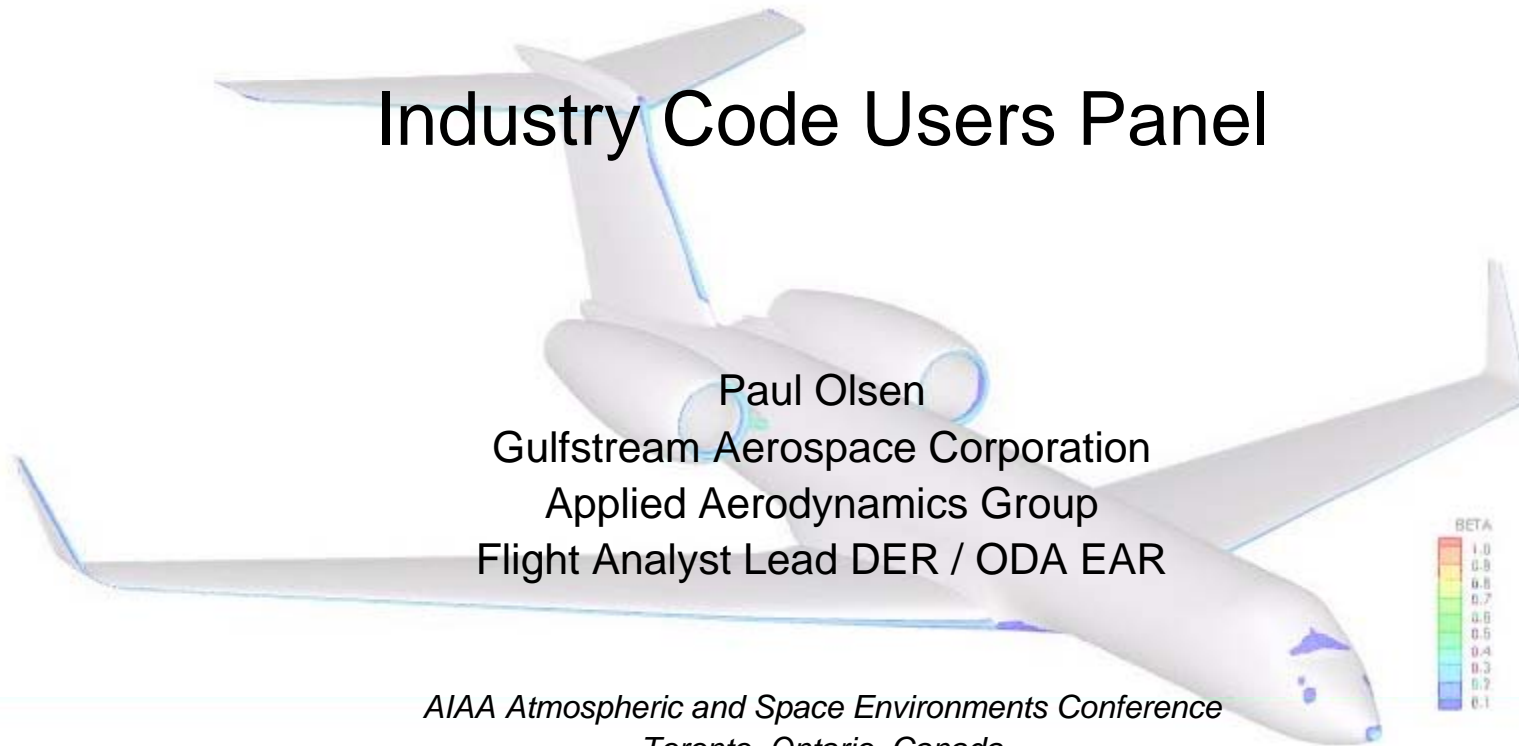


3D Ice Accretion Code Workshop

Industry Code Users Panel



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*AIAA Atmospheric and Space Environments Conference
Toronto, Ontario, Canada
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Overview

- Current Use of 3D Icing Codes at Gulfstream
- Issues of Code Acceptance
- Code Validation Experience
- Support of Studies and Working Groups

Gulfstream Uses NASA's LEWICE3D & TRAJMC3D

- *Protected Surface Icing / Ice Protection System Design & Certification*
 - Impingement limits
 - Water collection rates
 - Pre-activation ice shapes for dry air flight test
 - Failure ice shapes for dry air flight test
(No capability for runback ice shapes)

