SENS4ICE

SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES FOR SAFER AVIATION IN ICING ENVIRONMENT

Short Range Particulate (SRP)

FINAL DISSEMINATION EVENT OF SENS4ICE PROJECT

Pavel Badin - Honeywell

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Sensor Description

SRP – Short Range Particulate

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- Detection type: Atmospheric sensor
- Physical principle: Collecting backscattered light from particles
- Sensor high-level output description
  - App C flag, App O flag
  - LWC [g/m^3], MVD [µm], DV90 [µm], DV99 [µm], DMAX [µm]
- Air sensor specifications
  - Size: 290 x 180 x 130 x mm *(***)*
  - Weight: 4.7 kg *(***)*
  - Power: 300 W
- Equipment TRL 3 at project start, TLR 6 now
  - App C detection (TRL6), App O detection (TRL5), App O / C discrimination (TRL5), Ice Crystals Detection (TRL4)
- Icing Wind Tunnel tests: 2016, 2017, 2021
- Flight tests: 2016, 2020, 2023

1st gen. optical sensor
direct ptcl. sensing: 2 - 42 um

2nd gen. optical sensor
(developed under SENS4ICE)
direct ptcl. sensing: 50 - 1000 um
background signal sensing: 5 – 50 um

(***) applicable to technology demonstrator only, sensor size and weight to be reduced

SRP: Technology Overview

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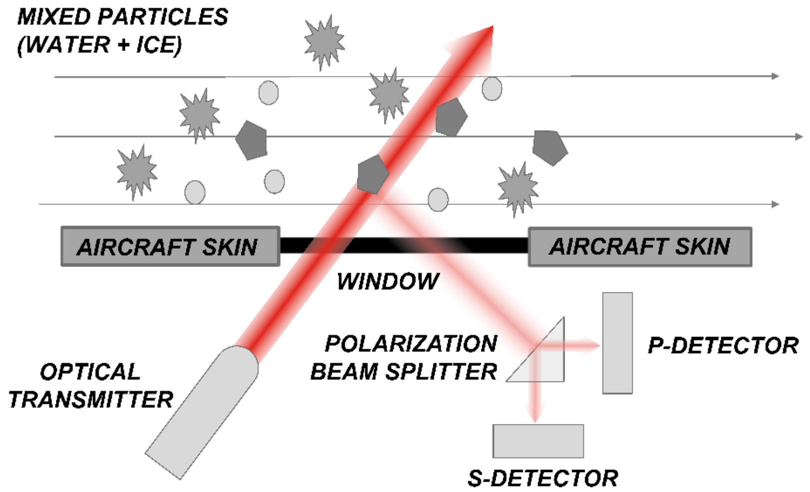
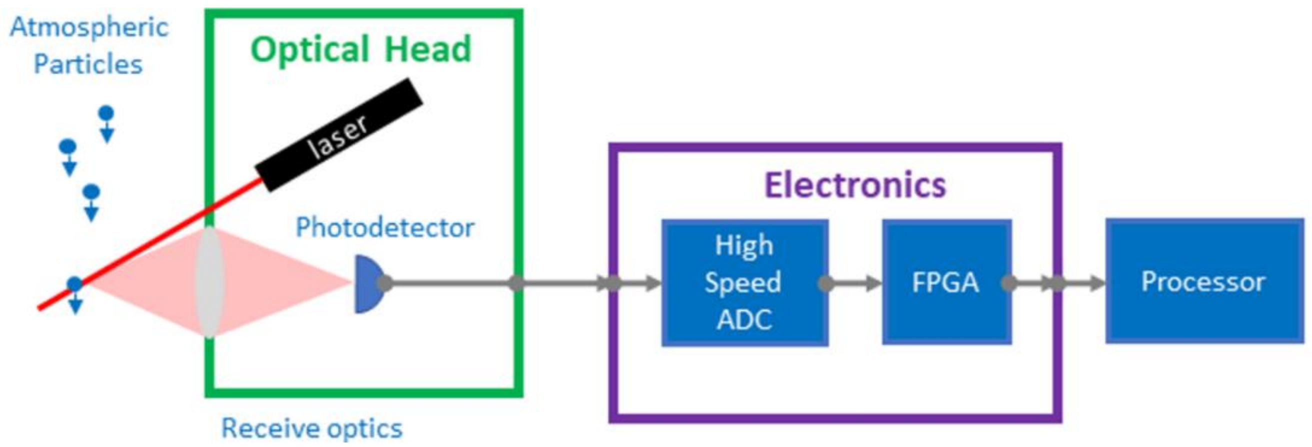
Optical sensor detecting particles through polarized backscatter

