# Icing Certification
# An Industry Perspective

SAE Aircraft & Engine Icing International Conference
September 24-27, 2007

# Agenda

- Common Industry And Regulatory Objectives
- Impact Of Certification Requirements On Aircraft Design & Operation
- Challenges Of Large Droplet Rulemaking

# Industry and Regulatory Objectives

# Industry & Regulatory Objectives

- Common Objectives
  - Designing and certifying aircraft that can be operated safely in icing conditions
    - Within limitations
  - Continued airworthiness
- Not so common objectives
  - Well defined scope
  - Schedule

# Common Objectives Defined Requirements

- Historically, icing programs have carried a lot of development uncertainty
  - Due to informal and negotiated policy
  - Policy development concurrent with certification programs
- Situation is improving as icing rules and guidance matures

# Alternatives

- Alternate venues for developing icing policy
  - Technical committees could provide expertise
- Provides for exchange of ideas and industry perspective

# Common Objectives Harmonization

- Harmonization allows manufacturers to meet the common objectives as well as the “not so common” objectives
- Icing rules are somewhat harmonized
  - Recent European participation in harmonization has been limited
- Harmonization makes best use of limited resources
  - Provides a “global” level of safety
  - Benefits both regulators and manufacturers

# Common Objectives Continued Airworthiness

- Improving safety for aircraft in the field
  - Icing seminars and on-line training
  - Aircraft specific operating guidance & limitations
- Scale effects limit the ability of small aircraft to operate unrestricted in icing
  - Requires monitoring aircraft effects
    - » Abnormal ice accretions
    - » Performance effects
  - Requires exiting severe icing conditions

# Impact of Icing Requirements on Aircraft Design & Operation

# Simulation of Ice Shapes

- Certification programs typically use simulated ice shapes to examine limits of icing envelopes
  - Allows simulation of low-probability icing encounters
  - Rigorous evaluation of aircraft performance and handling qualities
- Simulated ice shapes are designed to be conservative
  - However, excessive conservatism can alter aircraft design or limit aircraft operations

# Ice Shape Background

- Ice shape definition
  - Analytical, or observed in natural / icing tunnels
  - Roughness applied

# Simulated Ice Shape Testing

- Certification goal is to remain conservative
  - Conservative assumptions on weight, cg, airspeed, altitude, water content, drop size, etc.
  - Typically 45 minute holds at maximum water contents
- The effect is cumulative which can result in very conservative ice shapes
- Conservatism in ice shapes is necessary, but can have design consequences

# Conservative versus Accurate Simulated Icing Shapes

- Increased stall speeds
  - Increased approach and landing speeds
- Ice shapes can affect stability
- Excessive drag can affect performance and climb information
- As such, conservative <u>and</u> accurate ice shapes are necessary

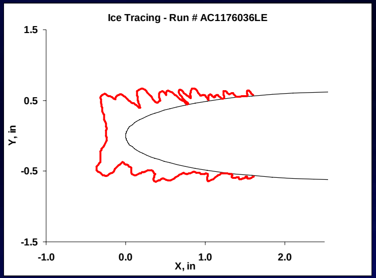
# Challenges of Large Droplet Rulemaking

