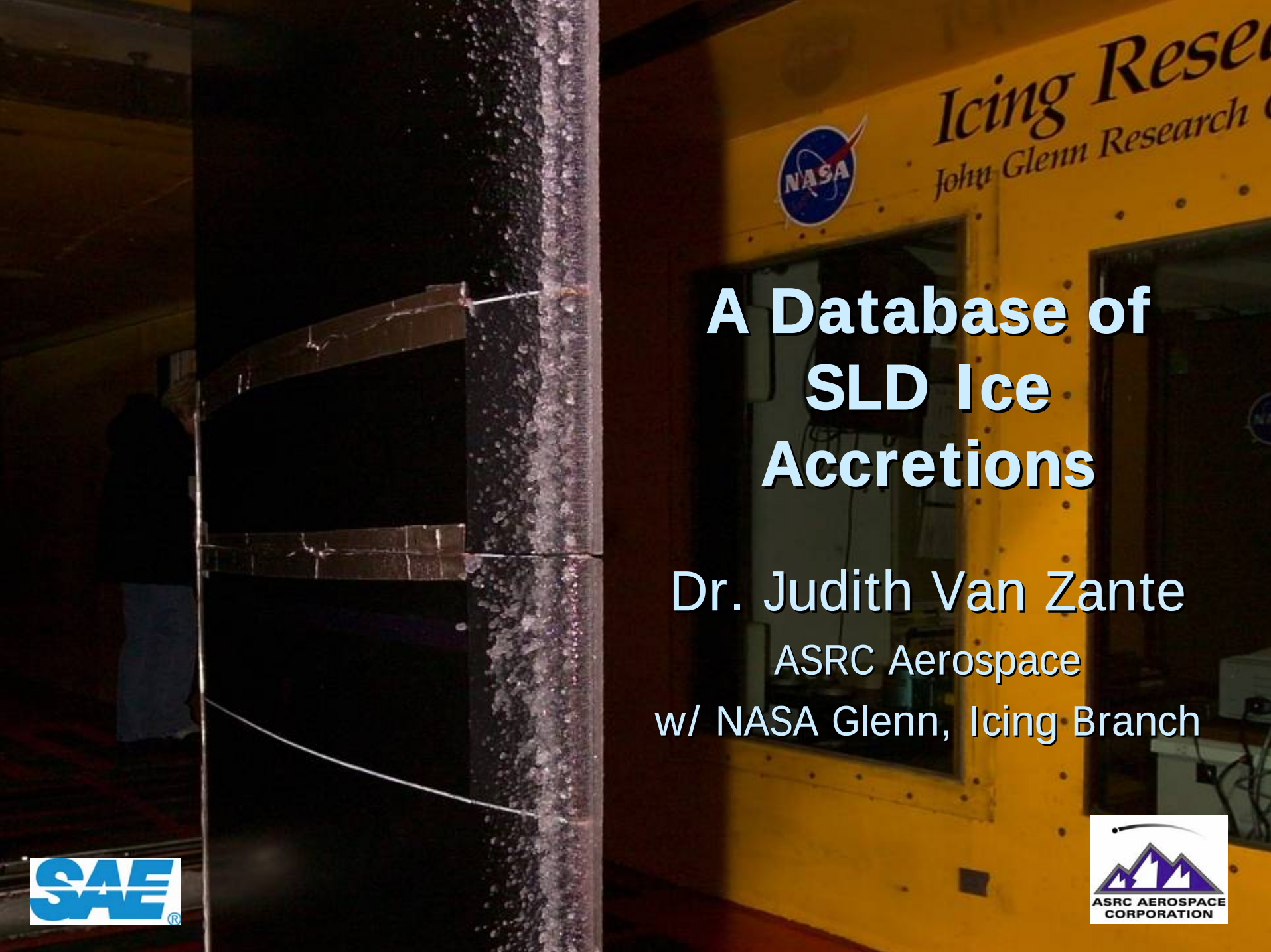

A Database of SLD Ice Accretions

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w/ NASA Glenn, Icing Branch

SAE®

ASRC AEROSPACE CORPORATION

Outline

1. Motivation
2. Models
3. Measurements
4. Accretion Conditions
5. Sample Data
6. Accessing Data on DVD
   a. “Do-it-yourself”
   b. JAVA crawler to auto-search (Demo)

Motivation

NTSB MOST WANTED Transportation Safety Improvements Aviation Issue Areas		
 *Unacceptable response*	**Reduce Dangers to Aircraft Flying in Icing Conditions** **Action Needed by The Federal Aviation Administration**	Use current research on freezing rain and large water droplets to revise the way aircraft are designed and approved for flight in icing conditions. *Conduct additional research with NASA to identify realistic ice accumulations* and incorporate new information into aircraft certification and pilot training requirements.

http://www.ntsb.gov/Recs/mostwanted/aviation_issues.htm

Objective: Build a publicly-available database of Supercooled Large Droplet (SLD) icing conditions.

Future: Modify accretion codes to better model SLD conditions (W. Wright)

Models – Icing Research Tunnel

Full Span

Test: Model

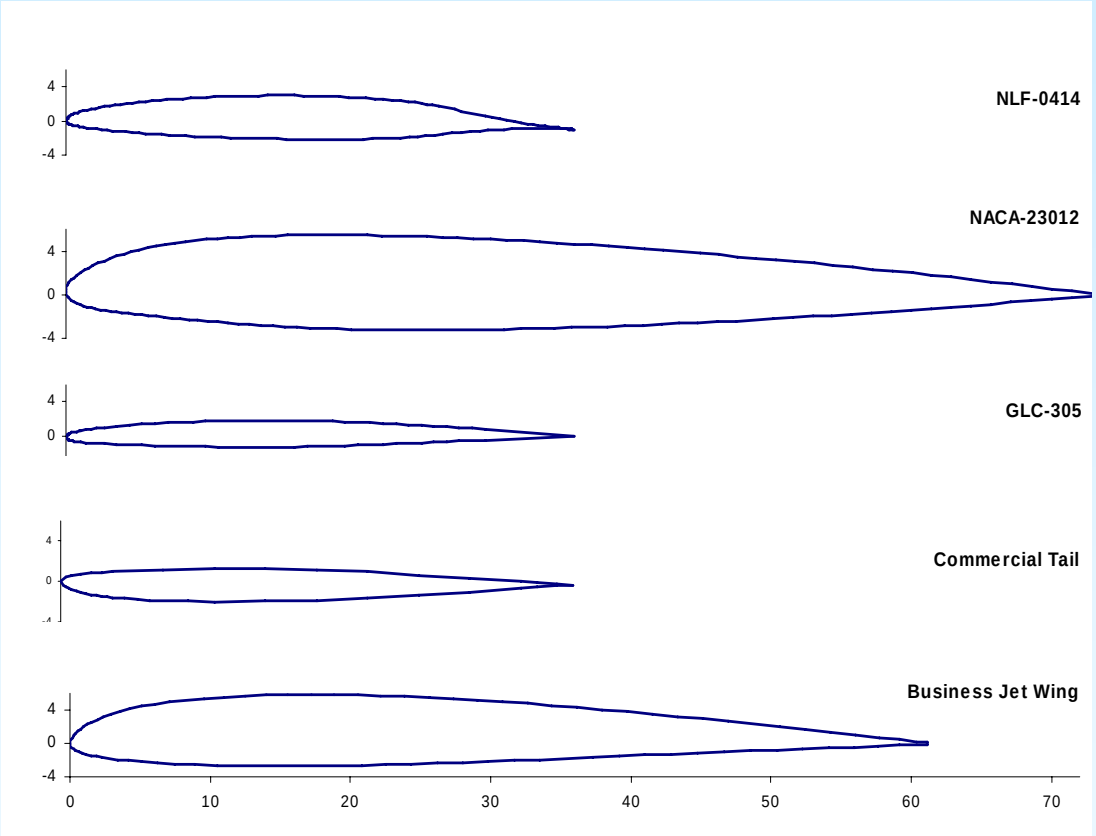
B: NLF 0414

C: NACA 23012

D: GLC 305

E: Commercial Tail

F: Business Jet Wing
w/ sweep, taper & twist



(inches)