- Extract data two ways
  - Direct particle by particle measurements (scattering from a single particle)
  - Aggregate particle scatter through shifts in the background signal





SRP: Technology Overview

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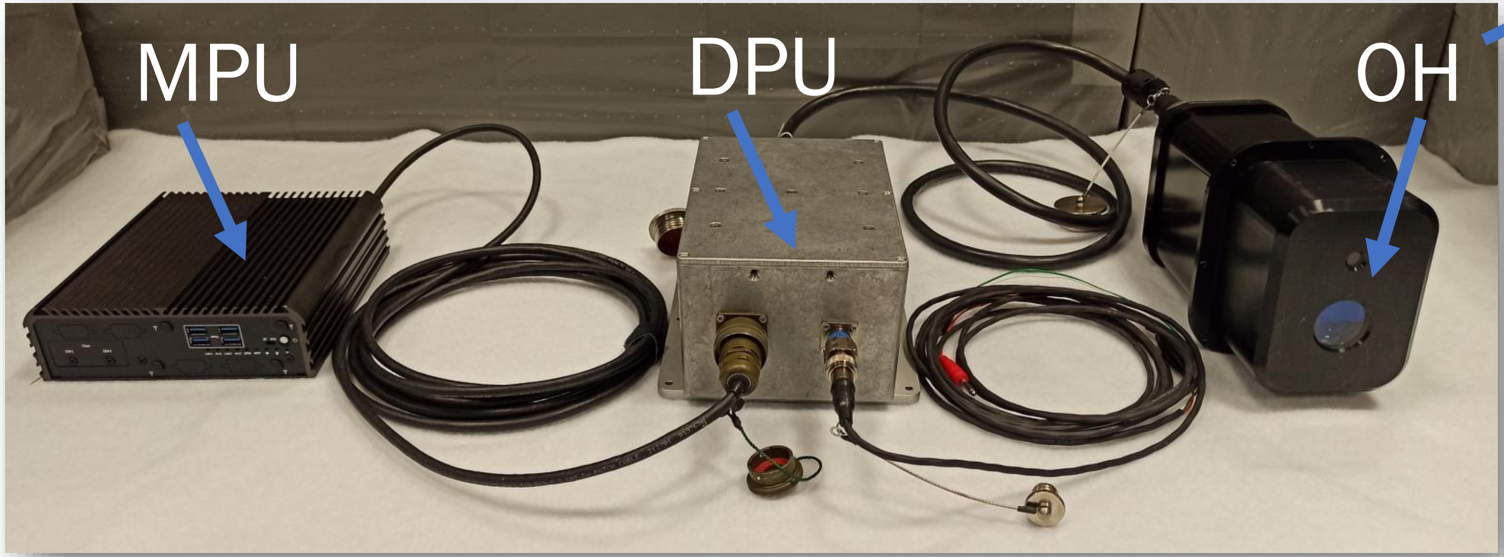
Sensor prototype description

- MPU: Main Processing Unit
- DPU: Digitalization and Pre-processing Unit
- OH: Optical Head



SRP installed on Embraer Phenom 300
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Icing Wind Tunnel tests

