SENS4ICE

SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES
FOR SAFER AVIATION IN ICING ENVIRONMENT

Collins Ice Differentiator Sensor

SAE AC-9C Meeting

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Virtual – 21 October 2021

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Outline

- SENS4ICE Project Overview
- Collins Ice Differentiator Technology Concept
- Technology Development and Testing
- 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 APPLIED RESEARCH AND TECHNOLY
17) SAFRAN AEROTECHNICS
18) HONEYWELL INTERNATIONAL INC
19) COLLINS AEROSPACE
20) NATIONAL RESEARCH COUNCIL CANADA

Collins Aerospace

Collins Aerospace

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 Timeline

Develop sensors/ technologies for detection of Appendix O

Upgrade icing wind tunnels for Appendix O

Icing wind tunnel testing

Sensor technology evaluation and selection

Flight testing

Reference instrumentation/ measurements

Reference measurement results

Reference probes for atmospheric conditions

2019 - 2020

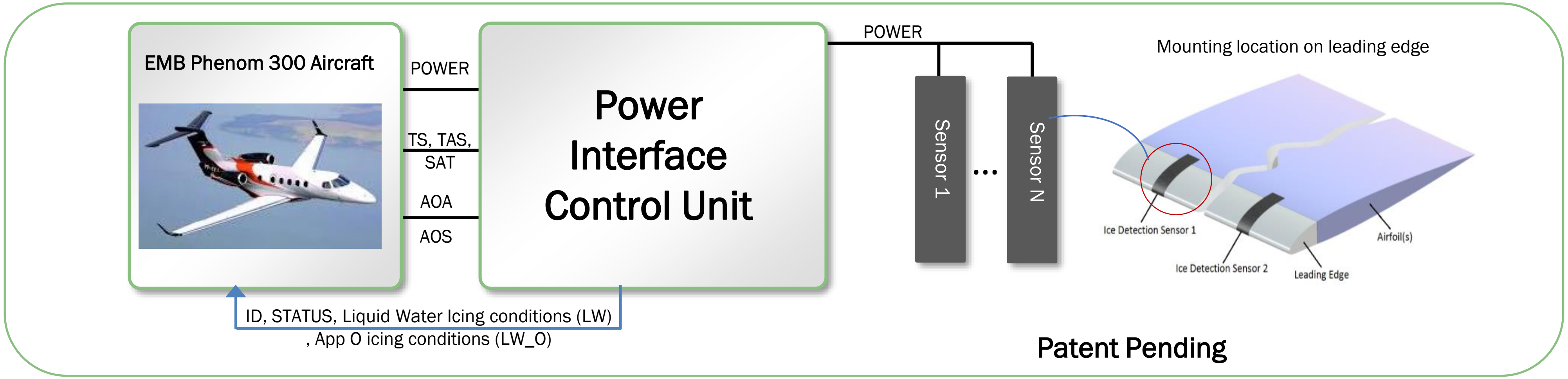
2021

2023

Collins Ice Differentiator Technology

Sensor Detection Concept

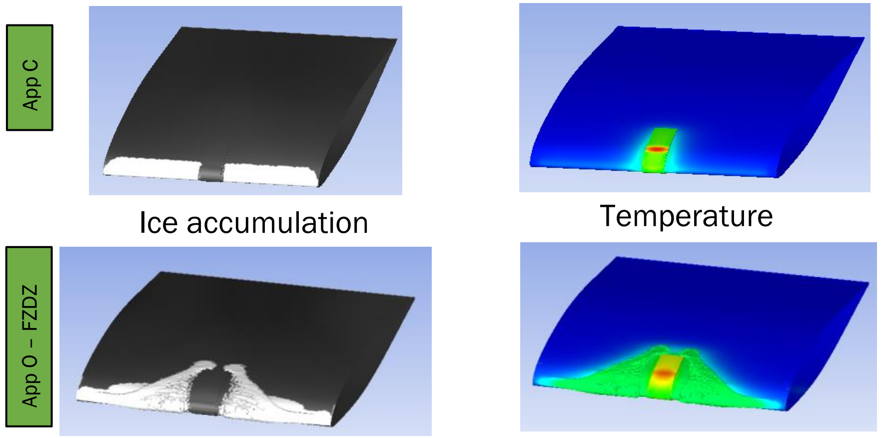
- Ice detection based on thermal response to a heat impulse that changes from dry to icing conditions
- Heat flux variation measured using composite heater
- System is made of two components: a sensing element (heater) and a power interface control unit
- Power interface unit analyses measurements and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



