SENS4ICE

SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES FOR SAFER AVIATION IN ICING ENVIRONMENT

Atmospheric Icing Patch

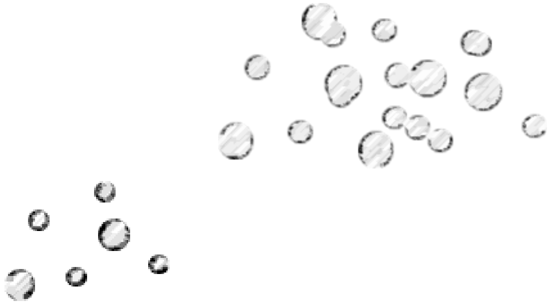
FINAL DISSEMINATION EVENT OF SENS4ICE PROJECT

Ian Roberts, AeroTex UK LLP

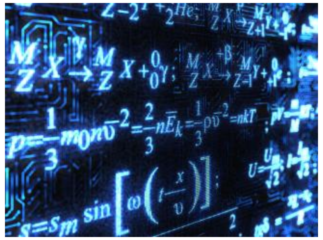
Directorate General for Research and Innovation, Brussels, Belgium – 29 November 2023

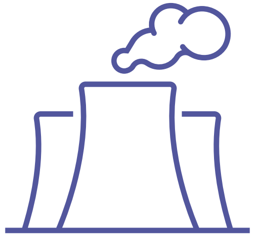
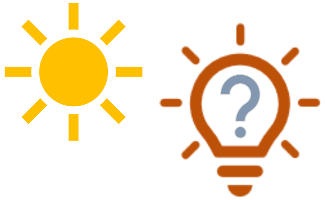
This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 824253

AIP - Atmospheric Icing Patch AeroTex UK LLP
Goals

- AIP Detection Goals
  - Develop technology to detect icing conditions
  - Develop technology to differentiate between Appendix C and Appendix O conditions
  - Develop a technology that could provide an indication of the icing severity
- AIP System Goals
  - Physics-based detection basis
  - Minimise power consumption
  - Minimise false positive detection



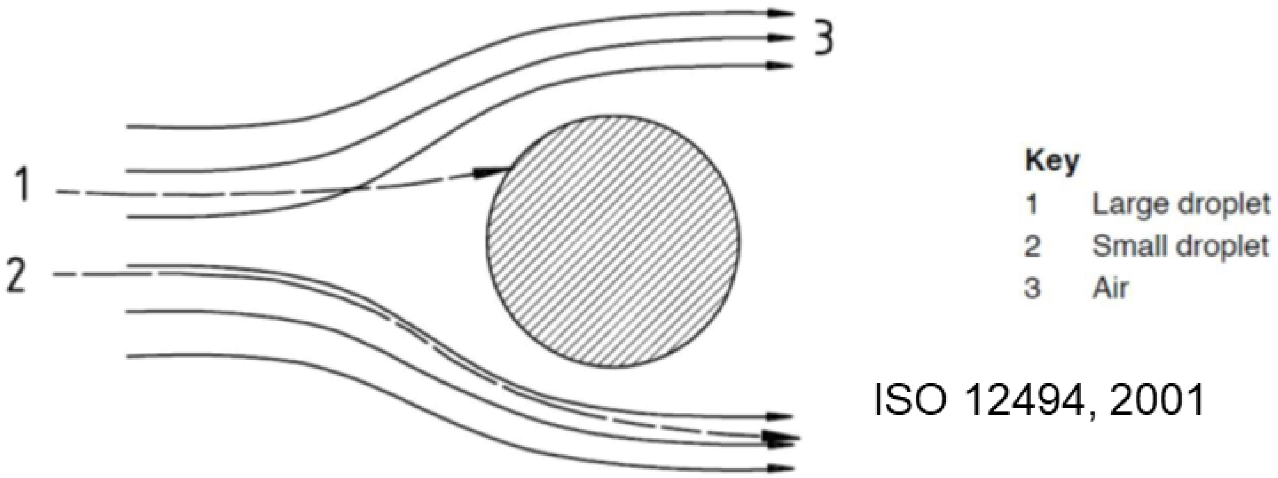
- SENS4ICE Goals
  - Make it to flight test!

