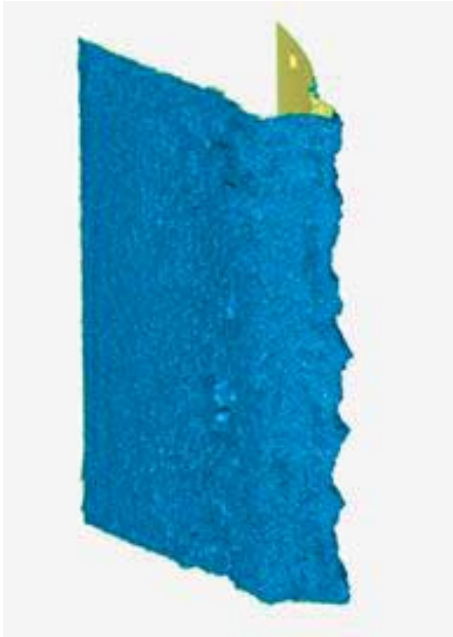


Laser Scan of Casting vs. Original Ice Scan

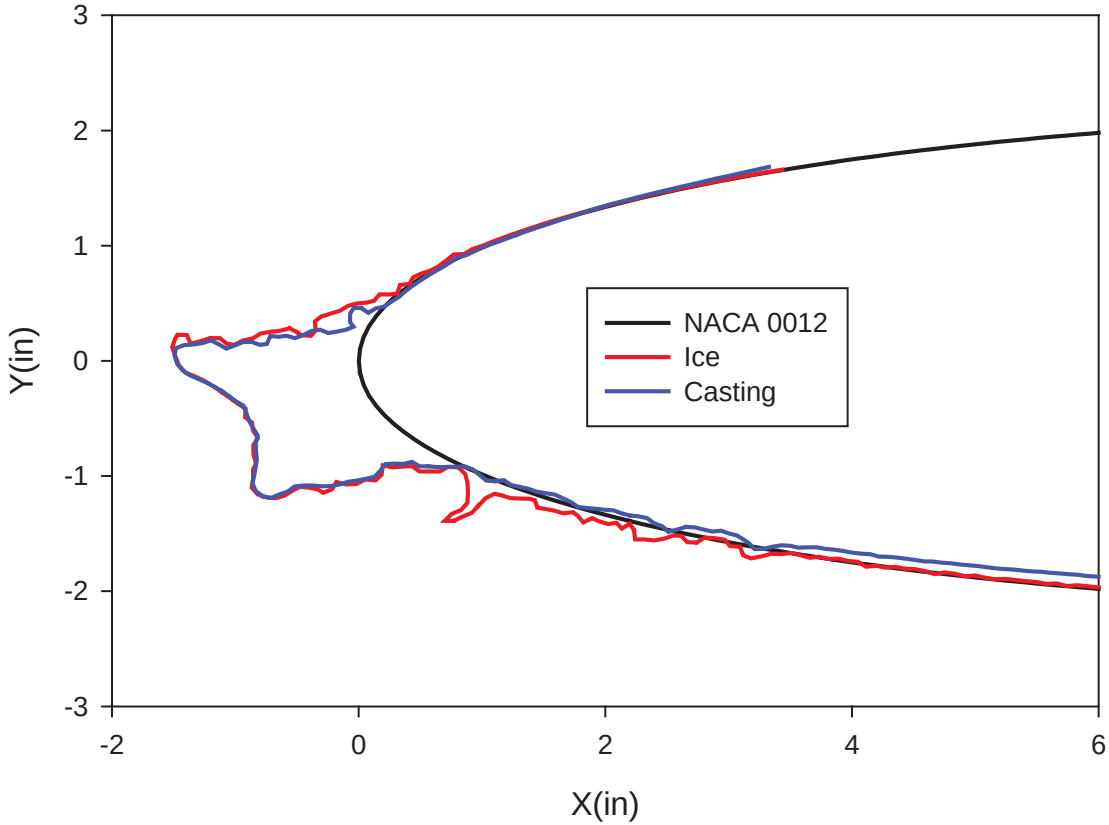


CT vs. Laser Scan of Casting

Swept Wing Results
Incomplete Scallop Shape

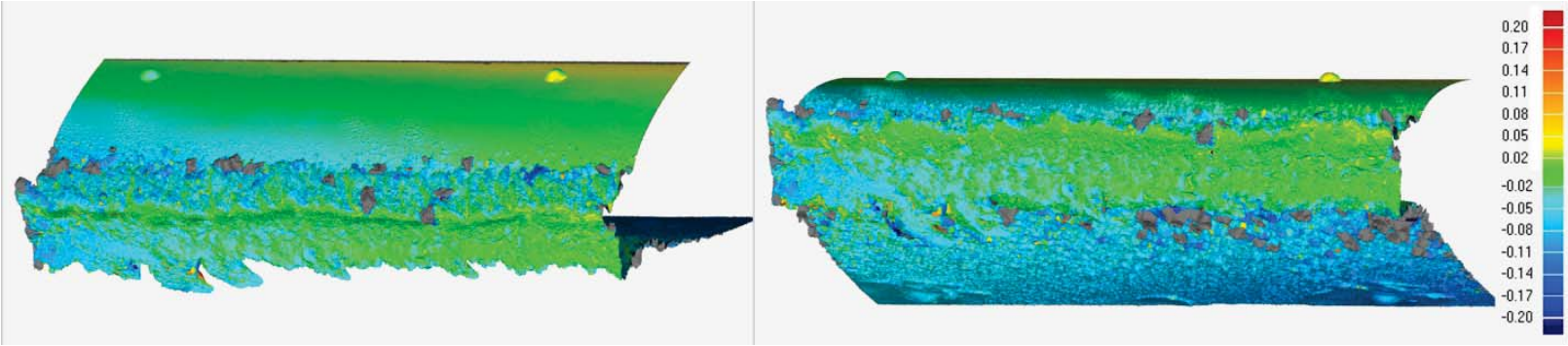


Water-tight model



Cross section cut

Swept Wing Results
Incomplete Scallop Shape



Casting vs. Original Ice Scan Deviation Map

Conclusion

- A research program implemented to develop and validate the use of a 3D laser scanning system to record ice accretion shapes in the NASA Icing Research Tunnel.
- Phase 1 - Identify the most suitable laser scanning hardware and software for further development.
- Phase 2 - Selected scanner system will be used to implement and validate the use of this technology through a series of icing and aerodynamic tunnel tests.
- Straight-wing ice shape models generated through the scan/RPM process compared well with the cast shapes.
  - Cast shapes appear to have shrunk during the mold/casting process.
  - Rapid prototype manufacturing process reproduce the original ice accretion scan normally within 0.01-inch.

Conclusion (cont'd)

- Swept wing results showed similar good results.
  - Significant portions of the scallop features were captured with the laser scanner
  - Results compared very well with the CT scanning method, except for the deep gaps between the scallops.
  - It is currently not known how aerodynamically important these deep gap regions are.
  - Missing scallop and feather features on the cast shapes that broke off during the mold/casting process.
- Increased utility of icing tests by developing robust means of recording and archiving fully 3-D descriptions of experimental ice accretion geometry.