SENS4ICE

SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES
FOR SAFER AVIATION IN ICING ENVIRONMENT

Collins IWT Capabilities and Icing Characterization

SAE AC-9C Meeting

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Virtual – 22 April 2021

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 824253

Outline

- SENS4ICE project overview
- SENS4ICE Icing Wind Tunnel Requirements
- Overview of Collins test facility capabilities
- Collins facility characterization and calibration
  - App. C calibration instrumentation and methodology
  - App. O characterization instrumentation and methodology with pictures
  - SENS4ICE CCP and Nevzorov measurements at Collins
- Collins Ice Differentiator overview
- Summary and Future Work

SENS4ICE Consortium Partners

1) DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT e.V. (DLR)
2) AVIONS DE TRANSPORT REGIONAL (ATR)
3) AEROTEX UK LLP
4) CENTRAL AEROLOGICAL OBSERVATORY
5) CENTRO ITALIANO RICERCHE AEROSPAZIALI SCPA (CIRA)
6) CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)
7) EMBRAER SA
8) STATE RESEARCH INSTITUTE OF AVIATION SYSTEMS
9) HONEYWELL INTERNATIONAL SRO
10) INSTITUTO NACIONAL DE TECNICA AEROESPACIAL ESTEBAN TERRADAS (INTA)
11) LEONARDO - SOCIETA PER AZIONI
12) L-UP SAS
13) OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES (ONERA)
14) FEDERAL STATE UNITARY ENTERPRISE THE CENTRAL AEROHYDRODYNAMIC INSTITUTE NAMED AFTER PROF. N.E. ZHUKOVSKY (TsAGI)
15) TECHNISCHE UNIVERSITAET BRAUNSCHWEIG
16) COLLINS AEROSPACE ADVANCED RESEARCH AND TECHNOLY CENTER
17) SAFRAN AEROTECHNICS
18) HONEYWELL INTERNATIONAL INC
19) COLLINS AEROSPACE
20) NATIONAL RESEARCH COUNCIL CANADA

SENS4ICE Overview

Objective: Increase flight safety in icing conditions and especially for the SLD conditions

Problem

- Detect icing conditions (including App. O/ SLD icing) – detection very challenging

Solution

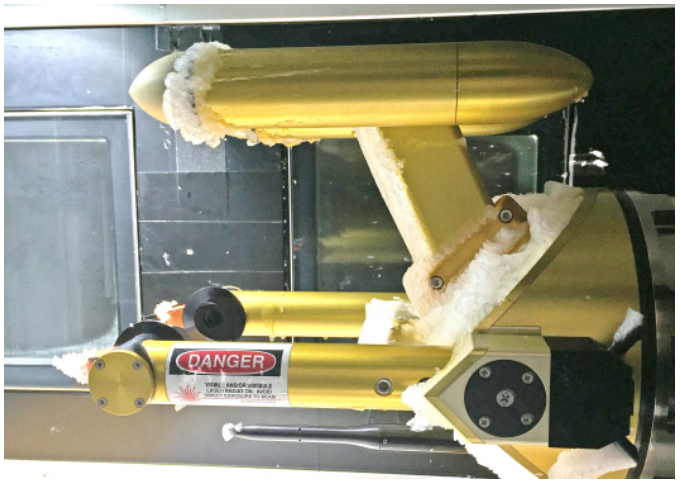
- Hybrid approach – fusion of input data: sensor(s) and indirect detection

Benefits

- Operational benefits: activate anti-/de-icing, avoid/ leave icing conditions
- Certification process benefits – flights in App. O/ SLD icing

Project duration: JAN 2019 - DEC 2022 (project extension expected)

Coordinator: DLR



SENS4ICE Icing Wind Tunnel Requirements

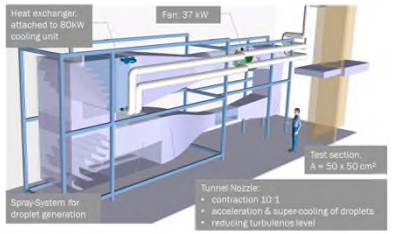
- One of the main objectives of SENS4ICE is to develop and mature different ice detection technologies with a focus on App O conditions
- There are 10 different ice detectors being developed by the project partners
- Most of these ice detectors target detection and discrimination between App. O and App. C conditions
- Detectors performance need to be tested in relevant environment at icing wind tunnel
- Extensive icing wind tunnel tests are planned in the project
  - 28 weeks of testing distributed over four facilities
  - Parallel testing planned to meet project timeline
- Testing will provide data for technology selection towards flight test