AIP - Atmospheric Icing Patch
AeroTex UK LLP

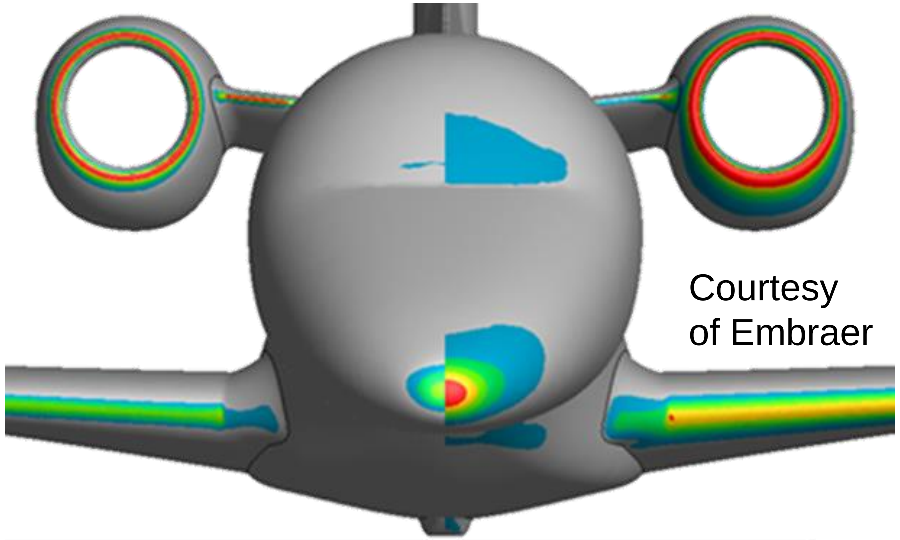
- AIP Characteristics
  - Atmospheric ice detector
  - Iso-thermal detection technology with inertial separation
  - Detection: LW, App O, LWC (approximation)
  - 22x22x10mm, 5 grammes and < 30W/sensor
  - Rack mounted processing unit < 500g
  - TRL2 at the start of the programme to TRL5/6 at the end (TRL4 for LWC estimation)
  - IWT Testing performed at NRC & TUBS under SENS4ICE with additional testing at RTA
  - Flight testing on the Phenom 300 in North America

AIP - Atmospheric Icing Patch AeroTex UK LLP
Concept Design

- Proposed Solution
  - Utilise iso-thermal detection technology but packaged into a patch
    - Reduce power as all power focused on forward face
    - Slight step to mitigate risk of runback contamination
  - Use the aircraft to inertially separate the droplets instead of wing leading edge
    - Inertial separation around the nose of the aircraft is much greater as a function of distance than on the wing and the variability in heat transfer coefficient is small
    - Mounting the sensors on the centreline minimises sensitivity to side-slip



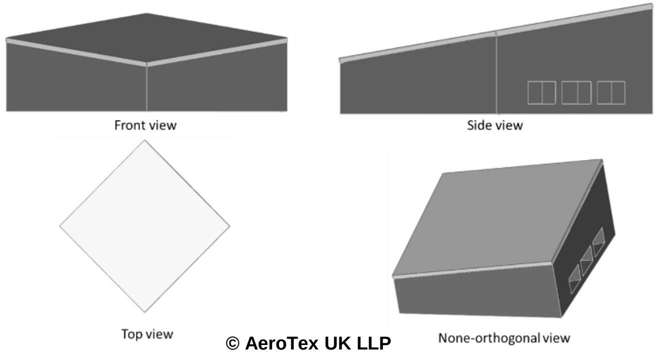
ISO 12494, 2001



Courtesy of Embraer

AIP - Atmospheric Icing Patch AeroTex UK LLP
Design & Development

- Analysis – Impingement and HTC calculations were performed for both the ATR & Phenom platforms to determine both sensor placement and the power density requirements
  - Available installation locations were better on the Phenom 300
- Sensor technology development
  - Sensor trials were performed to assess which technology was best suited to the requirements
    - Balancing response time, surface temperature, power consumption and manufacturability
  - Candidate technologies taken forward to tunnel testing in RTA, Vienna (outside of programme) and NRC, Ottawa
  - Technology proven but bespoke units would be required for flight through sub-contract
  - Final units subject to further testing in RTA, Vienna (outside of programme) and TU Braunschweig