Current Use of LEWICE3D/TRAJMC3D at Gulfstream

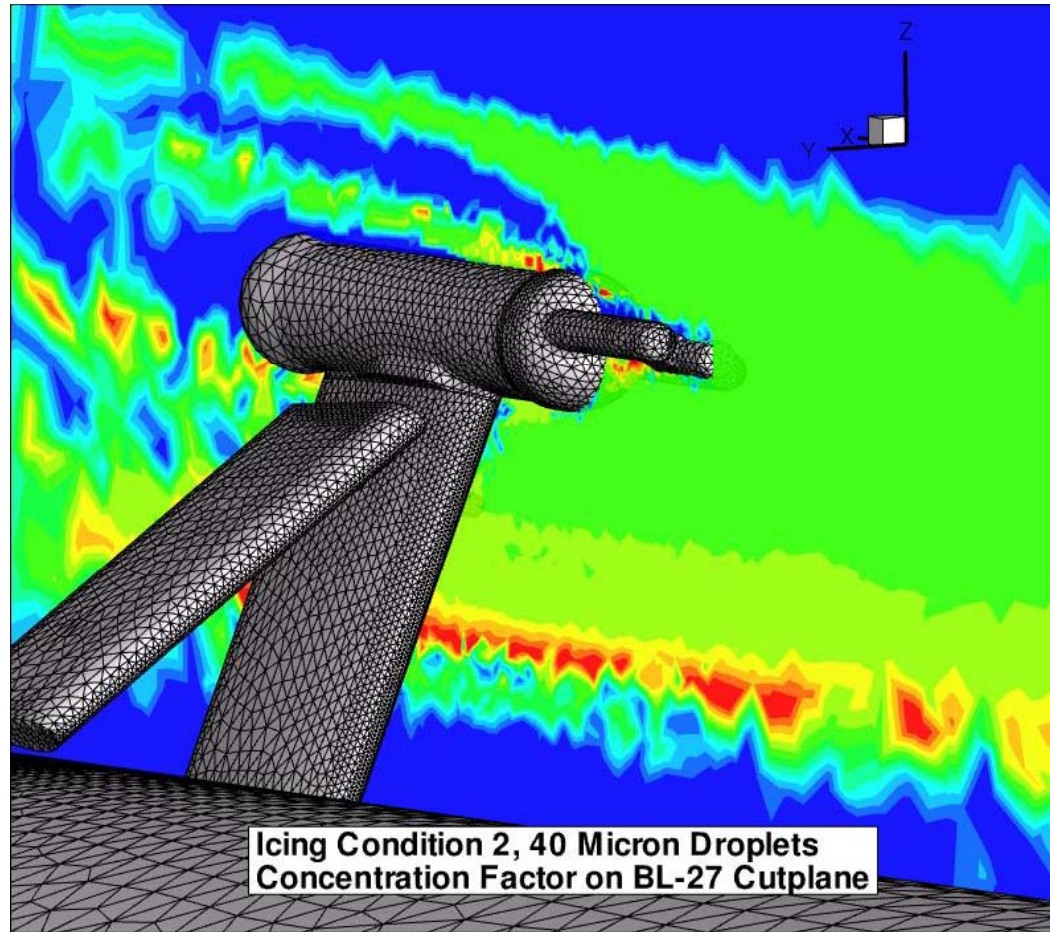
- *Unprotected Lifting Surface Icing & Cert.*
(Note: Gulfstream Winglet/Vertical/Horizontal Stabs unprotected)
 - Critical (maximum) ice shapes for tunnel and dry air flight testing.
 - Determining likely accumulation of ice for flutter analysis and certification.

