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SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES
FOR SAFER AVIATION IN ICING ENVIRONMENT

AIP - Atmospheric Icing Patches

A distributed system for ice detection

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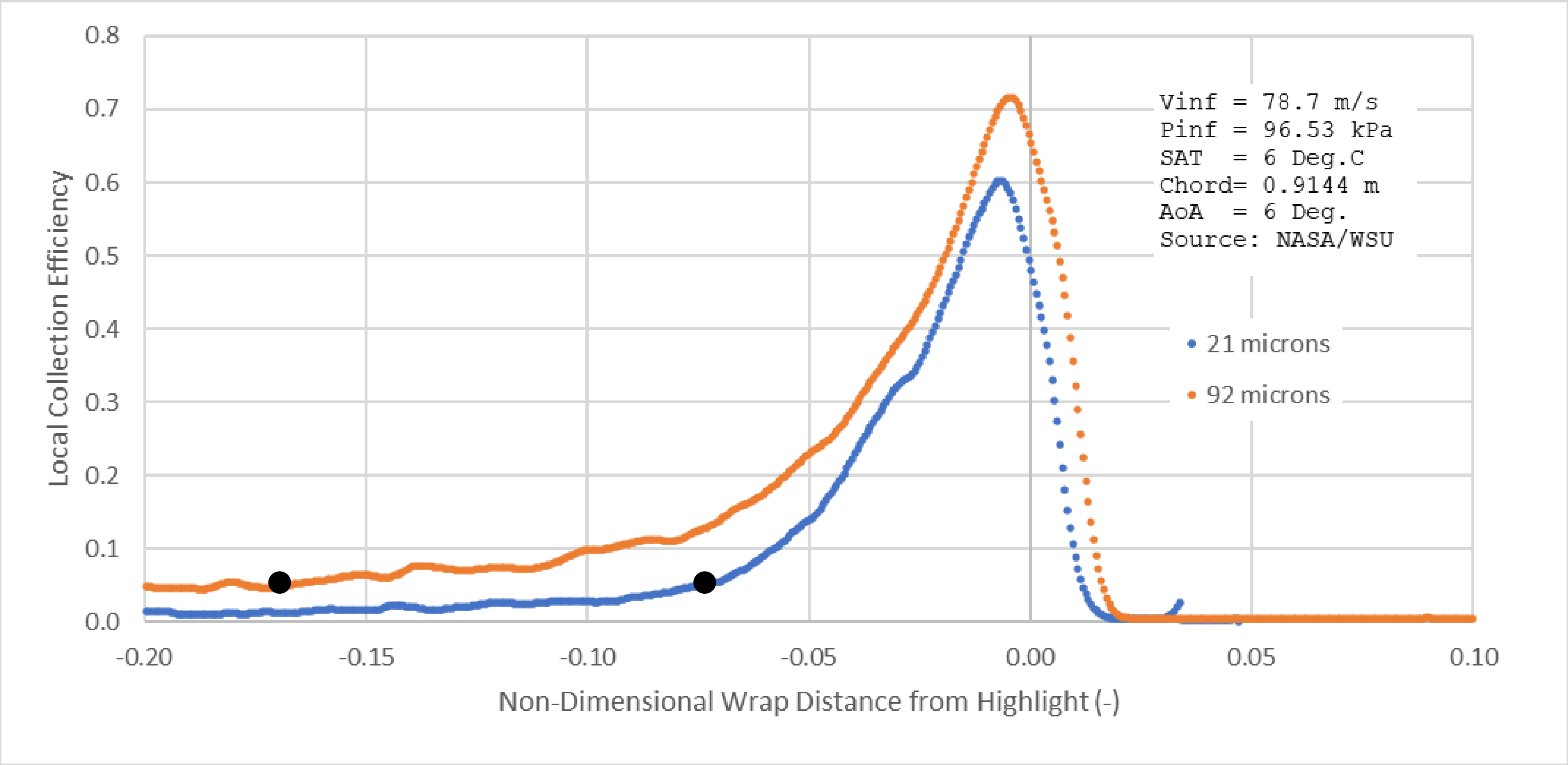
Overview

