Method to Generate Full-Span Ice Shape on Swept Wing Using Icing Tunnel Data

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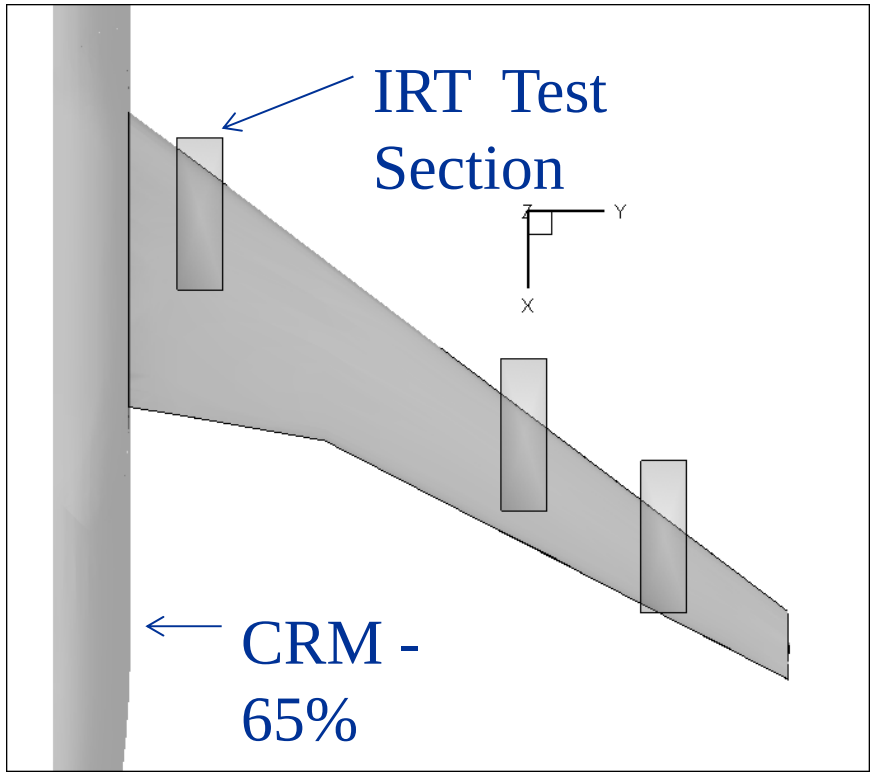
Introduction

- Current collaborative research program to improve the fidelity of experimental and computational simulation methods for swept-wing ice accretion formulations.
  - NASA, FAA, ONERA, and university partners.
- Utilize 65% scale Common Research Model.
  - Ice shapes obtained in NASA Icing Research Tunnel
  - Hybrid models from 20%, 64%, and 83% span used
  - Models have full-scale leading edge
- Full-span ice shapes required for aerodynamic testing.

Introduction (cont'd)

- Each IRT models can generate 1 ft span of ice.
- Full-span ice shapes require 75 ft of ice.
- Large gaps between the three spanwise ice sections.
- Method developed to generate full-span ice shapes from the three 1 ft span ice shapes

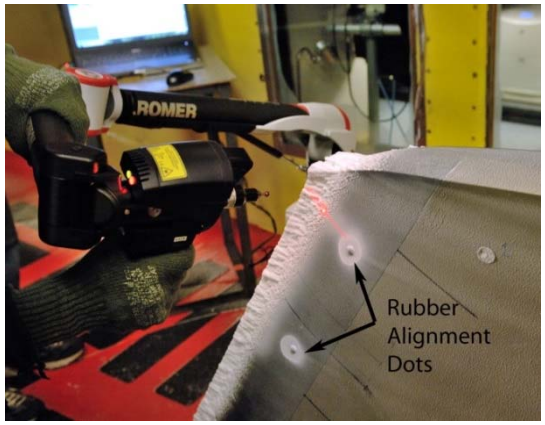
Introduction (cont'd)



Ice Scan Data Acquisition Procedure

The IRT scanner data acquisition procedure :

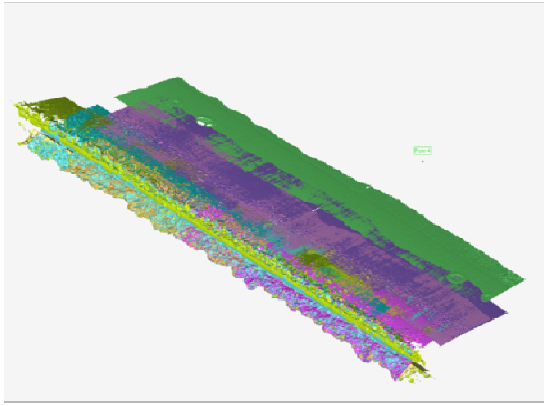
1. Accrete ice on the test article
2. Spray the ice with white paint
3. Install and set up the scanner
4. Scan the ice shape

