

Methods of Investigation

Flight Testing

- **State of the Art** – Typically some form of simulated ice shape is attached to wing or tail surfaces and maneuvers are performed to measure critical flight parameters during flight in clear air. Simulated ice shapes can be casts of real ice shapes or built from computer-generated or idealized ice shape profiles. Ice shapes can represent initial ice accretions (roughness), unprotected surfaces, IPS failure, and runback from thermal ice protection systems.
- **Issues** – Difficult to obtain detailed flow measurements needed to understand and analyze flow conditions; Range of conditions tested is limited by safety concerns

Flight Testing Using Simulated Ice Shapes

Flight Test Program to Obtain Data for Simulation Validation

- Tests performed on an instrumented flight test aircraft



Thomas P. Ratvasky, *NASA Glenn Research Center*, Billy P. Barnhart, *Bihrlle Applied Research*, Sam Lee, *ASRC Aerospace Corp*, Jon Cooper, *Cessna Aircraft Company*, “Flight Testing an Iced Business Jet for Flight Simulation Model Validation”

Four icing configurations tested:

- No-Ice baseline
- Pre-activation roughness
- Runback shape on wing
- 22.5-minute wing IPS failure shape



Experimental Methods

- Runback Ice Configuration
- Defined by flight test experience
 - **Upper surface shape (silicone hump)**
 - **Lower surface shape (foam wedge)**
- 45-minute hold shapes on unprotected surfaces
- Inter-cycle ice on horizontal tail pneumatic-boot

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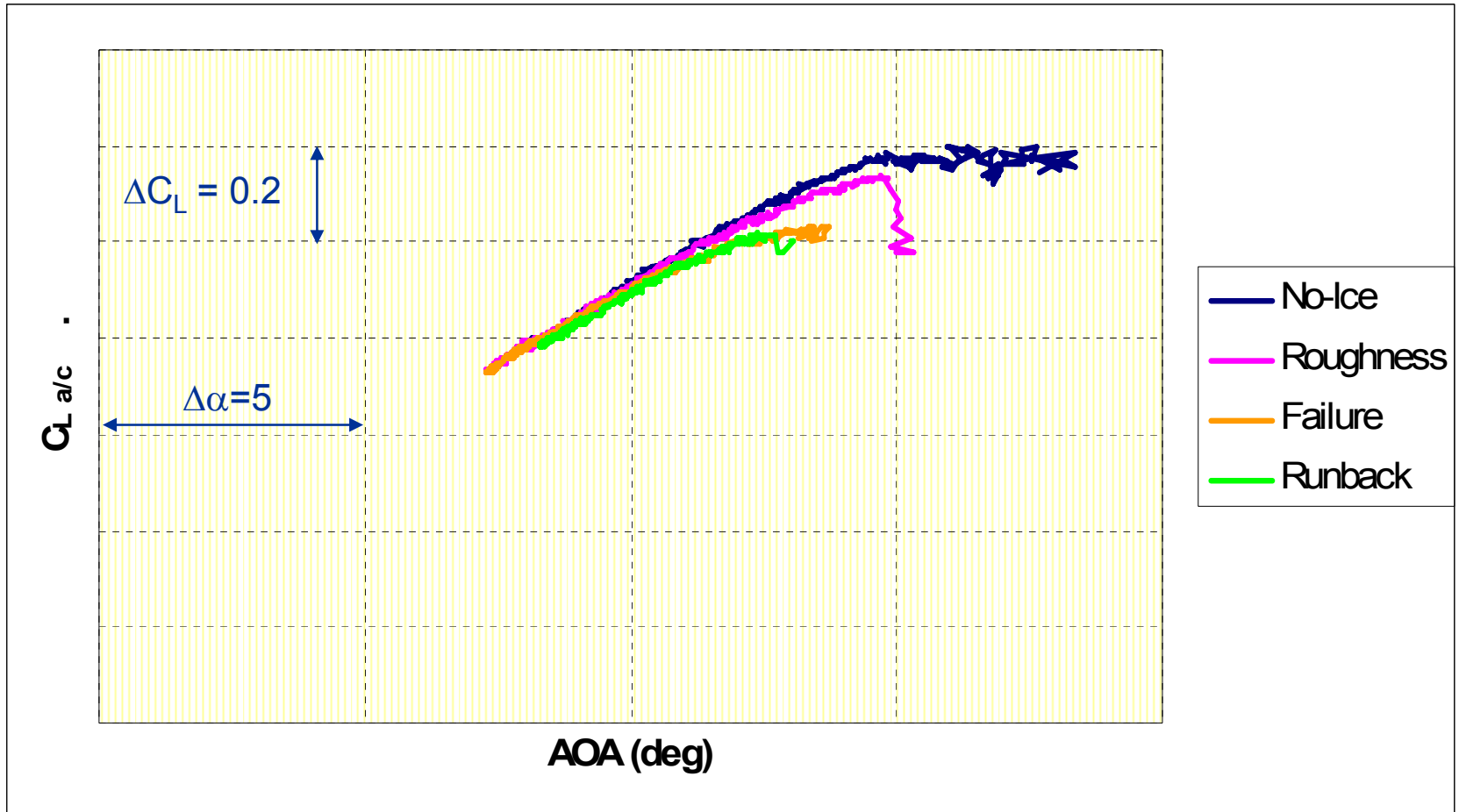
Experimental Methods

- Flight Test Maneuvers
- Maneuvers for each configuration included:
 - Idle-Power Stalls
 - Doublets in all three axis
 - Steady-heading Sideslips
 - Max Roll Rate
 - Maneuvering Characteristics
 - Thrust Transients
 - Flap Extensions
- Maneuvers were repeated for several initial airspeeds
- Maneuvers were performed for flaps up, partial flaps, and full flaps

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Simulation Model Validation

Icing Effects – Idle-power Stalls



Methods of Investigation

Flight Testing

- **Future Research** – Publicly available testing is limited to straight-wing aircraft and future tests will be conducted on swept-wing vehicles to provide
 - Detailed information on flow field variables
 - Full scale Reynolds number database
 - Broaden our understanding of icing effects upon control parameters

Summary

- **Experimental research needs**
 - Develop 3-D ice simulation methods. Where possible extend 2-D methods to 3-D.
 - Fundamental 3-D, unsteady experimental research to further our understanding of the physics. Requires continued improvements in experimental techniques.
 - Partner with CFD to improve understanding and modeling of 3-D unsteady iced aircraft aerodynamics.
- **CFD research needs**
 - Grid generation for 3D surfaces
 - Can turbulence modeling capture separated flow over ice shapes or is URANS or DES necessary?
 - Is 3D unsteady DES capable of capturing premature stall due to ice shape geometry? Can lower fidelity models be developed?
- **Flight test needs**
 - Need data on swept wing vehicles