Current Use of LEWICE3D/TRAJMC3D at Gulfstream

– *Unprotected Non-Lifting Surface Icing & Cert.*

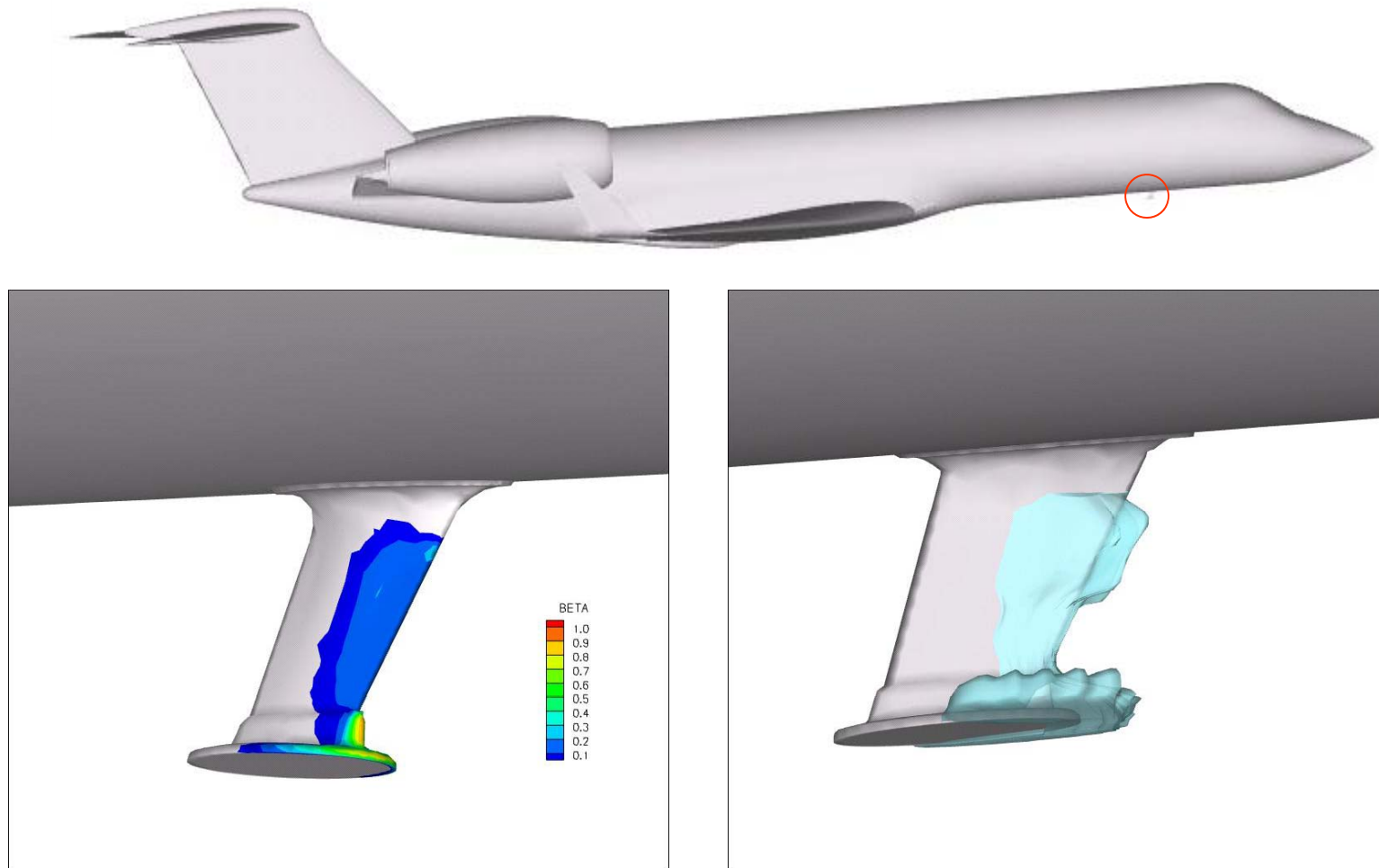
- Impingement studies for ice detector location.
- Water droplet concentration in flowfield.
- Radome and fairing ice shapes.
- Antenna, camera, probe & mast ice shapes.
- Inlet ice shapes.
- Special modification ice shapes:
 - Fuselage radomes & fairings
 - Wing stores
 - Large Probes