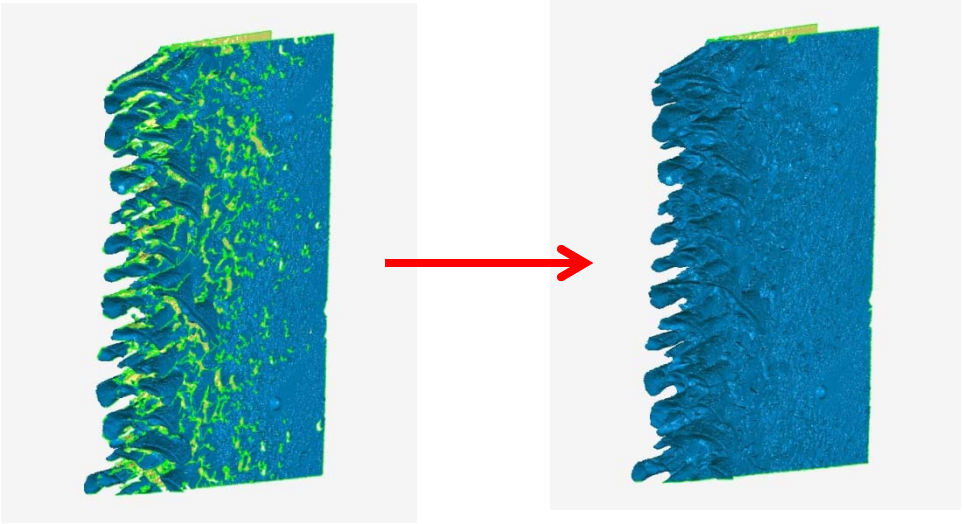


Ice Scan Data Processing Procedure

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





3D Ice Shape Scanning Methodology

Lee, S., Broeren, A.P., Addy., H.E., Sills, R., and Pifer, E., "Development of 3D Ice Accretion Measurement Method," AIAA 4th Atmospheric and Space Environments Conference, New Orleans, LA, June 25-28, 2012, AIAA Paper 2012-2938.

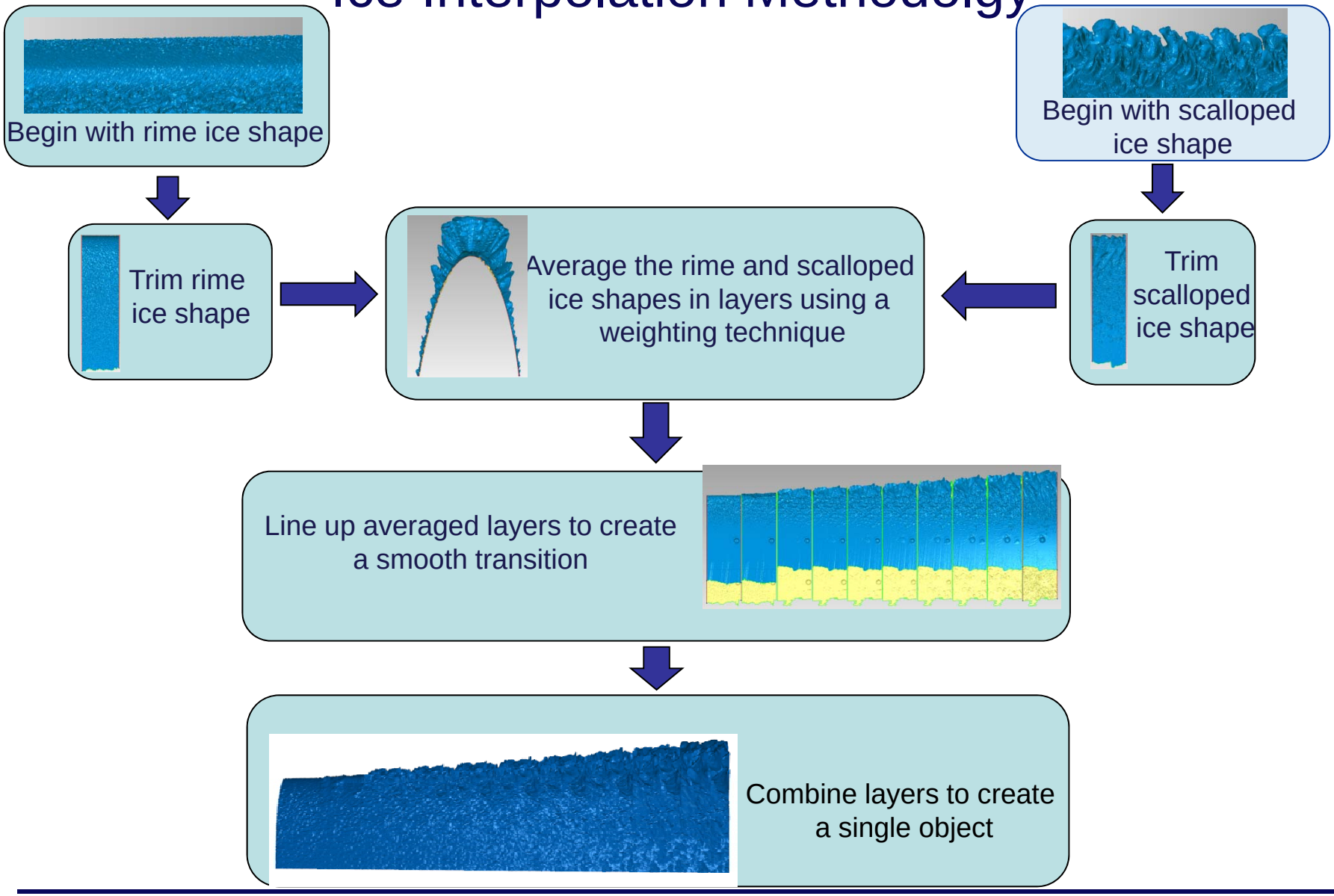
Lee, S., Broeren, A.P., Kreeger, R.E., Potapczuk, M., and Utt, L., "Implementation and Validation of 3-D Ice Accretion Measurement Methodology," AIAA 6th Atmospheric and Space Environments Conference, Atlanta, GA, June 16-20, 2014, AIAA Paper 2014-2613.

