National Aeronautics and Space Administration

Status of 3D Ice Shape Measurement Effort

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Outline

- Introduction
- Research Plan
- Project Status
- Future Plans

Introduction

- Main goal of the Airframe Icing Technical Challenge is to achieve acceptance of experimental and computational icing simulation tools
  - Supercooled Large Droplet Icing (SLD) conditions
  - 3D airframe components including swept wings.
- It is necessary to develop suitable means of recording and archiving fully 3D descriptions of experimental ice accretion geometry.
- Past research has shown that commercial laser scanners have the potential to be adapted to this task.
- A research plan has been developed to implement and validate the use of this technology for experimental ice accretions.

Introduction (cont'd)

- Phase 1 – Identify most suitable scanning system
  - Focus specifically upon measuring ice accreted in the NASA Icing Research Tunnel (IRT).
  - Built on recent demonstration tests of portable scanners in IRT.
  - Follow-on IRT testing and demonstrations conducted to complete a down-selection process to the most promising and suitable technology.
- Phase 2 – Validation exercises to define scanning capability.
  - Calibration block
  - 2D geometric and aerodynamic comparisons
  - Swept-wing geometric comparisons

NASA Milestones

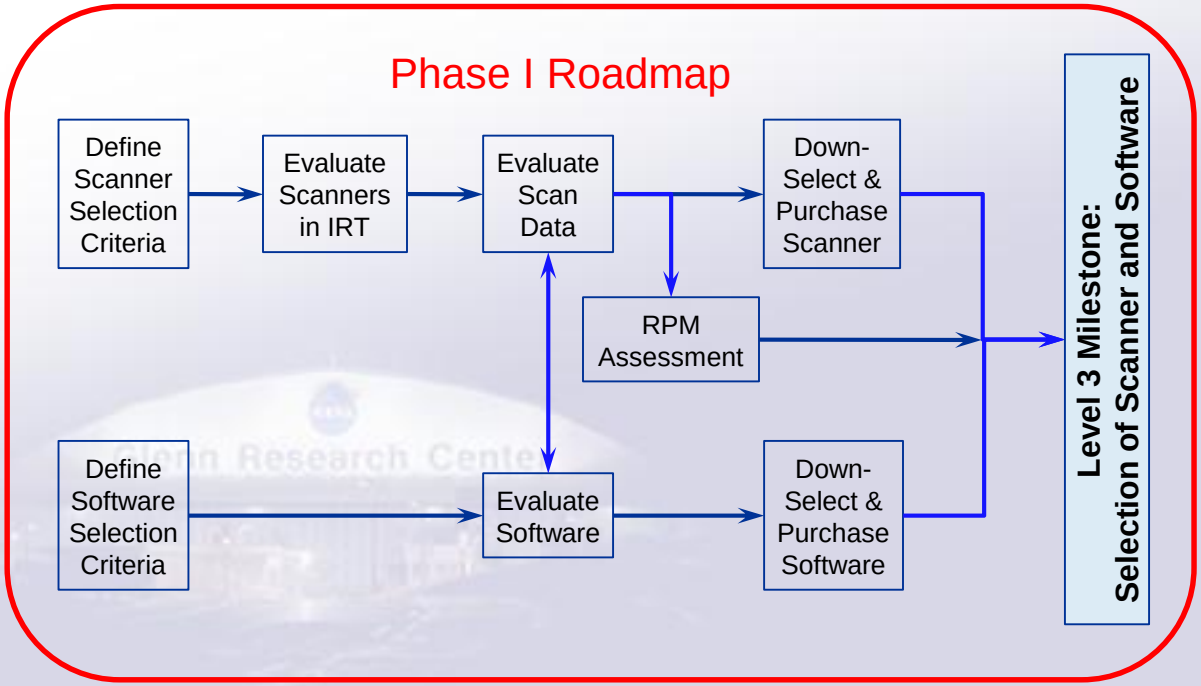
- Level 3 milestone
  - "Select Candidate Laser Scanning System"
  - Q1 FY2012
- Level 1 milestone
  - "Declare 3D Ice Accretion Measurement Capability"
  - Q4 FY2013

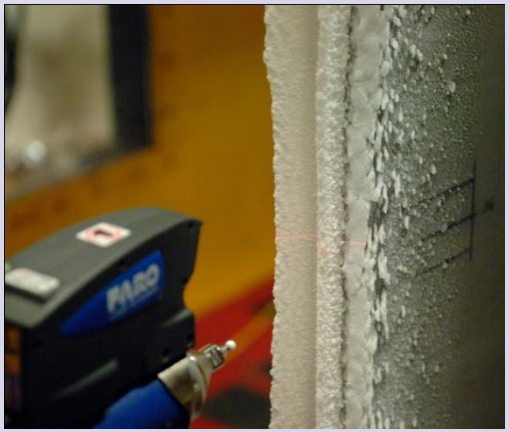
Research Plan – 1st Phase

- Evaluate candidate laser scanning system in IRT.
  - Demonstrate capability to operate in the IRT environment.
  - Evaluated on the basis of criteria having to do with operations, scanning capability/accuracy and cost.
- Evaluate candidate software used to post-process the scanner data .
  - Demonstrate ability to create “water-tight” surface.
  - Evaluated on the basis of criteria having to do with operations, efficiency, ease of use, and cost.
- Assessment of rapid-prototyping capability.
  - Scan data of ice accretion will be processed to water-tight surface.
  - Various RPM (rapid-prototype model) vendors will be contacted to ascertain the current state of capability to manufacture artificial ice shapes.