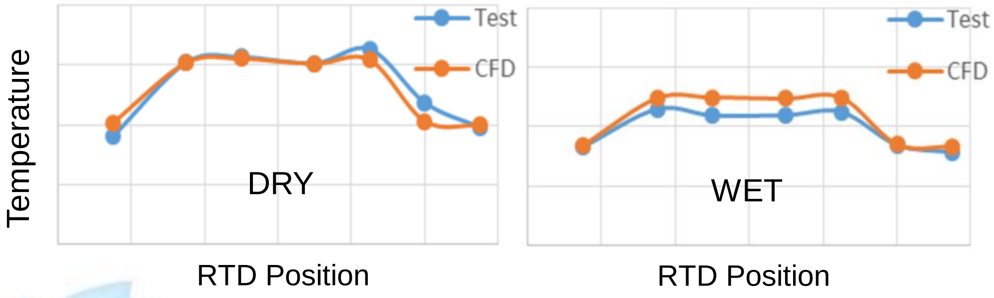
Collins Ice Differentiator Achieved TRL 4

NUMERICAL ANALYSIS

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

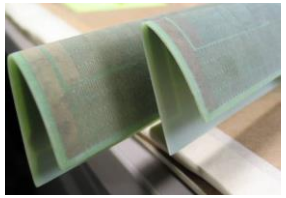


Model validation against IWT test data



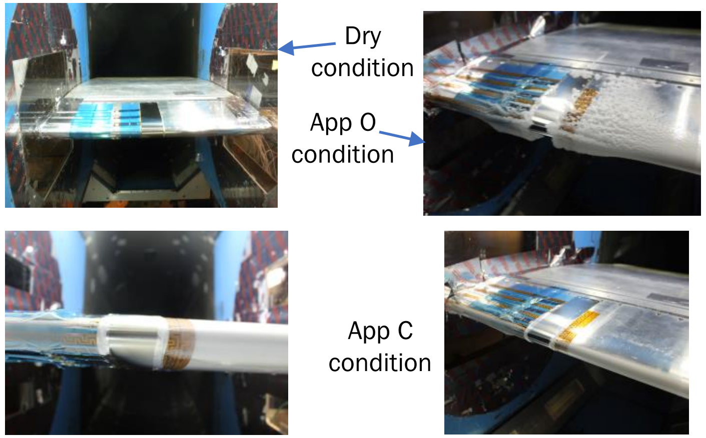
LAB AND IWT TESTING

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

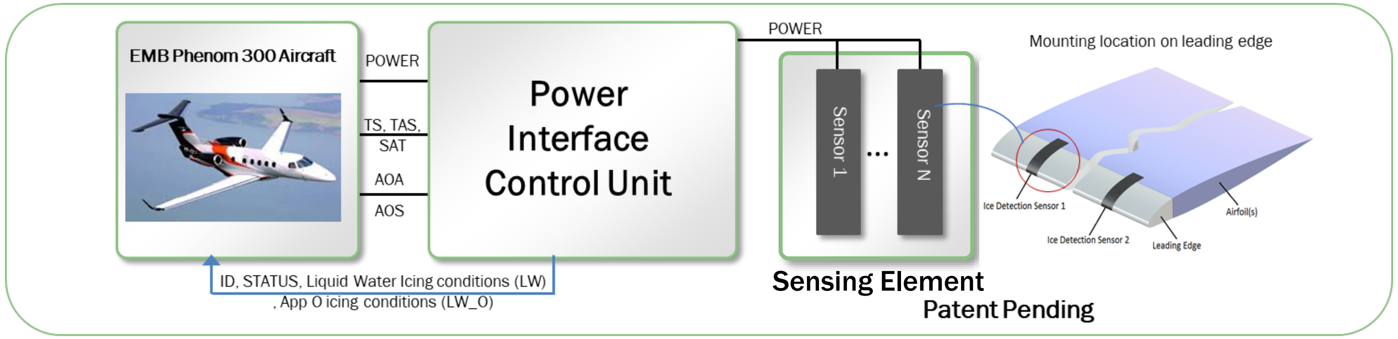


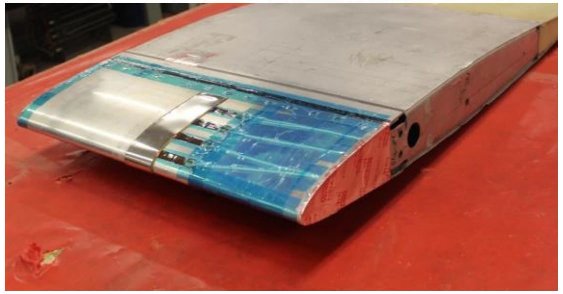
- Four rounds of IWT tests completed at Collins IWT – OH and NRC IWT

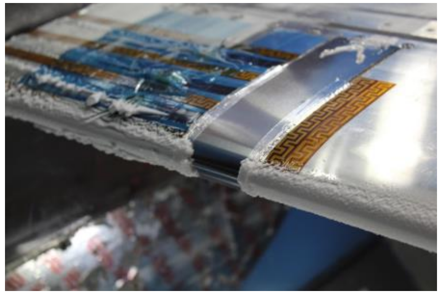
View of sensor during IWT tests



Collins Ice Differentiator Sensor







- Technology based on measuring heat flux variations in different icing conditions using a metallic or advanced CNT heater.
- **Sensing Element** uses a proven and certified construction made of high temp composite, temperature sensors and heater.