Broeren, AP, Addy, H.E., Lee, S., and Monastero, M.C., "Validation of 3-D Ice Accretion Measurement Methodology for Experimental Aerodynamic Simulation," AIAA 6th Atmospheric and Space Environments Conference, Atlanta, GA, June 16-20, 2014, AIAA Paper 2014-2614.

Ice Interpolation Methodology

- Interpolate ice shapes between the scanned sections.
  - Utilize weighted averaging function in Geomagic Studio.
  - Results in “morphing” of ice shape from scanned section into an unscanned section.
- Demonstrated using existing scanned ice shapes from a swept NACA 0012 airfoil

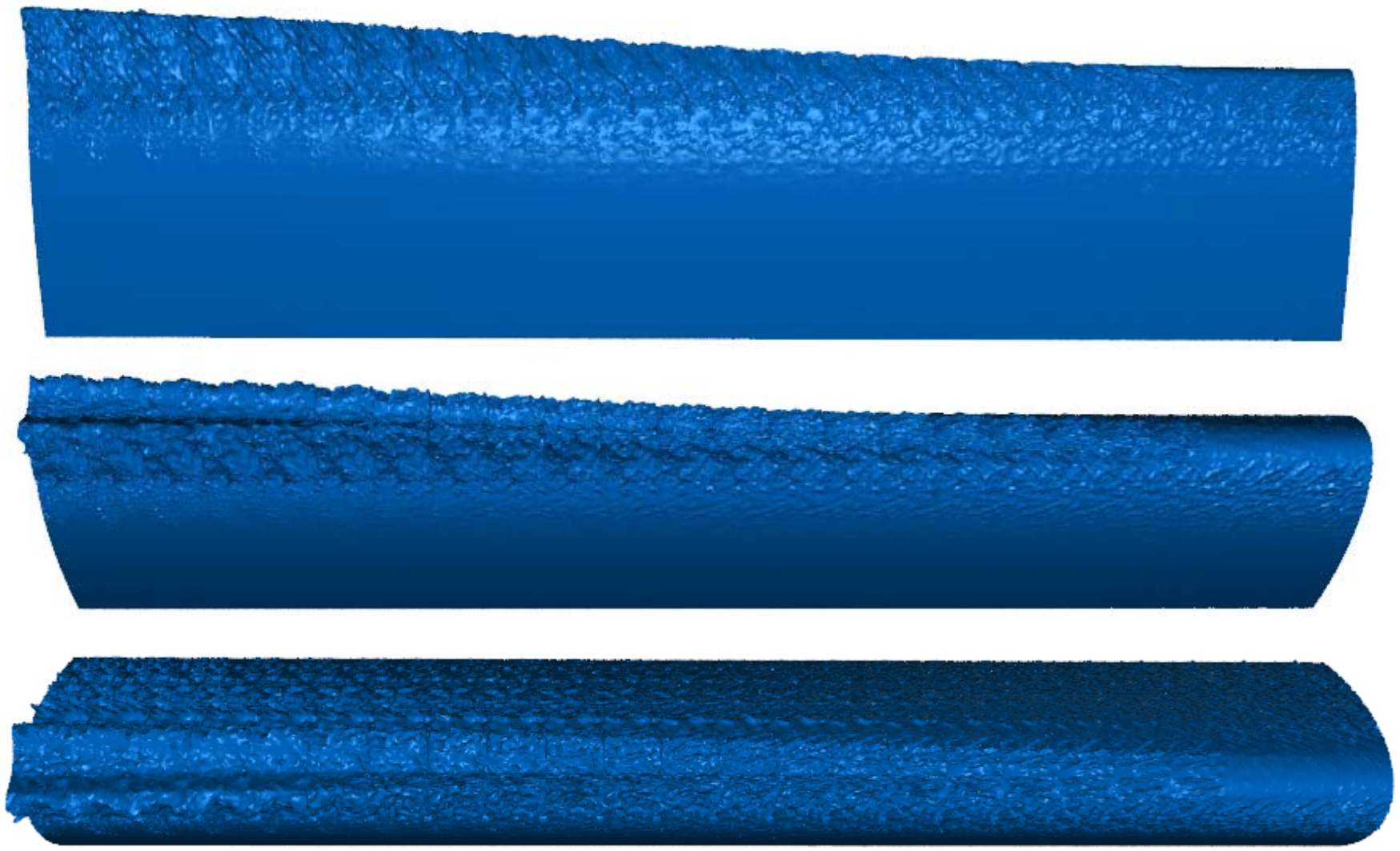
Ice Interpolation Methodolgy



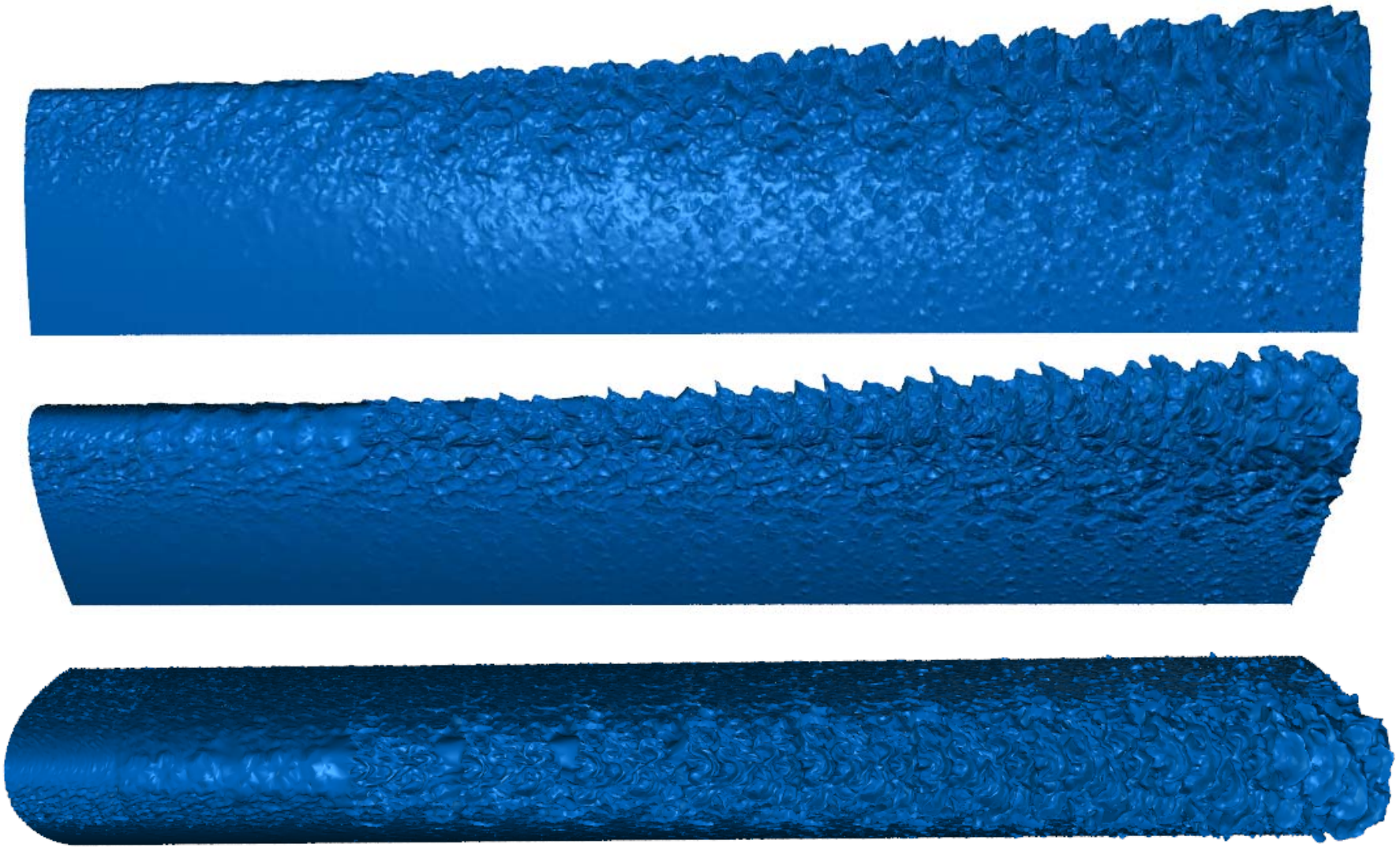
Ice Generation Methodology

- A variety of combinations of rime, horn, and scalloped ice were morphed
- 3 main categories
  - Basic morphing on a straight wing
  - Twist and taper without morphing
  - Twist and taper with morphing

