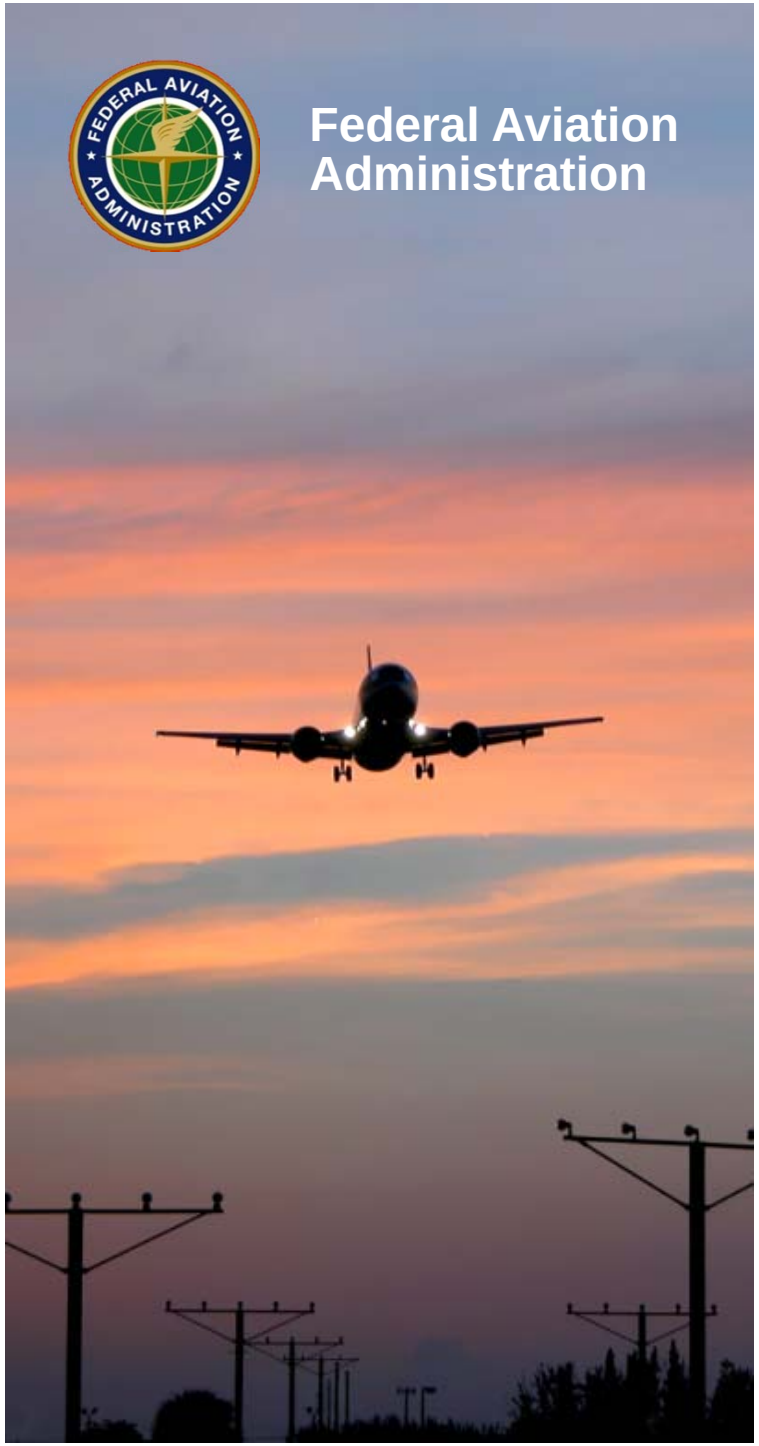
HAIC-HIWC Science Team Meeting

Ice Crystal Icing Rulemaking



Presented at: HAIC-HIWC Science Forum

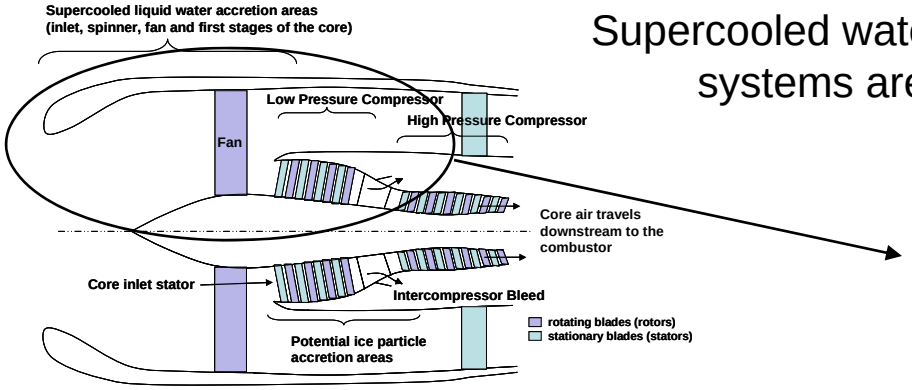
By: Tom Bond, FAA – Aircraft Icing Technical Advisor