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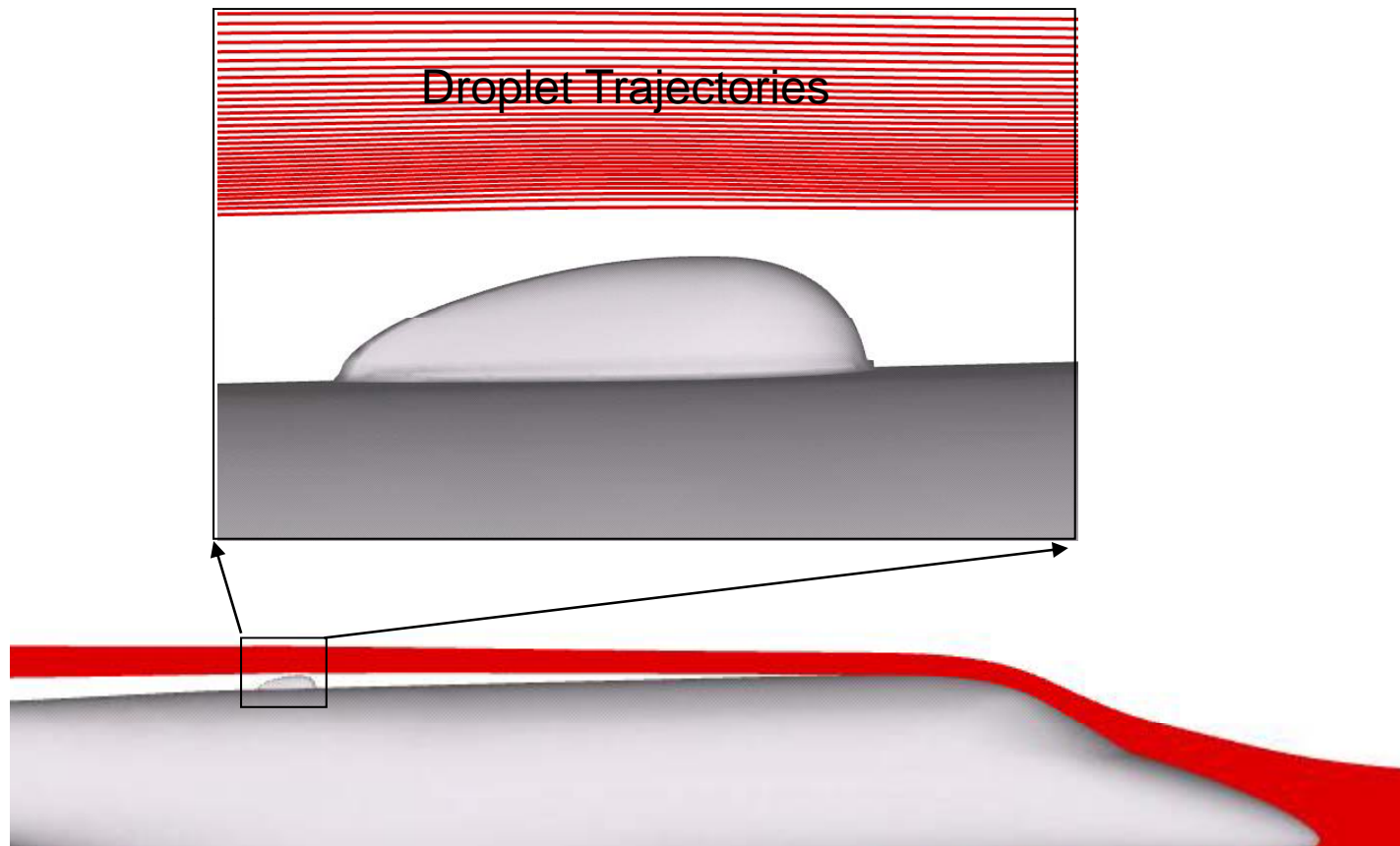
Example: Water Droplet Concentration for Large Probe Location Study

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Example: Antenna Icing

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Example: Antenna Icing, Shadow Zone

Issues of Code Acceptance – TRAJMC3D

- NASA Glenn, Colin Bidwell have greatly improved LEWICE3D over the years.
- Tremendous simplification in use of code.
- Much easier to obtain good results.
- Fantastic level of support and effort.
- Code is updated and improved continuously.
- GAC deeply appreciates NASA's work.
- Acceptance issues are minor.

Issues of Code Acceptance – TRAJMC3D

– 2D cutplane selection on nonlifting surfaces

- Ice shapes change slightly with cutplane selection.
- Best shapes generated from streamwise cutplanes.
- Procedure differs from lifting surface method (Cuts must be normal to LE. Produce ice growth in unrealistic direction).
- Radial cuts vs parallel cuts, choice not always obvious.
- Possible to automate process?

Issues of Code Acceptance – TRAJMC3D

– Variable density model (ice shape scaling)

- Code scales up ice shapes to account for voids and air gaps in 3D accretions
- Resulting ice shapes were scaled too large, based on Gulfstream natural icing flight data.
- Pre-activation sandpaper shapes should not be scaled (no void fractions), variable density turned off.
- Questions on applicability of variable density model for non-lifting & unswept surfaces.