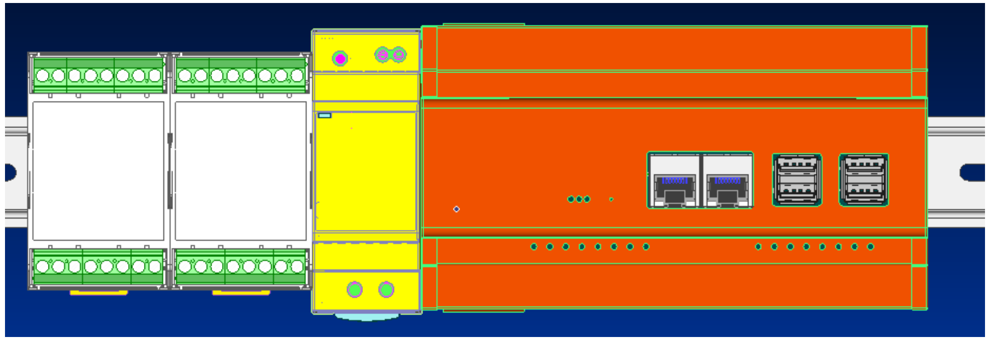
© AeroTex UK LLP

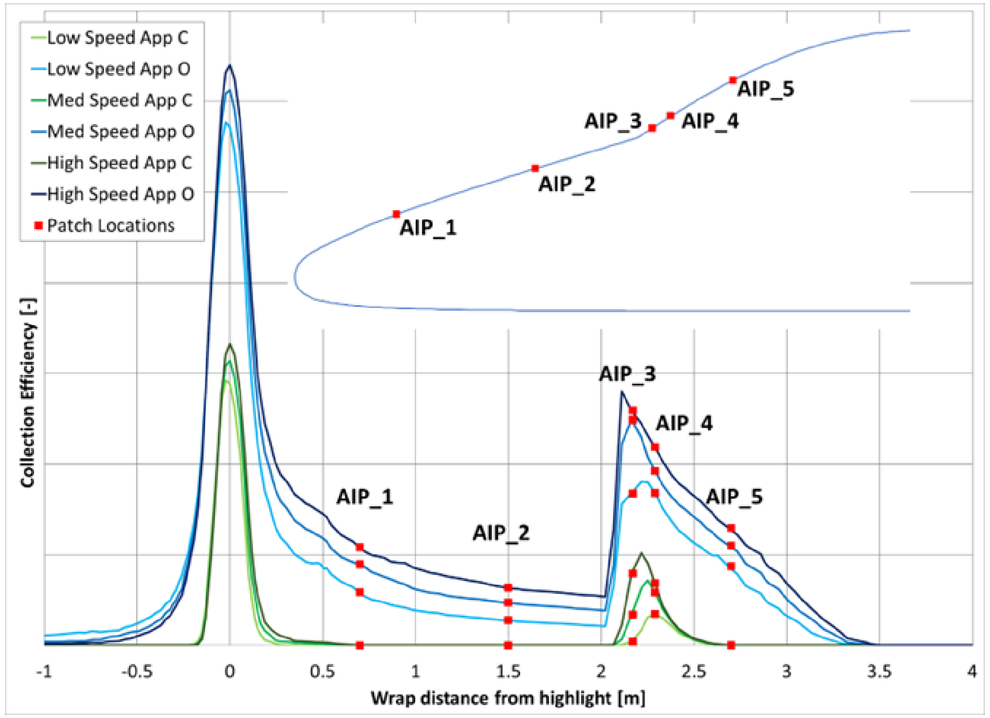
- Per patch properties
  - Dimensions: 22 x 22 x 10mm
  - Weight: <5g
  - Power consumption: <30W

