NASA Icing Update

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SAE AC-9C COMMITTEE MEETING
Webex
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Contents

NASA Icing Research Tunnel Update

Early February 2021

- IRT resumed on-site work, preparing the facility to resume customer testing.
  - Included overdue facility maintenance and facility instrument calibrations.
  - Will eventually finalize with facility check calibration tests to confirm test section conditions.

Late March 2021

- Found problems with some of the relief valves in the refrigeration system that will take an extended amount of time to fix.
  - Timelines are uncertain. The IRT is currently not expected to resume any testing before August 2021.

Multiscale, Physics-Based Modeling of Impact Ice Adhesion

Background

This project was funded by NASA Research Grant and Cooperative Agreement NNX16AN20A. This represents the conclusion of a highly-collaborative effort with Mississippi State University. This research generated 3 published conference papers. The data generated can be used to guide the development of future ice adhesion and shedding models.

Problem

Currently, it is not feasible to predict the adhesive stress for an aircraft icing scenario based purely on first principles. Some type of modelling is necessary.

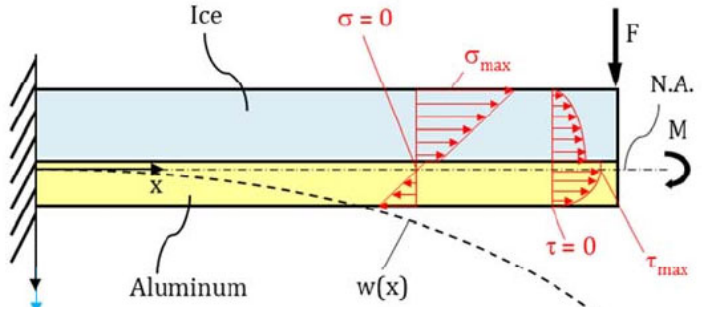
Objective

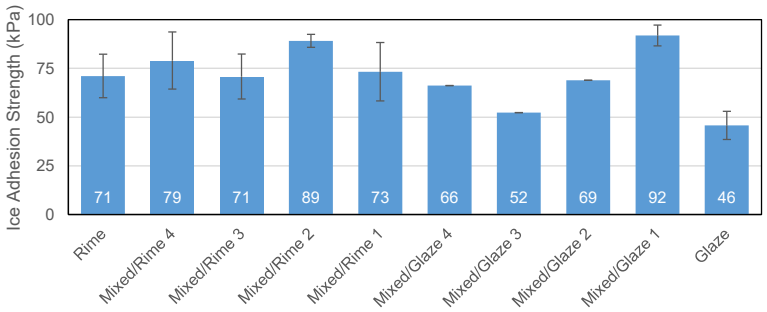
Prediction of icing mitigation on engineered surfaces using a physics-based, multiscale model for impact ice adhesion stress

- A reliable vibrating cantilever method to measure impact ice adhesion.
- A hybrid, multiscale, physics-based method to evaluate the effectiveness of a surface with respect to ice mitigation without á priori measurements given its mesoscale and nanoscale geometrical characteristics and chemical composition.

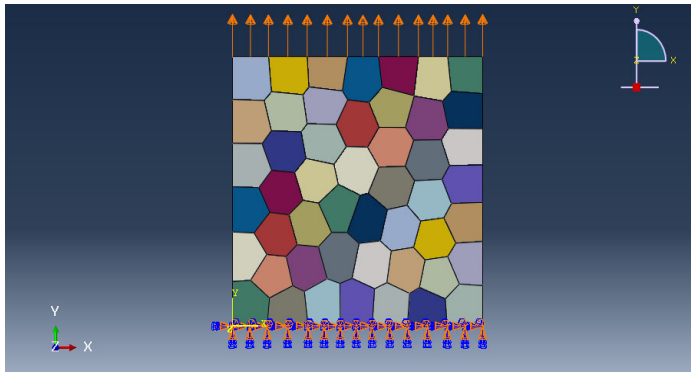
Results

- A database covering 9 surfaces in up to 10 icing conditions
- Adhesion data is highly non-linear. Machine Learning was tested and is a feasible tool to be incorporated into LEWICE in the future.
- Microscale simulations reveal molecular-level ice-substrate interfacial properties that are significantly different from bulk ice (structure, failure modes, crystallization rate).