Overview – General Requirements

- There is a desire to robustly differentiate between adverse icing environments associated with Supercooled Large Droplets (SLD) as defined by CS-25 Appendix O and smaller droplets associated with the Appendix C environment ('classical' icing)
- The requirement is particularly driven by aircraft in the regional airlines and business jet domains whose configurations can be more susceptible to these conditions
- The sensitivity is specific to each aircraft but current guidance is based on:
  - Freezing drizzle: containing droplets with a diameter < 500 microns
  - Freezing rain: containing droplets with a diameter > 500 microns

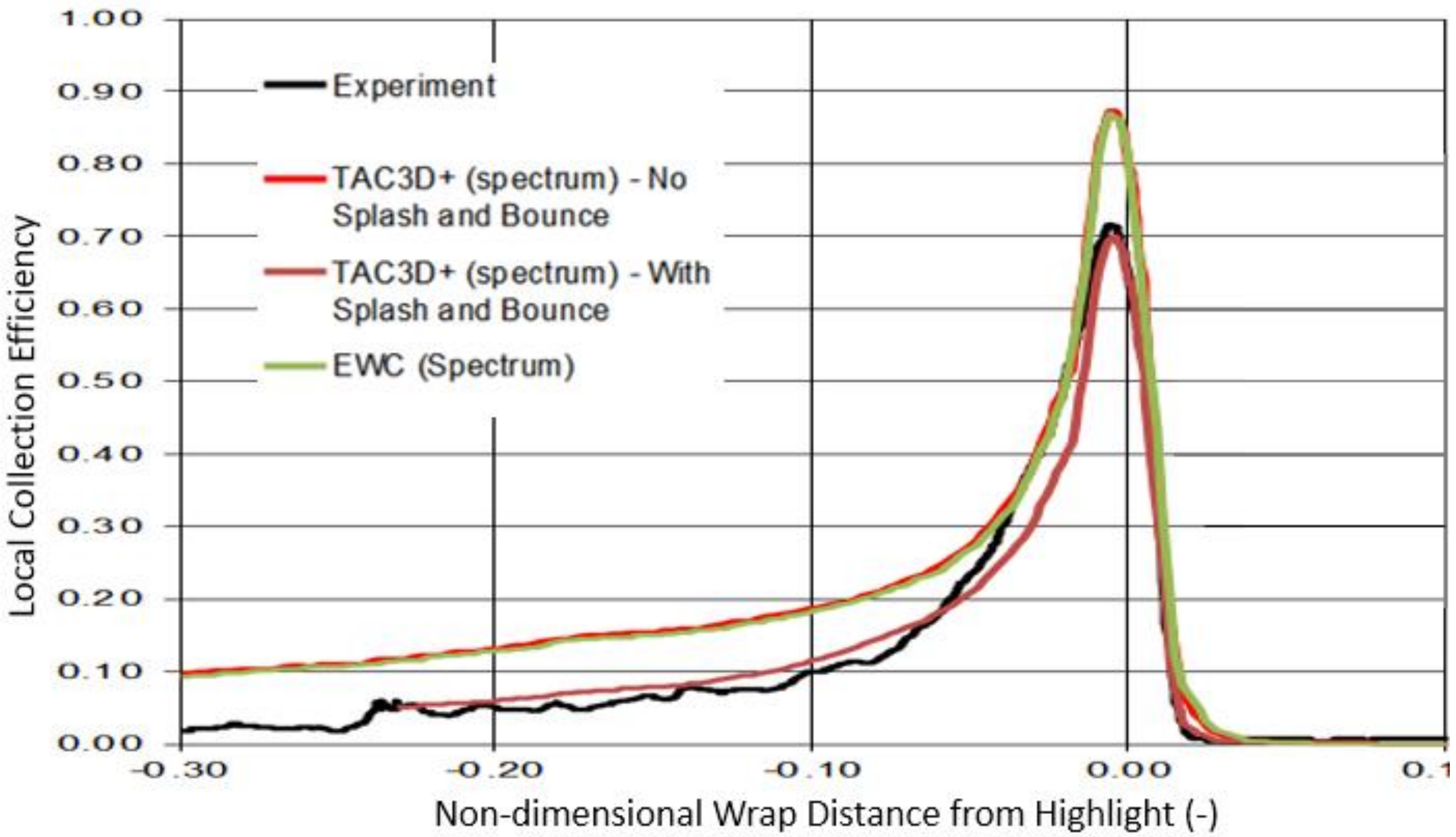
Overview – Impingement (1)