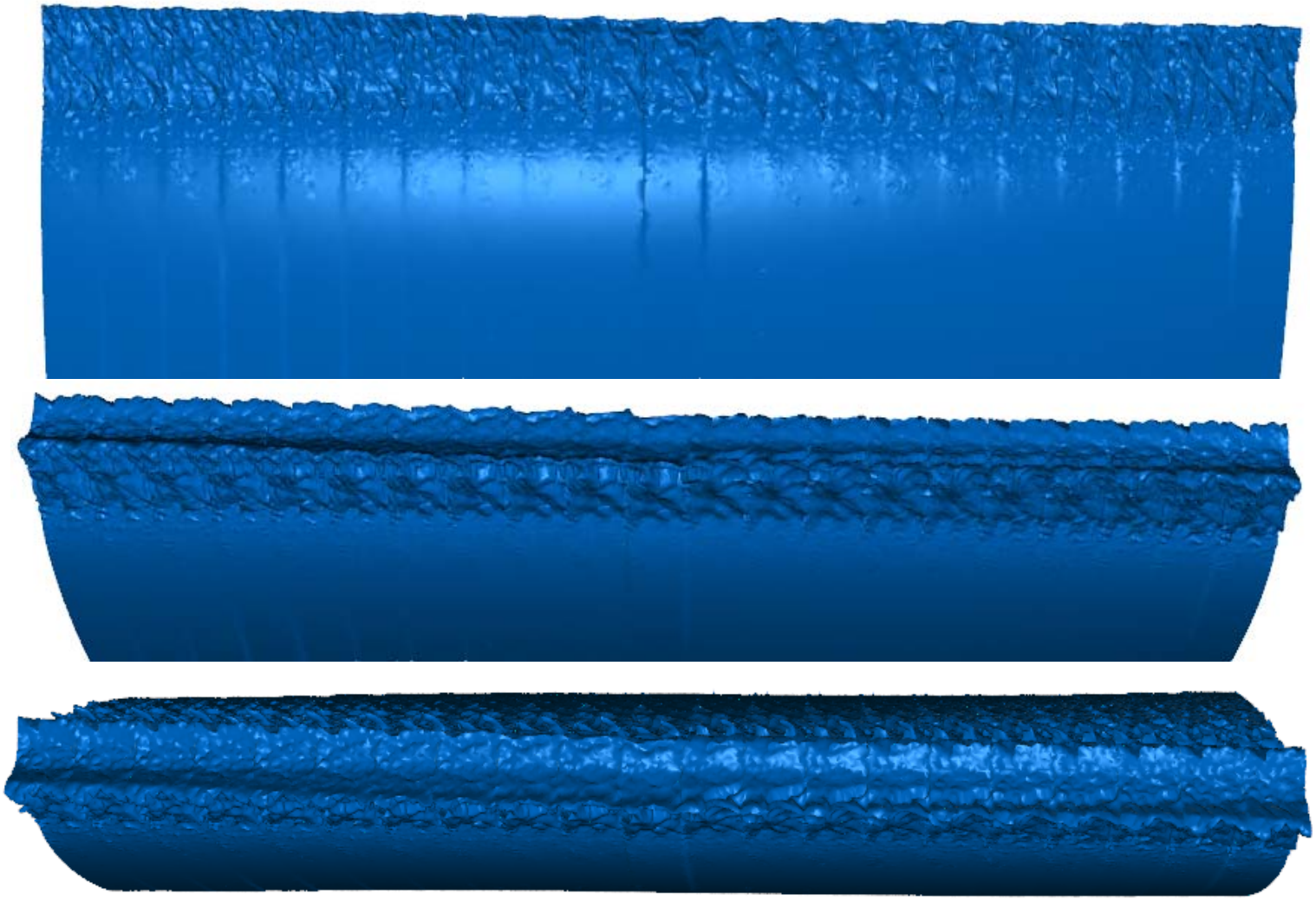
Rime to Horn



Rime to Scallop

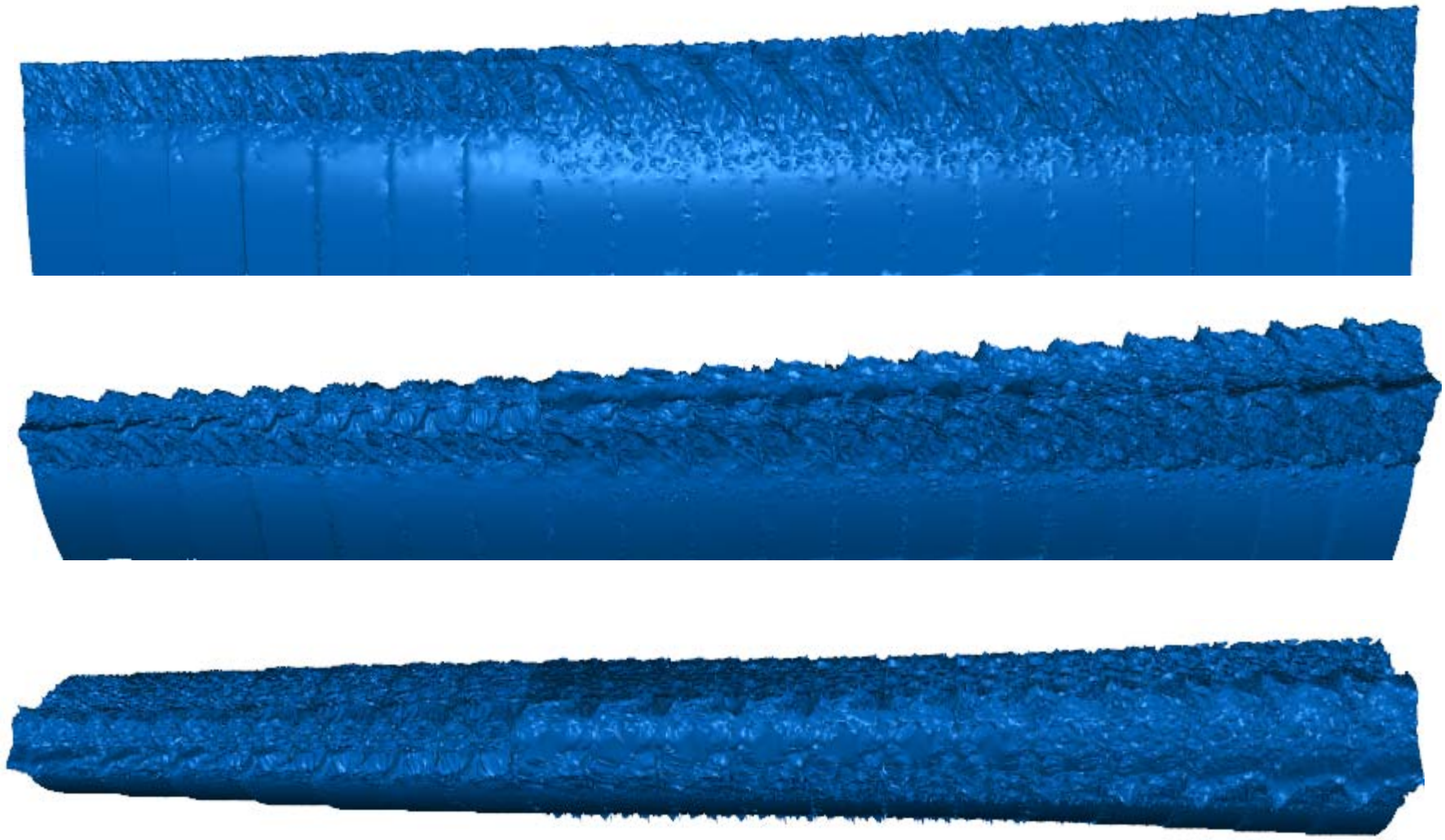


Horn With Twist



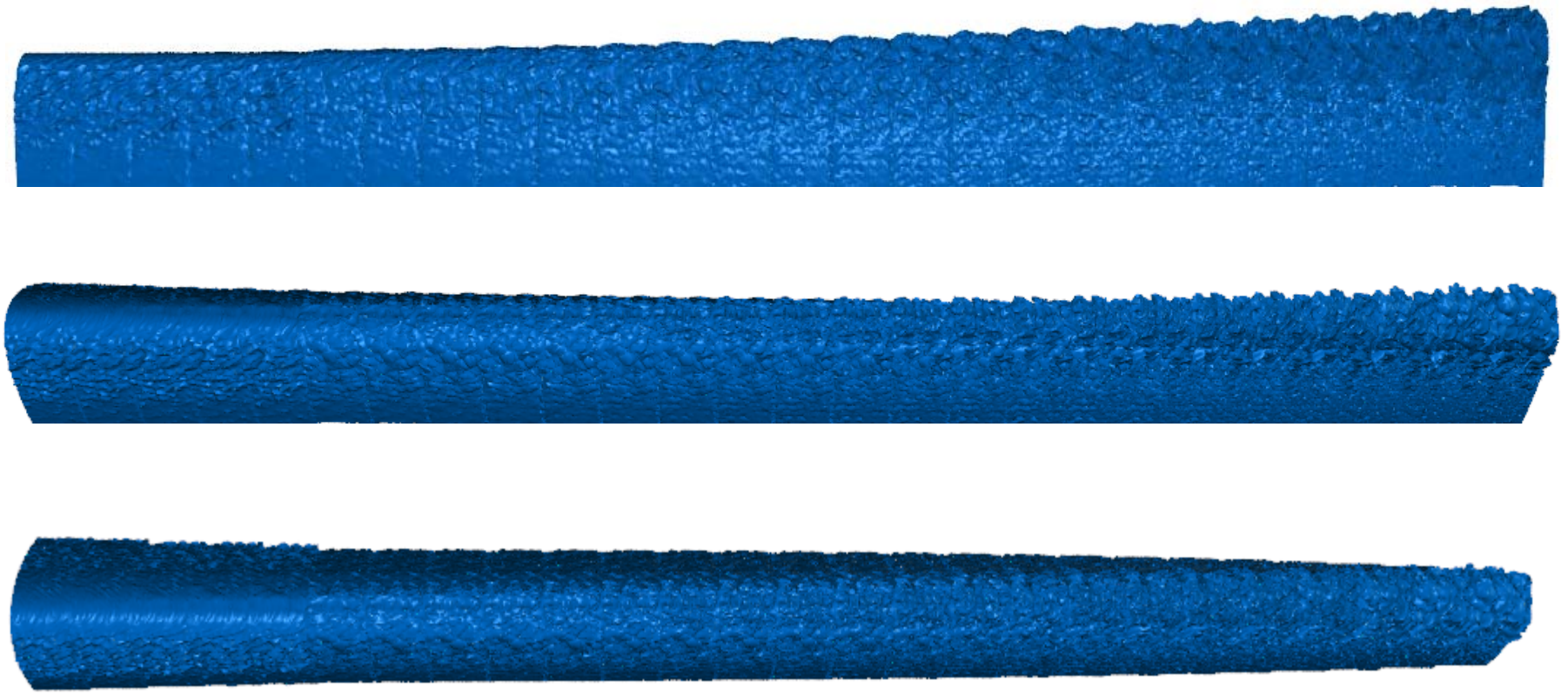
5° twist

Horn With Taper



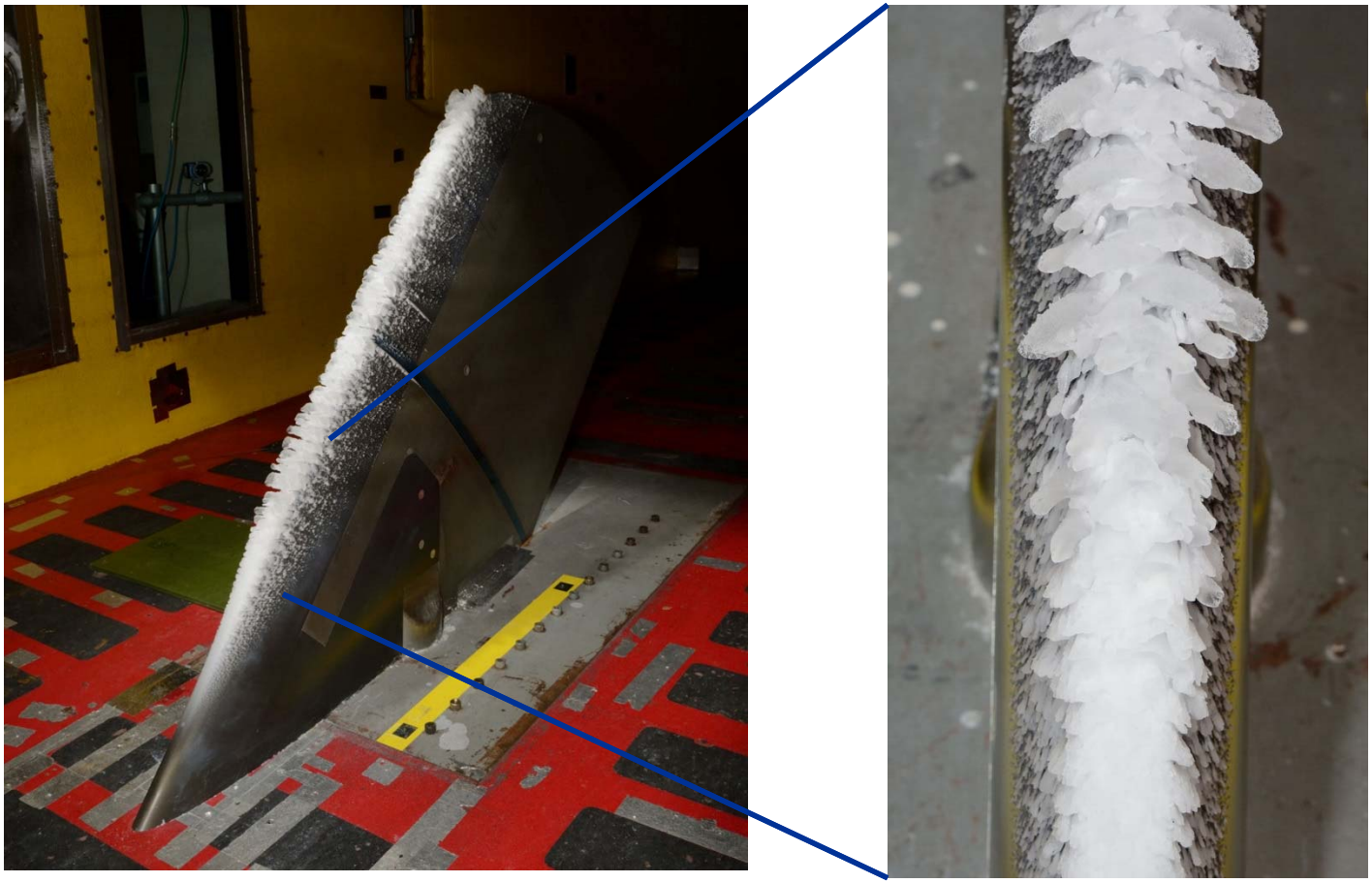
0.5 scale taper

Rime to Scallop With Twist and Taper



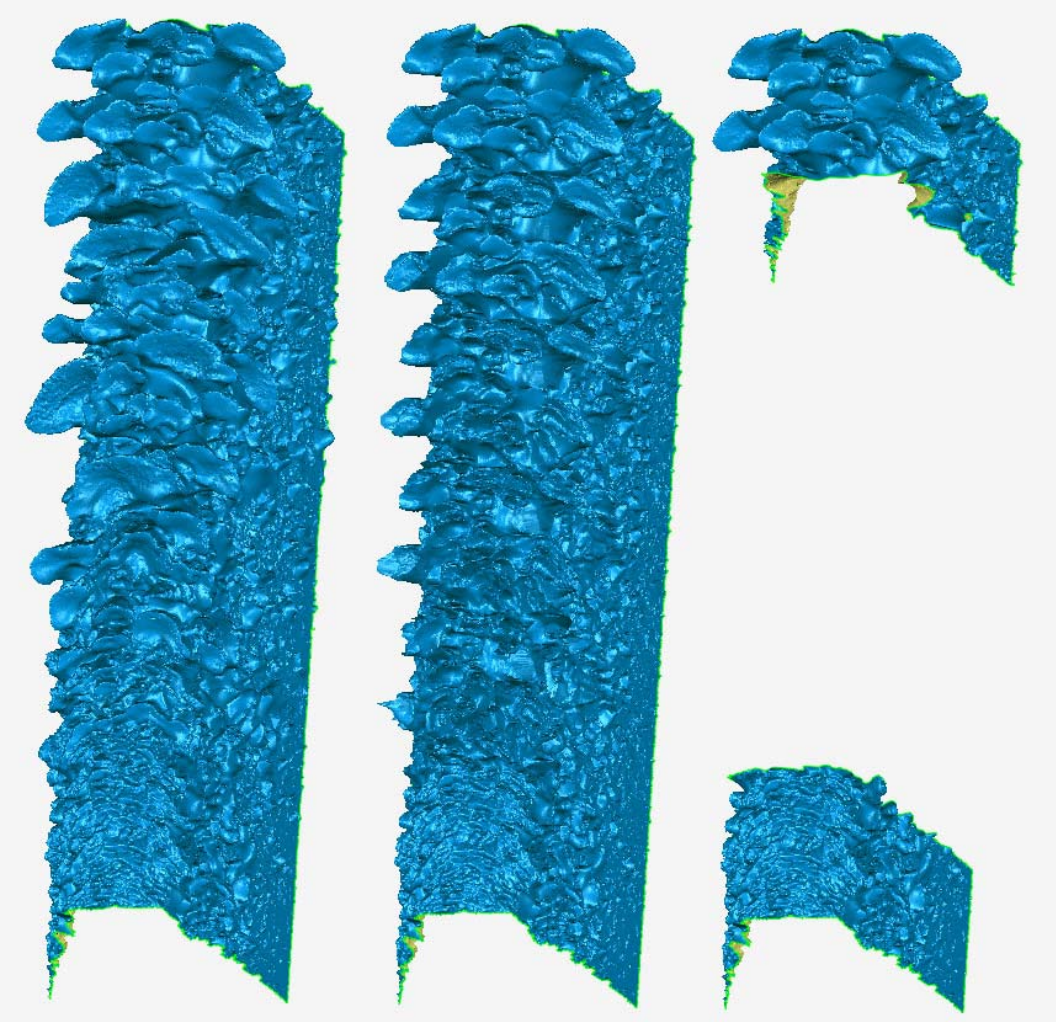
5° twist & 0.5 scale taper

Comparison of Interpolation Method to Real Ice