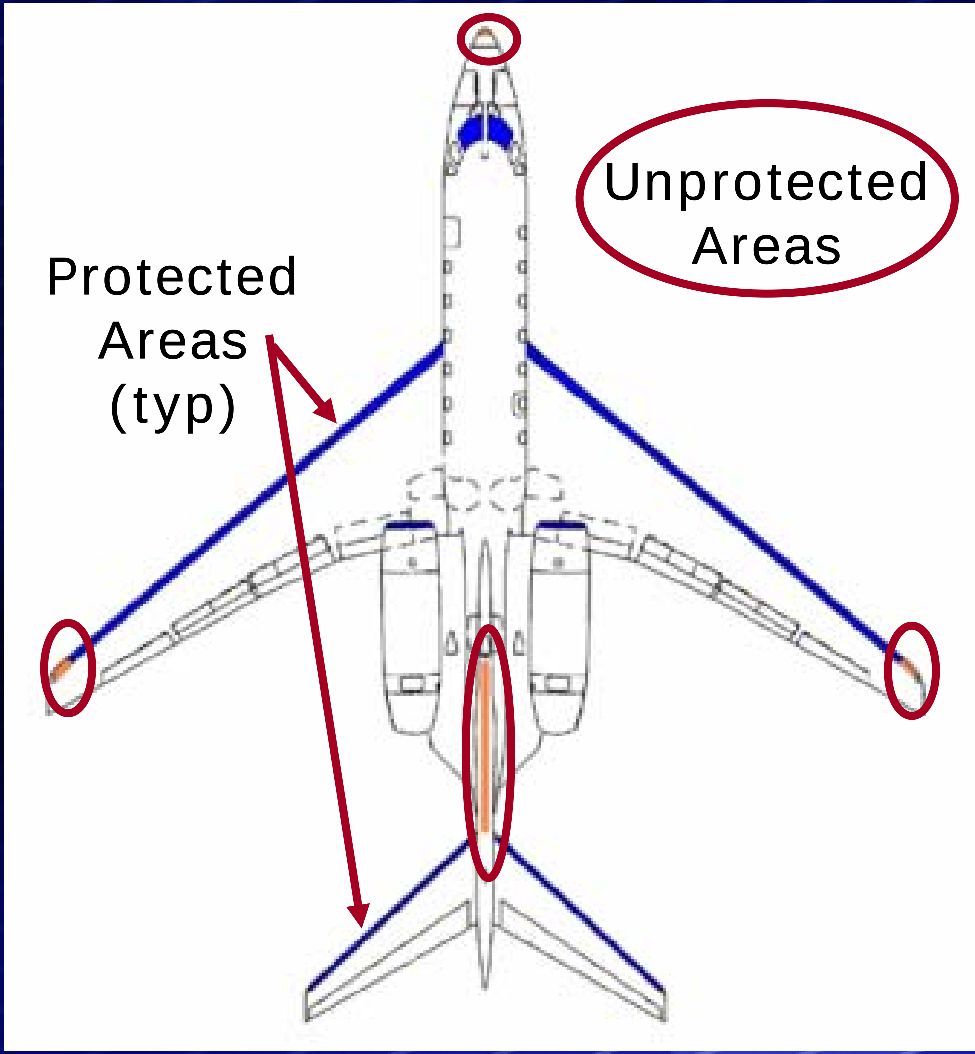
# Simulation of Large Droplet Icing

- Lewice 3.2.2 has some SLD capability
  - Splashing and breakup models
- Splashing models significantly reduce potential accretions in aft regions of leading edges
- Positive step towards modeling SLD

# Protected vs. Unprotected

- Large aircraft are mostly unprotected
- Small aircraft are mostly protected
  - Scale effect
- Most ice shape development and validation considers unprotected ice shapes



# Protected Area SLD Effects

- Protected areas have a much larger influence on small aircraft
  - Performance and handling qualities
  - Handling quality assessment is becoming more critical
- Accurate prediction/simulation of SLD roughness effects aft of protected areas
  - Important for smaller scale aircraft
  - Considering influence of various ice protection systems

# Large Droplet Simulation Example

- Used a generic business jet airfoil
  - Typical, but not representative of any specific aircraft; 50” chord
- Used LEWICE version 3.2.2; SLD flag active
  - Splashing and breakup
- Examined two airspeeds 100 & 200 KCAS
- Assumed a total air temperature of -2°C
- Water contents per Proposed Appendix “X”
- Assumed a 10 minute exposure

# ARAC - IPHWG Task 2 Report

Table 1. FZDZ distributions represented using 10 bins.