Overview of SENS4ICE IWT Capabilities

Collins Aerospace, USA

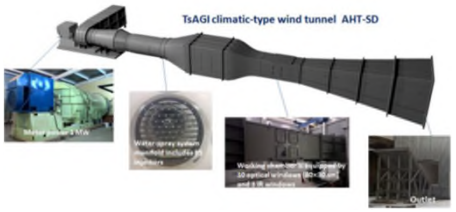
- 5-147 micron droplets
- LWC between 0.1 and 3 g/m3
- Temperature 0°C to -30°C
- Sustained speed 13-103 m/s
- Test section: 152×56×112 cm3
- Calibrated per SAE ARP 5905
- Compliant with AS9100C
- Controls and power supplies can simulate aircraft controls

TU Braunschweig, Germany



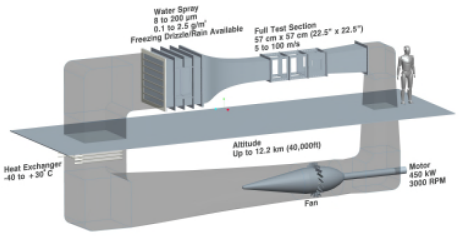
- MVD 9-60 micron droplets
- LWC between 0.1 and 1.5 g/m3
- Temperature 30°C to -20°C
- Sustained speed 10-40 m/s
- Test section: 150×50×50 cm3
- Calibrated per SAE ARP 5905
- Short spray transients ~ 15s
- Bi-modal SLD and mixed phase capability

TsAGI, Russia



- 10-90 micron droplets
- LWC between 0.5 and 6 g/m3
- Temperature down to -40°C
- Sustained speed up to 150 m/s
- Test section: 300×100×100 cm3
- PDI Artium 2D PSD calibration
- LWC calibration with EIV-2K
- High speed camera with long-focus microscope

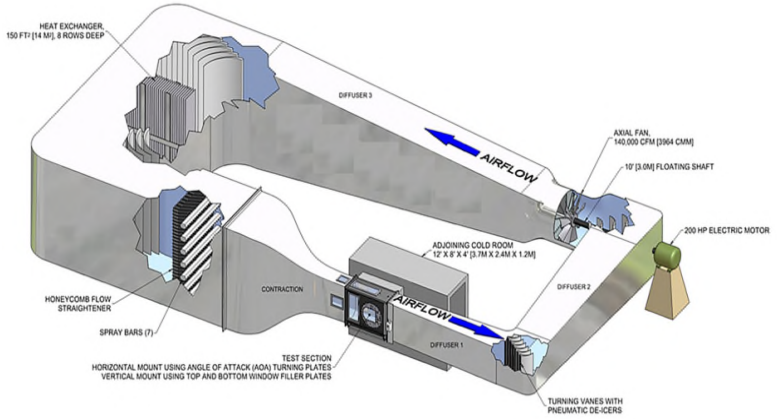
NRC, Canada



- 8-200 micron droplets
- LWC between 0.1 and 2.5 g/m3
- Supercooled Water: 10 to > 200 µm (incl. SLD bi-modal)
- Temperature +30°C to -40°C
- Sustained speed 5-100 m/s
- Test section: 57×57 cm2 (52x33 cm2 with insert)
- Sea level < Altitude < 40,000ft
- Calibrated per SAE ARP 5905