- The main hazard that Supercooled Large Droplet (SLD) conditions present to aircraft is that they impact further aft on the surface than the smaller droplets
  - The black dots in the figure below show where the collection efficiency drops below 5% for small and large droplet clouds



Overview – Impingement (2)

- A further challenge is reduced collection efficiency as SLD droplets are more prone to 'Splash and Bounce' effects where a significant fraction of the water is ejected back in to the flow as the large droplets impinge



Overview – SLD Detection

- Current main ice detectors fall in to two categories:
  - Optical detectors
  - Surface impingement/accretions detectors
- Optical detectors
  - Detect SLD conditions by directly measuring the droplets as they pass the aircraft
- Surface impingement/accretion detectors
  - Detect SLD conditions by sensing where SLD droplets impinge or where the impinging water freezes
- The remainder of this presentation discusses the issues and proposed solution for an impingement based approach

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Surface Ice Detection Issues

Surface Ice Detection Issues (1)

- Impingement Extent
  - Vulnerability to SLD is associated with droplets impinging further aft, potentially beyond the extent of the ice protection system
    - The extent of protection often cannot be increased due to constraints (structural, power availability, etc.)
  - This restriction may also cause issues for sensors aimed at detecting ice directly in sensitive areas (e.g. wing) as some sensors cannot be placed at spar locations or above fuel tanks
- Low impingement
  - Many concepts look at simple geometries such as aerofoils and detect when water impinges at aft locations
    - In these aft locations, the impingement can often be low due to both geometry and splash and bounce effects
- Flight condition impingement variability
  - The position at which both classical and large droplets impinge is a function of a number of aircraft parameters such as speed, pitch, yaw, altitude, etc.

Surface Ice Detection Issues (2)

- Runback water/ice
  - At warmer conditions not all the water freezes instantaneously but can run back over the surface
    - This is a function of both the external temperature and the volume of water impinging
  - Depending on the approach taken, this can be an issue for systems that are both detecting direct impingement and the presence of ice accretions
    - Need to ensure that runback water is not confused for SLD conditions
- Impingement bodies
  - Some detectors propose using accretion on a specific known body. These are vulnerable to:
    - Flight condition impingement variability (discussed previously)
    - Small bodies do not produce good separation of droplets
  - These impingement issues also apply to detection on lifting surfaces if they are not sufficiently large