| | | FZDZ/L (MVD < 40 µm) | | | FZDZ/G (MVD > 40 µm) | | |
|---|---|---|---|---|---|---|---|
| | (a) | | (b) | | | (b) | |
| Bin | Proportion of Mass | Left Boundary Point (µm) | Mass-weighted Midpoint (µm) | Right Boundary Point (µm) | Left Boundary Point (µm) | Mass-weighted Midpoint (µm) | Right Boundary Point (µm) |
| 1 | 0.100 | 1 | 9 | 10 | 1 | 11 | 15 |
| 2 | 0.200 | 10 | 13 | 16 | 15 | 22 | 36 |
| 3 | 0.200 | 16 | 18 | 20 | 36 | 64 | 106 |
| 4 | 0.200 | 20 | 23 | 27 | 106 | 150 | 197 |
| 5 | 0.100 | 27 | 29 | 33 | 197 | 221 | 247 |
| 6 | 0.050 | 33 | 36 | 40 | 247 | 261 | 276 |
| 7 | 0.050 | 40 | 48 | 66 | 276 | 292 | 309 |
| 8 | 0.050 | 66 | 97 | 137 | 309 | 330 | 354 |
| 9 | 0.025 | 137 | 163 | 202 | 354 | 370 | 390 |
| 10 | 0.025 | 202 | 252 | 388 | 390 | 417 | 473 |

Note: DSDs in one-micrometer-drop bin resolution are available in electronic files from the William J. Hughes Technical Center.

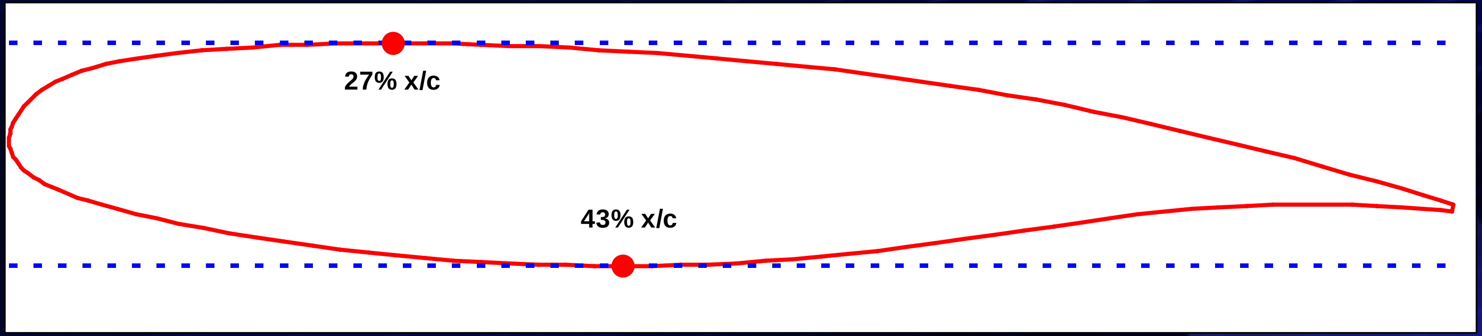
A distributions represented using 10 bins.

| | | | (MVD < 40 µm) | | FZRA/G (MVD > 40 µm) | | |
|---|---|---|---|---|---|---|---|
| | | | (b) | | | (b) | |
| | | | Mass-weighted Midpoint (µm) | Right Boundary Point (µm) | Left Boundary Point (µm) | Mass-weighted Midpoint (µm) | Right Boundary Point (µm) |
| | | | 7 | 8 | 1 | 9 | 14 |
| | | | 10 | 12 | 14 | 35 | 236 |
| | | | 15 | 19 | 236 | 399 | 526 |
| 4 | 0.200 | 19 | 25 | 53 | 526 | 645 | 765 |
| 5 | 0.100 | 53 | 255 | 468 | 765 | 833 | 912 |
| 6 | 0.050 | 468 | 534 | 595 | 912 | 957 | 1008 |
| 7 | 0.050 | 595 | 655 | 718 | 1008 | 1066 | 1129 |
| 8 | 0.050 | 718 | 792 | 883 | 1129 | 1197 | 1288 |
| 9 | 0.025 | 883 | 942 | 1034 | 1288 | 1345 | 1420 |
| 10 | 0.025 | 1034 | 1191 | 1553 | 1420 | 1545 | 2228 |

Note: DSDs in one-micrometer-drop bin resolution are available in electronic files from the William J. Hughes Technical Center.