SRP: Icing Wind Tunnel tests

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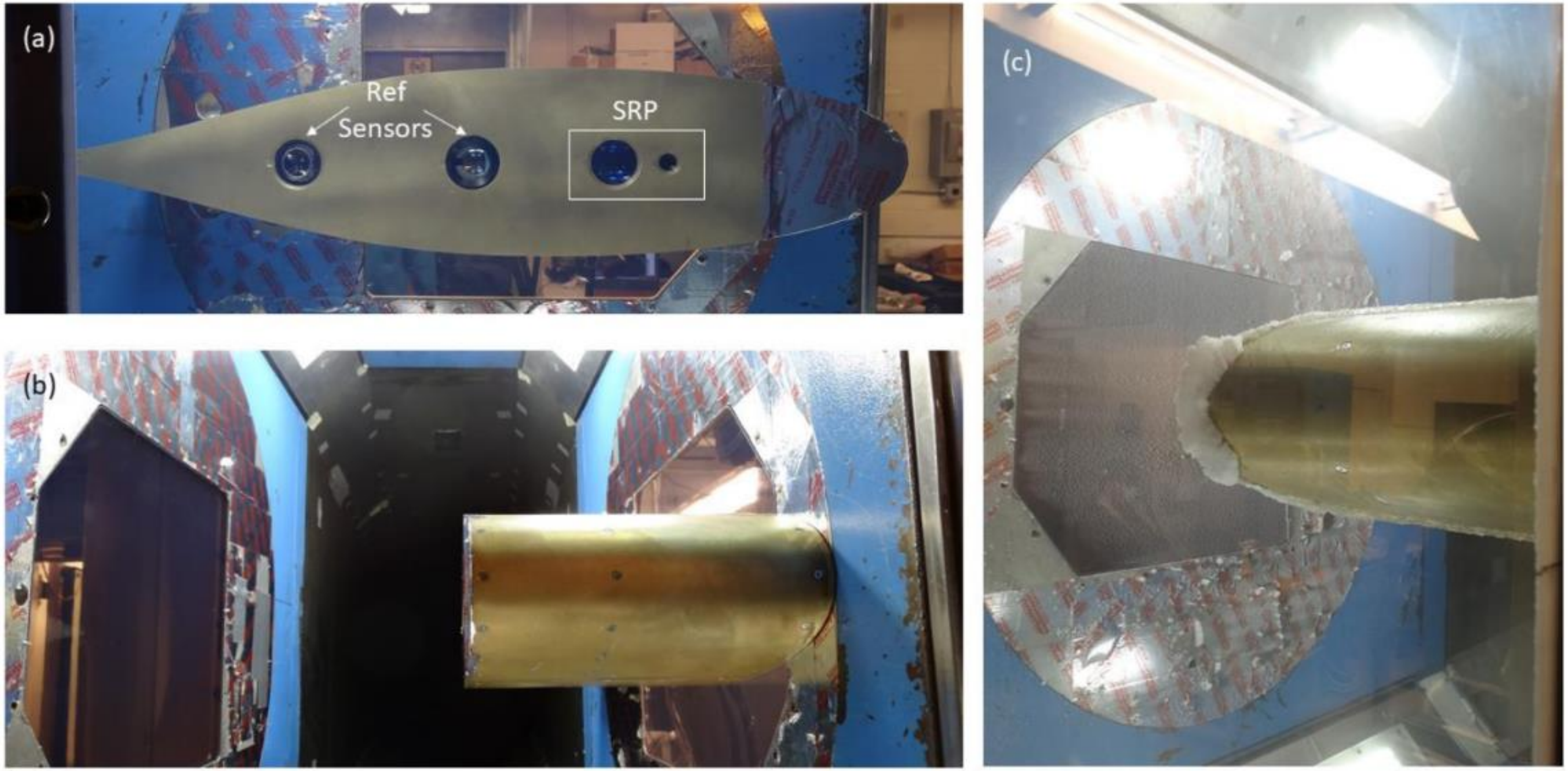
IWT Collins Facility (2021), App. C&O conditions



SRP: Icing Wind Tunnel tests

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- Excellent performance on response time metric across both icing appendices
- Parameter measurement accuracy differed between the two appendices
  - Good match with tunnel values for App. C
  - Higher Error for App. O – discussed in subsequent slide

Test	Test Points Detected within Response Time [%]	Average MVD Error [%]	Average LWC Error [%]
Appendix C Test Points	100%	14%	28%
Appendix C Repeat Points	100%	15%	27%
Appendix O Test Points	100%	41%	67%
Appendix O Repeat Points	100%	24%	59%