Research Plan – 1st Phase (cont'd)

- The outcome of Phase I will be a selection of both laser scanning hardware system and post-processing software.
  - This will satisfy the AEST level 3 milestone.





1st Phase Research Task

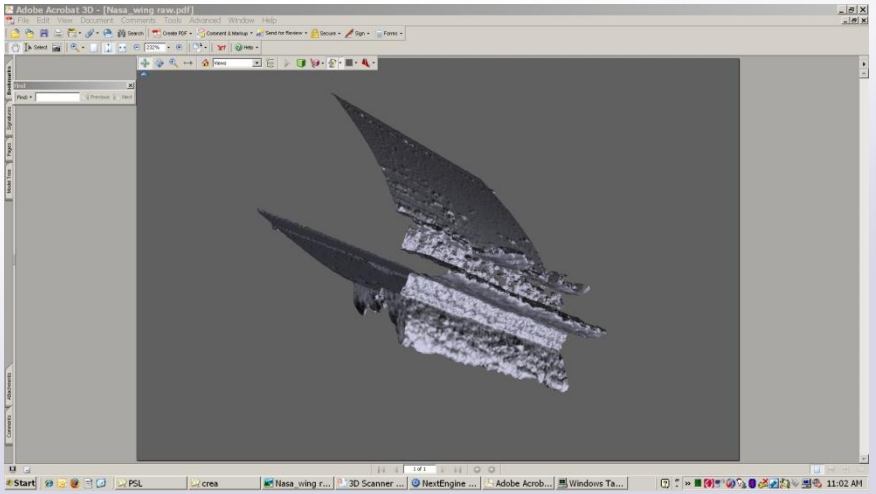
- Define evaluation/selection criteria for scanner hardware and software.
- Define specific laser scanner systems (hardware) and post-processing software to be evaluated.
- Develop test and evaluation plans.
- Evaluate candidate current laser-scanning systems in IRT.
- Evaluate candidate software systems.
- Conduct assessment of Rapid Prototype Method (RPM) capability.
- Down-select one hardware system and one software system for Phase II.
- Purchase hardware and software.

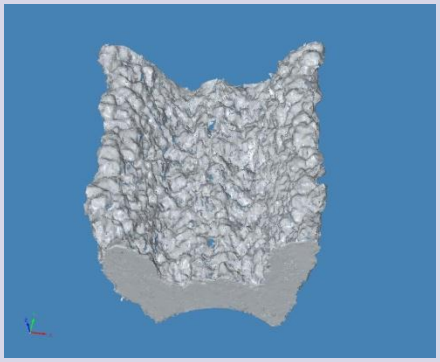
Selection Criteria - Hardware

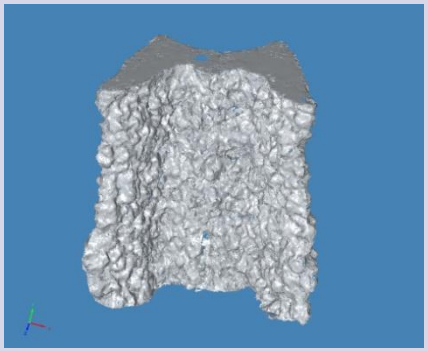
- IRT test section capability
  - Environment - operate in a wide range of IRT test section environment.
  - Usability
    - Portability
    - Ease of use.
    - Convenience of measurement procedure
- Scanning capability
  - Scan resolution
  - Scan speed
  - Ability to scan gaps and holes.
  - Accuracy
- Cost vs. capability

Selection Criteria - Software

- Scanner compatibility
- Water-tight modeling ability
- Noise filtering
- Efficiency
  - Ease of use
  - Speed
  - Processing time
  - Large file capability
- Cost vs. capability