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Models in IRT

Measurements: Ice Shape Tracing

1. Cut to surface at centerline
2. Trace on flush-mounted template
3. Result: x-y coords

Measurements: Photography

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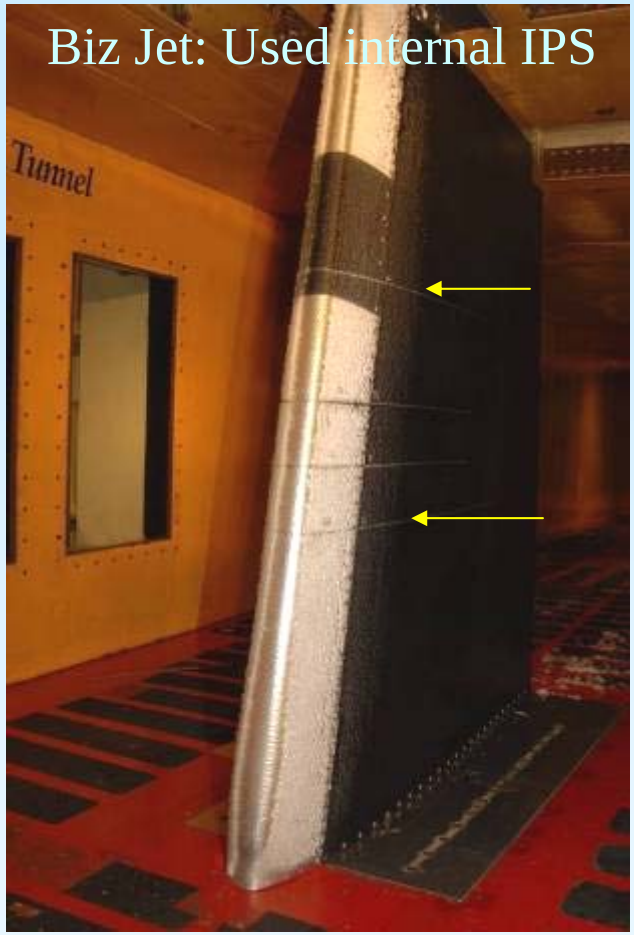
Measurements: Ice Mass



1. Scrape Ice from heater region
2. Measure difference between “clean” & iced pan
3. Result: mass of ice of airfoil section

Accretion Conditions

Every model encountered the same conditions (*Basic Matrix* & *Bimodal*) along with a *Flight Condition* unique to that airfoil and some temperature or angle effects (limited to IRT calibration points)

Each case is identified by a code (Reference #): **VTLM**

V = Velocity	**T = Temp**	**L = LWC (g/m3)***	**M = MVD (μm)***
1: 100 kts	(total)	3: Target = 0.25	3: Target = 50
3: 150 kts	5: -10 C	5: Target = 0.50	5: Target = 100
7: 200 kts	9: -5 C	7: Target = 0.75	7: Target = 150
9: 250 kts		8: Target = 1.00	9: Target = 200
		9: Target = 1.50	

Time ≡ 10 min

AOA: 2 or 3 deg
(except Flight Condition)

* The calibrated LWC and MVD points closest to the target values were selected.

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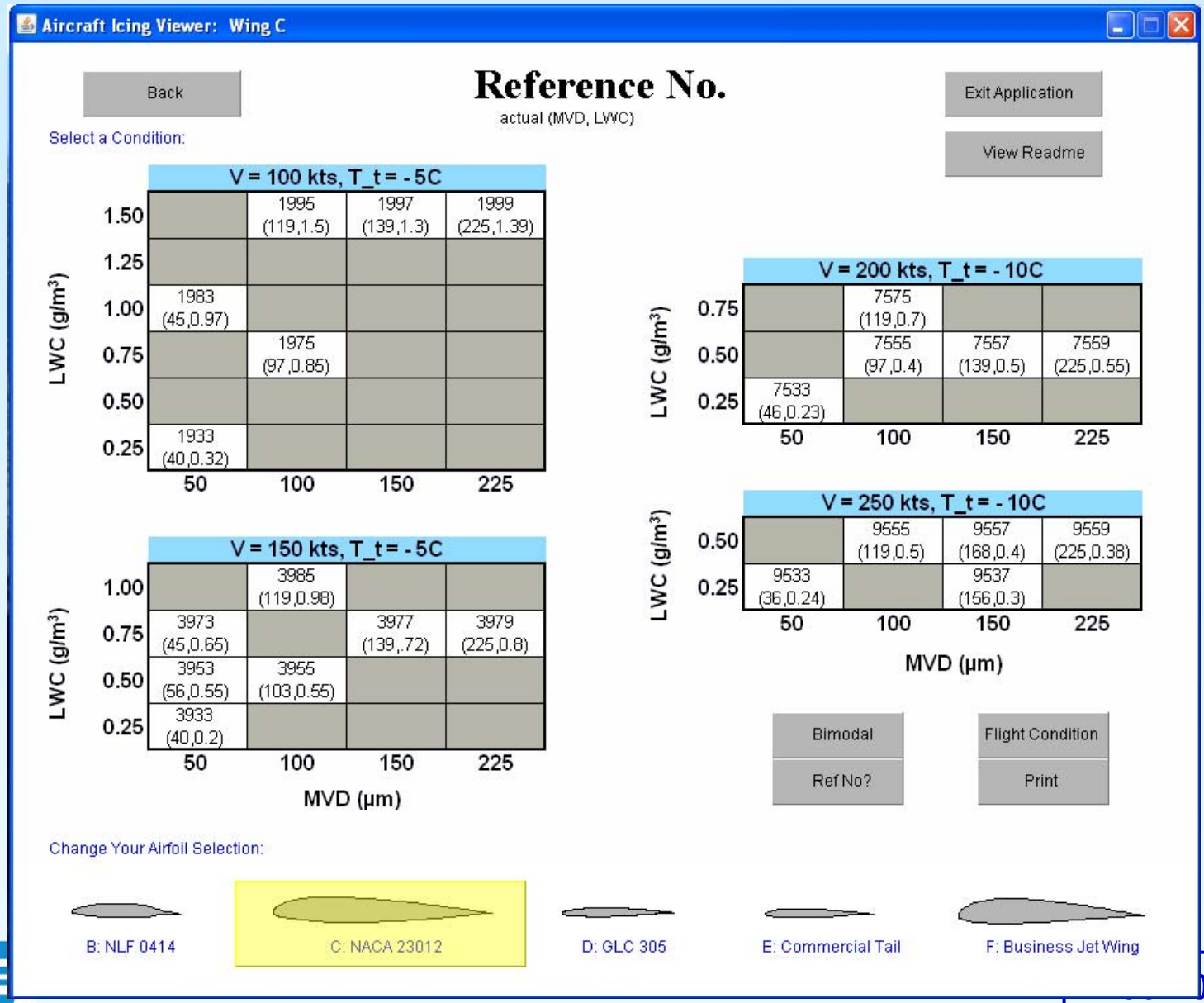
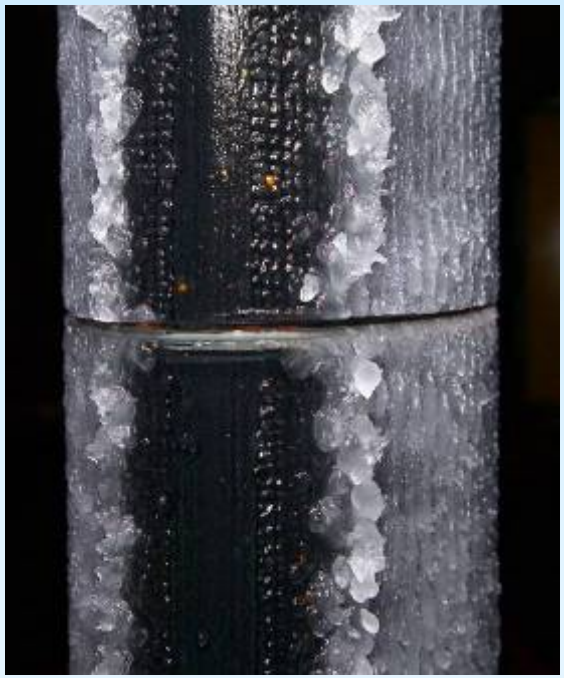
Accretion Conditions