AIP - Atmospheric Icing Patch AeroTex UK LLP

Design & Development

- Signal processing
  - The signal processing hardware was based on COTS technologies and tested during the TUBS test prior to flight
  - Software design logic was to take dry air condition data to act as reference (primarily a function of speed and temperature) and infer the presence of icing based on the excess power drawn
  - Differentiation based on which sensors responded
  - Level of power exceedance can be used to approximate severity or LWC but is challenging as it also relates to the drop size distribution





AIP - Atmospheric Icing Patch AeroTex UK LLP

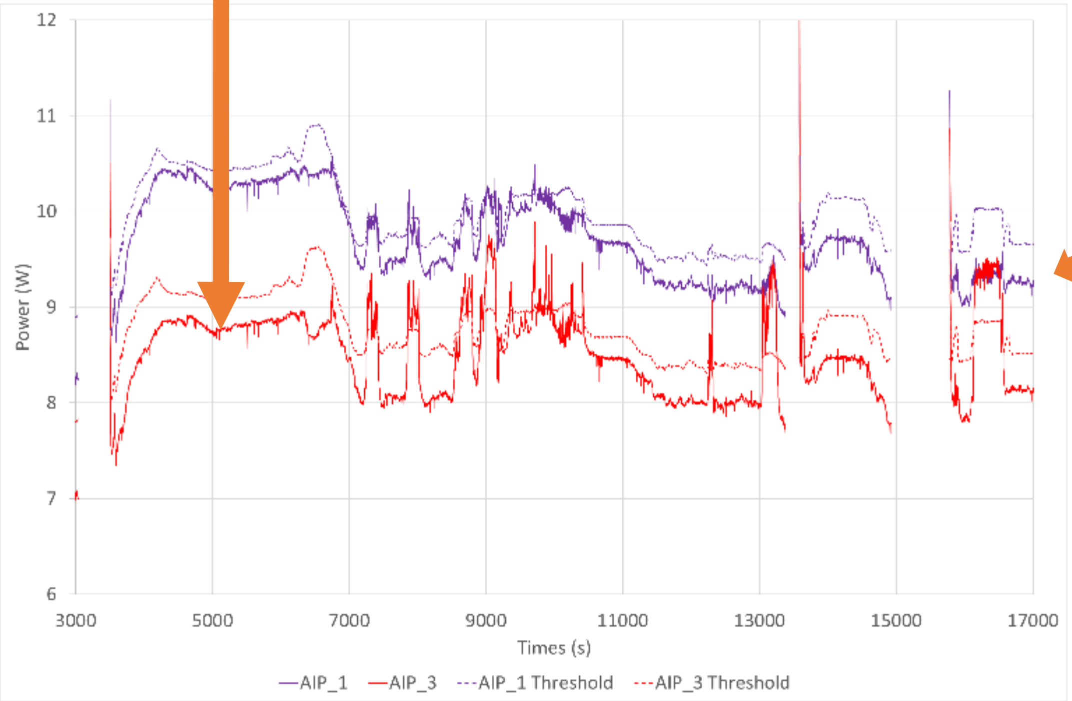
Design & Development

- Certification & Approval for Flight
  - The primary risk for the sensor was based on the sensor becoming detached from the aircraft as both the sensors and wiring was run externally
    - Fortunately, this was Embraer's responsibility
  - Other concerns that were addressed through design modifications and specialist testing were:
    - Skin overtemperature addressed through WoW switch and dual skin mounted RTDs on each sensor patch
    - Endurance testing performed using the same units as had been used in the TUBS test without failure
    - Crashworthiness of processing unit mounted inside the cabin mitigated through subcontract testing
    - Emissions testing performed through subcontract
    - Power interruption testing to assess instantaneous current using a variety of power units types e.g. batteries, power supplies etc.