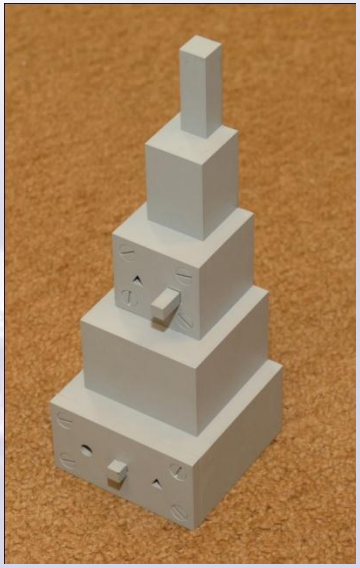


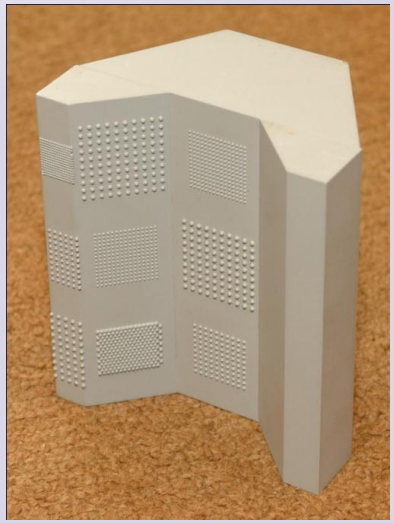




Research Plan – 2nd Phase

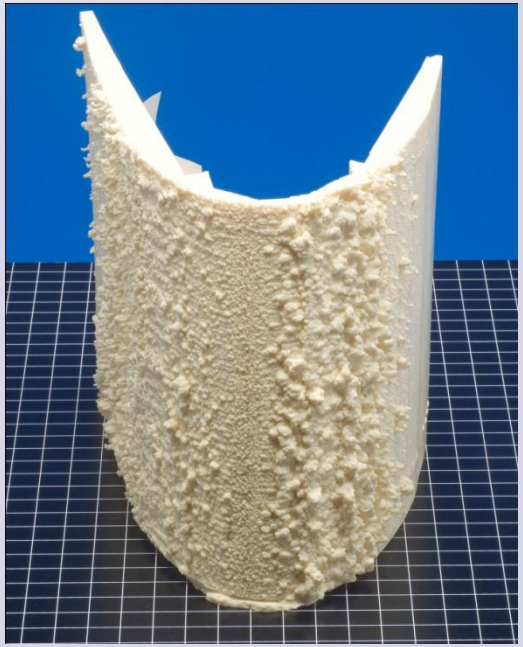
- Implementation and validation of the selected system.
- Validation exercise with known geometry to define the measurement capability.
  - Benchmark measurements performed on the metal calibration blocks.
  - These data can be used as a type of check standard to ensure uniform capability over time.





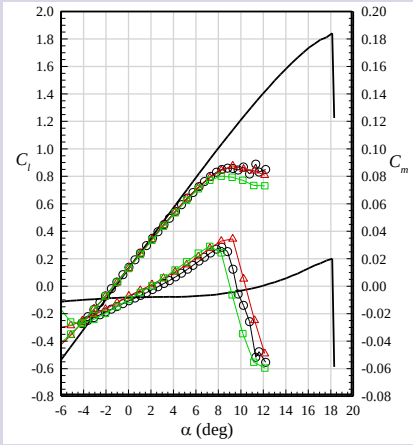
Research Plan – 2nd Phase (cont'd)

- "Circular" validation along with aerodynamic assessment based upon a 2D airfoil geometry.
  - Perform laser scans and pour molds of selected ice accretion.
  - Use scan data to create high-fidelity (RPM) artificial ice shapes along with castings from molds.
  - Compare scanned and cast geometries



Research Plan – 2nd Phase (cont'd)

- A closely related 2D aerodynamic evaluation will also be conducted
  - RPM artificial shapes made from ice scans will be tested against castings.
  - Use methods established during NASA/ONERA/UIUC Aerosim Project
  - These validations (both geometric and aerodynamic) should be conducted for each of the four basic categories of ice accretion: roughness, horn, streamwise and spanwise ridge.



Research Plan – 2nd Phase (cont'd)