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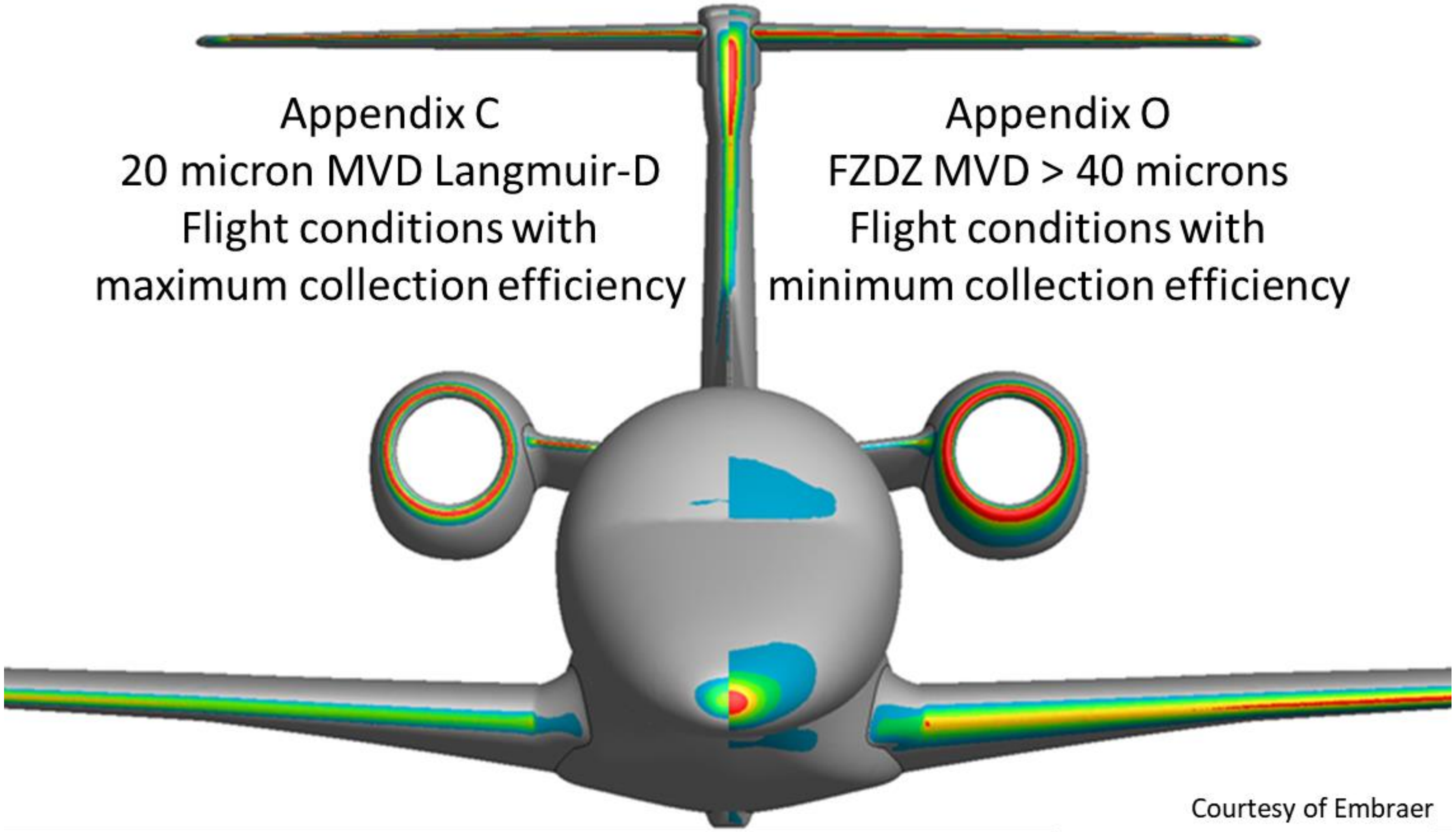
AIP Approach

AIP Approach – Aircraft as a Detector (1)