- **Power Interface Control Unit (PICU)** that provides the necessary power to the sensing element & analyses measurements.

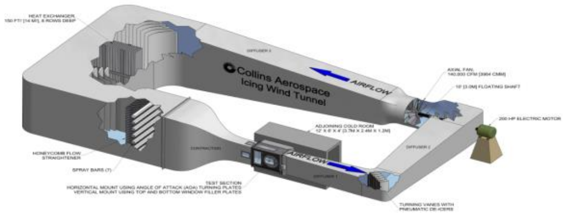
SENS4ICE Start

- Q1 2019
- Sensor components design complete
- Q4 2019 – TRL3 Review, Nov 2019
- Numerical model developed using updated sensor construction
- Q2 2020 – Power interface control unit HW developed and tested in lab
- First sensor prototype developed and tested in icing wind tunnel
- Q4 2020 – TRL4 Review, Dec 2020
- Second round of IWT tests at Collins IWT, OCT 2020
- Q1 2021 – SENS4ICE icing wind tunnel campaign using integrated sensor
- Q2 2021 – SENS4ICE Gate 2 Review, Jun 2021
- Q4 2021 – TRL5 Review, Q4 2021
- Q2 2022 – IWT tests on vertical fin leading edge
- Sensor refined with safety of flight (SOF) requirements
- Q1 2023 – Flight Test with Embraer Phenom 300
- Q2 2023 – TRL6 Review, Q2 2023

SENS4ICE End

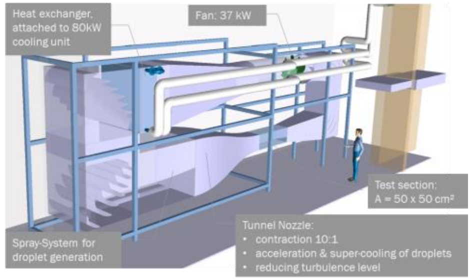
Collins-IDS Tested in Two IWT Facilities