SRP: Icing Wind Tunnel tests

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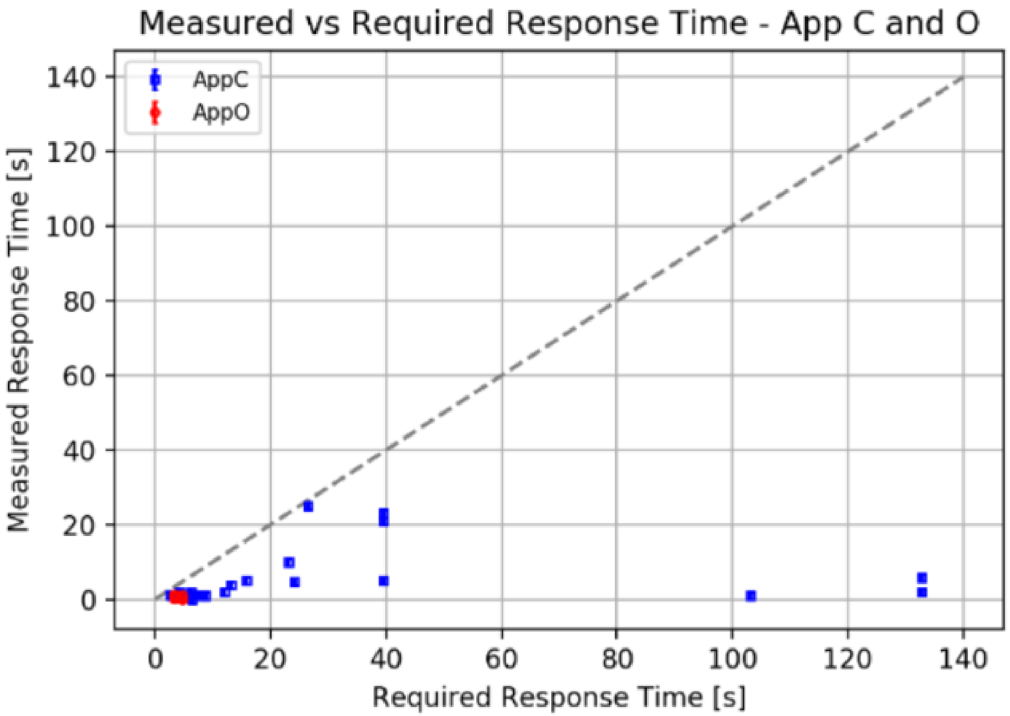
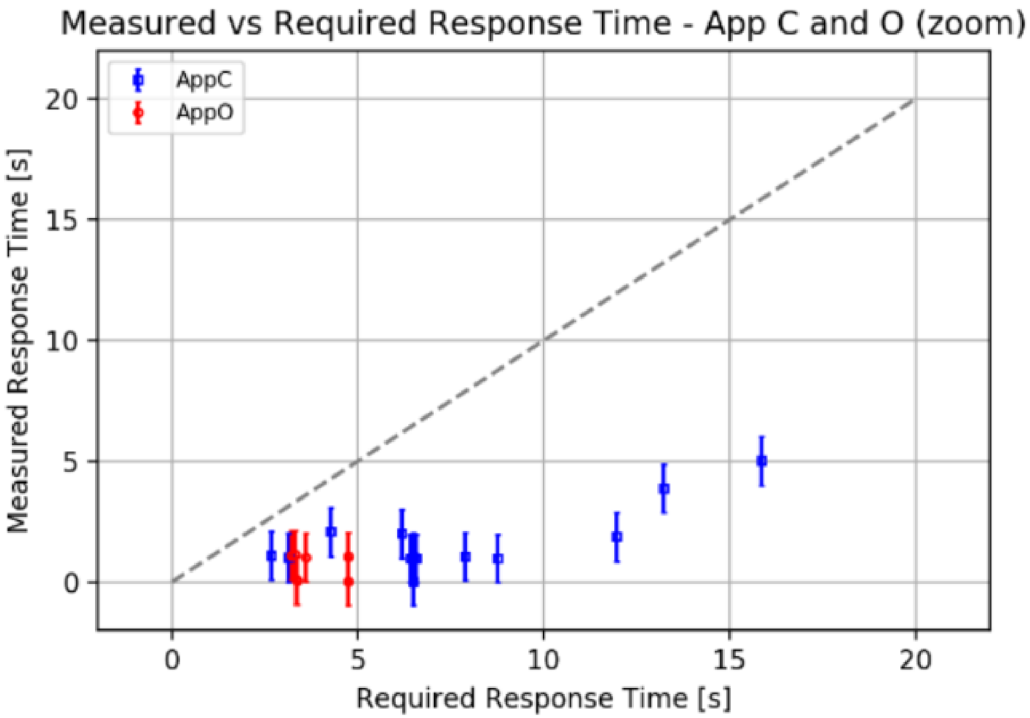
Response time