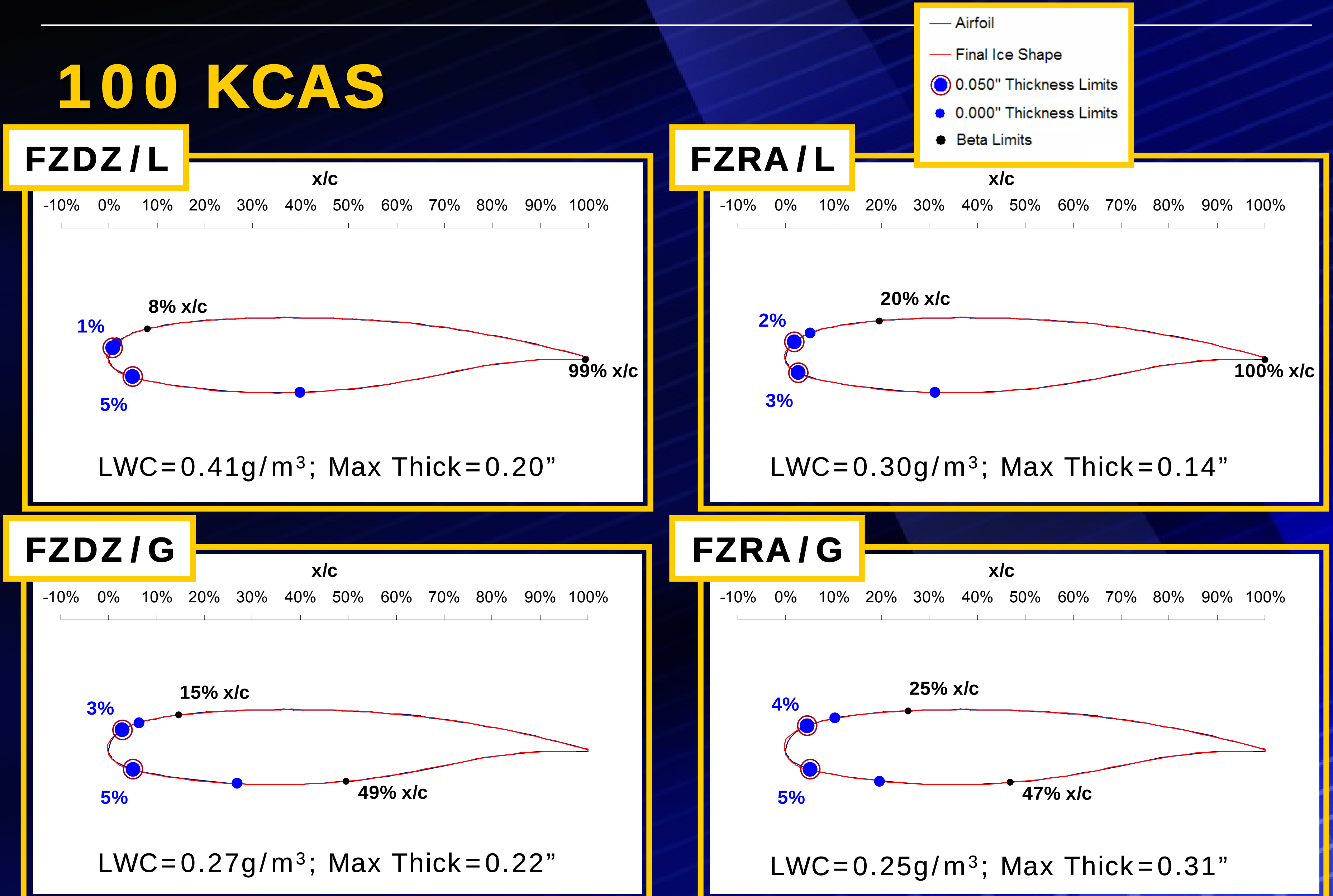
# Large Droplet Effects

- Beta curves indicate that impingement can approach max thickness of airfoil



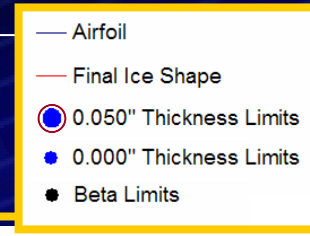

- However, impingement doesn't appear to be strongly correlated to ice thickness or ice limits
  - Splashing removes significant mass aft of protected regions

