

# Engine Harmonization Working Group Activities

## Ice Crystal Engine Icing

### *Working Group Origins – Activities Began in 2003*

- October 31, 1994 Crash of ATR72 series airplane in Roselawn, Indiana in supercooled large droplets (SLD) conditions, which are outside the envelope of Appendix C of Part 25 of the Federal Aviation Regulations
- National Transportation Safety Board Recommendations -*define an icing environment that includes supercooled large droplets (SLD), and devise requirements to assess the ability of aircraft to safely operate ... in SLD ... and in mixed phase conditions if such conditions are determined to be more hazardous than the liquid phase icing environment containing supercooled water droplets*

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### *Working Group Origins – Activities Began in 2003*

- Ice Protection Harmonization Working Group (IPHWG) – Aviation Rulemaking Advisory Committee
  - Conducted atmospheric research – leading to “Appendix X” Supercooled Large Drop icing environment
  - Proposed a new rule CFR 14 25.1420 Supercooled large drop icing conditions
  - Conducted a study which concluded that mixed phase (ice crystals+liquid water) conditions were no worse than the same water content as supercooled liquid water for airframe surfaces
  - Solicited engine experts to review propulsion related CFR 14 Part 25 rules and Part 33 rules (Engine Certification Standards) in 2003

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### *Working Group Activities 2003-2006 Preliminary Work*

- Engine Harmonization Working Group and Powerplant Installations Harmonization Working group Joint Committee was formed with engine manufacturers, airframers, FAA, CAA and Transport Canada members
- Developed a database of 222 events related to engine (turbojets, turbofans, turboprops) icing for years 1989-2003
- Events were categorized as SLD, Mixed Phase/Glaciated, Appendix C
  - Glaciated cloud  $\equiv$  cloud composed of ice particles only with no liquid component
  - Mixed phase  $\equiv$  cloud composed of a mixture of ice particles and supercooled water droplets

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### *Working Group Activities 2003-2006 Preliminary Work*

- Glaciated/Mixed phase events were determined to be the leading cause of icing-related engine powerloss (97 events)
- Fan damage events occurred in SLD, mostly on takeoff power application (38 events) - assumed ice accreted during ground taxi
- No in-flight SLD accretion – presumably due to current rigorous Appendix C means of compliance

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### *Working Group Activities 2003-2006: Draft Regulations*

- Wrote draft revisions for FAR33.68 Induction System Icing (Engine), and FAR25.1093 Induction System Icing (Airframe)
- Developed “Appendix D to FAR33” – new ice crystal envelope defining ice water content, temperature, and particle size
- Wrote draft revision to AC20-147 with new section for ice crystal compliance by similarity, ice slab compliance by analysis
- Draft rules currently under review by the FAA. Consideration is being given to accelerating release of rules related to ice crystals, due to the seriousness of the engine powerloss events

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### *Working Group Activities Technology Needs*

- The EHWG recognizes that further work is needed:
  - The nature of high altitude convective clouds isn't well understood
  - Instrumentation used for existing atmospheric characterization now known to underestimate the concentration of crystals
  - Engine committee developed a threat level, Appendix D, using the best data available. Research is needed to confirm the threat concentration with distance and particle size distribution
  - Basic research is needed to understand the fundamental physics of ice crystal accretion in an engine
  - Research is needed to develop simulation methods (test cells and analytical tools) to demonstrate engine capability to the threat

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### *Working Group Activities 2006-07: Technology Plan Development*

#### **Task 1.**

Instrumentation development and evaluation for high ice water content.

#### **Task 2.**

Flight test research for characterization of high ice water content environments.

#### **Task 3.**

Physics of ice crystal accretion and shedding: experimental testing in support of ice accretion model development and validation for high ice water content environments.

#### **Task 4.**

Test facilities requirements for demonstrating engine compliance with ice particle threat.



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### *Task 3 – Fundamental Physics of Ice Crystal Accretion*

The engine is a unique environment: the ice accretion site is continually bathed in warm air while ice is accreting

This may be a key difference between supercooled liquid ice accretion, and ice crystal accretion on a heated surface in the freestream such as the anti-iced surface of a wing

Other differences from supercooled droplet accretion:

- Ice particles are irregular – trajectories and particle drag/bouncing/breaking/sliding/splashing are all unknown
- It is believed that water is needed for the ice accretion to start, but how much? Where does it come from?
- Research is needed on heat transfer issues such as residence time, melting, evaporation, and erosion
- The physics may change due to the particle size distribution:
  - small particles accrete whereas larger particles act like hail
  - small particles may melt in the airflow and provide a source of liquid
  - small particles may collect in stagnation areas and begin accreting

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### *Task 3 – Fundamental Physics of Ice Crystal Shedding*

Ice adhesion and shedding may be different than ice formed from supercooled liquid because of continuous heat transfer from metal surfaces bathed in the warm airflow

Altitude research will be required to validate the understanding of physics derived from ground test

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## Ice Crystal Engine Icing

### *Task 3 – Fundamental Physics of Ice Crystal Accretion*

#### Simulation Approach:

- Initial modeling
- Single airfoil testing
- Airfoil cascade testing
- Rotating rig
- Engine testing
- Model validation

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## The Ice Crystal Engine Icing

### *Task 3 – Fundamental Physics of Ice Crystal Accretion*

Status of test plan development

Physical phenomenon requiring research has been defined

Detailed test plans are in work

Funding of only basic tests exists (NRC, FAA, NASA)

Industry partnership is needed to fully fund the testing