Ice Adhesion Strength Database Stainless Steel 304



Finite Element Simulation of Ice Fracture on Substrate

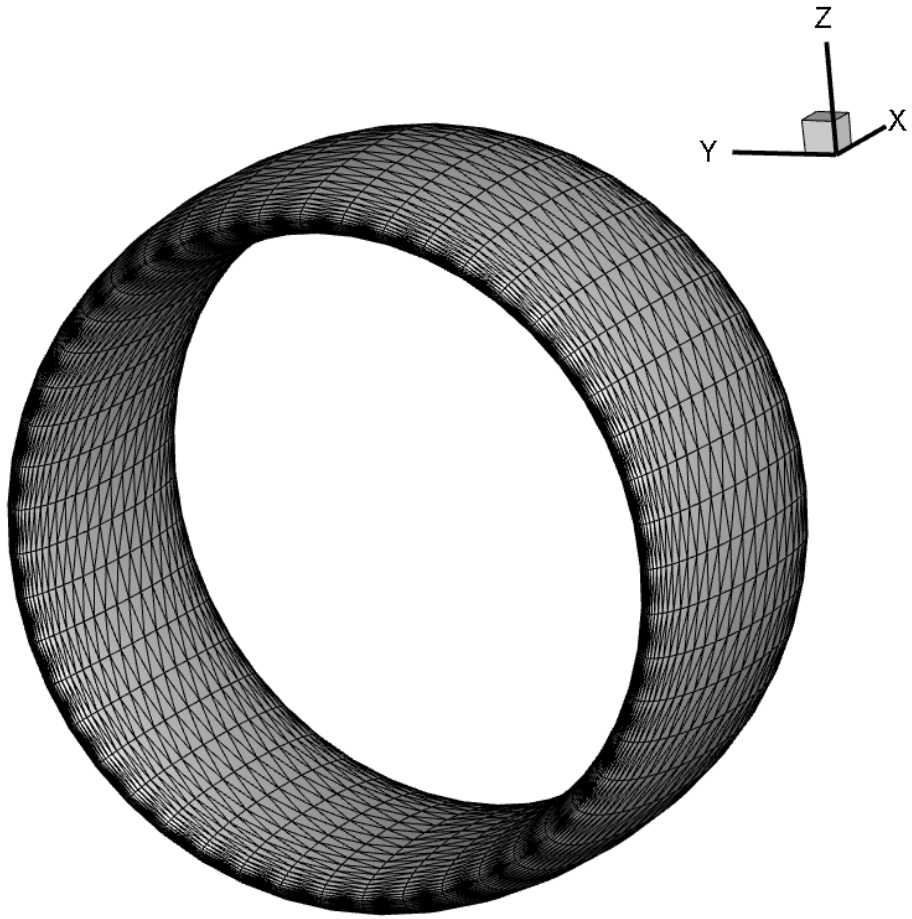
GlennICE Software Development Update
Adaptive Refinement of Drop Release Points

- Minimal user input
- Robust
  - Works for general cases
  - No knobs to turn
- Efficient
  - Release trajectories that are likely to impinge
  - Avoids release of trajectories in areas unlikely to impinge
- General
  - No algorithmic restrictions on adding points arbitrarily

GlennICE Software Development Update
Adaptive Refinement of Drop Release Points

An annular test case is utilized here to demonstrate this adaptive refinement algorithm. The geometry of the annular test case is defined as follows:

- The annulus is defined by an ellipse in the xz-plane rotated a full revolution about the x axis.
- The ellipse has coefficients a and b of 0.1 and 0.5 respectively with a center located at (0,0,1).
- The semi-major axis is in the x direction and the semi-minor axis is in the z direction.