Sample Cases for NACA 23012

C-1933



V = 100 kts
T_t = -5 C
LWC = 0.32 g/m^3
MVD = 40 μm

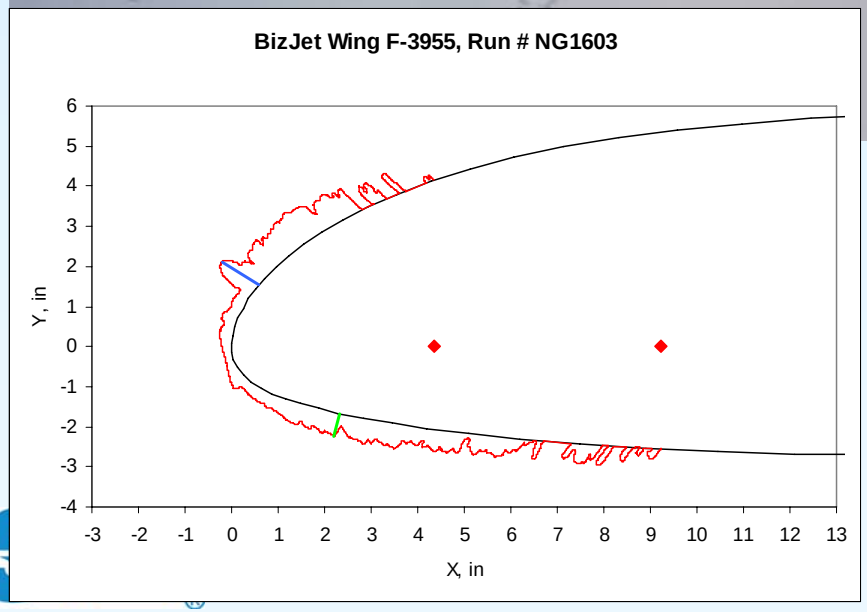
C-1999

V = 100 kts
T_t = -5 C
LWC = 1.39 g/m^3
MVD = 225 μm

C-9559

V = 250 kts
T_t = -10 C
LWC = 0.38 g/m^3
MVD = 225 μm

Sample Case for Biz Jet Wing



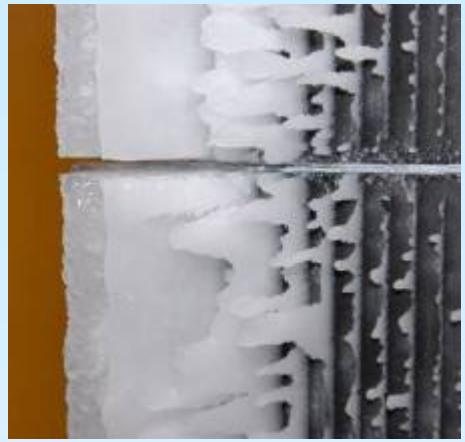
F-3955

V = 150 kts
T_t = -5 C
AOA = 3
LWC = 0.55
MVD = 103
t = 10 min

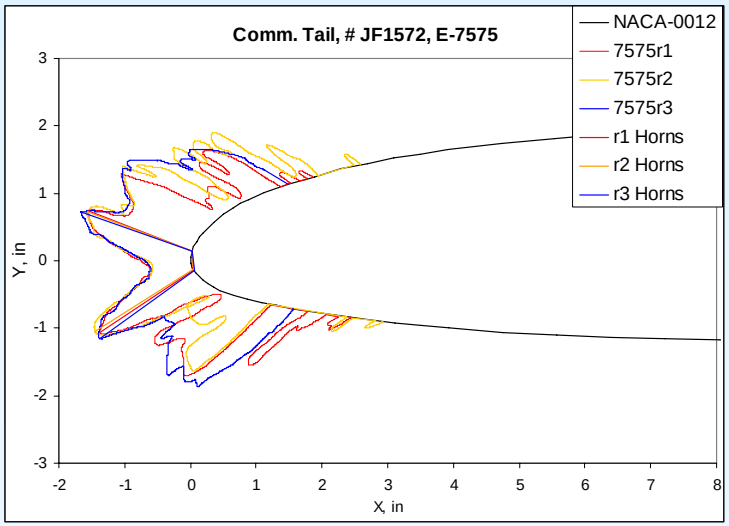
Sample Data, E-7575

pressure surface

leading edge



suction surface



Commercial Tail, V = 200 kts, T_t = -10C, AOA = 2 deg								
Ref. #	LWC	MVD	Mass	Pressure Side Horn		Suction Side Horn		LE Min
				Thick.	Angle	Thick.	Angle	
E-7575r1	0.7	119	970	1.706	219.0	1.691	156.1	0.611
E-7575r2	0.7	119	977	1.757	217.3	1.692	156.9	0.580
E-7575r3	0.7	119	975	1.757	221.1	1.788	157.8	0.624
E-avg	*0.7*	*119*	*974*	*1.733*	*218.9*	*1.700*	*156.5*	*0.600*

THICK data

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Cautions

The heater region presented several issues:

- Heaters created artificial accretion sites for the aft feather region. Therefore, one night was run without heaters (Entries C-E).

  Outcome: There is minimal apparent effect on feather density and characteristics.

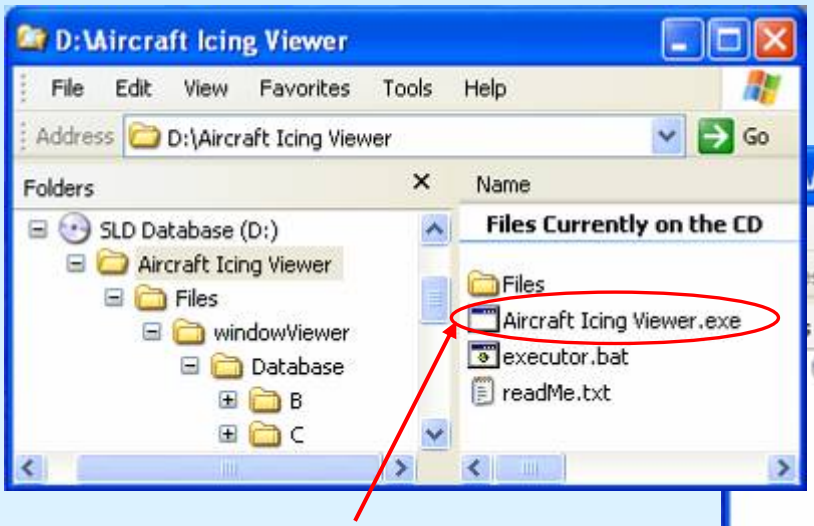
- What is value of tracing artificially aligned feathers? This detail adds 10x to the digitization process time. Therefore, only the tops of feathers were recorded and digitized. ***Detailing the aft feather region was outside the realm of this study.***