Issues of Code Acceptance – TRAJMC3D

– Use of Flow Solution Temperature Distribution

- LEWICE3D originally calculated temps from edge velocities and Karman-Tsein relationship.
- This produced good lifting surface ice shapes.
- TRAJMC3D allowed use of NS code temps, more accurate at higher Mach, but too much runback at low Mach typical of max accretion conditions.
- Option to revert to LEWICE3D model was selected to avoid problems.

Issues of Code Acceptance – TRAJMC3D

- Postprocessing 3D shapes from 2D cuts
 - Some artistic license required.
 - Deleting odd standout points in adjacent cuts.
 - Resulting ice shape faceted by no. of cuts.
 - Validity of smoothing faceted ice shape.
 - Possible to automate 3D shape generation similar to current Rime Surface output?

Issues of Code Acceptance – TRAJMC3D

– Users Manual

- Manual needs updating.
- Provide comprehensive description of namelist inputs.
- Several new inputs not documented.

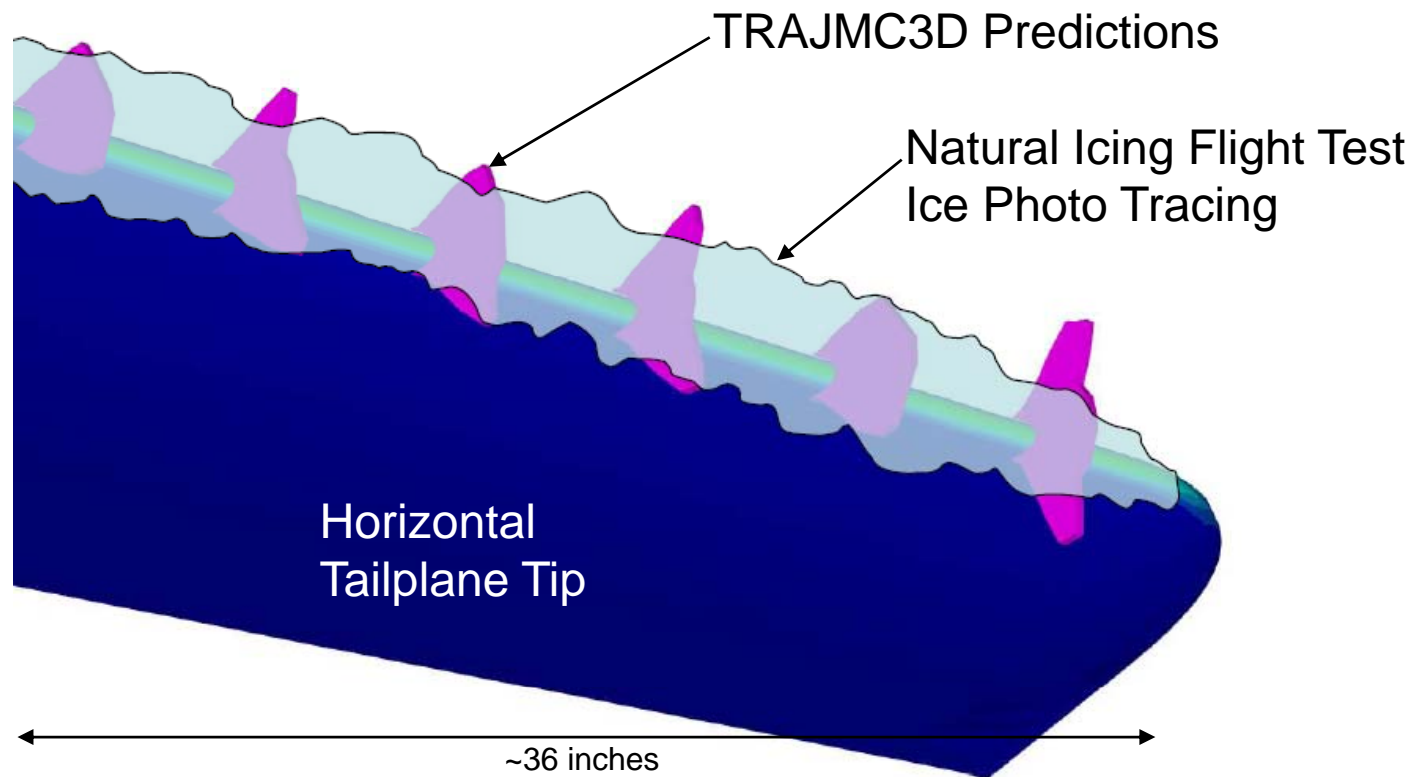
Issues of Code Acceptance – TRAJMC3D

– Metric Units

- Most US airplane companies use English units.
- Aircraft use English units (Altitude in feet, speeds in knots, etc).
- NASA codes are only available within US, where English units prevail.
- Metric unit usage introduces potential for input errors.
- LEWICE should have a toggle for English/metric units, or eliminate metric units altogether.