- Sensor meets SAE AS5498B (or equivalently ED-103B from EUROCAE) requirements on response time





SRP: Icing Wind Tunnel tests

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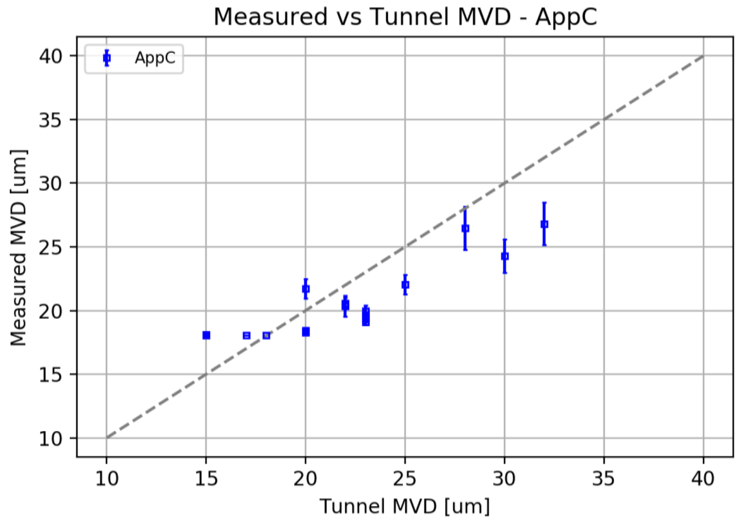
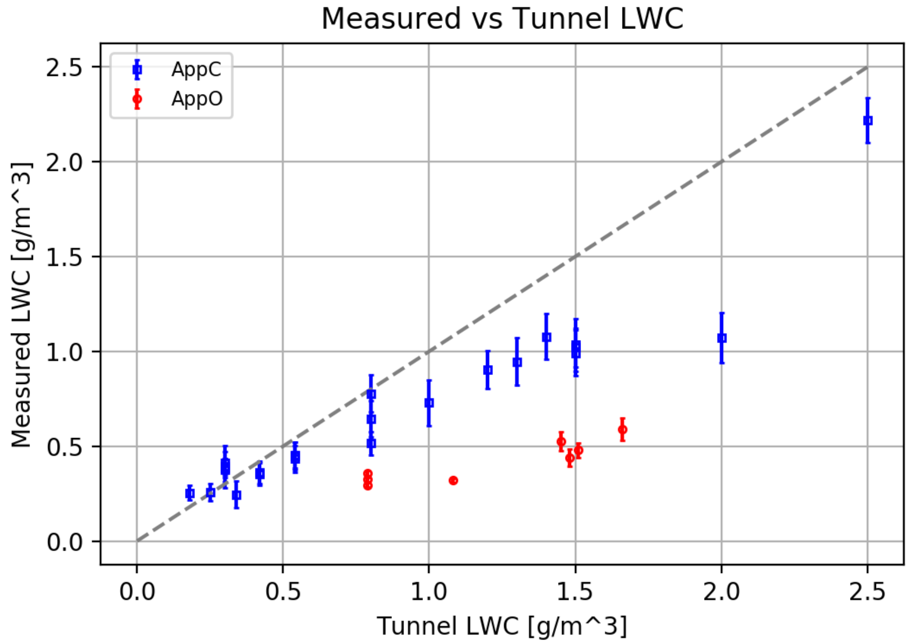
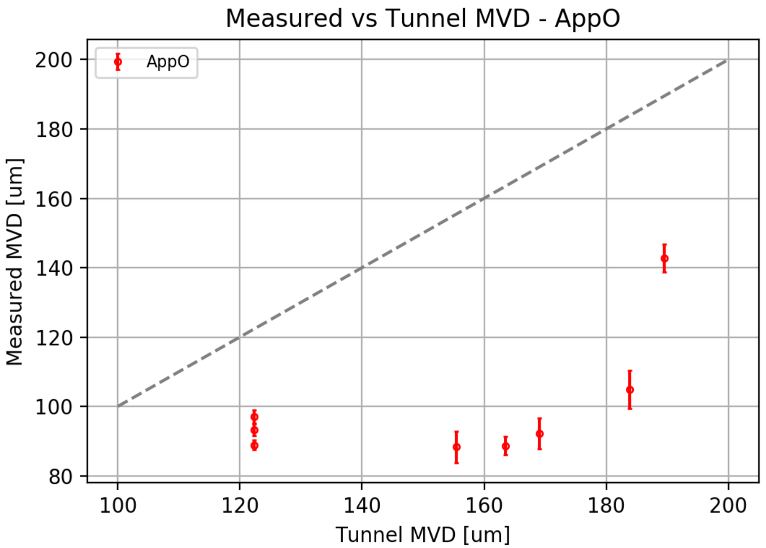
MVD / LWC Measurements