Date: November 9, 2015

Location: Bureau of Meteorology, Melbourne, Australia

Jet Engine Icing – Ice Crystal Accretion

- Frozen ice crystals impinging on a warm surfaces inside the engine compressor
- Some crystals melt, creating local mixed phase conditions
- Crystals impinging on wetted surface stick, cool the surface to 0 C, then ice begins to form
- At high altitude, ice can form deep in the engine core



Supercooled water drops – impact where hot air ice protection systems are designed to keep surfaces clear of ice

Graphics Courtesy of Boeing

Ice Crystals Encounter Heated Engine Surfaces and Form Ice Inside the Engine Core

Potential ice crystal accretion areas

Background – How did we get here (1/4)

- **1994 American Eagle ATR-42 Roselawn accident: NTSB recommendations (1996) to the FAA were to review the icing environments and account for conditions that exceed current Appendix C icing certification standards.**
  - FAA tasked the Aviation Rulemaking Advisory Committee in 1998 to develop the Ice Protection Harmonization Working Group to harmonize icing rules and to specifically look at supercooled large drops (SLD), mixed phase, and glaciated (ice crystal) icing conditions.
  - IPHWG Actions:
    1. Flight research needed for winter weather environments to characterize SLD icing conditions – NASA, EC, and NRCC
    2. Meteorology sub-group: develop a new engineering standard for SLD icing conditions (Appendix O)
    3. Task Engine Harmonization Working Group (EHWG) to determine if conditions outside of Appendix C effect turbine engines

Background – How did we get here (2/4)

- **EHWG review of ice crystal event history identified high-altitude convective weather where the water is frozen ice particles, not super-cooled liquid drops**
- Ice crystal icing (ICI) does not affect cold airframe surfaces, only some heated engine surfaces
- Ice crystal encounters affecting engines are typically:
  - Within 30 nmi of convective weather
  - In mild or moderate turbulence
  - Reported as rain on windshield at very high altitudes where liquid precipitation is not possible (it is hypothesized that small frozen ice particles are melting on heated windscreen upon impact)
- The aircraft ice detector does not detect ice crystals
- The highest concentrations of ice crystals are near the updraft areas of convective cloud.

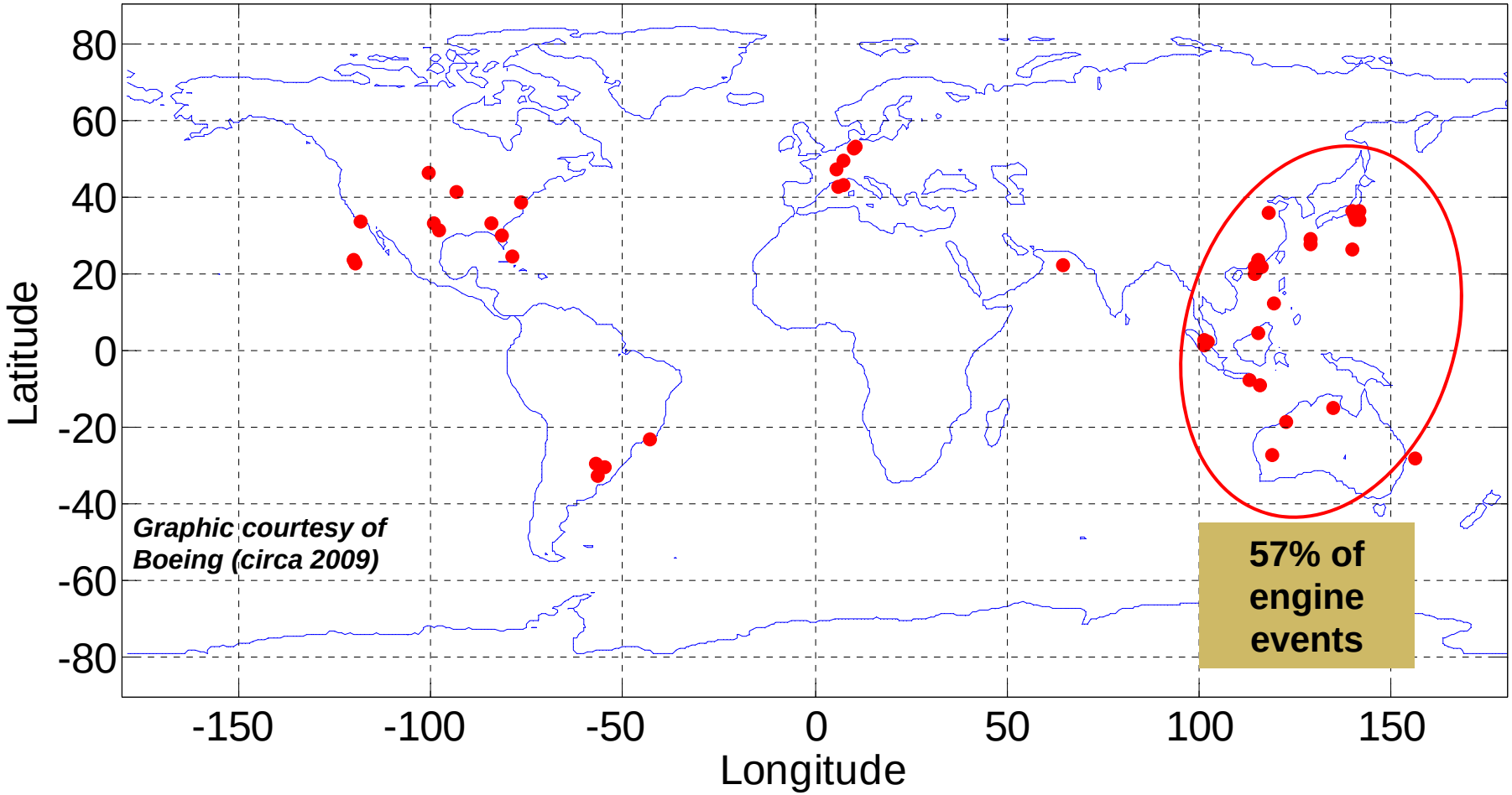
Background – How did we get here (3/4)