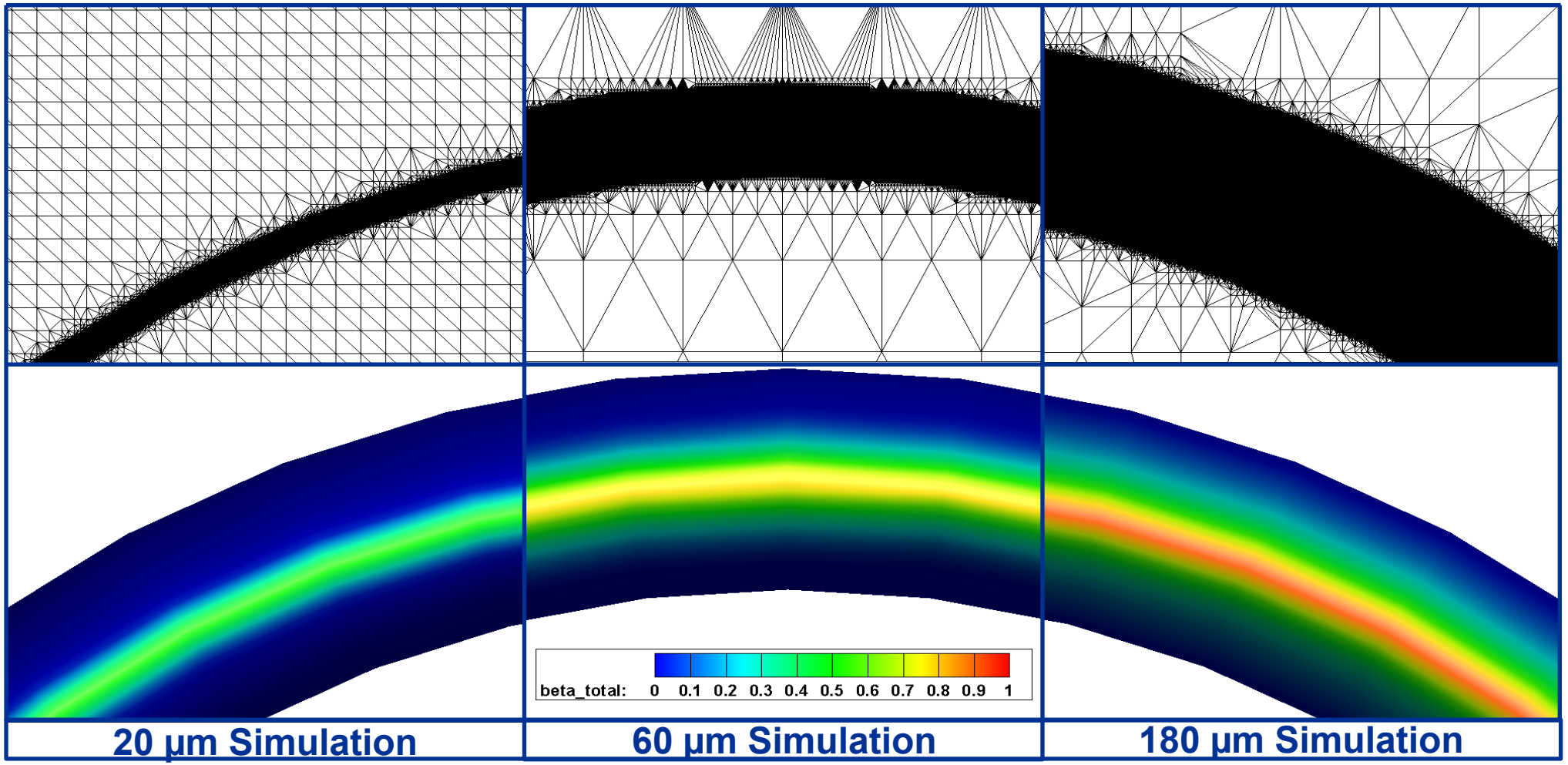


GlennICE Software Development Update

Adaptive Refinement of Drop Release Points

Drop Release Locations

Collection Efficiency Profiles