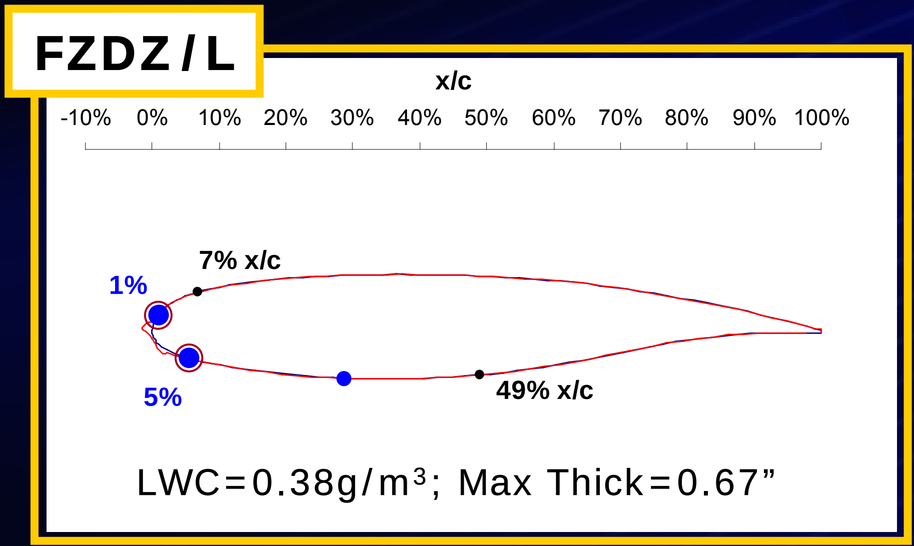
# 100 KCAS

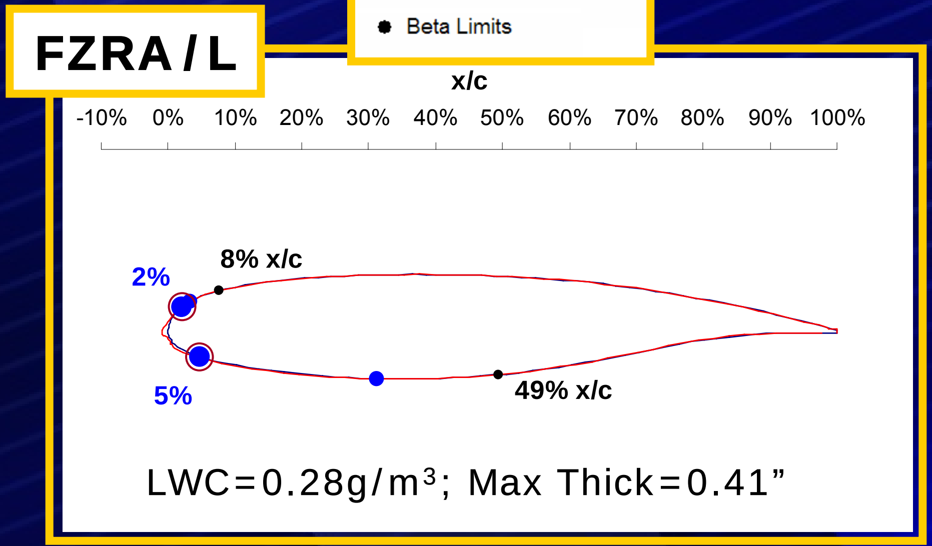


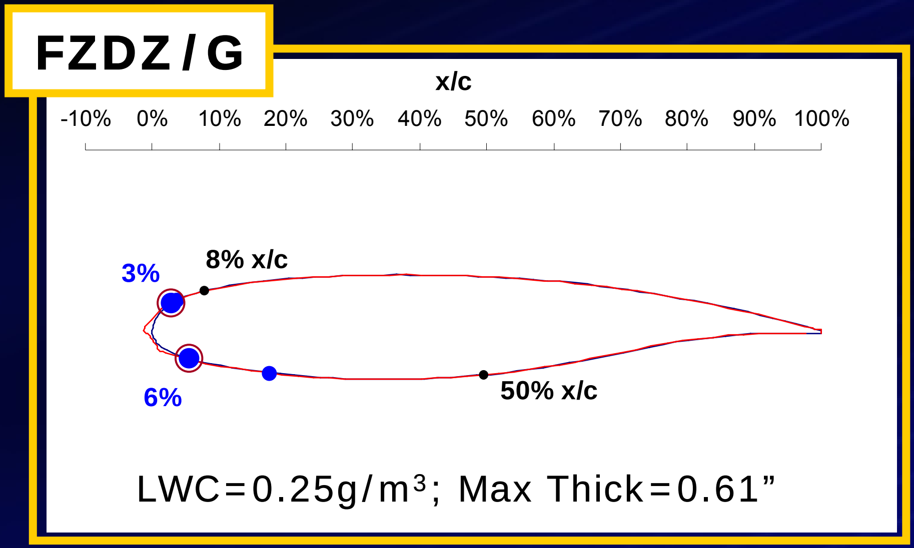

LEWICE 3.2.2; 8,000ft; -3.7°$C_{sat}$; -2.0°$C_{tat}$; 100 KCAS; 2°α; +splash; 10 minutes; 50” chord