AIP - Atmospheric Icing Patch AeroTex UK LLP

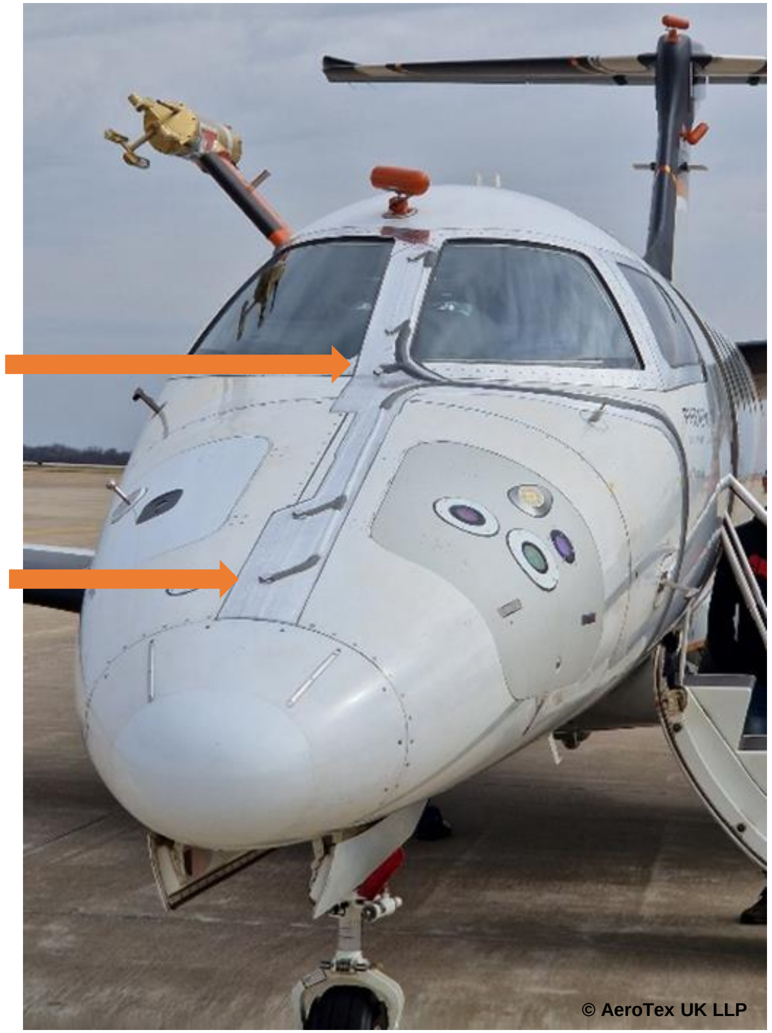
Flight Test

- Example results from flights 1475-1 and 1475-2 (outbound and return flights)
- Raw results showing the power drawn compared to the calculated dry air “threshold”