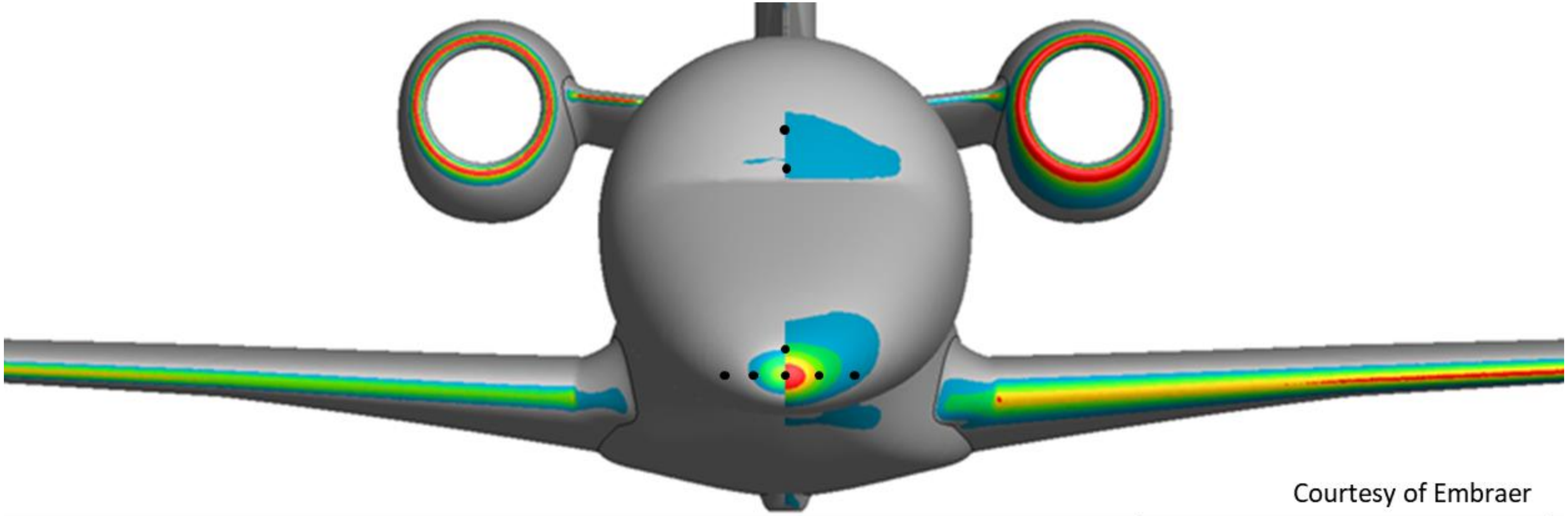
- The AIP approach to ice detection uses the aircraft, and specifically the nose and forward fuselage, as part of the detection system
- Using the fuselage has a number of advantages:
  - The fuselage is a large body so it provides a large amount of inertial separation of the droplets
  - Relatively easy sensor integration – plenty of space
  - Fuselage has a large straightening effect minimising the variability associated with AoA, etc.
  - Possible discontinuities where collection efficiency can be enhanced
  - Sensor can be used as a more automated version of a visual cue

AIP Approach – Aircraft as a Detector (2)



AIP Approach – Distributed Sensor Array (1)