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

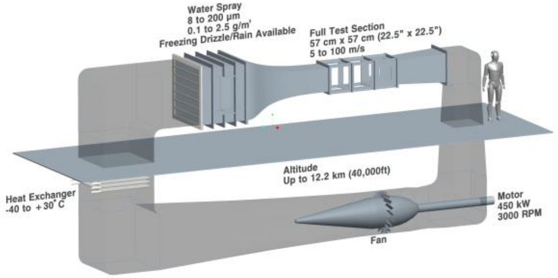


- MVD 9-60 micron droplets
- LWC between 0.1 and 1.5 g/m3
- Temperature 30°C to -20°C
- Sustained speed 10-40 m/s
- Test section: 150×50×50 cm3
- Calibrated per SAE ARP 5905
- Short spray transients ~ 15s
- Bi-modal SLD and mixed phase capability

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-IDS Tested in Two IWT Facilities

Sensor completed 140 hours of icing wind tunnels tests over four rounds of tests at Collins and NRC test facilities

IWT test	Test Facility	Duration	Description
Round 1, May 2020	Collins, Ohio	40 Hours	Feasibility tests to validate CFD models over Dry, App C and App O conditions and to verify App C/O discrimination.
Round 2, Oct. 2020	Collins, Ohio	40 Hours	Tested operation of integrated system over a wide range of icing conditions. Data used to validate the detection algorithm and its ability to detect and discriminate App C/O conditions.
Round 3, Jan. 2021	Collins, Ohio	40 Hours	Demonstrate (1) reduction in power requirements and improved sensor performance (2) the online ice detection and differentiation between App C and App O icing conditions taking the sensor to the next level towards flight test.
Round 4, Mar 2021	NRC, Canada	20 Hours	NRC facility provided more capabilities within the App O icing envelope. The data was used to expand the detection envelope beyond the capabilities in the Collins facility and to demonstrate the efficacy of the sensor in differentiating the App C and App O as well as extend the points for our simulation verification & validation.