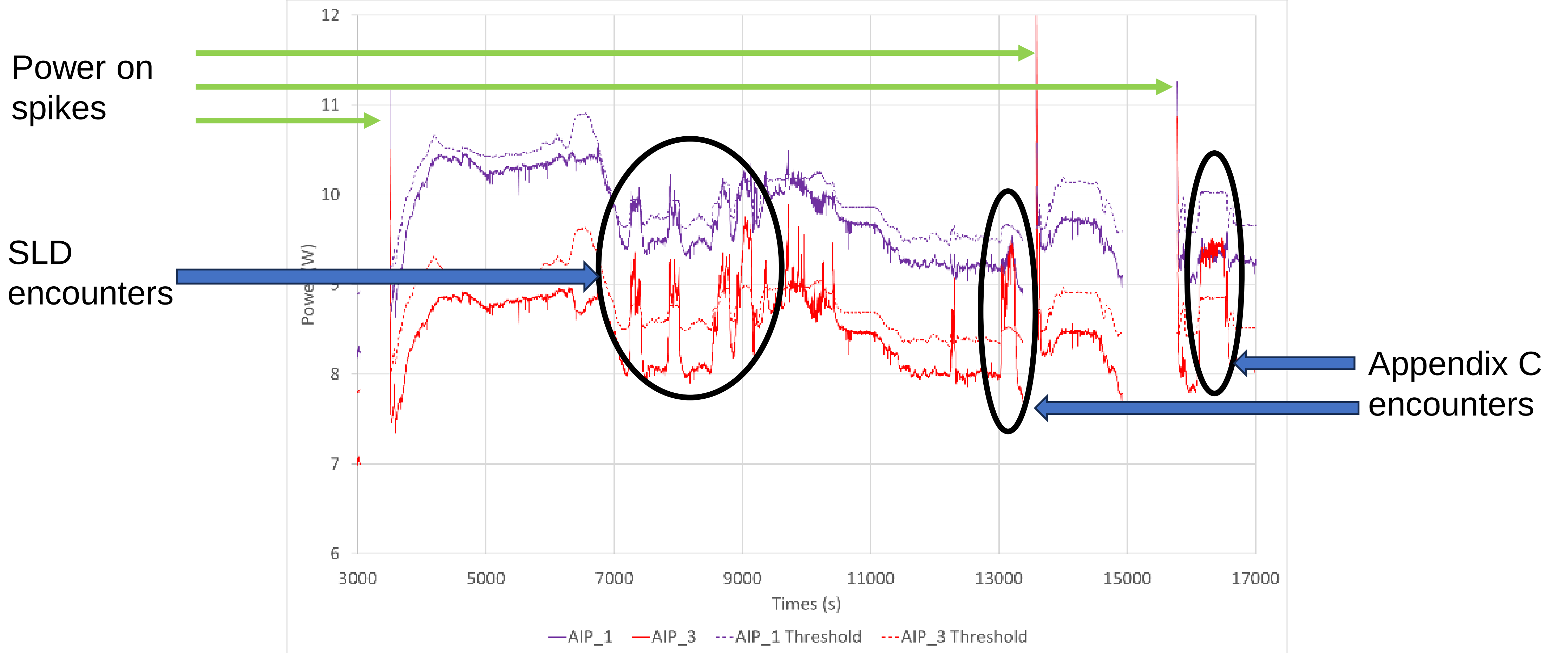
AIP_3

AIP_1



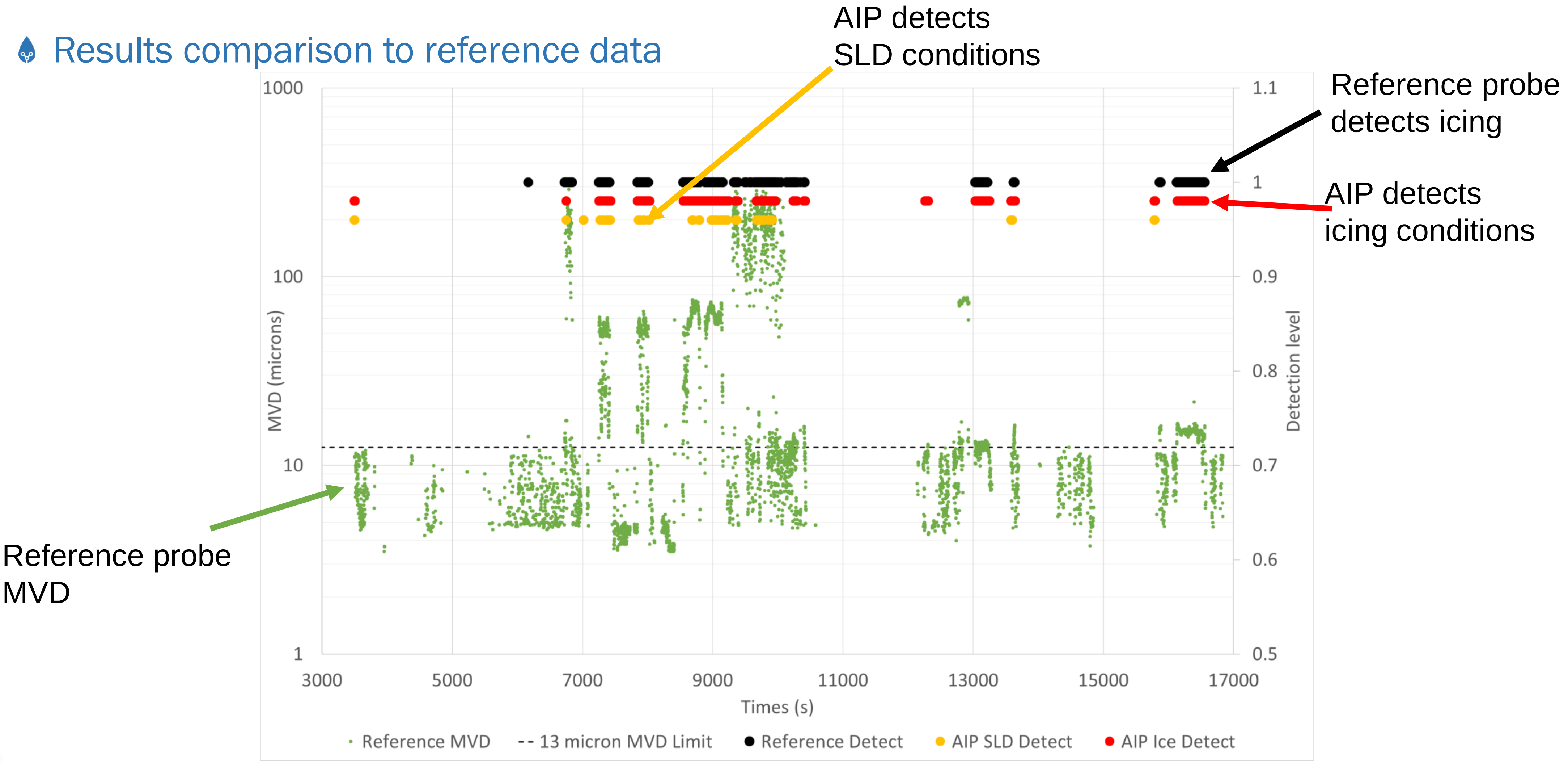
AIP - Atmospheric Icing Patch AeroTex UK LLP
Flight Test