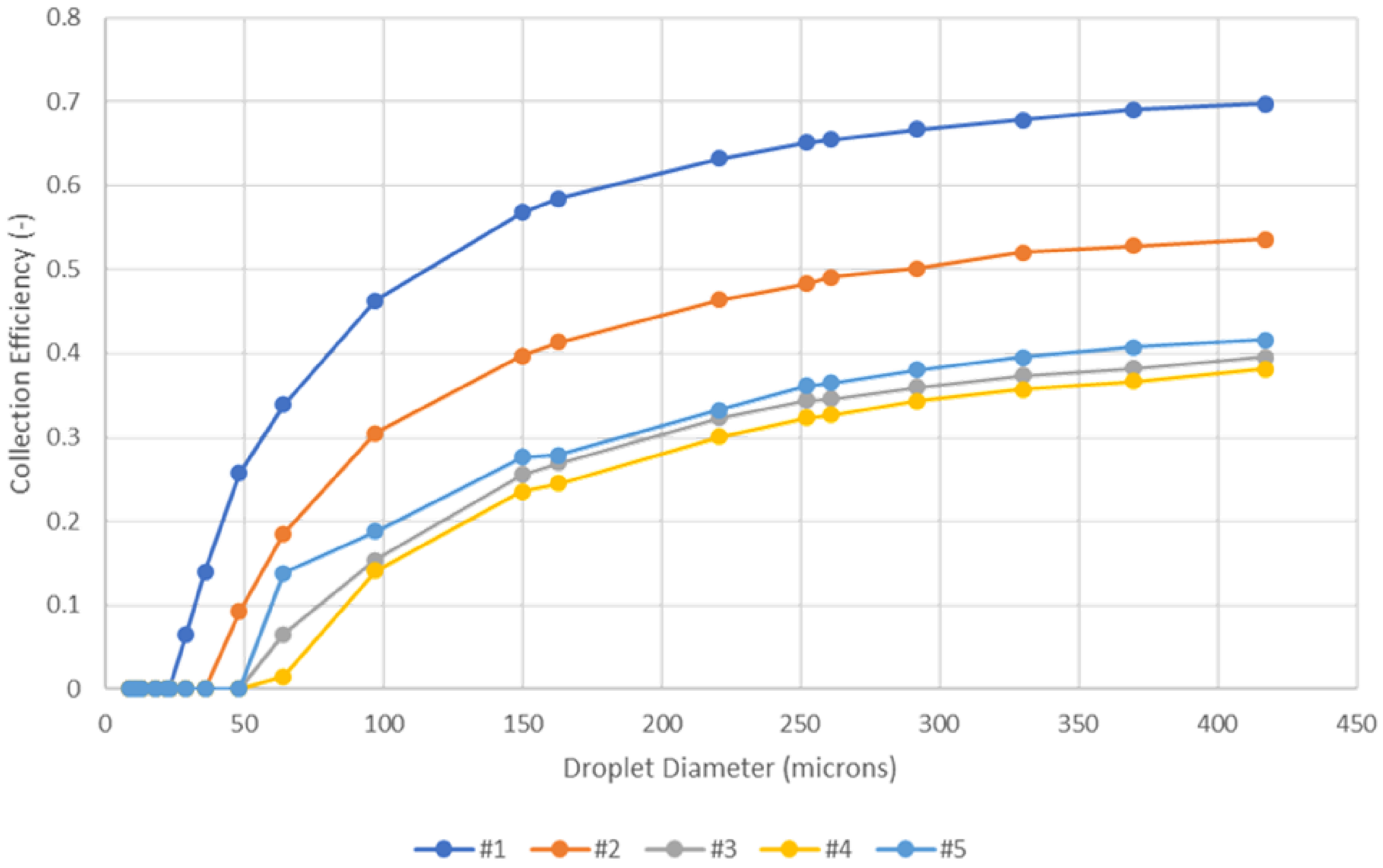
- To produce a system that can detect icing even when flight parameters change an array of sensors is proposed
- A distributed array could also have the benefit of differentiating between droplet sizes



Courtesy of Embraer

AIP Approach – Distributed Sensor Array (2)

- Depending on the position of the sensor the collection efficiency will vary in a manner similar to that shown below
  - By monitoring the response of each sensor the cloud droplet content can be approximated