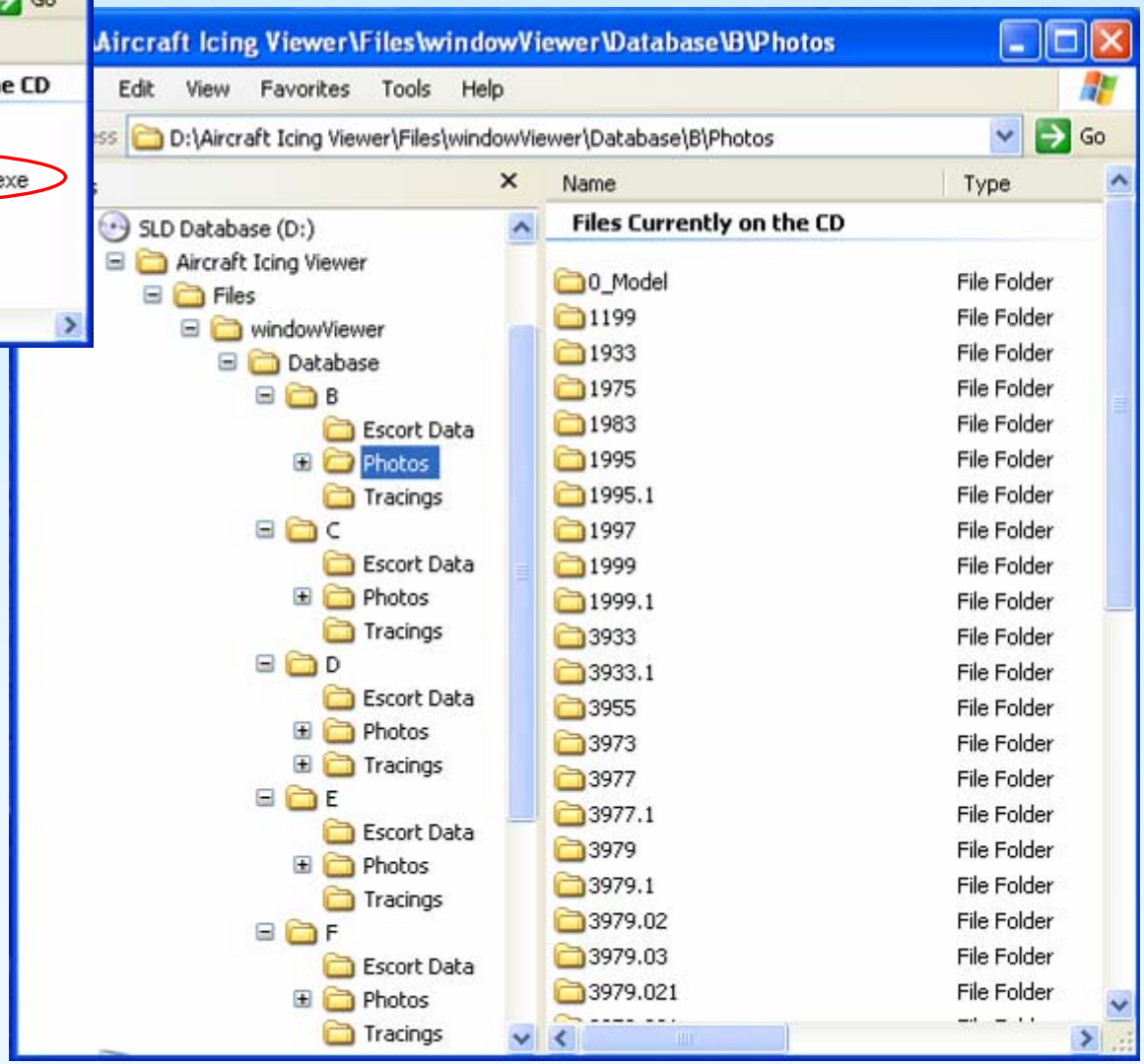
  Caution: Attempts to glean information from this region must be made with caution, and in conjunction with the photos.

What's on the Database DVD?

1. **A copy of the Paper (pdf)**
2. **A JAVA-based Crawler to "mine" the data.** (*Demo*)
   (Note: Sun Microsystems JAVA 6.0 is included on the DVD)
   - For Windows systems
   - Not for Mac (yet), Unix, Linux, etc…
3. **Access to all the data (Do-it-Yourself)**
   - 2D Ice shape tracing data for each Run (Excel)
   - Photographs for each Run (jpeg)
   - Actual accretion conditions ("Escort", in Excel)
4. **Readme files (txt)**
   - Photo file name decoder
   - Summary Excel sheets (V150_shape.xls)

Accessing the Data on the DVD



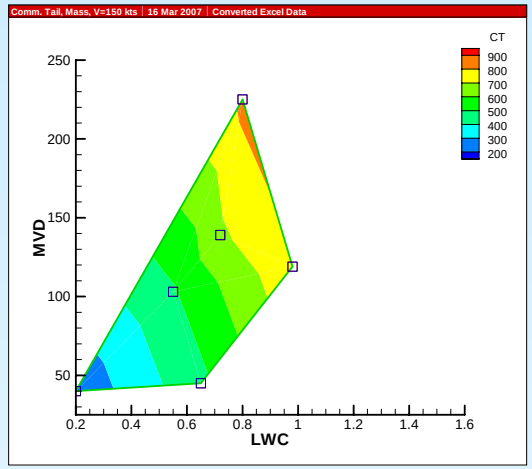


Aircraft Icing Viewer.exe to launch the JAVA crawler. Otherwise,

Read the Readme

DVD Demo

Will demo the DVD after…



Future Plans:

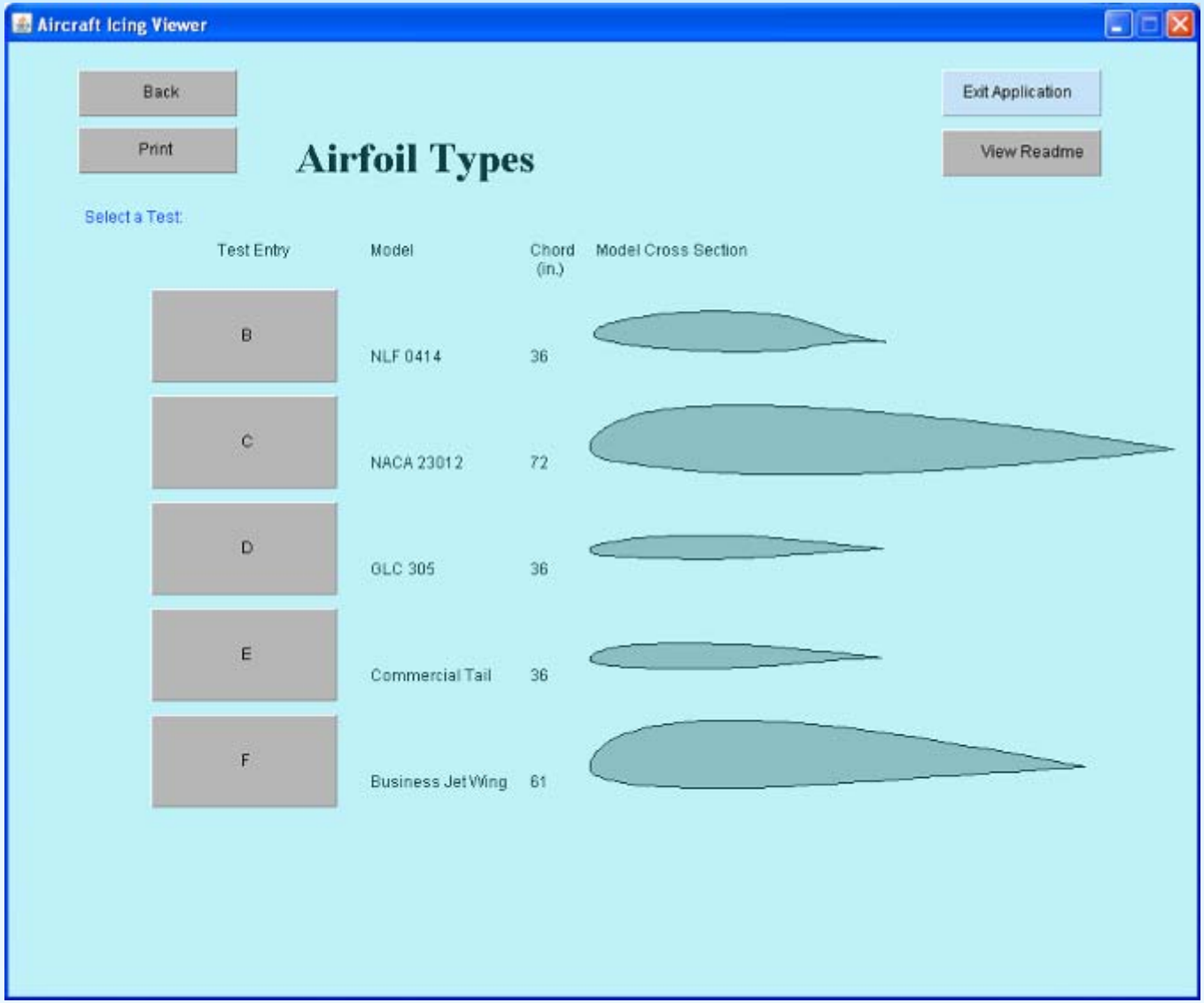
- Analyze data for trends in Mass and Ice Shape Characteristics.
- Examine data for potential LEWICE code modifications (Dr. William Wright / ASRC)

Acknowledgements:

- **Dr. Mark Potapczuk & Dean Miller** / NASA Glenn
  for their support and advice.
- **Tammy Langhals** / ASRC
  for digitizing and running THICK on all 220 files
- **Matthew R. Ferraro** / Summer Intern @ NASA Glenn
  for programming the JAVA database crawler

Aircraft Icing Viewer – DVD Demo

Java Crawler – p2



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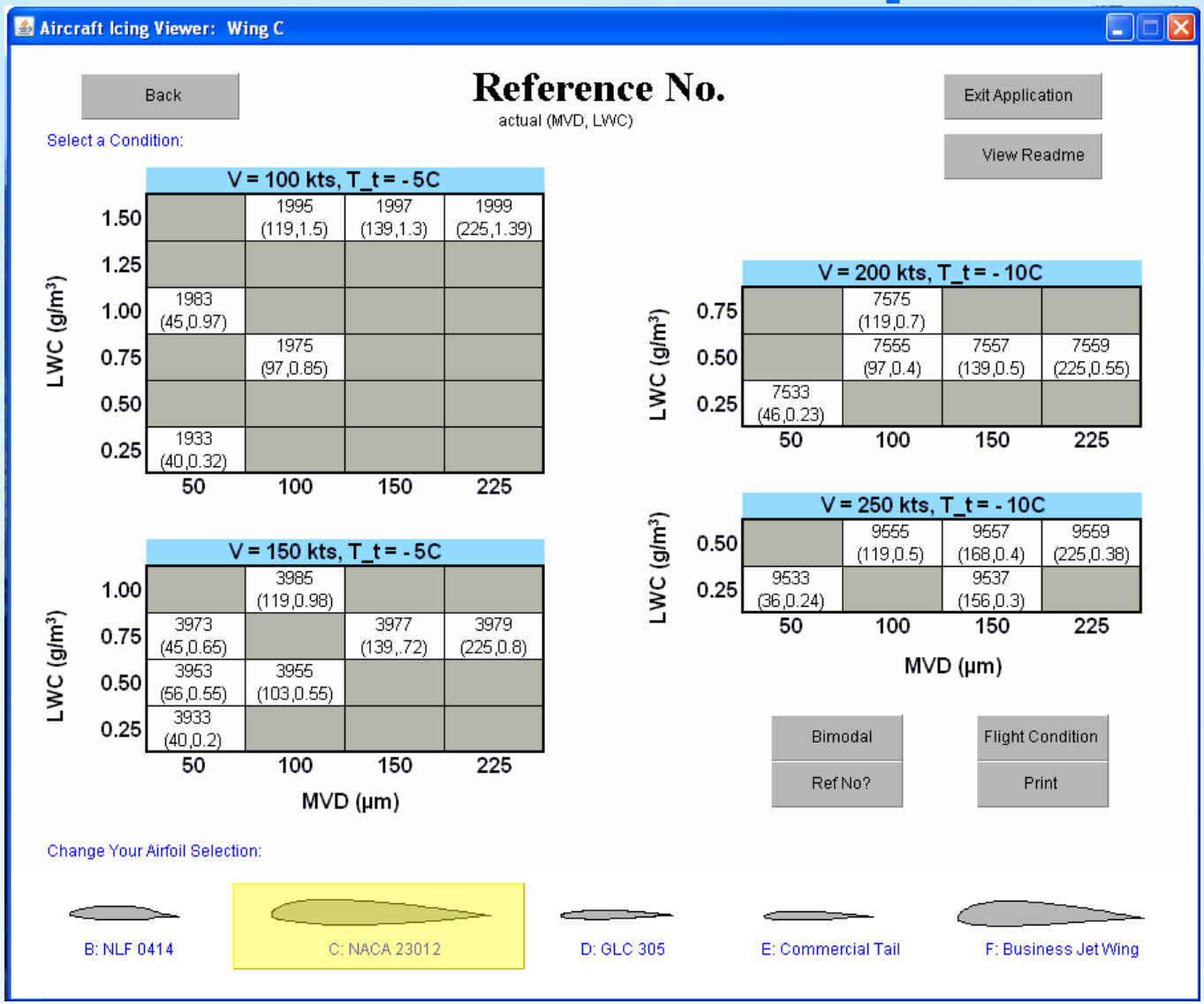
Java Crawler – p3



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Java Crawler – Data page

Aircraft Icing Viewer: Wing C Case Number - 7575

Back

Print

Run Log

Exit Application

C: NACA 23012 - 7575

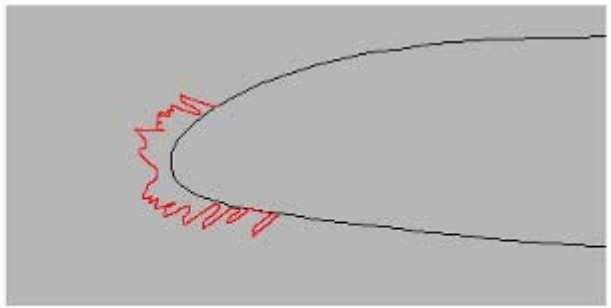
Accretion Conditions

Ref	Speed	AOA	TI	Ts	LWC	MVD	Pair	DP	Time
7575	200 kts	2°	-10.0°C	-15.3°C	0.62 g/m³	119 µm	5 psig	50 psid	10 min