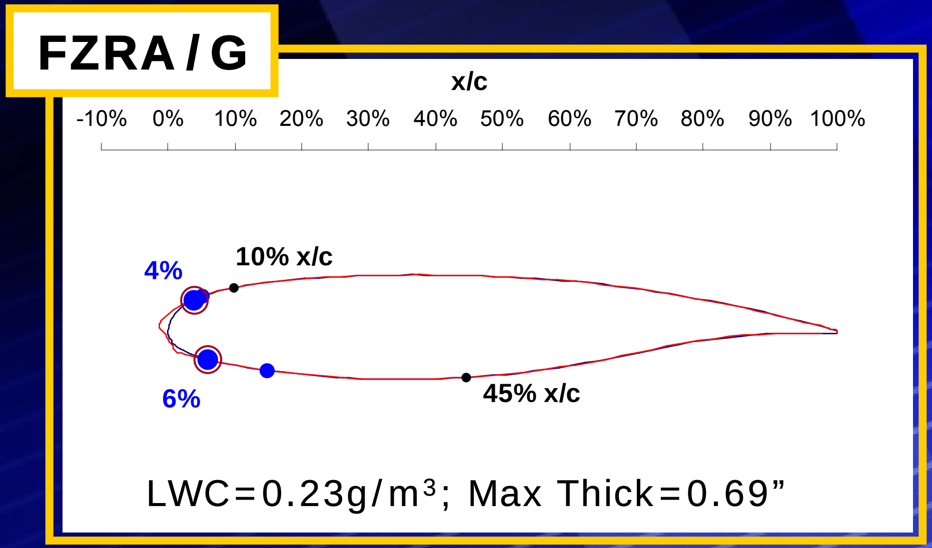
# 200 KCAS



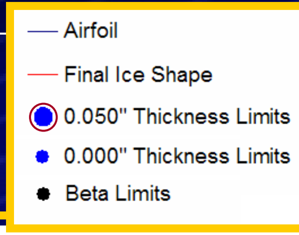



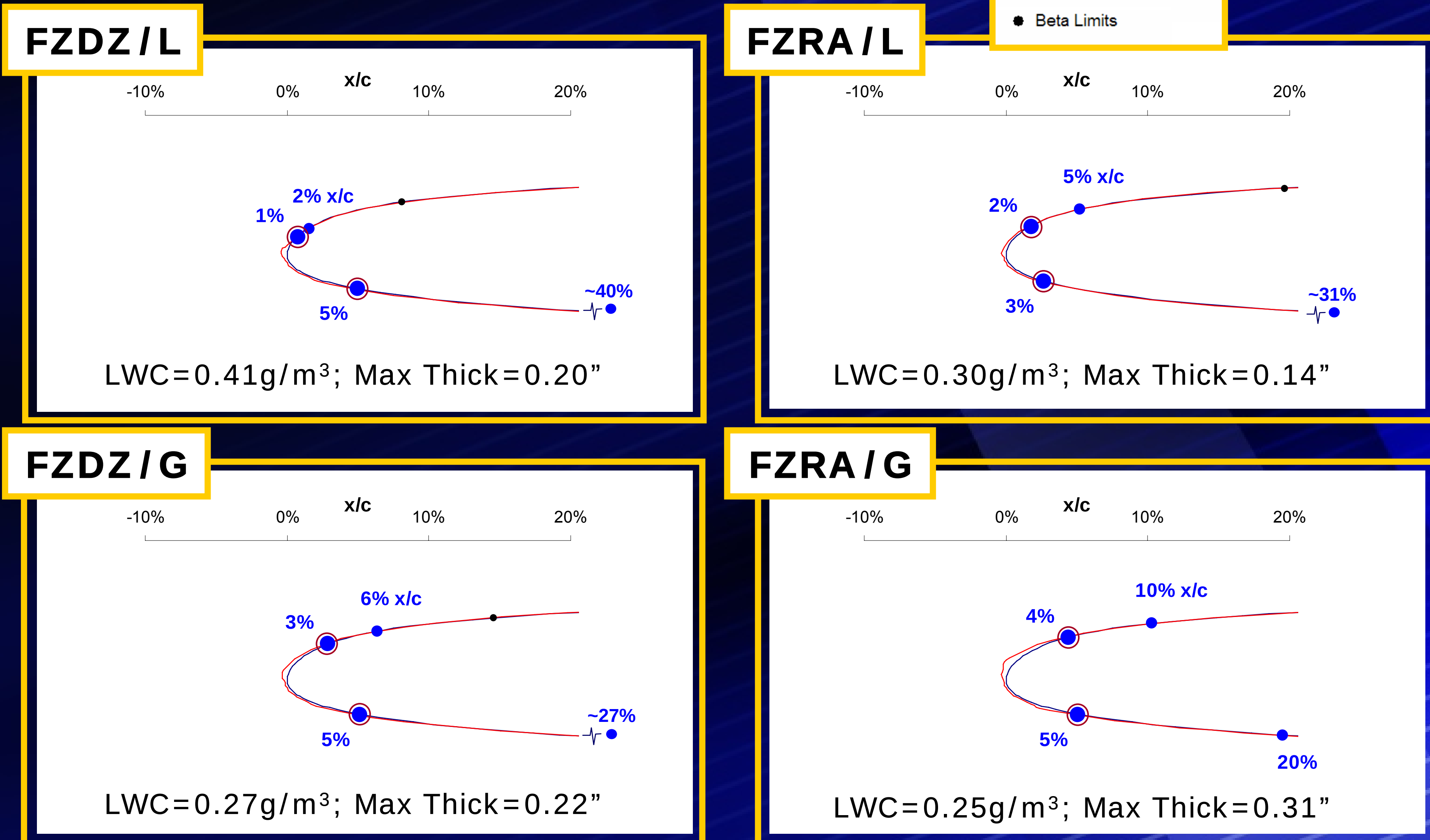

LEWICE 3.2.2; 8,000ft; -5.2°$C_{sat}$; -2.0°$C_{tat}$; 200 KCAS; 2°$\alpha$; +splash; 10 minutes; 50” chord

# Large Droplet Effects

- Ice shapes on leading edge regions similar to Appendix C
- At lower airspeeds, splashing effect is not as strong
- Operation at slower airspeeds appears to extend ice limit
  - Opposite behavior from classic impingement effects (e.g. larger drops impinge further aft)
  - Could increase severity of effect for smaller, slower aircraft