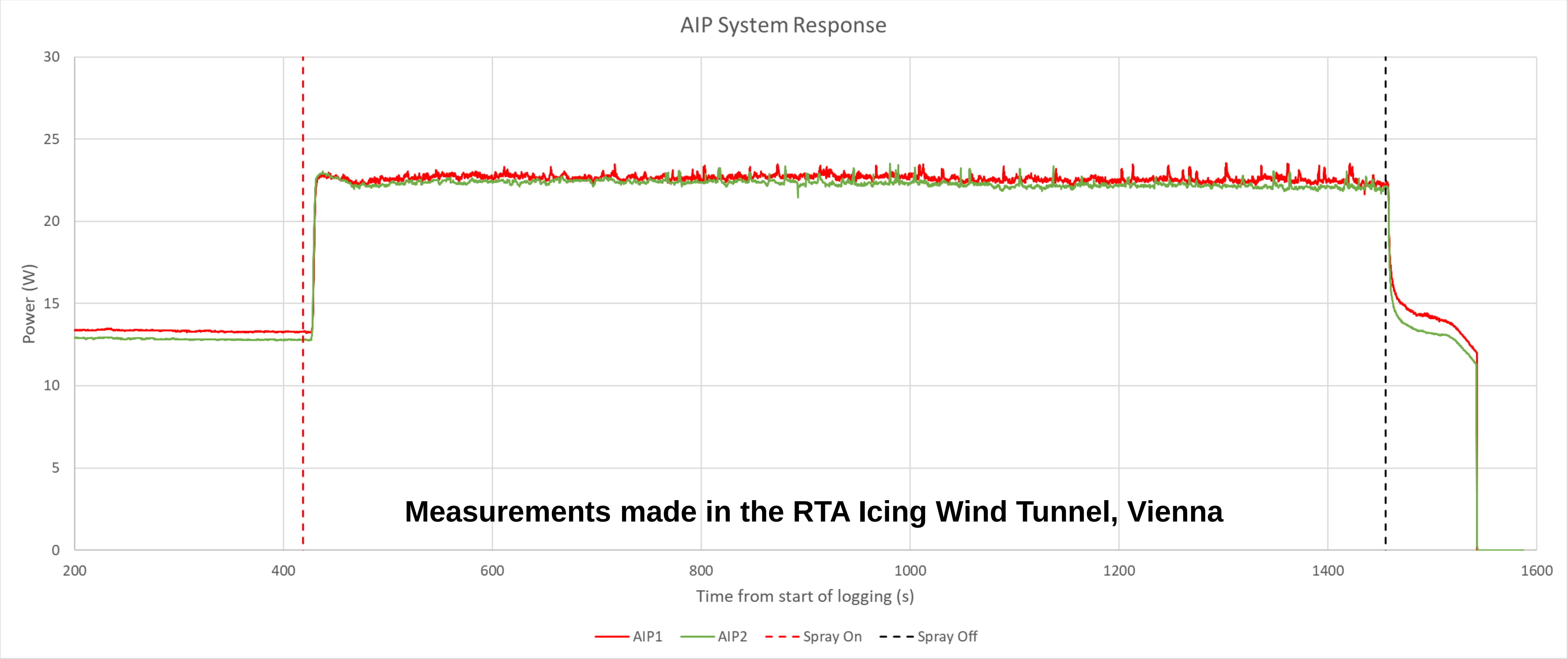


AIP Approach – Sensor Technology (1)

- An array of sensors requires that the individual sensors have low power consumption and any deicing should be scheduled to prevent all sensors being de-iced at the same time
- AIP sensor technology
  - Sensor patches mounted at the required sensor locations
    - Small – 20mm x 20mm x 4mm
    - Intrinsically temperature limiting
      - No thermal control system required
    - < 20W per patch
  - Power drawn will be related to:
    - Flight parameters – e.g. speed, altitude, OAT, etc.
    - Water impingement
  - Correlating power drawn against dry air conditions allows limits to be set at which icing is annunciated and types differentiated
  - Sensor location is less sensitive on a fuselage than on a wing so the sensor can sit just off the surface so is less prone to runback

AIP Approach – Sensor Technology (2)