Ice Characterization

Minimum of 5 Photos

		Ref	Mass	Suction Side Thickness	Suction Side Angle	Pressure Side Thickness	Pressure Side Angle	LE_Min	Day, Run	Escort
Tracing	Photos	7575	1850 g	1.36 in	148.92°	1.52 in	228.92°	0.59 in	1,2	367
Tracing	Photos	7575r1	1867 g	1.44 in	147.74°	1.73 in	230.04°	0.55 in	1,3	368
Tracing	Photos	7575r2	1886 g	1.31 in	145.68°	1.52 in	230.83°	0.55 in	3,6	386
Tracing	Photos	7575m	n/a	1.28 in	146.26°	1.48 in	232.76°	0.56 in	5,2	404



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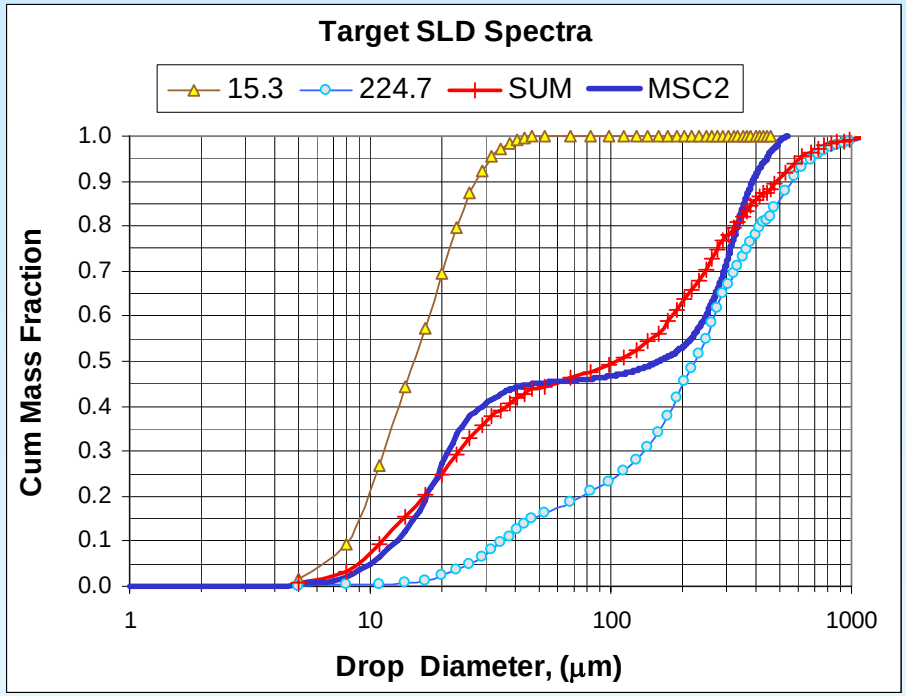
Bimodal Conditions

Found a condition within IRT calibration matrix that met MSC2 condition.

Ref:

- 3979 – SLD only
- 3979b – bimodal
- 3979c – App. C only

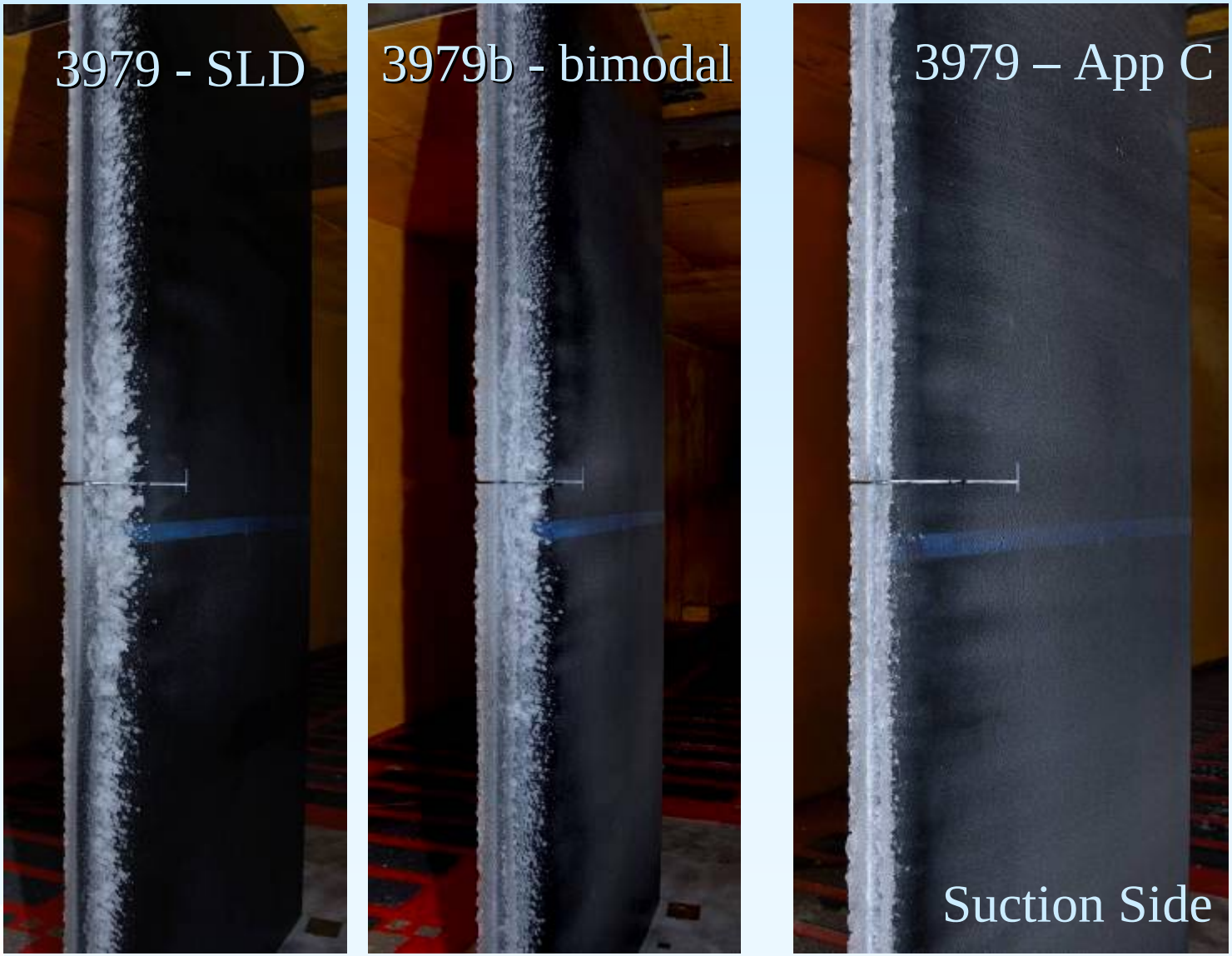
V = 150 kts; T_t = -5 C



	"SLD"	"Appendix C"	n
LWC (g/m3):	0.79	0.94	0.29
MVD (μm):	225	15	0.21
time (min)	7 (3x 2.33)	3 (2x 1.50)	

