High Altitude Inclement Weather

Ice Crystal Icing

Presented to: Singapore Aviation Academy Workshop

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Agenda

- **High altitude icing – Ice Crystals**
- **Incident history**
- **Effects on engines**
- **Mitigations**
- **Research and rulemaking**

Ice Crystal Environment

Courtesy of CNRS and NASA

- Convective Weather
- High Altitude

New Certification Icing Environment As Of January 2015

Ice Crystal Environments

- Typically found in regions with deep convective lifting.
- Light to moderate turbulence.
- Rain reported on windshield.
- No airframe icing; ice detector does not detect ice particles, measures liquid water.
- Total Ambient Temperature (TAT) probe indicates 0° C. This does not consistently occur.

Ice Crystal Effects on Aircraft Probes

- Unheated aspirated probes are less affected by ice crystal clogging
- Heated probes can become quickly overwhelmed in ice crystal icing
- TAT probes often indicate 0°C when clogged with ice.
  - Often this precedes an engine rollback in power.
- New probe certification compliance guidance has been developed with industry

Ice Crystal Effects on Engines

- **Can accrete deep within engine where air temperatures could be as high as 40°C**
- **Accretion can:**
  - choke off engine's core air flow
  - Ice accretions can shed during throttle-up
  - Ice can cause blockage and malfunction of probes
- **Engine Operational Effects:**
  - Engine compressor stall – power loss
  - Engine compressor blade damage
  - Combustor flameout (quench) – power loss
  - High engine fan vibrations

Service Events

Mixed Phase & Ice Crystal

Engine Incident History
Mixed Phase & Ice Crystals (1/2)

<u>Overall Fleet</u>

A total of approximately 200 power-loss events

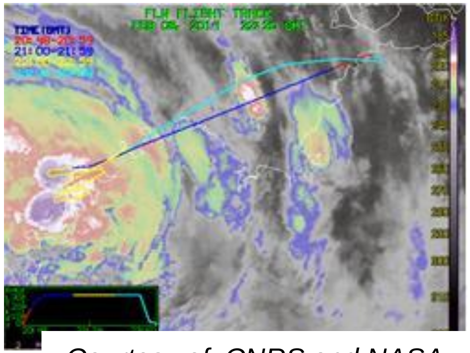
- Some all engine powerloss events
- New engines:
  - can self-recover from flameout events
- Older engines:
  - Use continuous ignition and nacelle anti-ice when near convective weather
  - Restart engines as soon as possible after a flameout

Power loss events still occur within the current fleet

Engine Incident History
Mixed Phase & Ice Crystals

– <u>Power loss events: flight phase & recovery</u>
  - About half occurred during descent
  - About half occurred during climb/cruise
  - Total power loss events from flameout
    - Most successfully restored power, except for:
      - ➢ 3 -forced landing (ice crystal)
      - ➢ 1 -forced landing, engine damage (snow)

Mitigating the Ice Crystal Threat
Design & Ops



Courtesy of CNRS and NASA

- **Operations:**
  - Flight crew educational opportunities
  - No over-flying convective systems
  - Avoid convective systems by at least 30 nm
  - Newer engines:
    - Self-recover from flameout events – auto relight feature
  - Older engines (without auto-relight):
    - Use continuous ignition and nacelle anti-ice when near convective weather
    - Restart engines as soon as possible after a flameout
  - Follow airframe manufacturer's recommendations
    - e.g. radar down-tilt 3-5 degrees when approaching convection

Rulemaking Activity

- **Airworthiness certification regulations revised**
  - Applicable to *new* engines/aircraft
    - Does not affect the current fleet
  - FAA and EASA both revised regulations
  - FAA regulations effective in January 2015

Ice Crystal Icing R&D

- There is an international partnership with Europe, N. America, Australia, Airbus and Boeing to investigate ice crystal effects on aircraft engines and air data systems
  - Composed of research organizations, industry, and regulators
  - Goals:
    1. Characterize ice crystal icing environments that cause engine events
    2. Develop mitigation strategies for aircraft to avoid high altitude ice crystal environments
    3. Develop means of compliance to support new icing regulations

Research Flight Tests

- **Three flight tests performed to date in convective weather high altitude ice crystal environments:**
  - Darwin, Australia (2014)
  - Cayenne, French Guyana (2015)
  - Ft. Lauderdale, FL, USA (2015)
- **Airworthiness regulations will be revised based on the flight test results**

Questions?

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Backup Slides

Atmospheric Icing Threats

- **Supercooled clouds**
  - Stratiform clouds and Cumuliform clouds
- **Supercooled (freezing) fog**
  - Ground Operations
- **Supercooled Large Droplet (SLD)**
  - Freezing <u>rain</u> and Freezing <u>drizzle</u>
- **Mixed Phase Icing & Glaciated Ice Crystals**
  - High concentrations near thunderstorm or convective cloud structures
  - Threat to aircraft probes and engine operation
- **Snow**
- **Rain & Hail**
  - Extreme rain and hail
  - Convective weather at lower altitude near storm core