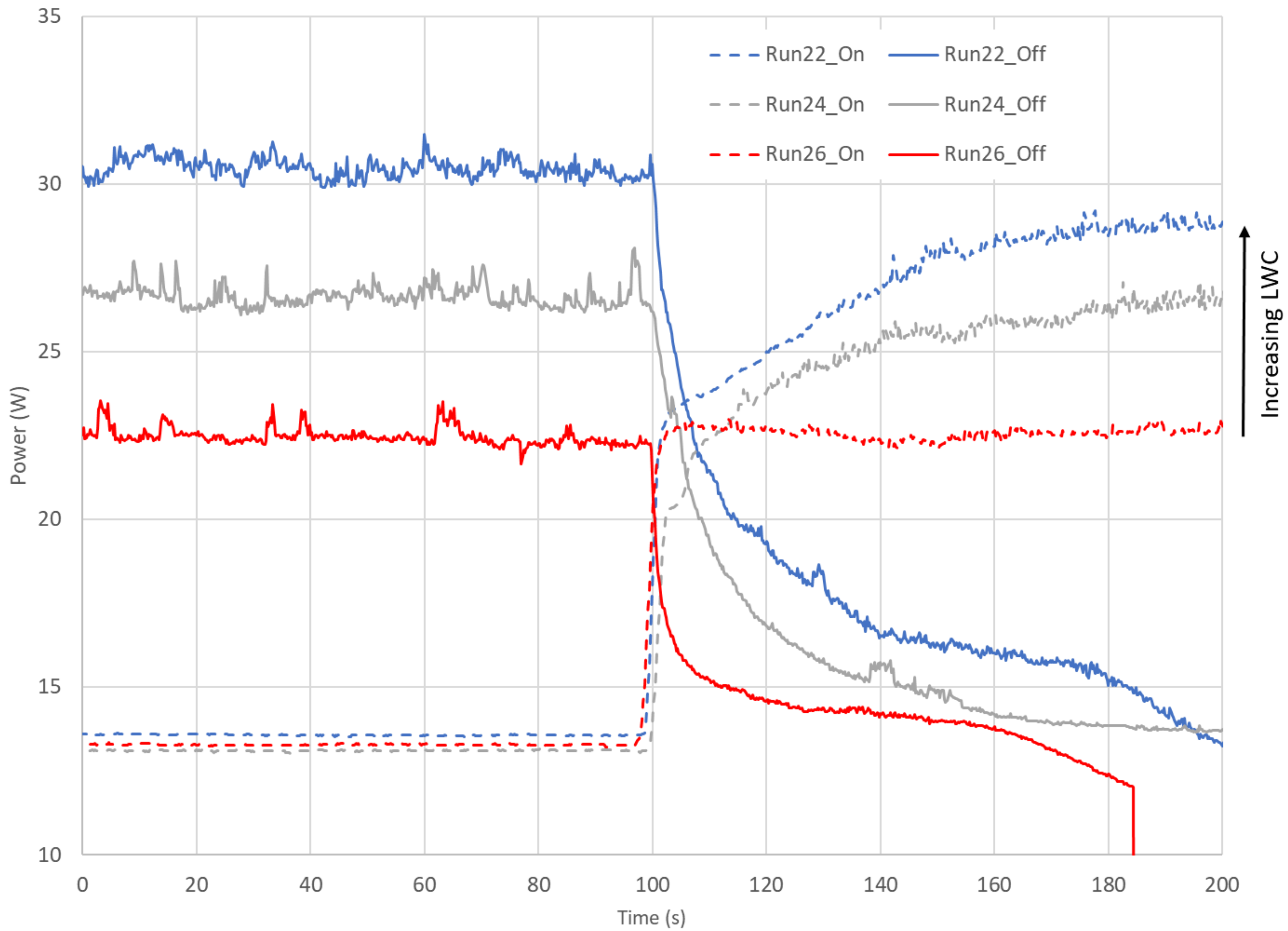
- Example of the system response during an icing encounter (larger patch than final version therefore higher power)



AIP Approach – Sensor Technology (2)

- Example of the system responses for various LWC
  - Figure shows power draw related to LWC
- Time base has been shifted to align curves and show both entrance and exit from icing on one graph
  - Dotted lines show the response on encountering the icing cloud
  - Solid lines show the response when exiting an icing cloud

Measurements made in the RTA Icing Wind Tunnel, Vienna



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Summary

Summary

- The importance of detecting SLD conditions has been described
- The issues associated with surface ice detection technologies (direct impingement or ice accretion) have been highlighted
- The AIP approach has been described that uses:
  - The aircraft as part of the detector
  - An array of sensors to detect the presence at different locations over the forward fuselage
  - Small, robust, low drag and low power sensor patches
- Combining the various parts of the AIP technology provides a means of detecting icing and differentiating icing conditions

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