- If both powers exceed reference SLD
- If only AIP_3 exceeds Appendix C conditions



AIP - Atmospheric Icing Patch AeroTex UK LLP
Flight Test

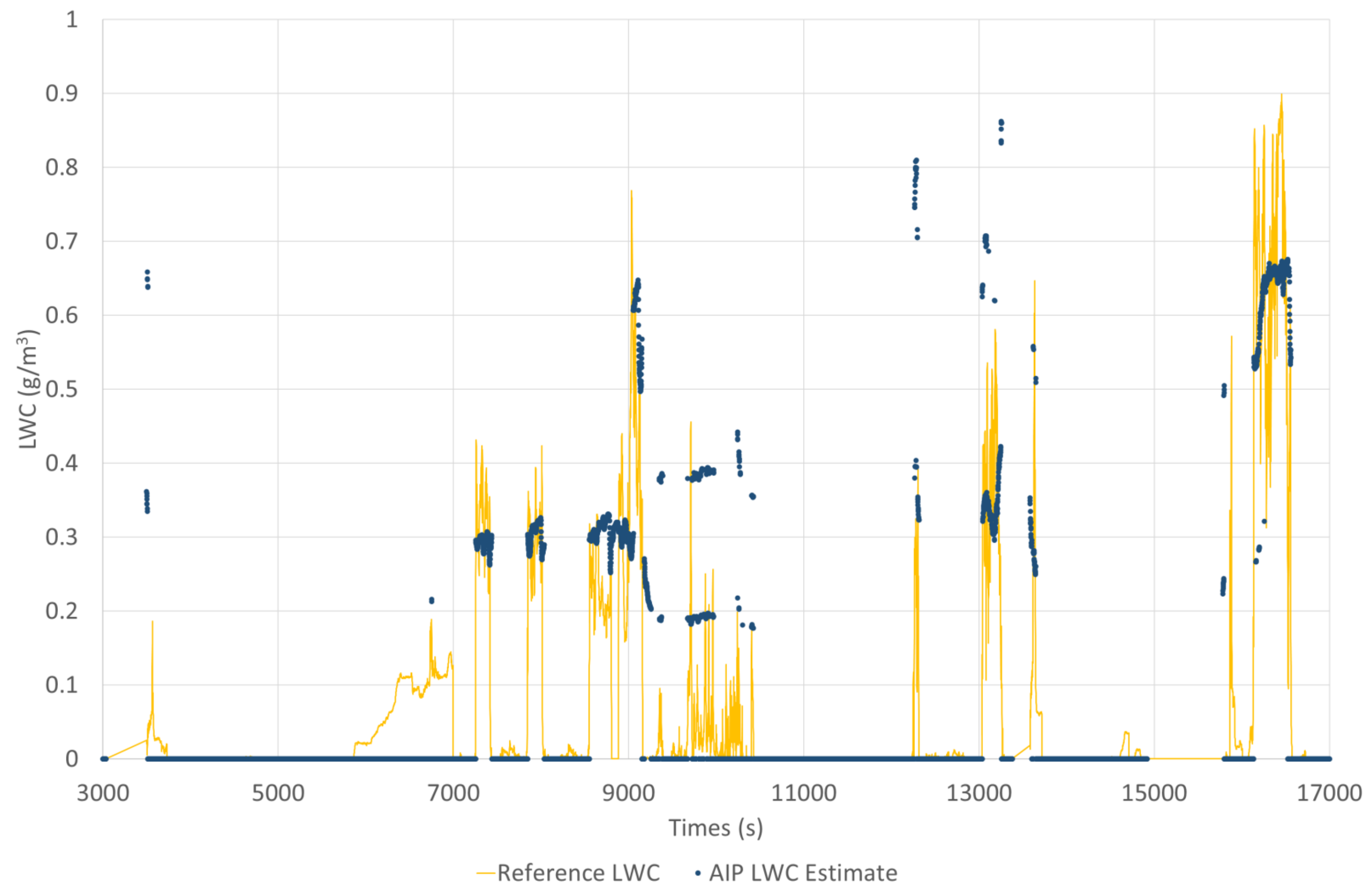
- Results comparison to reference data



AIP - Atmospheric Icing Patch AeroTex UK LLP

Flight Test

- A trial system to estimate the icing severity in the form of the LWC based on the excess power and approximated collection efficiency has been developed
- The logic combines the power with an assumed collection efficiency based on which sensors are responding



Conclusions

- **SENS4ICE provided a unique platform where micro-SMEs like AeroTex are on the same level as multi-billion Euro industrial players**
- Under SENS4ICE AeroTex rapidly developed the AIP ice detection system from TRL2 to flight test
- Our deep background in icing physics from research to certification was vital to ensure our proposed solution was robust and achieved the goals under the programme
- Further development of the AIP technology is underway as part of an Innovate UK/NATEP/ATI programme, this will address:
  - Miniaturisation and flexibility for local ice detection in small components
  - Improved estimation of LWC
  - Application of the technology to ice crystal detection
  - Sensor redesign address degradation that was observed during flight test

RAID Robust Atmospheric Ice Detection

AEROSPACE TECHNOLOGY INSTITUTE | Department for Business, Energy & Industrial Strategy | UKRI | Innovate UK | NATEP

Outlook

- Future challenges
  - Highly optimised electrical ice protection systems are required for a range of future platforms to enable flight in icing conditions covering App C, SLD and ice crystals
  - New concepts from air-taxis to regional aircraft struggle with the power requirements
  - Commercial aircraft face the future where bleed air may not be available or disruptive technologies such as hydrogen may change requirements
  - Route-to-certification/demonstration of compliance complicated ➔ partial envelope clearance
- Smart Ice Protection System (SIPS)
  - AeroTex are developing SIPS which combines:
    - distributed detection technology, ⟷ **nerve receptors**
    - verified AI designed control system and topology, ⟷ **brain**
    - and modular protection system ⟷ **muscle**
    - to minimise power consumed ⟷ **food**
  - AIP development is primarily focussed on being one of the receptors that will provide the inputs to SIPS, other detection technologies such as IIDS and wide area sensors can support the inputs
  - SIPS can only be developed through programmes such as SENS4ICE where leading technologies from around the world can be integrated

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

If not acknowledged, images courtesy of the consortium partners.

This presentation reflects only the consortium's view. The European Commission and the European Climate, Infrastructure and Environment Executive Agency (CINEA) are not responsible for any use that may be made of the information it contains.

SENS4ICE

Visit our website www.sens4ice-project.eu
and Linkedin #sens4iceproject