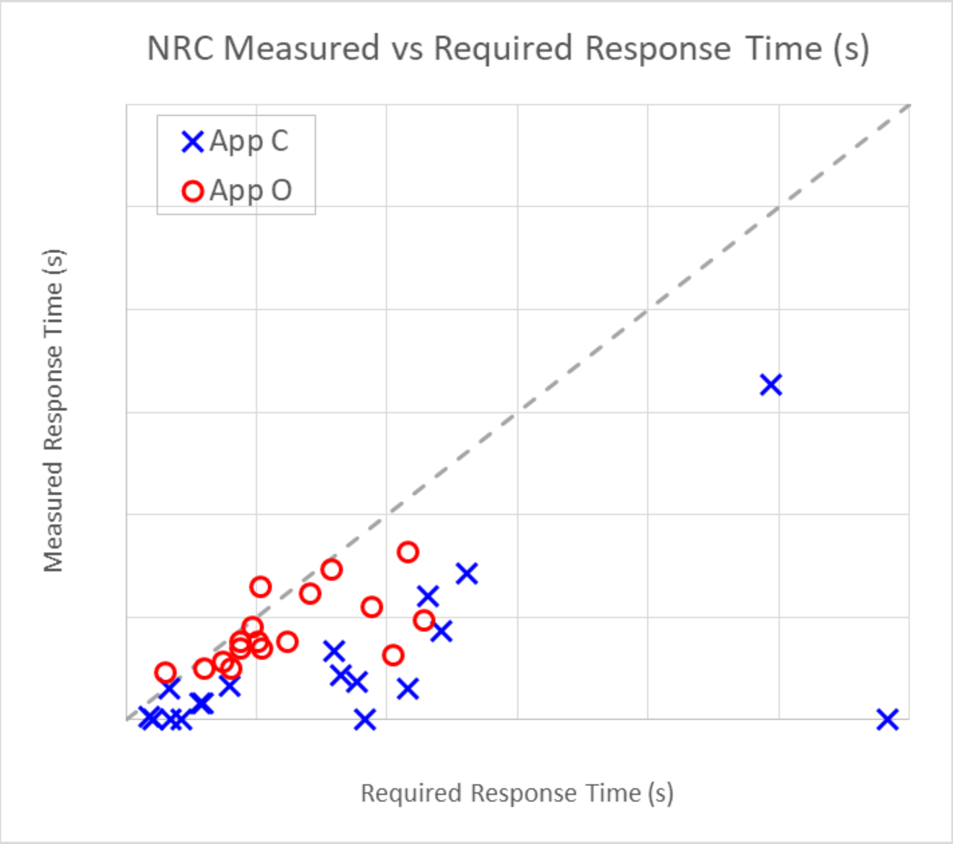
Test Matrices

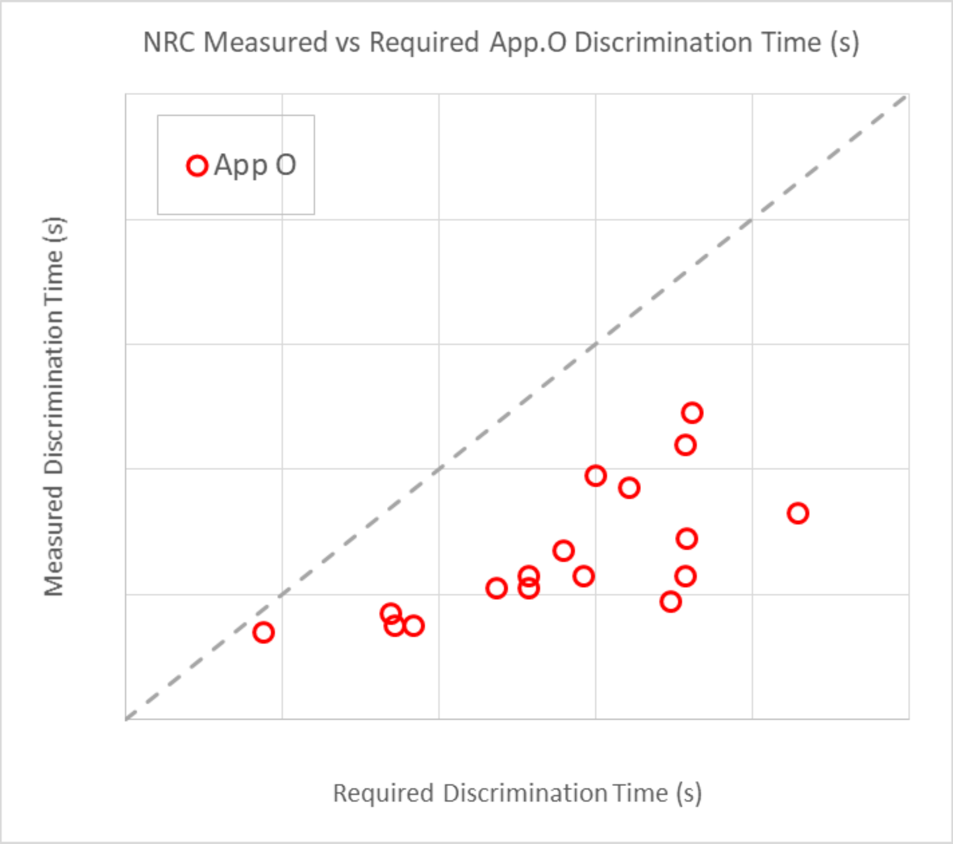
- Standard Test Points of Test Matrix: Example Test Matrix - NRC
  - Standard tests for atmospheric sensors
  - Includes required response time (LW:Enter) as per ED-103
  - Includes required discrimination time (LW_O:Enter) as per ED-103
  - Colour coding follows ED-103:
    - Green for App. C – CM
    - Blue for App. C – IM
    - Dark orange for App. O, MVD>40 µm
    - Light orange for App. O, MVD<40 µm