- Appendix C tracks well for both MVD and LWC
- Larger errors in Appendix O resulting from loss of signal in IWT vs lab calibration
  - Window fogging is expected the root-cause of the issue. Mitigations being developed







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Flight Test Campaign

SRP: Flight Test Campaign

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Fight test preparation

- Flight test campaign executed late Feb - early Mar in North America
- Prior to flight test, sensor went through flight worthiness
  - Qualified against a subset of DO-160G tests, including temperature, vibration / shock, power input, lightning, and ESD

SRP: Flight Test Campaign

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Flight Test Execution

- Embraer‘s Phenom 300 optical sensor integration
  - Communication issue between sensor & aircraft was resolved without any impact on the campaign
- Flight Test Campaign
  - Eight flights for which reference data were successfully measured
  - Appendix C and Appendix O conditions encountered multiple times
  - Optical sensor data collection successful
- Sensor data analysis and preliminary results
  - Performance compared with reference data provided by DLR
  - Good results for events in which particulate MVD > 25 microns
  - Sensor underestimates TWC for events in which particulate MVD < 15-20 microns
  - Detailed results provided for flights 1476 and 1481

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SRP: Flight Test Campaign (Flight 1476)

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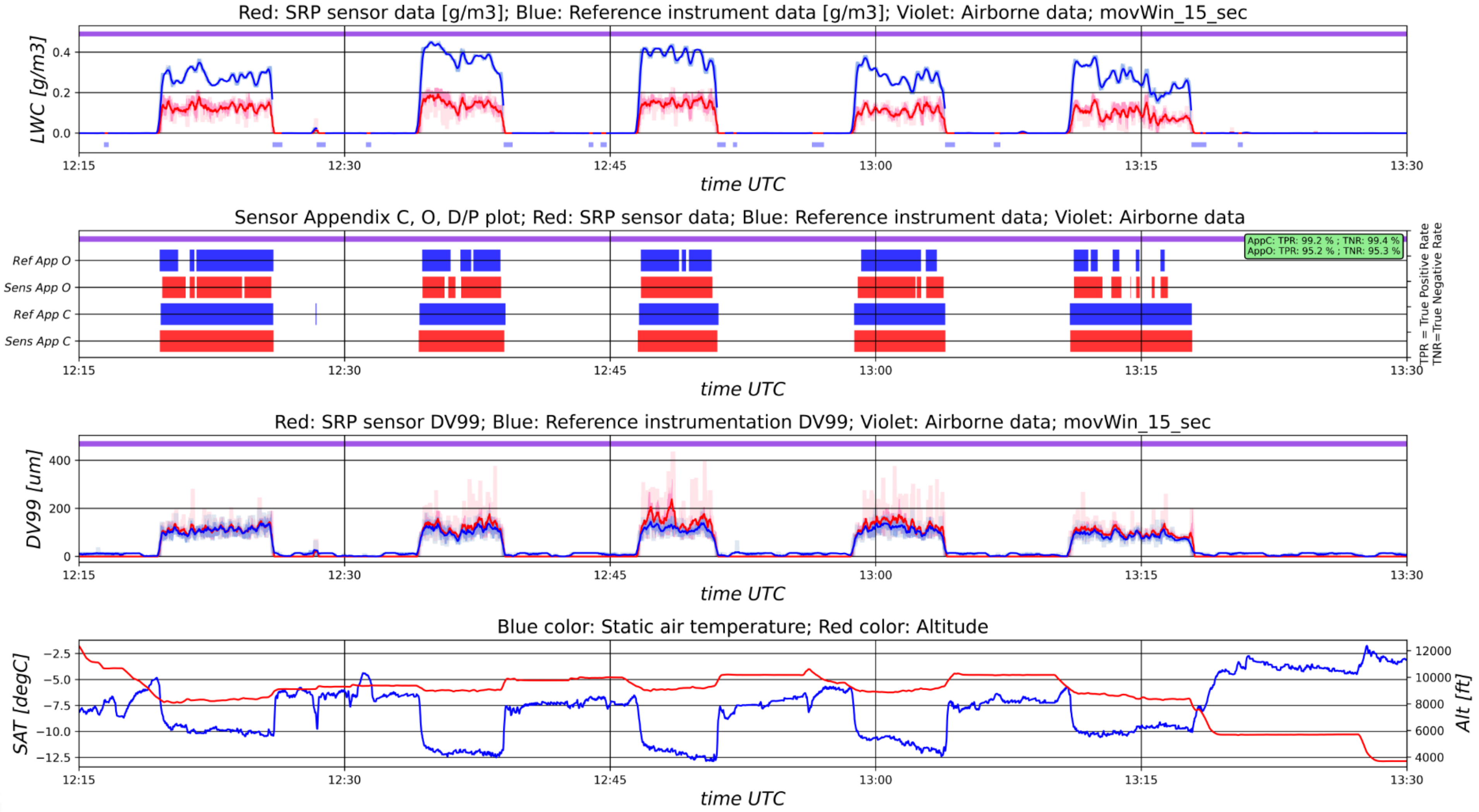

High correlation between reference and optical sensor data

App. C and App. O flags are well matched with reference instrumentation data

DV99 values are well matched with reference instrumentation data

SRP: Flight Test Campaign (Flight 1481)