NACA 0012, α = 0°, Λ = 45°

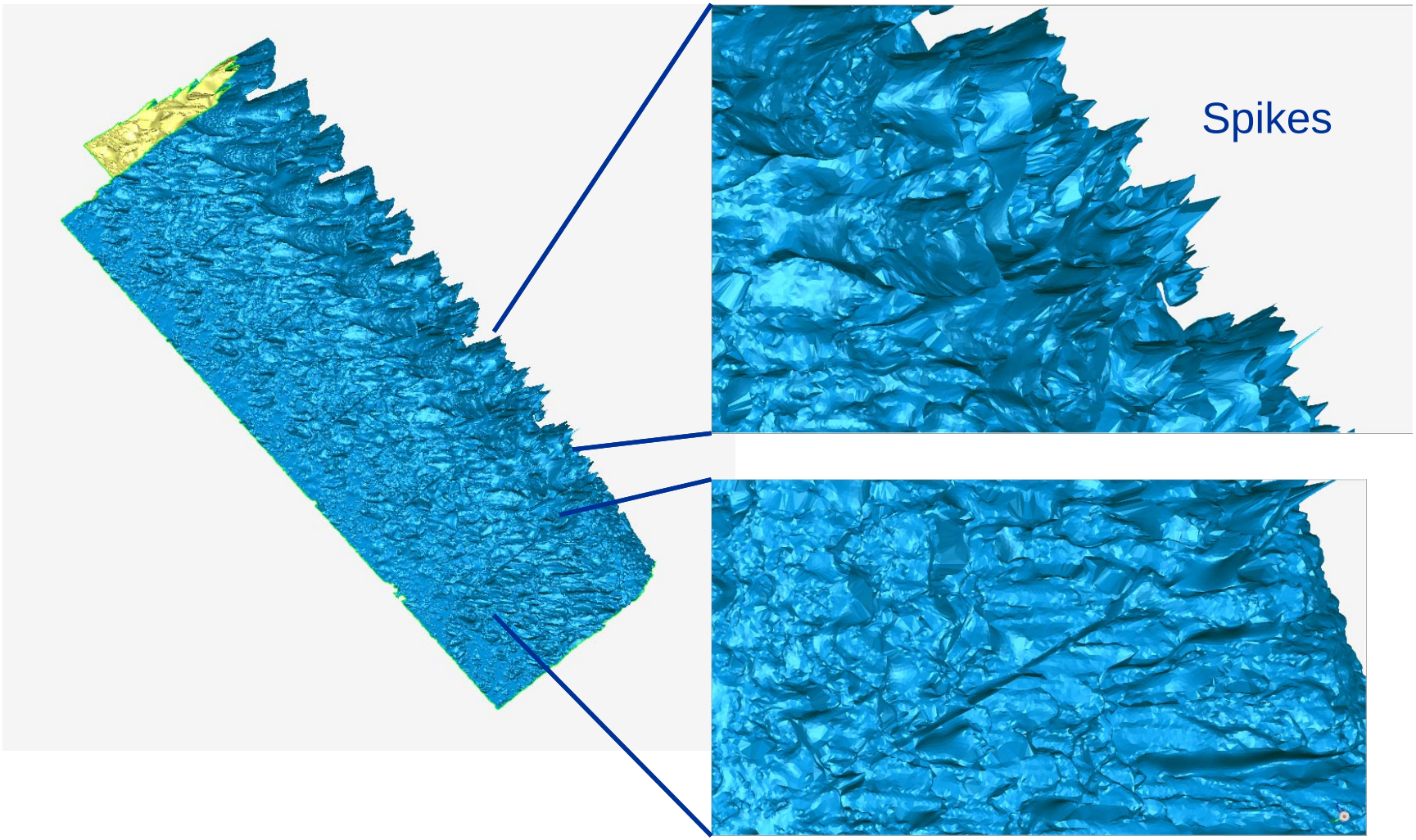
Comparison of Interpolation Method to Real Ice



Actual Ice

Interpolated Ice

Areas for Improvement



Conclusion

- Method developed to generate a full-span ice shape from partial spanwise section.
- Interpolated the ice shapes between the scanned sections using the weighted averaging function in Geomagic Studio.
- This procedure demonstrated using existing scanned ice shapes from a swept NACA 0012 airfoil.
- Initial results are promising.
- It was used to interpolate ice shapes between horn and rime shapes as well as scallop and rime shapes. This could also work with twisted and tapered wing.
- The ability to interpolate between two very different types of ice shape demonstrated.

Conclusion (cont'd)

- The resultant interpolated or "morphed" ice shape usually contains some surface artifacts, such as spikes or repeated patterns.
- These will be removed using a commercially available software called Geomagic Freeform.
- This software allows the user to hand-manipulate the interpolated ice shapes and will be used to remove these artifacts and also perform final touch-up on the ice shapes.