Validation Experience

- Previous flight validation, GV natural icing flight testing
- Example of close match to 60 min horizontal tail ice shape:



Validation Experience

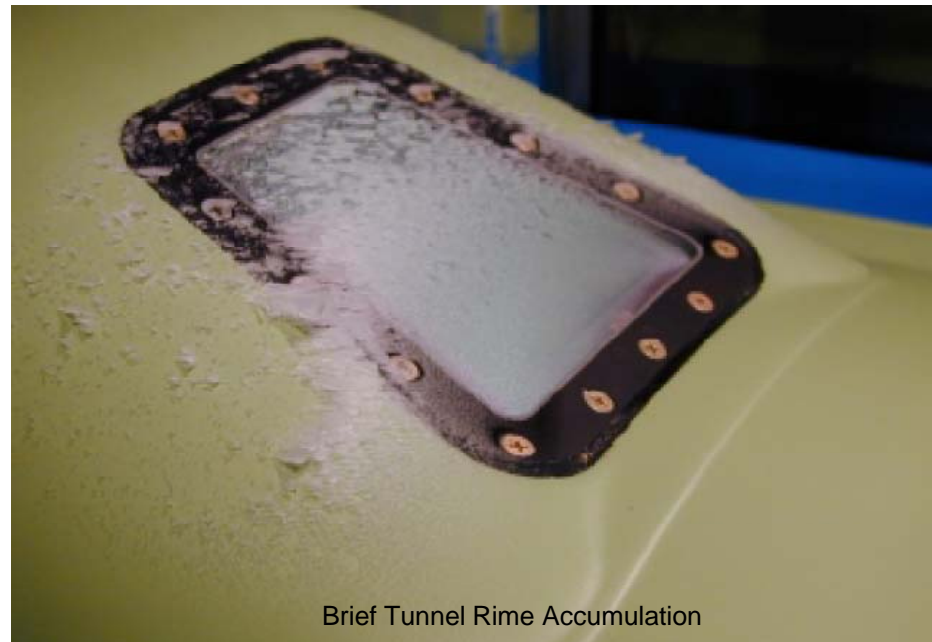
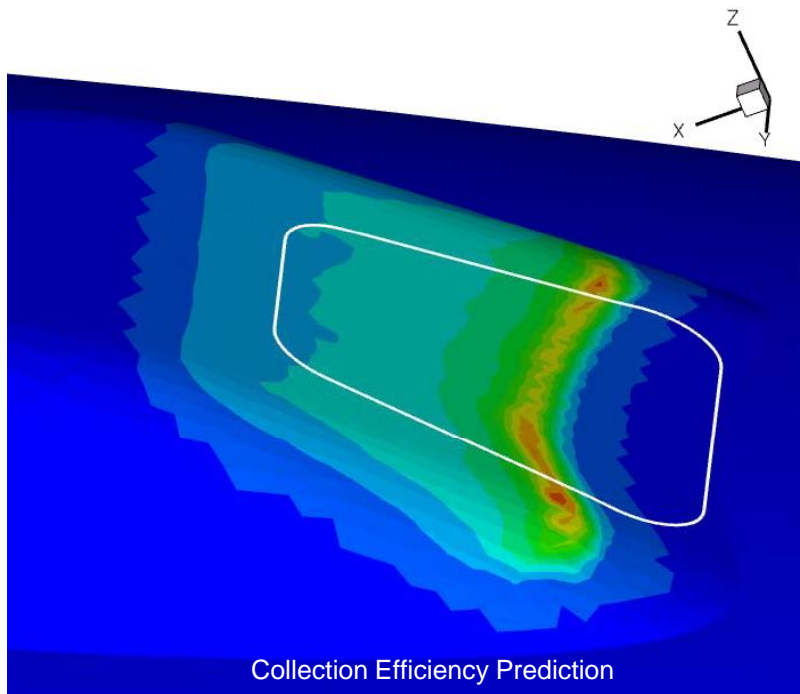
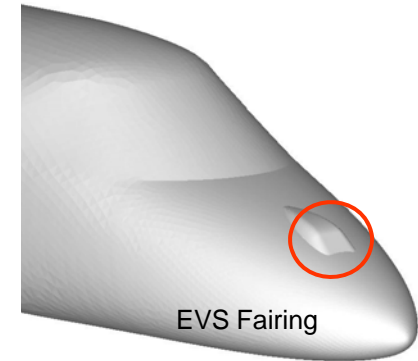
- Upcoming flight validation
 - G250 & G650 natural icing flight testing
 - Extensive camera coverage of accretions on full aircraft.
 - Flight & atmospheric conditions measured and recorded.
 - Ice shapes will be computed at measured conditions and compared to photographs.