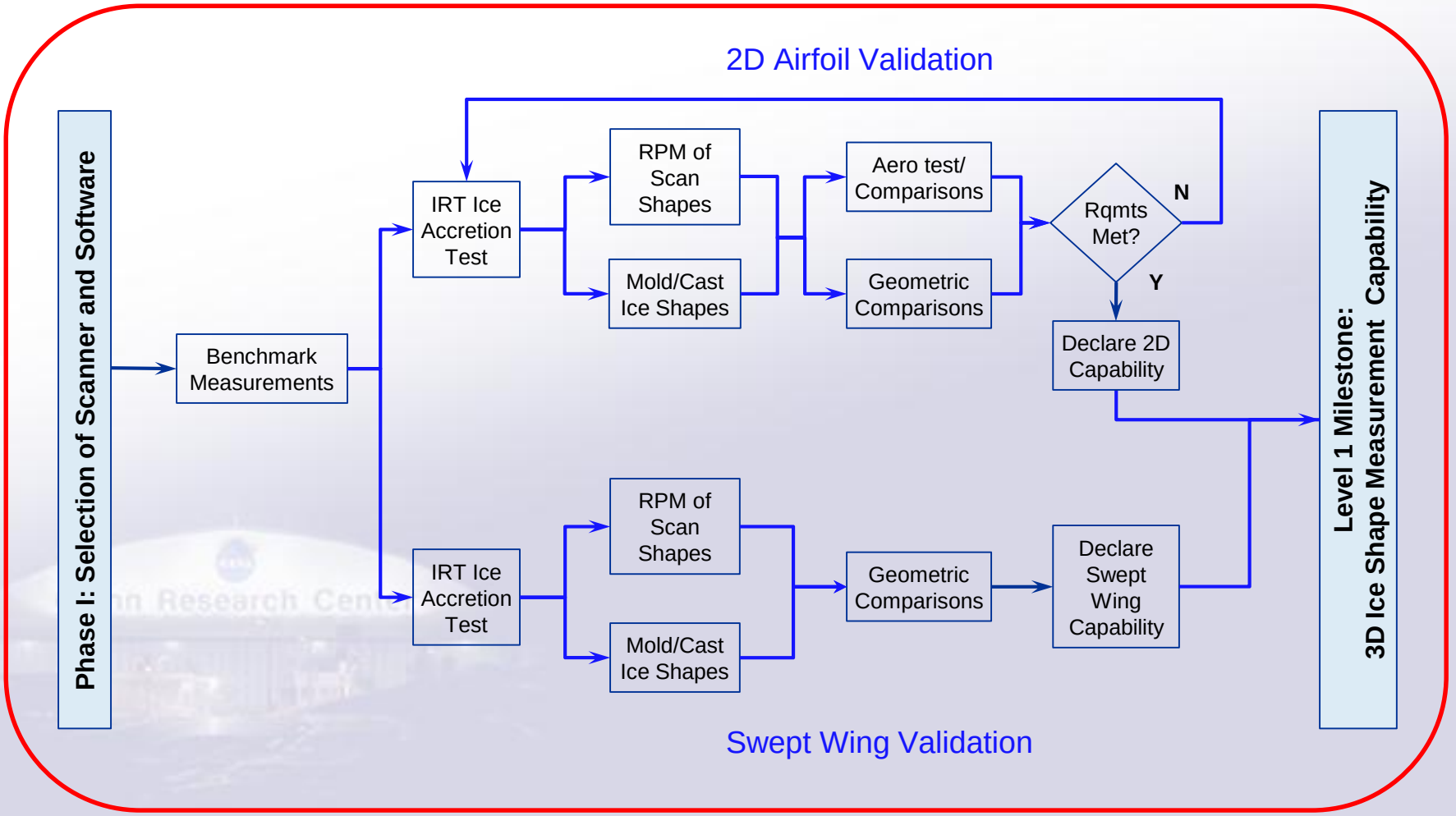
- Geometric validation test on a swept-wing model.
  - This exercise will consist of scanning an ice accretion, making a mold and casting of that ice accretion.
  - The scan data used to create an RPM artificial shape that can be scanned and compared to the original ice accretion.
  - A scan of the casting can also be compared to the original ice accretion scan.
  - Aerodynamic assessment not possible at this time due to lack of established method.

Research Plan – 2nd Phase (cont'd)

- Develop procedures for using the scanner in the IRT as well as for post-processing the data.
  - Document to serve as an internal reference guide for continued IRT testing and use of the scanner and software system.
  - Include all aspects of the measurement
    - Preparation of the ice accretion (e.g., "painting")
    - Set-up of the scanning (e.g., any in-situ calibration or homing)
    - Scanning of the ice (e.g., software settings, resolution vs. time and desired accuracy)
    - Saving of the data (e.g., file types and sizes)
    - Post-processing of the data (e.g., procedures for hole-filing, software settings, extracting tracings, etc.).
- The outcome of Phase II will be declaration of 3D ice accretion measurement capability.
  - This will satisfy the AEST level 1 milestone.

Research Plan – 2nd Phase (cont'd)

Phase II Roadmap



2nd Phase Research Tasks

- Benchmark scanner with calibration blocks
- 2D airfoil model evaluation
  - Geometry comparisons
  - Aerodynamic comparisons
- Swept wing model evaluation
  - Geometry comparisons
- Standardize methods for laser scan data acquisition and post-processing.
  - Write process description with quantifiable standards
- Declare 3D ice accretion measurement capability.
  - Satisfy AEST Level 1 milestone.