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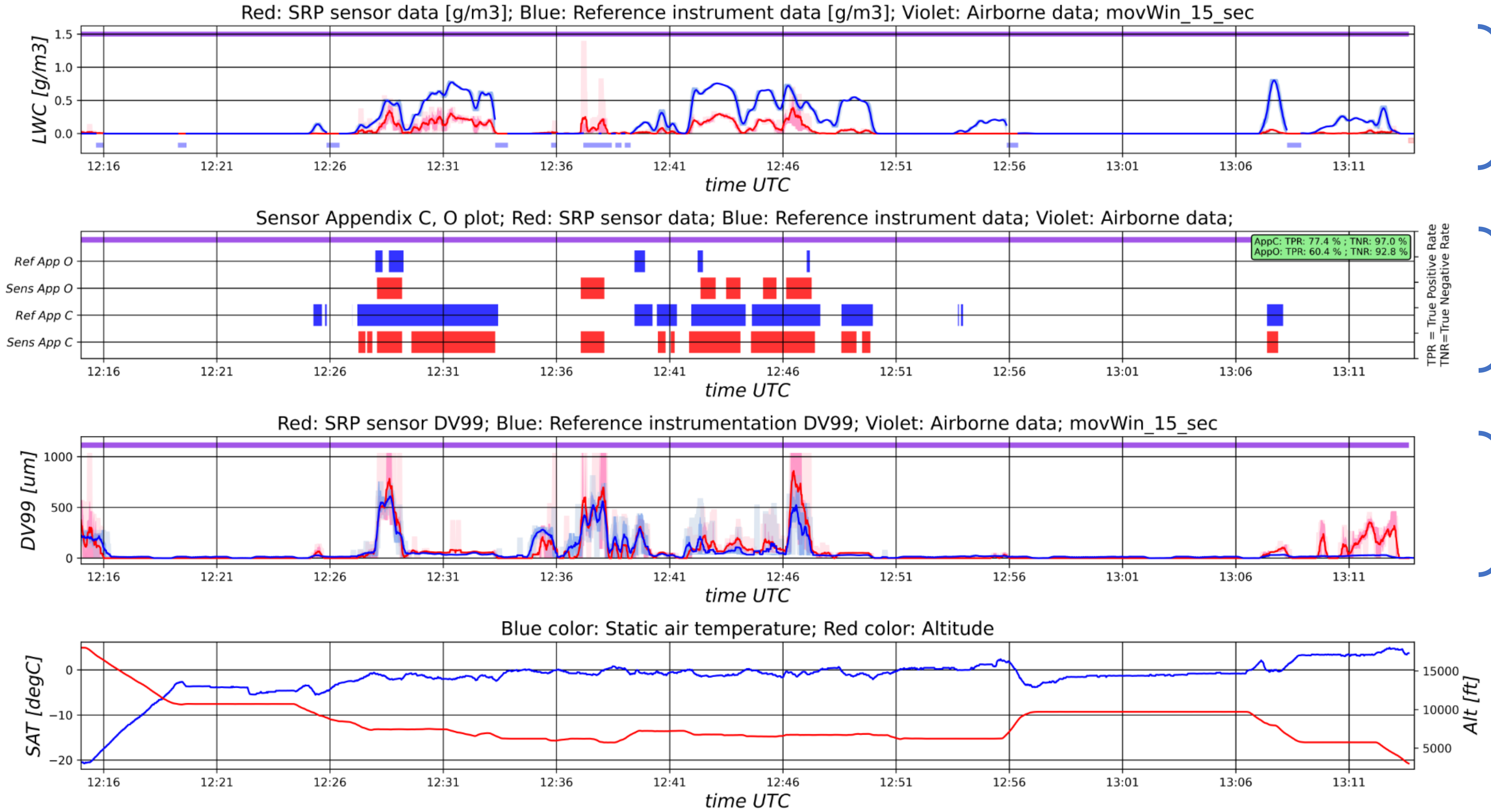

High correlation between reference and optical sensor data

App. C flag is well matched with reference instrumentation data. False alarm presence in App. O flag estimation

DV99 values are well matched with reference instrumentation data

SRP: Conclusions and Outlook

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Conclusions

- High measurement performance for events in which particulate MVD > 25 microns
- Small particulate detection successfully evaluated under previous program (1st gen. optical head)

Next gen. optical sensor development

- Design single sensor covering icing appendixes C, D, O
- Develop ash / dust / sand sensing functionality

Use-cases

- Safety, autonomy, situation awareness
- Reduce fuel consumption, reduce CO_2 emissions
- Predictive health maintenance

SRP: Conclusions and Outlook

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Sensor design update

- Current state
  - 1st generation sensor: Appendix C; 2nd generation sensor: Appendix O, D/P
- Goal
  - Merge both designs into single sensor unit
  - Reduce sensor complexity, size and weight to meet customer requirements

Appendix D/P characterization

- Evaluate sensor capability to differentiate Liquid Water Content and Ice Water Content
  - Specifically, particles of following diameter: 50 – 1500 microns

Certification

- Define steps required for sensor certification
- Validate if IWT shattered ice crystals are optically equivalent to natural ice crystals

Volcanic ash / dust / sand detection

- Develop & Integrate ash / dust / sand sensing capability into the sensor

SRP: Acknowledgment

Honeywell Aerospace

- Gratitude to Collins Aerospace and National Research Council Canada for Icing Wind Tunnel test preparation and execution
- Thank you to Embraer, DLR and all SENS4ICE partners for US flight test preparations and execution
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Pavel Badin

Honeywell International s.r.o
Tuřanka 1387/100
627 00 Brno
Czech Republic

+420 532116533
Pavel.Badin@Honeywell.com

Matt Wiebold

Honeywell International Inc
12001 State Highway 55
Plymouth MN 55441
USA

Matthew.Wiebold@Honeywell.com

Vladimír Hamada

Honeywell International s.r.o
Tuřanka 1387/100
627 00 Brno
Czech Republic

+420 532114029
Vladimir.Hamada@Honeywell.com

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