NRC Atmospheric Sensors Results Table - Standard Tests

Conditions								Requirements		Measurements / Results							
Case	Test Type	Condition	Airspeed	Static Temp.	Altitude	MVD	LWC	LW: Enter	LW_O: Enter	LW: Enter	LW: Exit	LW_O: Enter	LW_O: Exit	False Alarm	LWC	MVD	DMAX
[-]	[-]	[-]	[m/s]	[deg. C]	[feet]	[microns]	[g/m^3]	[s]	[s]	[s]	[s]	[s]	[s]	[-]	[g/m^3]	[microns]	[microns]
1	Repeat 2	LW-C CM	40.1	-20	0	15	0.3	36	-								
2	Endurance	LW-C CM	40.1	-10	0	20	0.42	23	-								
3	Standard	LW-C CM	84.9	-10	0	23	0.34	11	-								
4	Repeat 3	LW-C CM	40.1	0	0	23	0.54	126	-								
5	Standard	LW-C CM	84.9	-20	0	30	0.11	33	-								
6	Standard	LW-C CM	84.9	-10	0	40	0.1	36	-								
7	Standard	LW-C CM	84.9	-10	0	35	0.15	24	-								
8	Standard	LW-C CM	84.9	-30	0	35	0.05	72	-								
9	Standard	LW-C CM	84.9	-3.5	0	30	0.35	29	-								
10	Repeat 1	LW-C IM	40.1	-20	0	22	1.5	6	-								
11	Standard	LW-C IM	40.1	-10	0	28	1.2	10	-								
12	Standard	LW-C IM	84.9	-20	0	23	1.3	3	-								
13	Standard	LW-C IM	40.1	-20	0	42	0.3	26	-								
14	Standard	LW-C IM	84.9	-20	0	20	1.75	3	-								
15	Standard	LW-C IM	84.9	-10	0	20	2.25	5	-								
16	Standard	LW-C IM	84.9	-10	0	20	0.5	8	-								
17	Standard	LW-C IM	84.9	-20	0	31	0.75	5	-								
18	Standard	LW-C IM	84.9	0	0	20	2.5	57	-								
19	Standard	LW-C IM	84.9	-3.5	0	35	1	25	-								
20	Standard	unimodal	76.1	-17.7	0	163.5	0.82	4	5								
21	Standard	unimodal	40.1	-17.7	0	122	0.46	15	24								
22	Repeat 4	LW-FZDZ	79.7	-20	0	106	0.4	9	17								
23	Standard	LW-FZDZ	79.7	-25	0	20	0.29	15	169								
24	Standard	LW-FZDZ	84.9	-15	0	20	0.35	12	132								
25	Standard	LW-FZDZ	84.9	-10	0	20	0.38	11	122								
26	Standard	LW-FZDZ	84.9	-3.5	0	20	0.42	28	110								
27	Standard	LW-FZDZ	84.9	-25	0	20	0.15	27	308								
28	Standard	LW-FZDZ	84.9	-15	0	20	0.18	22	257								
29	Standard	LW-FZDZ	84.9	-10	0	20	0.2	20	231								
30	Standard	LW-FZDZ	84.9	-3.5	0	20	0.21	29	221								
31	Standard	LW-FZDZ	84.9	-25	0	110	0.18	18	35								
32	Standard	LW-FZDZ	84.9	-15	0	110	0.22	15	29								
33	Standard	LW-FZDZ	84.9	-10	0	110	0.23	14	28								
34	Standard	LW-FZDZ	84.9	-3.5	0	110	0.26	28	29								
35	Standard	unimodal	84.9	-10	0	180	0.25	13	15								
36	Standard	unimodal	84.9	-10	0	220	0.25	13	14								

Collins Aerospace: Ice Differentiator Sensor (Collins-IDS) - Atmospheric





Preparation for Flight Test
SENS4ICE Flight Test Platforms

- total flight test time: 125h in natural icing conditions
- planned main time frame: Q1/2022 *(delays due to Covid-19)*