Project Status

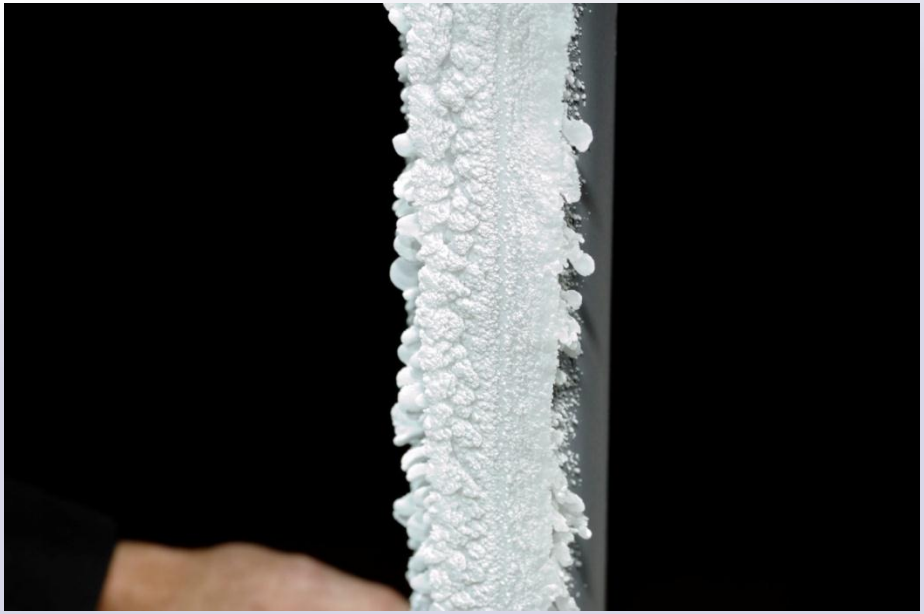
- Hardware/software selection criteria established
- Evaluated candidate scanners in IRT
  - Creaform – Oct 2009
  - Faro Arm– Nov 2009, March and April 2011
  - Romer – March 2011
  - nVision – April 2011
- Tested ice shapes from identical model and icing conditions
  - Glaze, rime, roughness on straight NACA 0012
  - Scallop ice shape on 45 deg swept NACA 0012
- Purchased software to evaluate scan data (Geomagic)

IRT Scanner Evaluation Procedure

1. Accrete ice on test article
2. Photograph ice
3. Spray paint accreted ice using airbrush
4. Install/set up laser scanner
5. Scan ice
6. Cut ice and make tracing

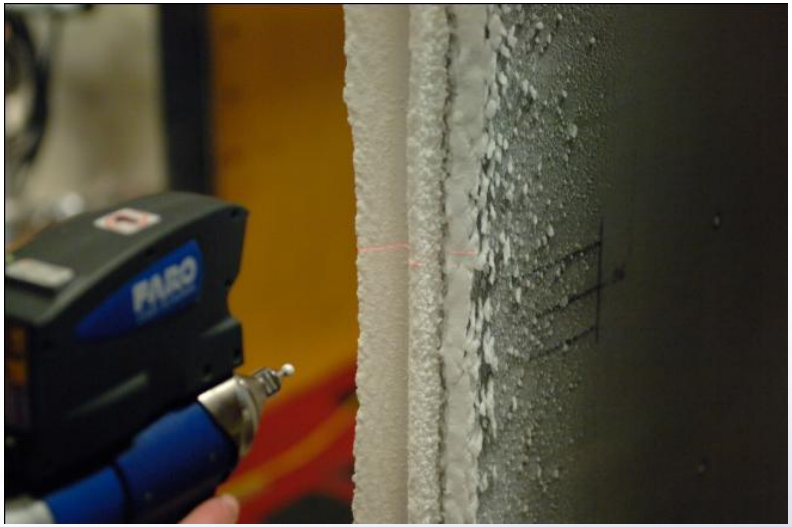
IRT Scanner Evaluation

Painting ice with air brush paint



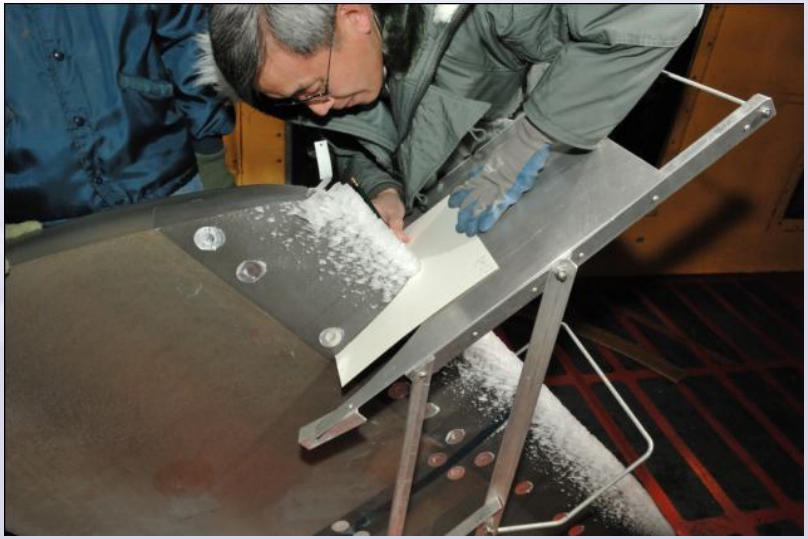
Painted ice

IRT Scanner Evaluation



Scanning ice shape with 3D scanner.