return

Bimodal Conditions: Comm. Tail



return

Flight Condition & Misc. Cases

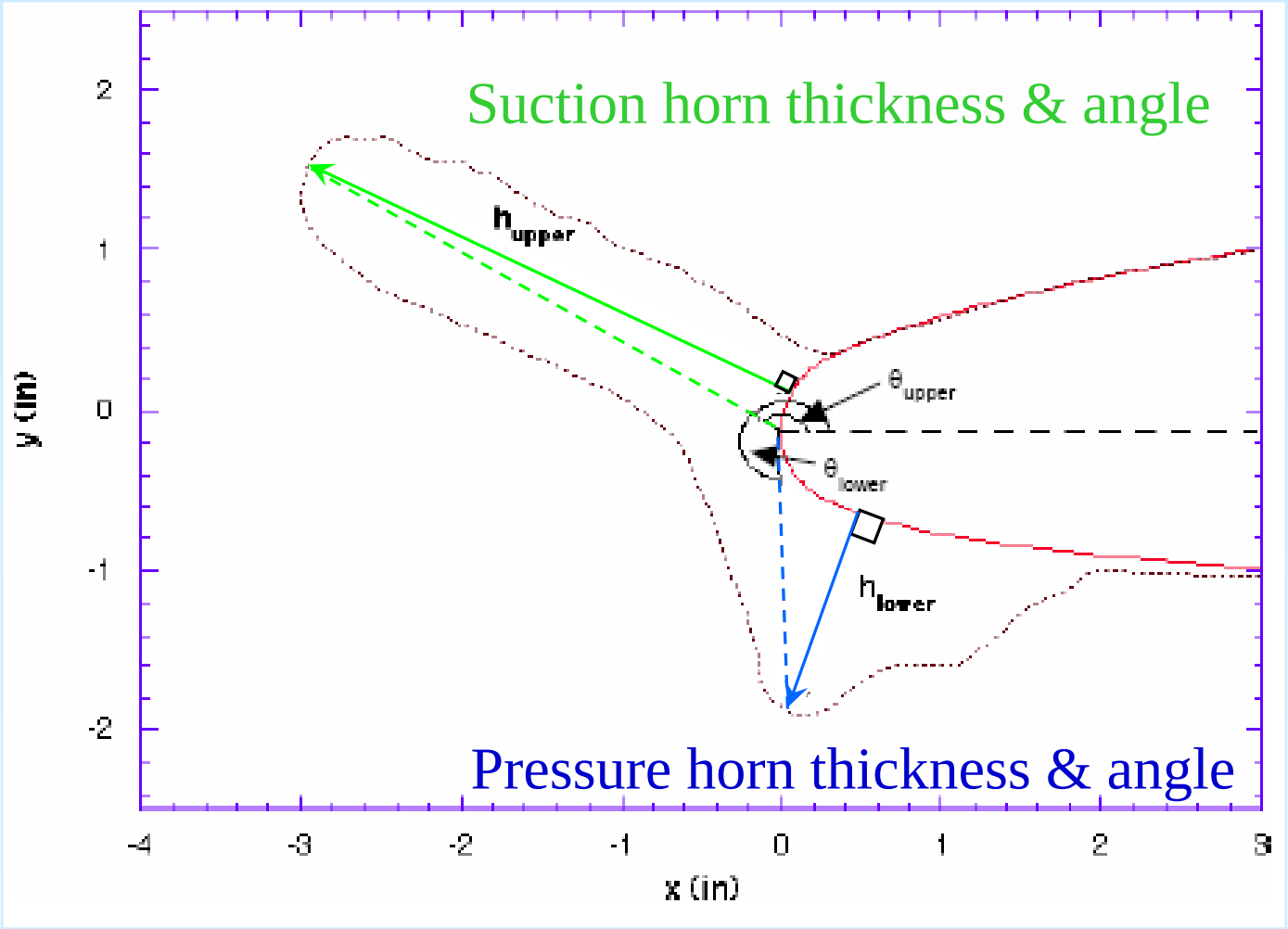
Ref No.	Spd (kts)	AOA (deg)	Tt (C)	MVD (um)	LWC (g/m3)	Condition
B: NLF 0414 (Basic: AOA = 2)						
B-7955	200	3	-1.7	97	0.40	Hold
B-1199	100	2	-15.0	225	1.39	Temp
B-7959	200	3	-1.7	225	0.55	Temp
C: NACA 23012 (Basic: AOA = 2)						
C-7955a	200	2	-5	97	0.40	Hold
C-7975	200	3	-5	119	0.70	Hold
D: GLC 305 (Basic: AOA = 2)						
D-5955	175	6	-5.0	97	0.48	Hold
D-1895	100	2	-6.7	119	1.50	Temp

Ref No.	Spd (kts)	AOA (deg)	Tt (C)	MVD (um)	LWC (g/m3)	Condition
E: Comm Tail (Basic: AOA = 2)						
F-9955	250	-1	-5.0	119	0.50	Hold
F-9959	250	-1	-5.0	225	0.38	Hold
E-3960	150	0	-5.0	97	0.60	Angle
E-3964	150	4	-5.0	97	0.60	Angle
F: BizJet Wing (Basic: AOA = 3)						
F-9555a	250	-1	-10.0	119	0.50	Descent
F-3185a	150	-1	-15.0	119	0.70	Temp
F-3585a	150	-1	-10.0	119	0.70	Temp
F-3985a	150	-1	-5.0	119	0.70	Temp

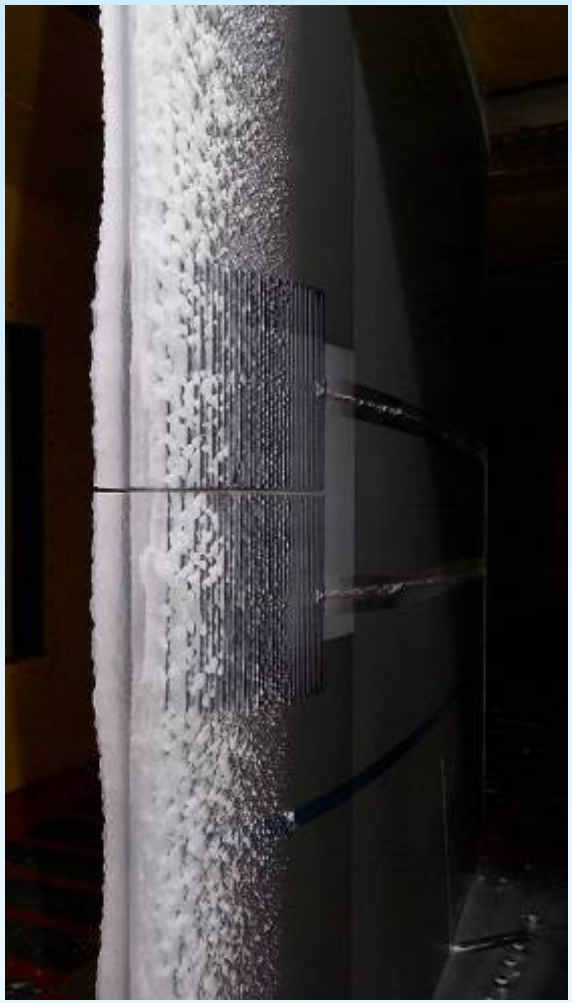
Where possible, flight conditions angles and speeds were matched to previous IRT data sets, including *Modern Airfoils*, Addy