- **Overall Revenue Service Fleet**
  - A total of 148 power-loss events identified in review of service history
    - Initial review of service history developed database of 97 engine events in 16-years (1988-2003)
    - 51 Additional events identified since original effort closed (review in 2012).

Note: A power-loss event is a surge, stall, rollback, or flameout of one or more engines.

Turbine Engine Powerloss Events

- There is a large concentration of events in Pacific-Asia region. This may be due to the fact that the highest sea surface temperatures are also found in this region.



Background – How did we get here (4/4)

New rulemaking proposal submitted to ARAC – Notice for Proposed Rulemaking (NPRM) in June 2009:

- Expands icing conditions used for certification of aircraft to include:
  - SLD icing conditions for transport category airplanes most affected by these icing conditions
  - Mixed phase and ice crystal conditions for all transport category airplanes, and
  - SLD, mixed phase, and ice crystal icing conditions for all turbine engines
- FAA conducted internal review process for acceptance of NPRM – includes regulation and guidance material development, cost benefit analysis, and public comments

New Icing Regulations

- Final rule – Amendments 25-140 and 33-34

  Effective date: 1/5/2015

  – Part 25 Appendix O (large drops)

  – ***Part 33 Appendix D, (ice crystals)***

  – Choices for certification in App O

    - Detect and exit
    - Consider/detect portion and exit when exceeded
    - Consider whole environment

  – Revises numerous rules to consider these new icing environments

Engine Ice Crystal Research

- **The ARAC Engine Harmonization Working Group (EHWG) determined that further research was needed to support means of compliance and developed a technology plan with the FAA to support continued research in ice crystals.**
  - *Mixed-Phase/Glaciated Icing Technology Plan, EHWG Technology Plan Document – Version 1.1, December 2005. Available from FAA*
- Flight research field campaigns were developed by an international partnership (including funding by EASA):
  - High Altitude Ice Crystal (HAIC) project – European Commission funded work package 5: Airbus (lead), CNRS, SAFIRE, Meteo France, and CIRA
  - High Ice Water Content (HIWC) project - *FAA, NASA, Boeing, Environment Canada, Australian Bureau of Meteorology, National Research Council of Canada, Science Engineering Associates, National Center for Atmospheric Research, Airbus, and Transport Canada.*

HIWC Field Campaign – Objectives

- Collect data to evaluate atmospheric ice crystal properties:
  - Compare to proposed Appendix D envelope
  - Determine/verify ground test facility spray simulation criteria
- Ice crystal weather tools development for nowcast/forecast capabilities
- Evaluate current on-board reactive detection
- Falcon 20 research radar – provide real-time weather information and a data base describing reflectivity-mass relationships. Helps identify design goals needed for a cockpit weather radar

Thank you

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