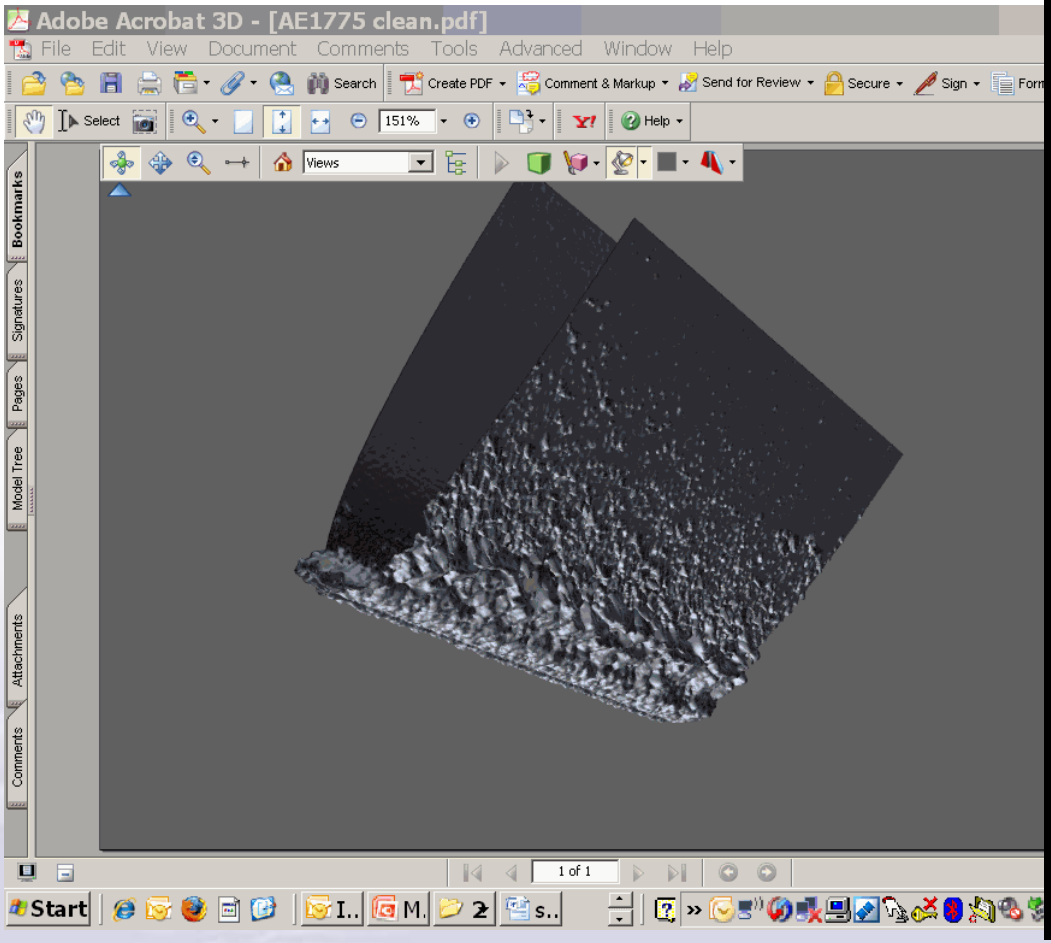
IRT Scanner Evaluation



Hand tracing of ice shapes for comparison to scanner.