Larger Drops > Greater Impingement > More Trajectories

Ice Crystal Icing Research

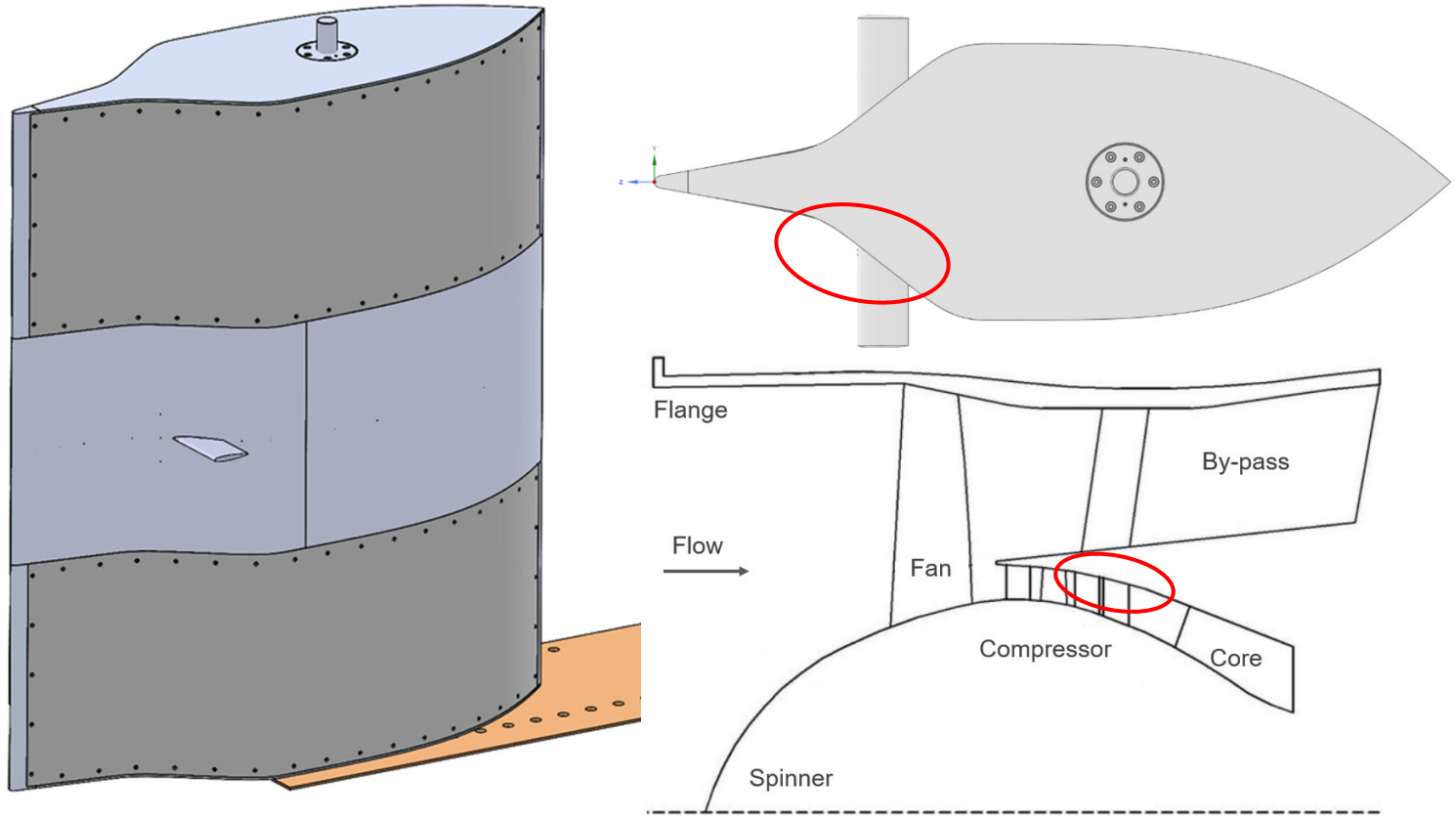
Engine Icing Physics and Validation Data