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Validation Experience

– Tunnel validation

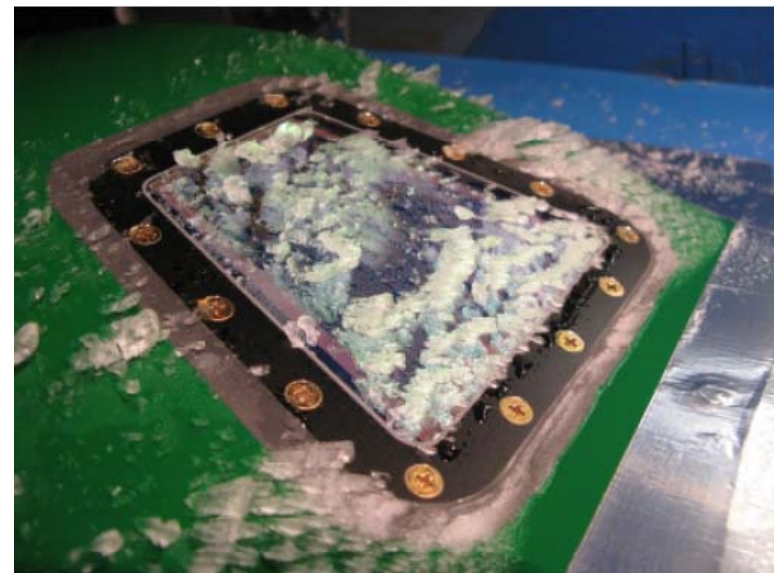
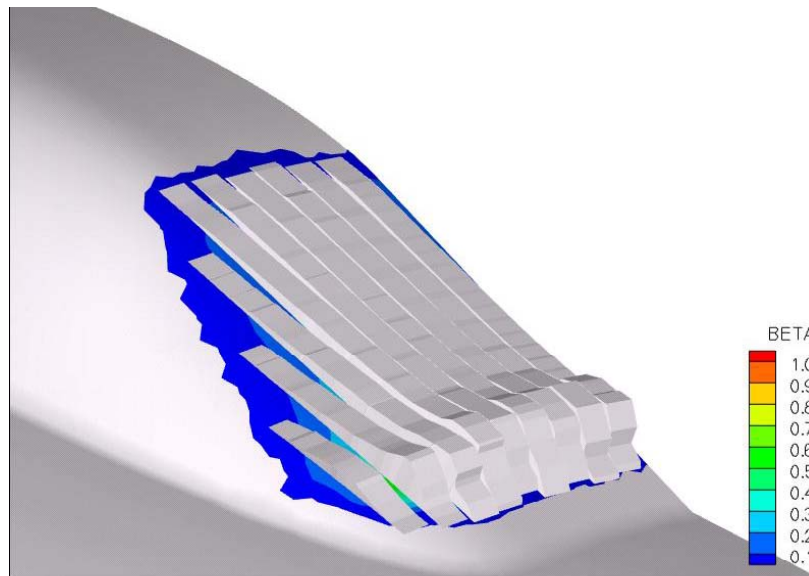
- Non-lifting surface water collection



Validation Experience

– Tunnel validation

- Non-lifting ice shapes – conservatism due to lack of ice shedding modeling.



Gulfstream interest in studies/working groups

- Gulfstream encourages efforts to improve codes.
- Limited Gulfstream proprietary validation data may be available with NDA but no rights to publish.
- Support of studies would depend on direct benefits realized to Gulfstream.
- Future support of this working group likely.