# 100 KCAS

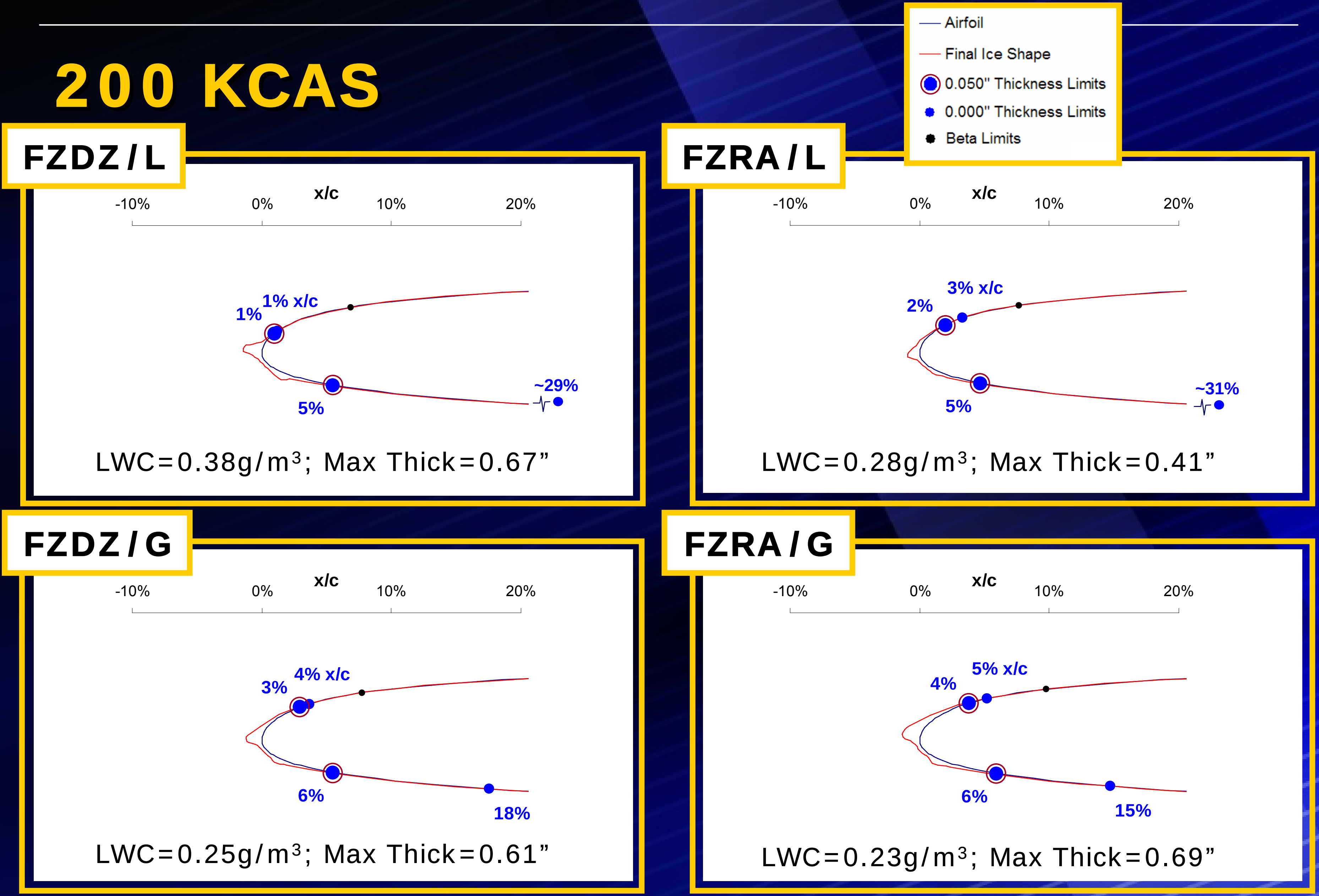



LEWICE 3.2.2; 8,000ft; -3.7°$C_{sat}$; -2.0°$C_{tat}$; 100 KCAS; 2°$\alpha$; +splash; 10 minutes; 50” chord

*(Same data as previous slides, rescaled to leading edge region)*

# 200 KCAS




LEWICE 3.2.2; 8,000ft; -8.5°$C_{sat}$; -2.0°$C_{tat}$; 200 KCAS; 2°$\alpha$; +splash; 10 minutes; 50” chord

*(Same data as previous slides, rescaled to leading edge region)*

# Conclusions

- Common Industry And Regulatory Objectives
  - Safe operation in icing conditions within operating guidance & limitations
  - Addressing issues that provide the largest safety benefit
    - » Best use of limited resources
- Conservative <u>and</u> accurate ice shape simulation necessary
- Significant challenges remain in simulation of large droplet icing
  - Particularly with respect to roughness aft of protected areas