Past

- A variety of engines were simulated in the Propulsion Systems Laboratory
- Produced useful qualitative data
- Fundamental tests on NACA0012

Present & Future

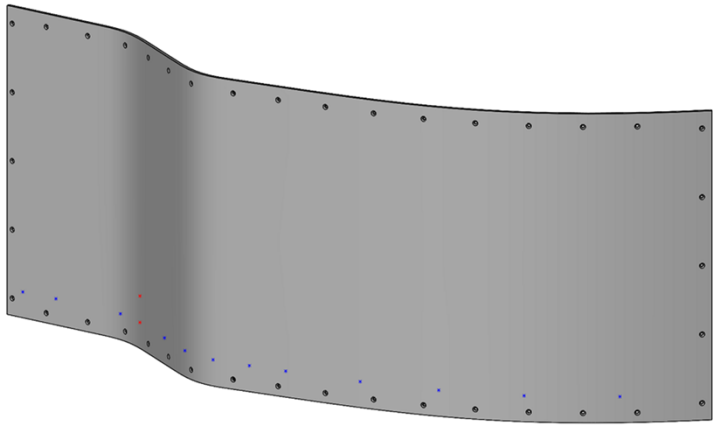
- Focus is shifting towards: *"How do we obtain relevant quantitative data?"*
- In a facility that is easy to access!
- This data is necessary for tool validation.



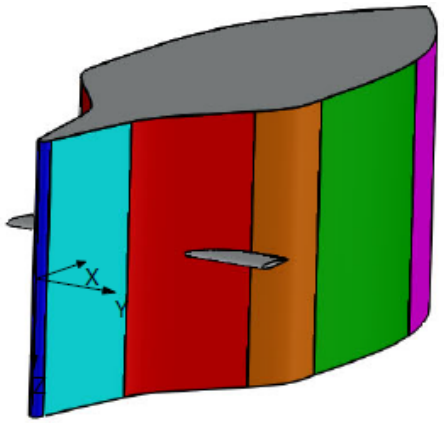
Component test concept for use in the Icing Research Tunnel at NASA Glenn Research Center.

Ice Crystal Icing Research

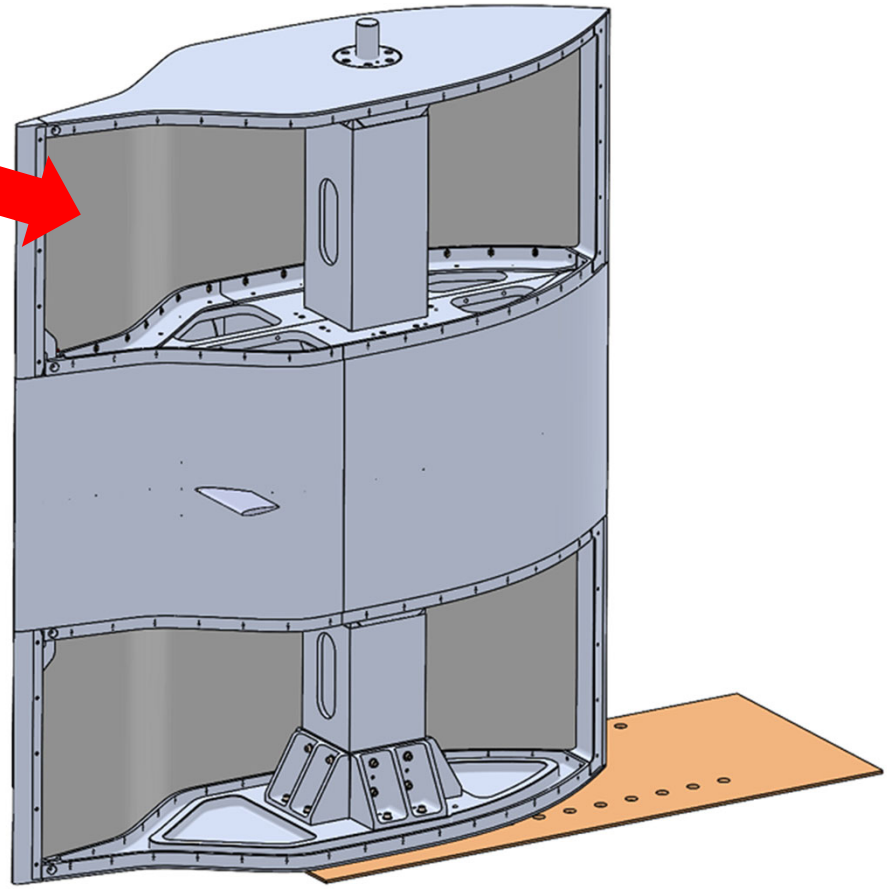
Engine Icing Physics and Validation Data