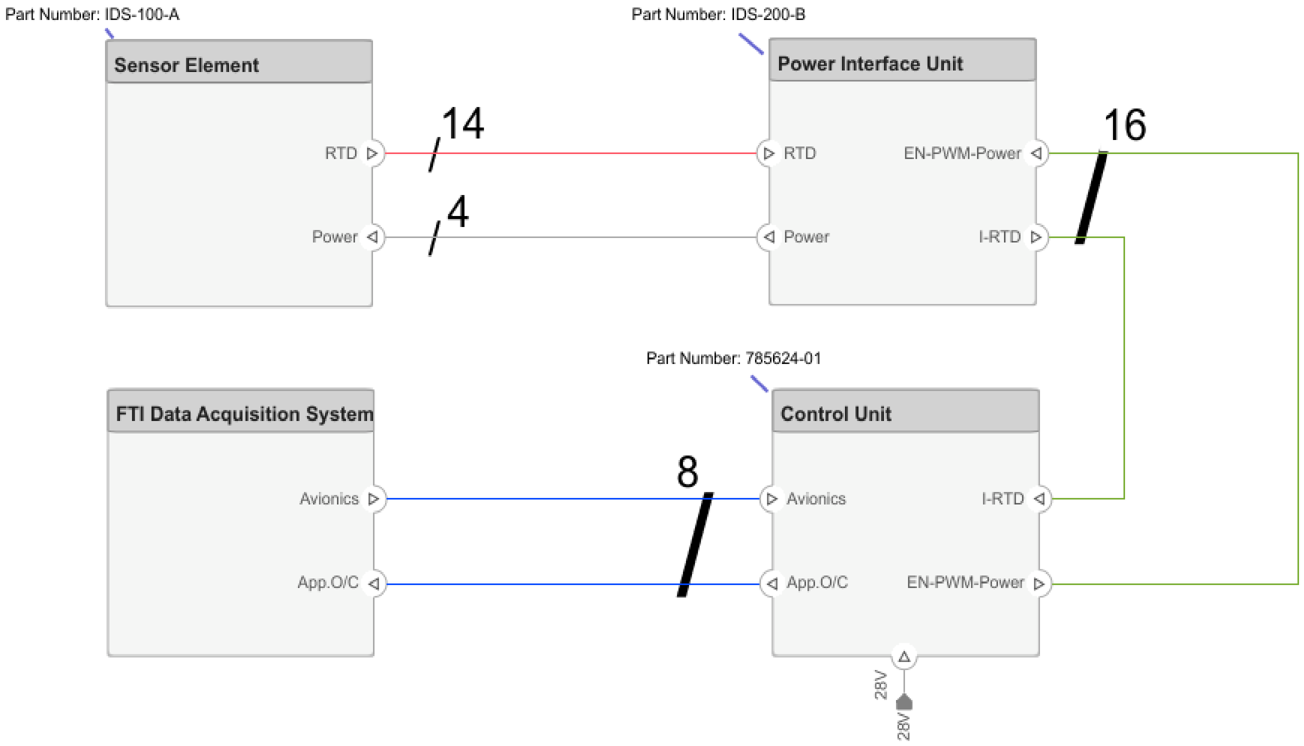
SAFIRE ATR-42

Embraer Phenom 300

CAO Yak-42D Roshydromet

Preparation for Flight Test

- Interfaces defined between Collins-IDS and the aircraft



Required real time data inputs for Collins-IDS

Full Name	Short Name	Data Type	
Timestamp	TS	Number	REQ
True Air Speed	TAS	Number	REQ
Static Air Temperature	SAT	Number	REQ
Angle of Attack	AOA	Number	REQ
Angle of Side Slip	AOS	Number	REQ
Weight on Wheels	WOW	Boolean	OPER

Summary and Future Work

SUMMARY

- Collins IDS technology achieved TRL4 and progressing towards TRL5 (Dec 2021)
- Sensor completed 120 hours of icing wind tunnel tests at Collins IWT and NRC IWT
- Sensor successfully demonstrated the capability to differentiate different environment conditions as dry, App. C and App. O

NEXT STEPS

- Icing wind tunnel tests on vertical fin to prove scalability of the technology
- Preparations for 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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