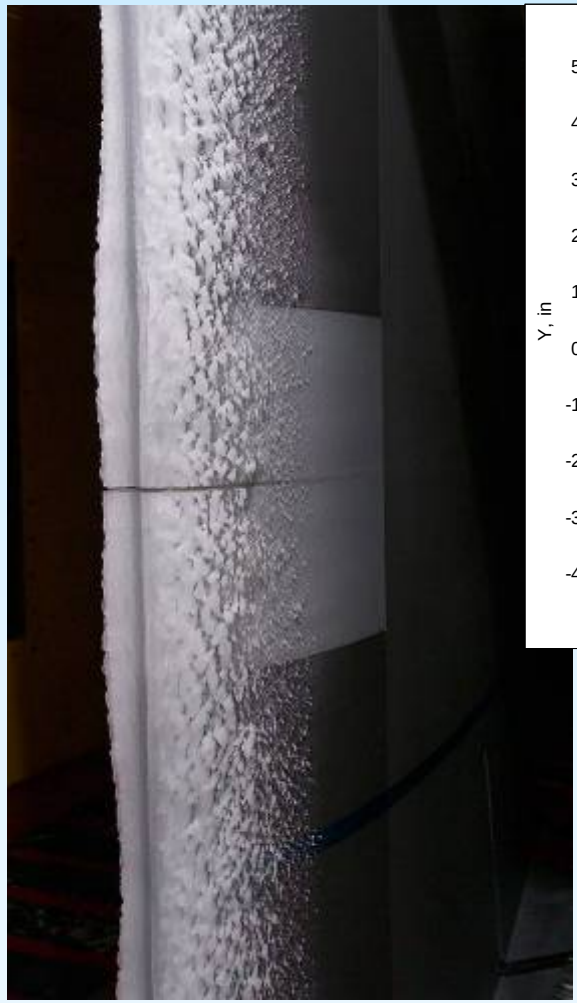
return

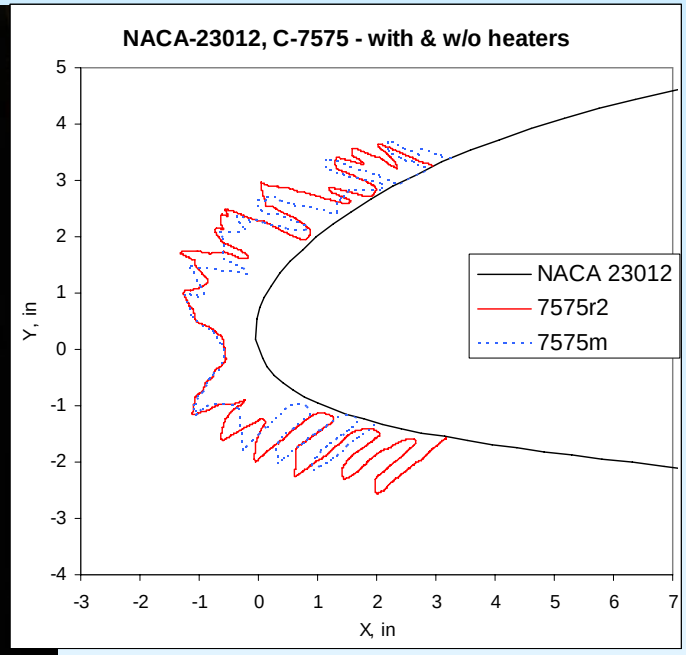
LEWICE's THICK Output



Overall effect of Heaters

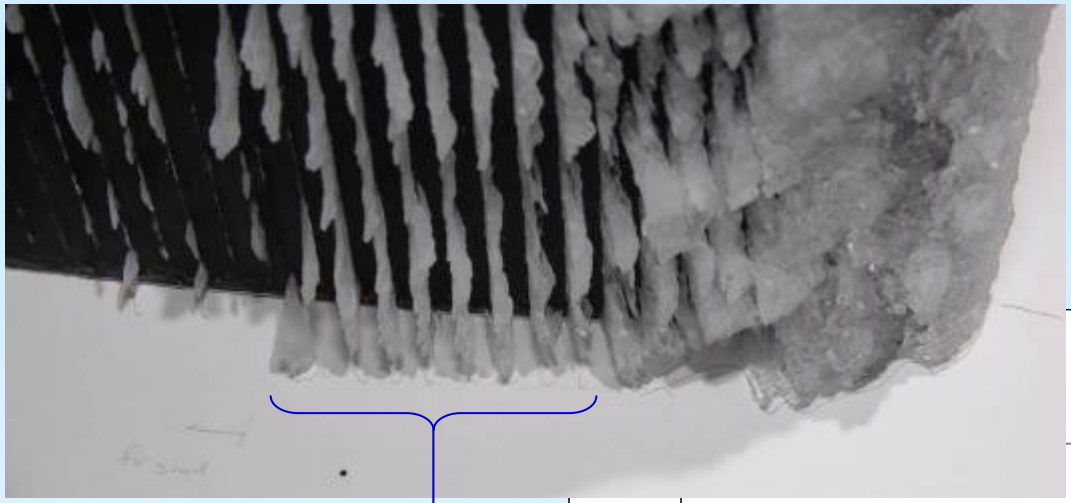


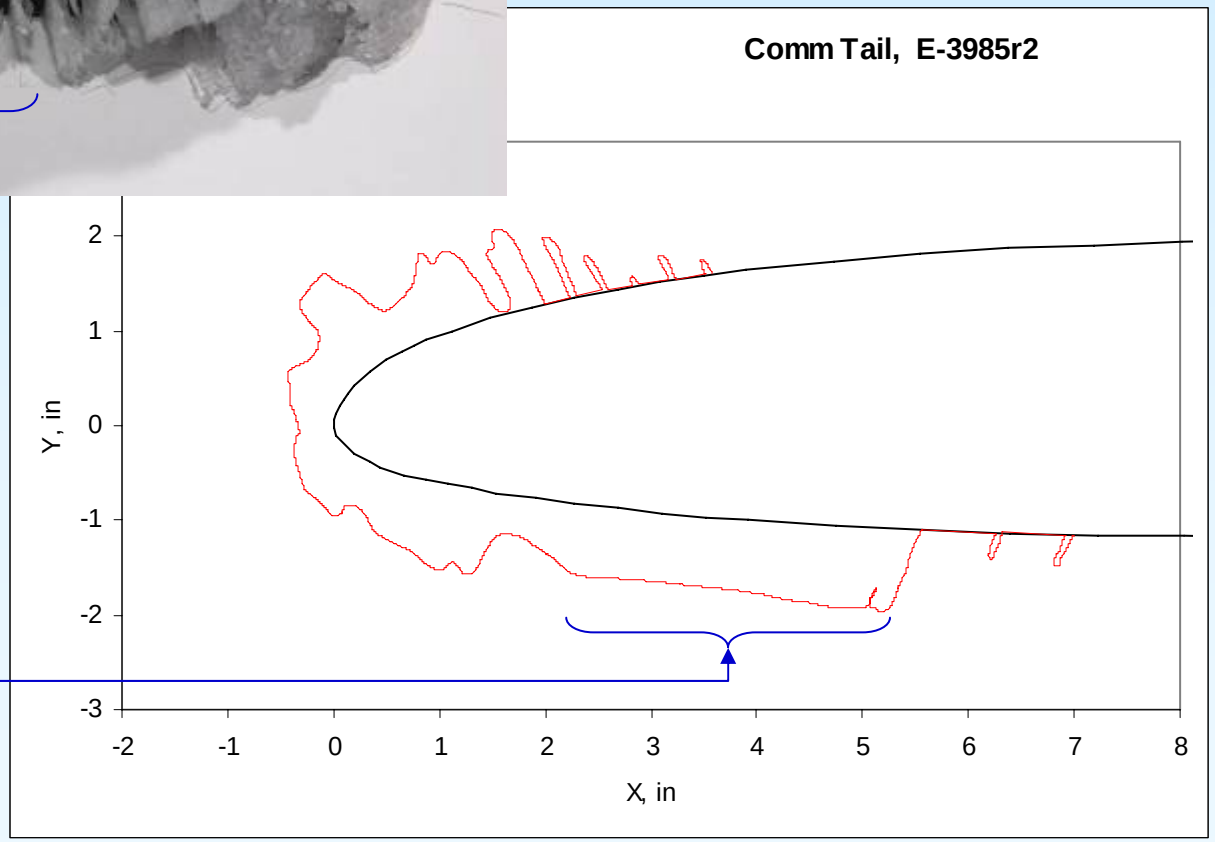




C-7575r2 &
C-7575m

Tracing Feathers in the Heater Region





return