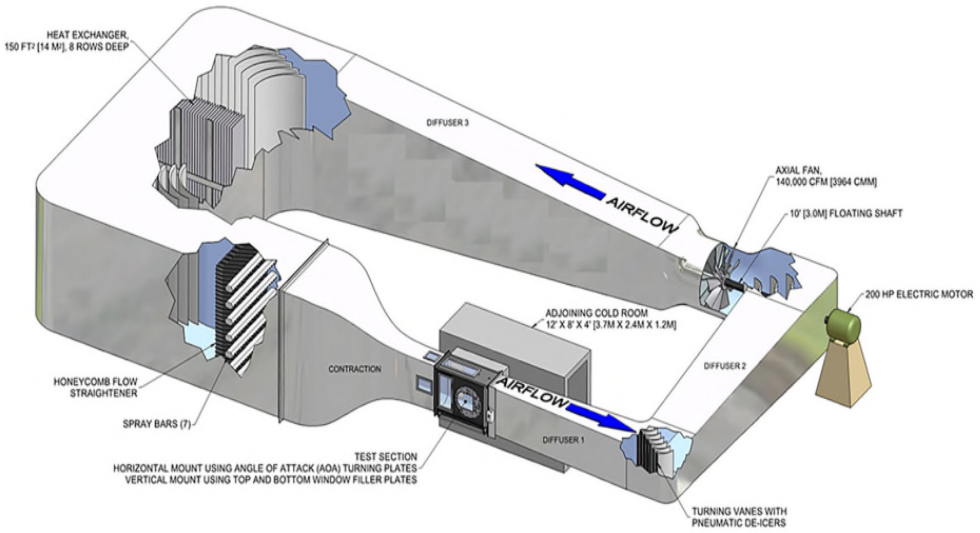
Collins Icing Wind Tunnel Overview

- The Collins Aerospace Icing Wind Tunnel (IWT), constructed in 1988, is a closed-loop refrigerated tunnel measuring 40' x 70' (12.2 m x 21.3 m) overall. Tunnel had series of upgrades including control system, structure and heat exchange (additional tonnage).
- The IWT has been used for the development and design validation testing of a variety of aerospace models including airfoils, engine nacelle sectors, struts, and inlet guide vanes.
- The IWT utilizes an external 200 hp electric motor driving a 79" (2.0 m) diameter axial fan to provide wind velocity, a 70 ton capacity refrigeration system for cooling, and a series of de-ionization tanks to continuously produce DI water for use in the spray bar system.



Collins Icing Wind Tunnel Capabilities

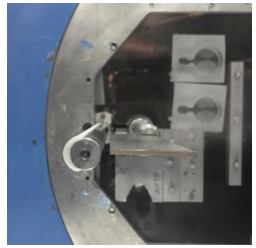
- Test Section Dimensions:
  - 22" (0.6 m) wide x 44" (1.1 m) high x 60" (1.5 m) long
- Temperature Range:
  - -22°F to 32°F (-30°C to 0°C)
- Test Section Airspeed Range:
  - 30 mph to 230 mph (26 kn to 200 kn)
- App C LWC Range:
  - 0.15 g/m^3 to over 3.00 g/m^3
- App C MVD Range:
  - 15 µm to over 40 µm



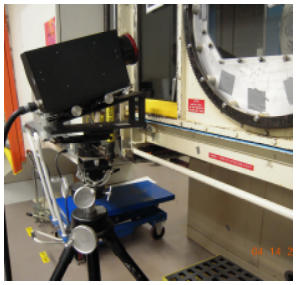
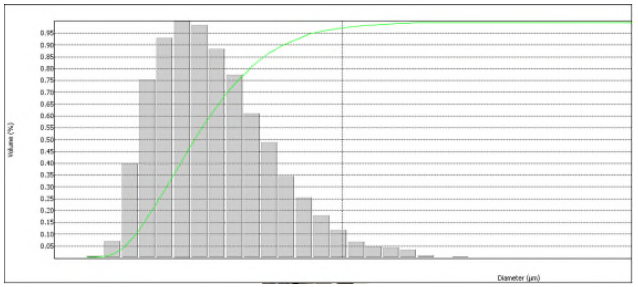
Collins IWT - Appendix C Calibration

- App C calibration procedure based on the best practices outlined in SAE ARP5905.
- LWC calibration is performed using an icing blade.
- MVD calibration is performed using a PDI laser manufactured by Artium Technologies.
  - When configured with a 500mm focal length lens, the PDI system has an effective measurement range of 3µm - 300µm

Icing Blade:

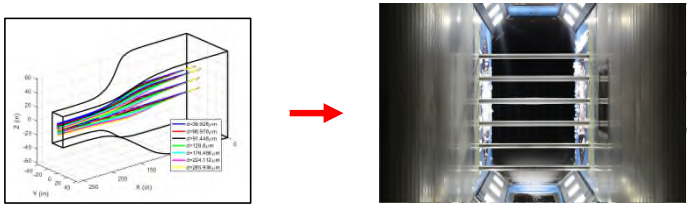

PDI:

Collins IWT - Appendix O Characterization

- The IWT's Appendix O capabilities were characterized in preparation for the SENS4ICE testing campaign.
  - Process for developing App. O was an iterative loop, computer simulation was used to inform which conditions to actually test in the IWT and vice versa.
- LWC characterization was performed using an SEA Multi-Element Probe.
- MVD characterization was again performed using the PDI laser manufactured by Artium Technologies.
  - For App. O conditions, a lens with a 1000mm focal length was used.
  - This augmented the PDI's measurement capabilities to an effective range of 6µm - 570µm.

App O Characterization Process:

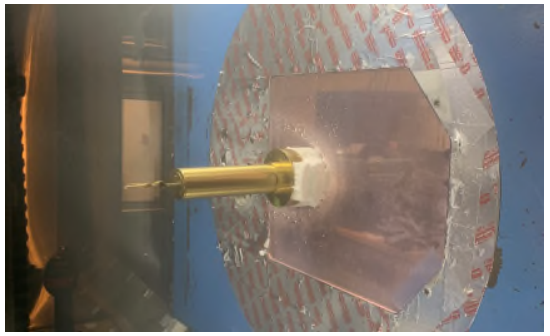


SEA Multi-Element Probe:

SENS4ICE Testing – CCP & Nevzorov Probes

- The CCP and Nevzorov probes are serving as reference probes for the icing wind tunnels participating in the consortium
- The Nevzorov probe was tested at Collins for 2 days.
  - The entirety of the App C and App O test matrices were completed.
- The CCP probe was tested at Collins over the course of 3.5 days.
  - The entirety of the App. C and App O. test matrices were completed.
  - During the test only one of the CCP probe's measurement volumes could be positioned in the centerline of the tunnel at a time.
  - For that reason, many of the test conditions were repeated in two configurations so that data could be collected with each measurement volume centered in the tunnel.

Nevzorov Probe:

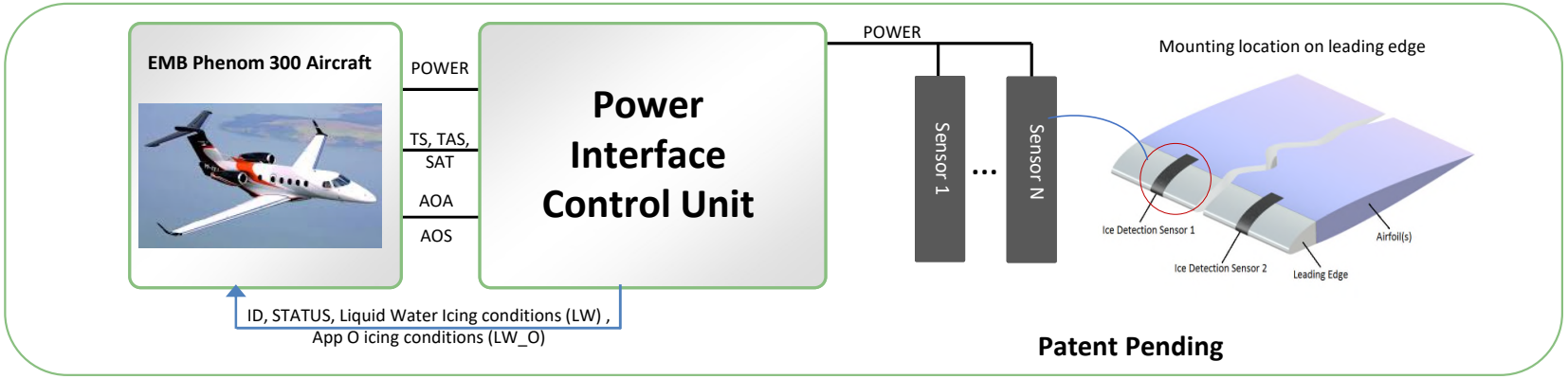


CCP Probe:

Collins Ice Differentiator Technology

Sensor Detection Concept

- Ice detection based on thermal response to a heat impulse that changes from dry to icing conditions
- Heat flux variation measured using composite heater
- System is made of two components: a sensing element (heater) and a power interface control unit
- Power interface unit analyses measurements and makes recommendations on icing conditions Dry/ App. C/ App. O

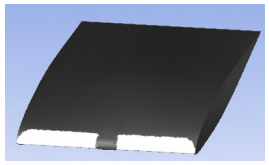


Collins Ice Differentiator Achieved TRL 4

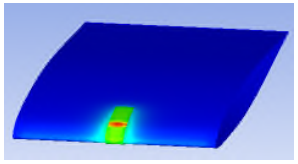
NUMERICAL ANALYSIS

- Numerical analysis used to define sensor design parameters
- Model validated against IWT test measurements

App C

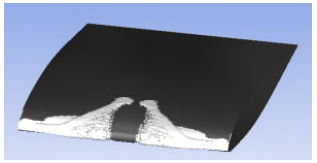


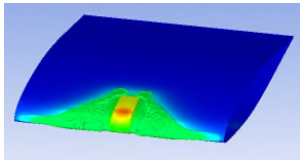
Ice accumulation



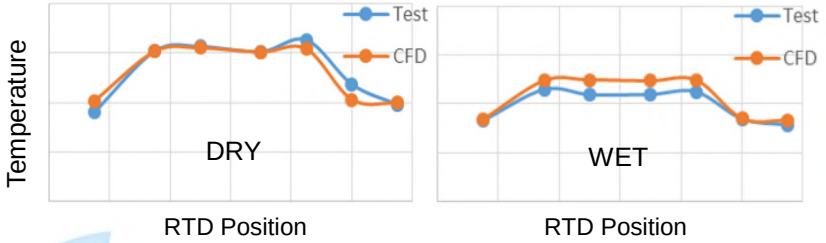
Temperature

App O – FZDZ



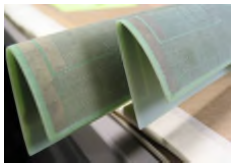


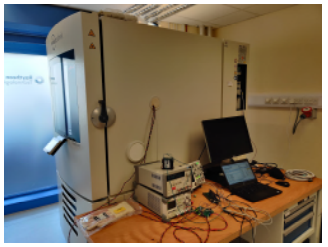
Model validation against IWT test data



LAB AND IWT TESTING

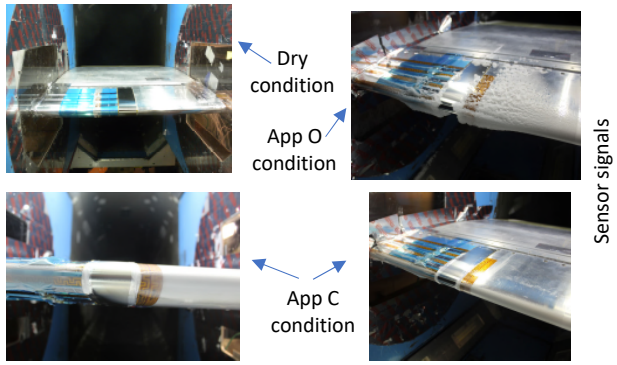
- Sensor prototype power delivery on controller request and data acquisition tested
- Integration tests performed using a thermal chamber





- Four rounds of IWT tests completed at Collins IWT – OH and NRC IWT

View of sensor during IWT tests



Summary and Future Work

- Collins IWT facility offers App C and App O capabilities
- Four weeks of SENS4ICE testing were completed at Collins IWT
- CCP and Nevzorov successfully tested in the Collins IWT
- Collins IDS (Ice Differentiator Sensor – CIDS) tested during 120 hours at Collins IWT
- Collins IDS tested at NRC icing tunnel for additional test points
- Collins IDS achieved TRL4 following IWT tests and is capable of detection and differentiation between Dry, App. C and App O. icing conditions
- Icing wind tunnel tests on vertical fin planned in Q4 to prove scalability of the technology
- Preparations for potential flight test with Embraer

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 824253.

SENS4ICE

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