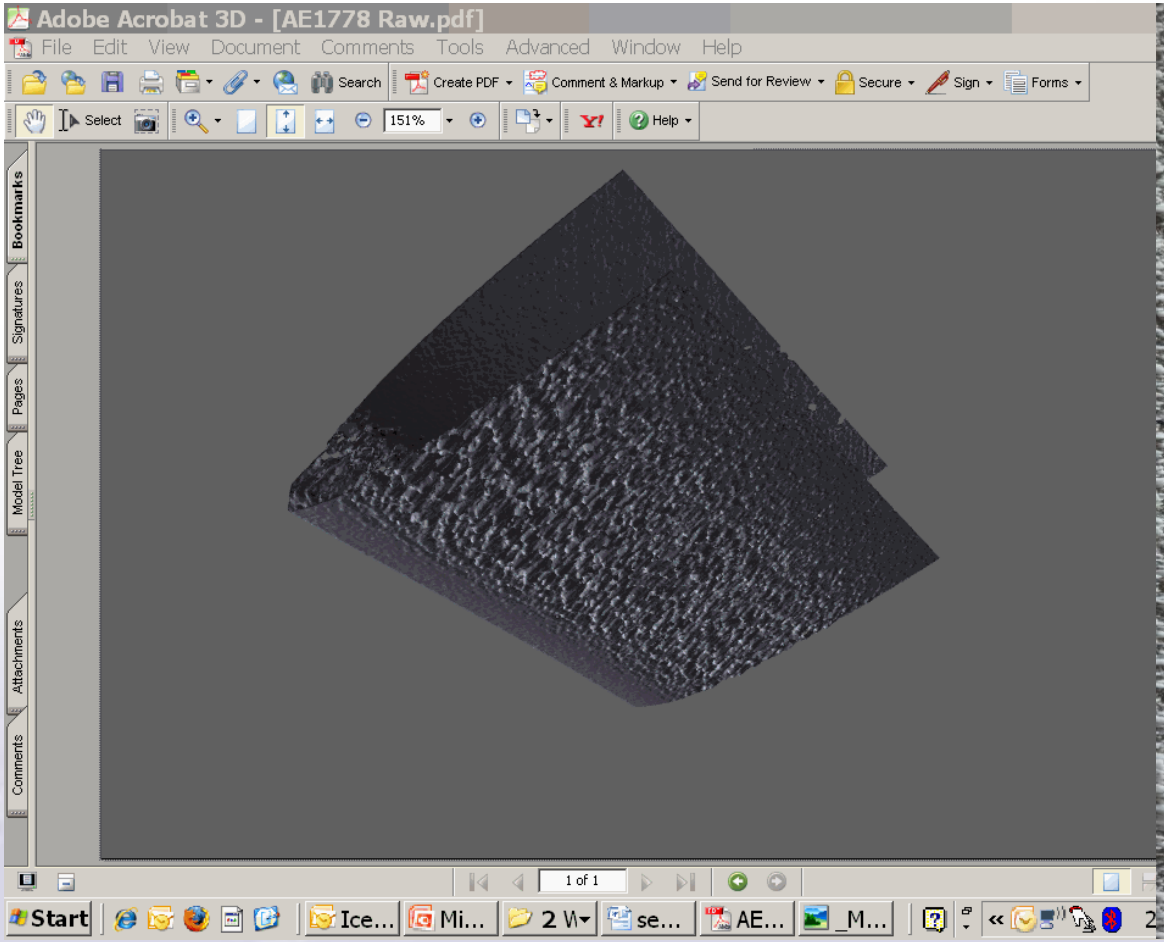
Water Tight Scanned Data

Glaze Ice



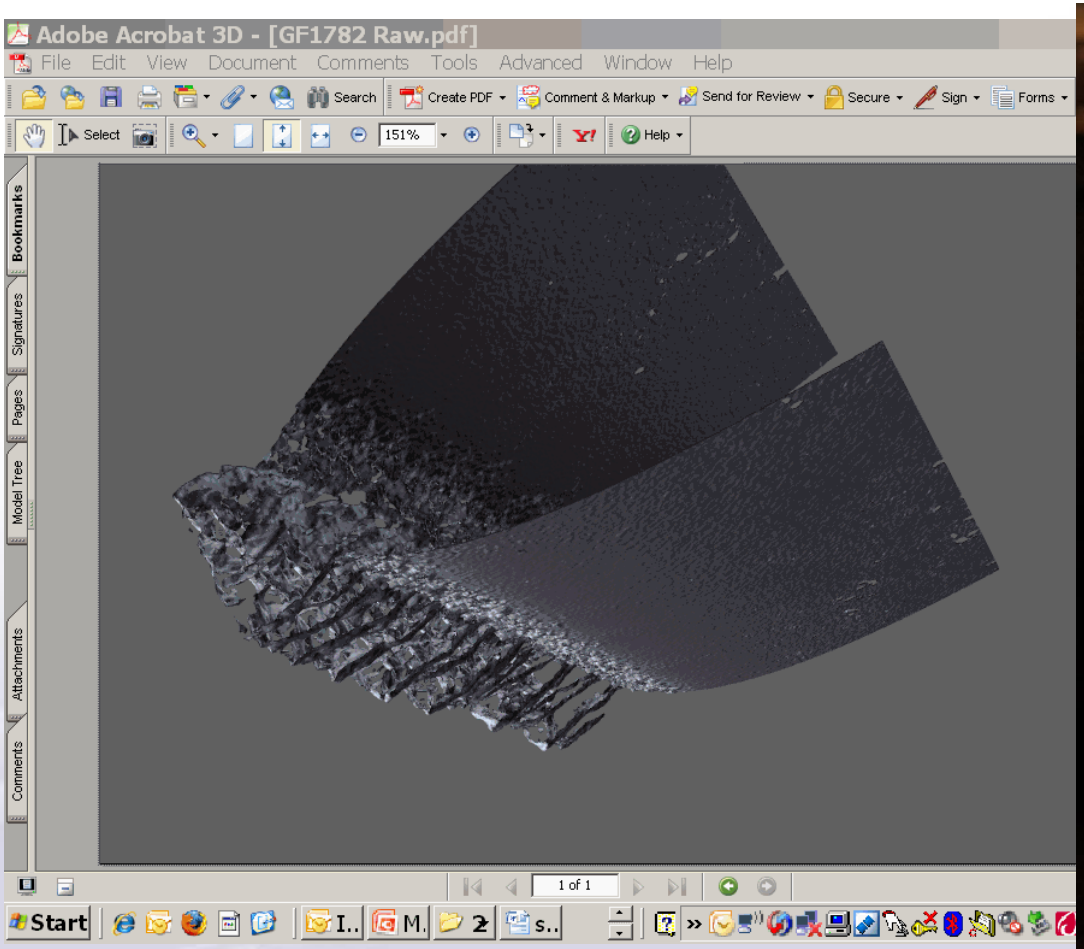
Water Tight Scanned Data

Rime ice

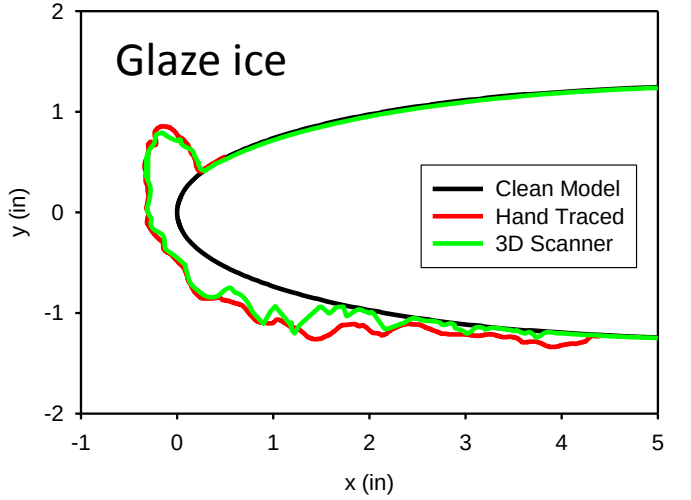


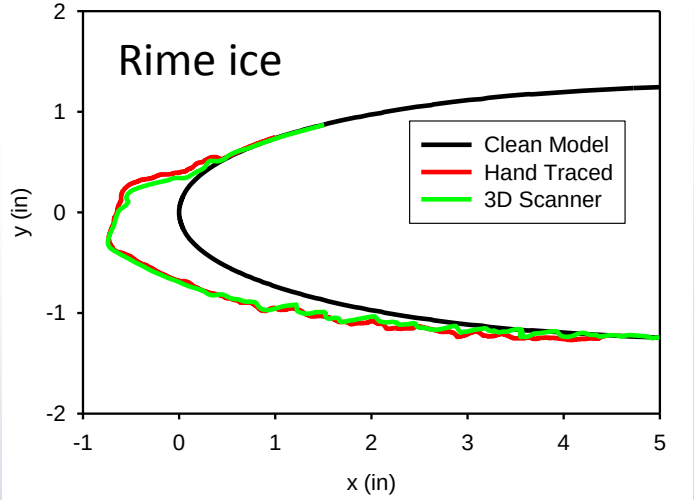
Scanned Data

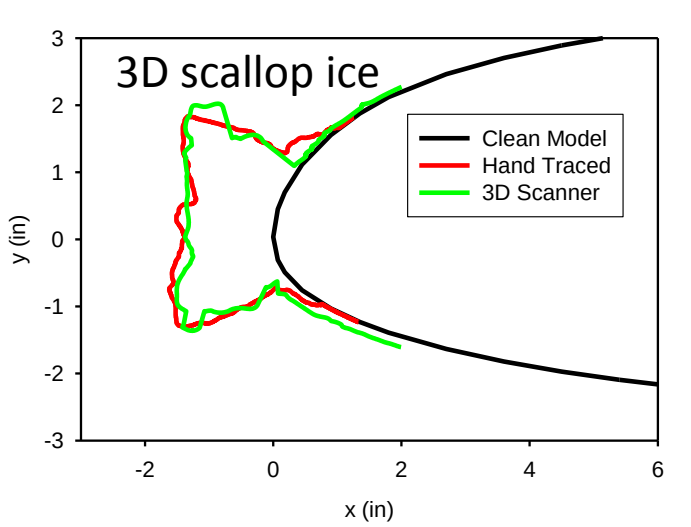
3D Scallop Ice



Comparison of 3D Scanned Data to Hand Tracing







Future Plans

- Evaluate data from candidate scanners
- Down-select and purchase scanner
  - Q1 FY2012 (L3 milestone)
- Assess and validate scanning system and methods
  - Straight and swept wing geometry
  - Compare aero results with scanned and cast ice shapes
- Declare 3D ice shape scanning capability
  - Q4 FY 2013 (L1 milestone)