Unheated composite skin



Heater zones within aluminum center section

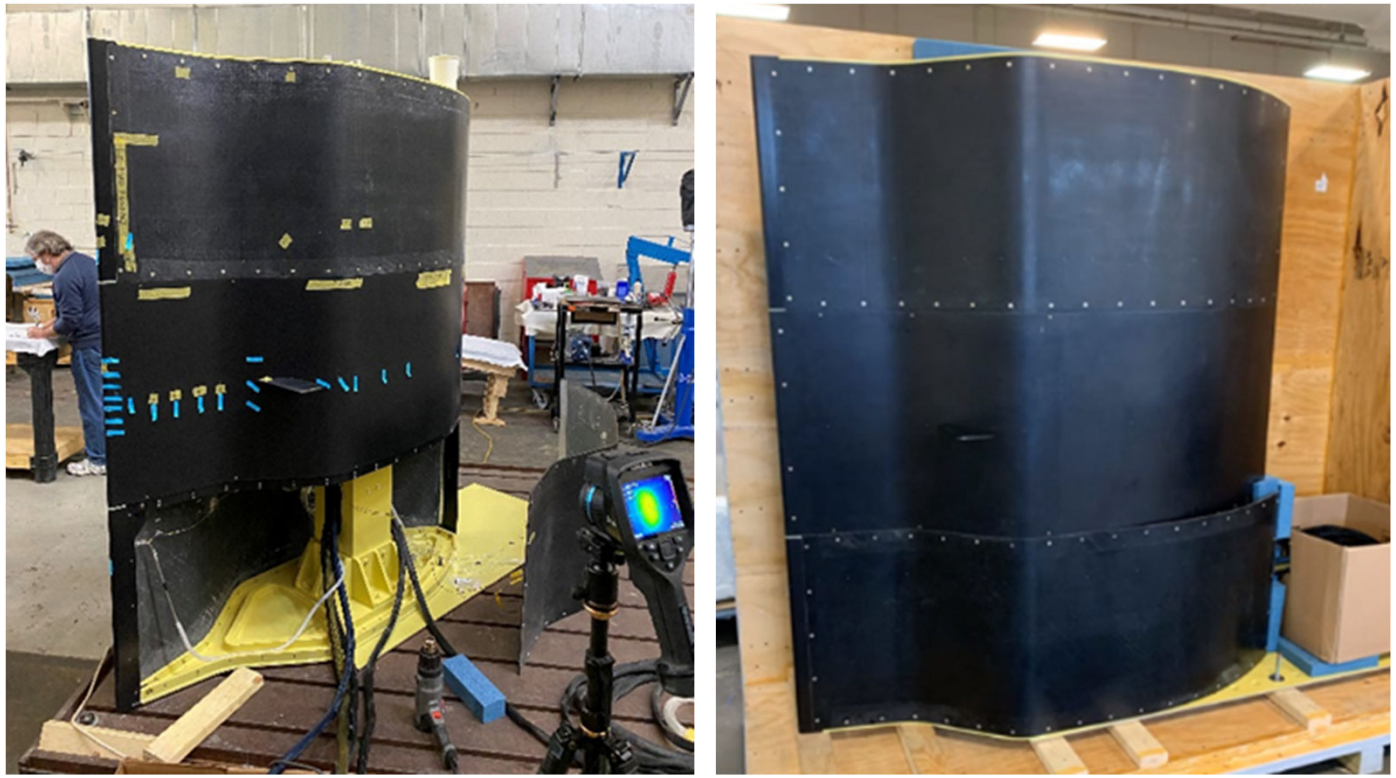


Ice Crystal Icing Research

Engine Icing Physics and Validation Data

Test Objectives

- Measurements on a shape representative of compressor duct outer wall and strut
- Data from supercooled water and ice crystal clouds in the IRT
- Embedded heaters used to enable ice growth from impact of ice crystals on the surface
- Ice shape measurements
- Ice mass measurements
- Temperature and heat flux measurements

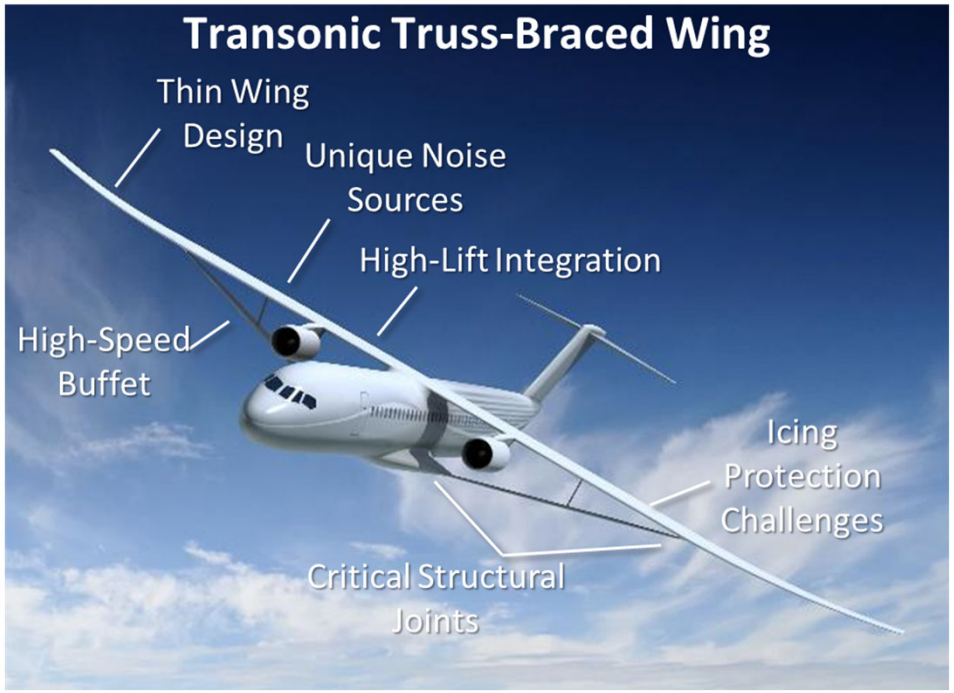


Component test concept for use in the Icing Research Tunnel at NASA Glenn Research Center.

Icing Risk Mitigation for Advanced Aircraft Configurations - TTBW

Objective

- Provide a validated capability to determine the impact of ice accretion on the Transonic Truss Braced Wing aircraft
- Reduce conservatism while maintaining safe operation in an icing encounter
- Identify potential impact of ice protection system on fuel burn objective
- Develop potential materials that are both durable and icephobic



Approach

A three-pronged approach is proposed to assess and reduce the risk to operation of the TTBW when in an icing encounter.

1) Ice accretion prediction and validation database

2) Impact of ice accretion on TTBW performance

- Validated icing risk assessment for Transonic Truss Braced Wing configuration
- Database of relevant ice shapes and performance impact
- Capability to accurately assess icing certification issues
- **Provide input data for determination of impact on fuel burn**

3) Development of icephobic materials for mitigation

- Reduced ice adhesion strength on non-heated surfaces
- Reduction of energy required for deicing/anti-icing equipment
- **Potential for low power, reduced weight mitigation solution**