NASA Glenn Propulsion Systems Lab (PSL) Icing Facility Update

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Outline

• PSL Background
• PSL Icing Status
• Icing System Design
• Facility Modifications
• Calibration
• Icing Testing Capabilities
PSL Background

- Two test sections share common inlet and exhaust
- Continuous Operation at high air flow rates
  - Altitude 90,000 ft (-90 deg F)
  - PSL-3 Mach 3.0 (600 deg F)
  - PSL-4 Mach 4.0 (1000 deg F)
- PSL3 recently upgraded for icing capability
- Multi-axis thrust measurement
- Real time, high speed data acquisition and display

*NASA PSL is one of the Nation’s Premier Direct Connect Altitude Simulation Facilities for Full-Scale Gas Turbine Engine and Propulsion System Research*
NASA PSL Icing Status

• Initial icing calibration completed Nov. 2012
• Inaugural icing test of Honeywell ALF502-R5 engine completed April 2013.
• Second icing calibration completed June 2014.
• Second icing test was rig driven and completed March 2015
• Third icing calibration completed May 2015
## Icing System Design

<table>
<thead>
<tr>
<th>Specification</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine / Rig Dia. (in</td>
<td>cm)</td>
<td>24</td>
</tr>
<tr>
<td>Air Flow Rate (lbm/s</td>
<td>kg/s)</td>
<td>10</td>
</tr>
<tr>
<td>Altitude, pressure (kft</td>
<td>km)</td>
<td>4</td>
</tr>
<tr>
<td>Total Temp (°F</td>
<td>°C)</td>
<td>-60</td>
</tr>
<tr>
<td>Mach Number</td>
<td>0.15</td>
<td>0.80</td>
</tr>
<tr>
<td>TWC (g/m³)</td>
<td>0.5</td>
<td>8.0 *</td>
</tr>
<tr>
<td>MVD (um)</td>
<td>15</td>
<td>&gt;100 #</td>
</tr>
</tbody>
</table>

* Evidence that probe under-measured
# Particles larger than ≈ 60 um are NOT fully glaciated.
PSL Icing Cloud Hardware

Spray Bars – Cloud Generation

• Ten Spray Bars; total of 110 Standard
  • nozzles and 112 Mod1 nozzles.

• Each nozzle is individually controlled.

• Nozzle controls:
  ▪ Pair, atomizing air pressure: 10 – 90 psid,
    Tair temperature: 45 – 180 F.
  ▪ Pwat, water pressure: 10 – 300 psid,
    Twat temperature: 45 – 180 F.
  ▪ DeltaP = DP = (Pwat – Pair)
  ▪ SBCA, Spraybar cooling air.
    P: 5 – 40 psid, T: -40 – 40 F.

(Pair, DeltaP) => (MVD, TWC)

At a given air mass flow rate
Steam Injection System is used to provide a constant relative humidity in the inlet plenum to stabilize cloud.

Steam is injected into the inlet airstream as the supply air enters the building.

Relative humidity is measured at the injection point and in the inlet plenum.
Facility Modifications

Installed Deionized water system for Conventional Icing (CI). Can perform a continuous spray for up to 60 minutes.

- 600 – gallon tank takes 60 – 90 minutes to fill
- Monitor resistivity in real-time
Facility Modifications

Tomography laser system installed and used on previous calibrations/tests to measure cloud uniformity.
Icing Calibration Configurations

PSL Configuration – 1st Cal

Configuration 1:
- Engine
- 27:1 CR

PSL Configuration – 2nd Cal

Configuration 2:
- Component
- 11:1 CR
- 22:1 CR with bullet nose*
* approx. representation

Modification upstream of spraybars
PSL Clouds

- Ice Crystals
  - Cold spray bar air & water temps
  - City or De-ionized water
  - Fully glaciated up to MVD 60 um
  - Wet Bulb temp < 0 C

- Supercooled Liquid
  - Hot spraybar air & water temps

- Supercooled Large Drops (SLD), but not bimodally distributed.
Inaugural Engine Icing Test

Honeywell ALF502R-5 engine installation in PSL. Validation test was able to replicate both roll back and non-roll back events previously experienced by the engine in flight test.
Rollback Indicators Chart - roll back test point

PSL-3, FLT850-2

Cloud On

Initial T/C Decrease

1X TWC

Secondary T/C Decrease
Facility Icing Testing Capabilities

• Full sized Engines
  ▪ Massflows up to 330 pps
  ▪ Exhaust flows up to 500 pps

• Rig Tests
  ▪ For engines that are too large to fit inside of PSL
  ▪ Successfully completed a booster rig test in 2015
Summary

- Continuous flow facility
- Maintain a constant facility inlet temperature within +/- 2 deg F
- Maintain a constant relative humidity
- Vary cloud water content and particle sizes
- Run full scale engines
- Run LPC Driven Rigs
Questions?/Comments!

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