SENS4ICE

SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES
FOR SAFER AVIATION IN ICING ENVIRONMENT

Fiber optic based ice detector

to discriminate between App O and App C condition

Malte Frövel, Miguel Gonzalez, INTA, Spain

Virtual - 22/10/2020

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

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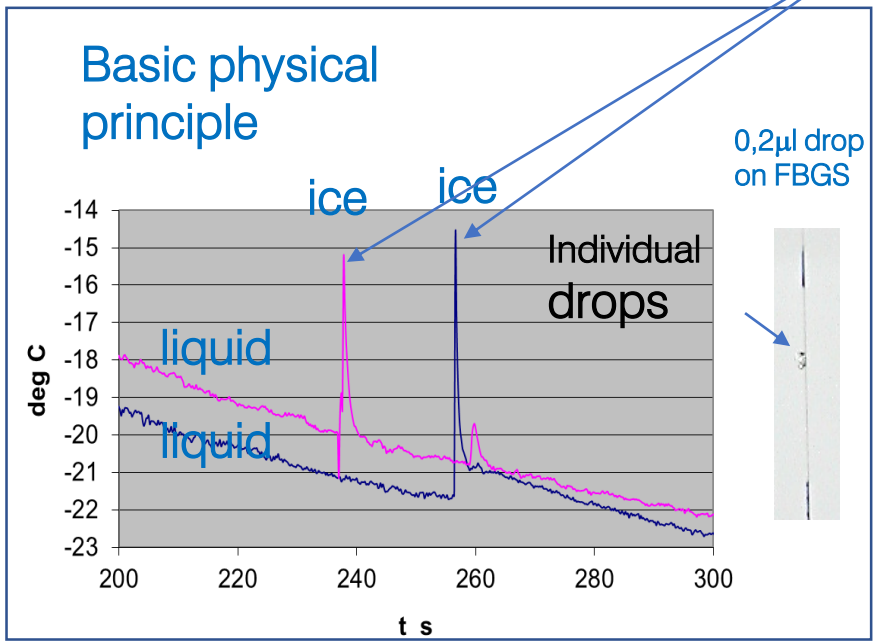
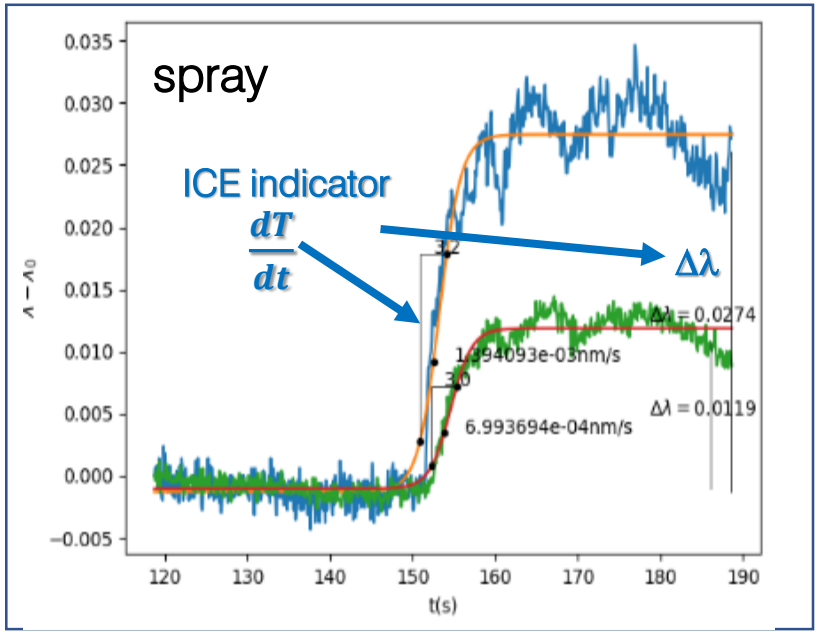
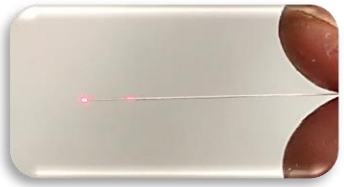
Basic Physical Principle

INTA Ice detection: FOD

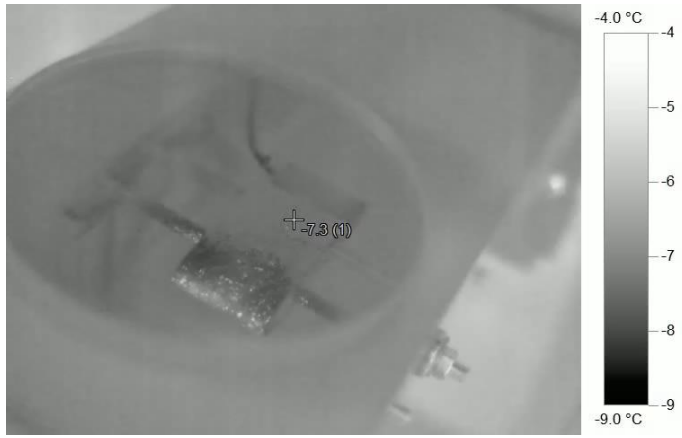
- Basic physical principle:
- Fiber optic Bragg grating sensors (FBGS)_ Energy release due to liquid/ solid transformation







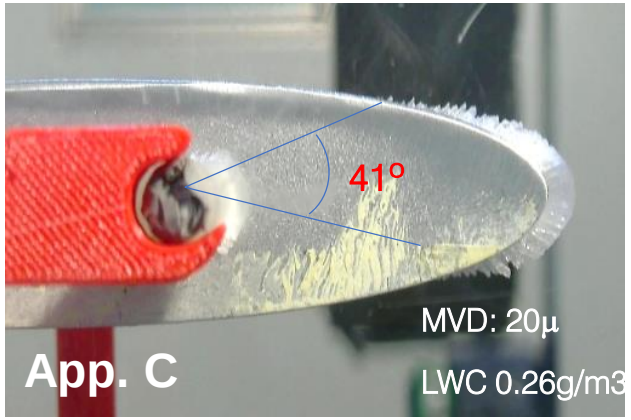
spray

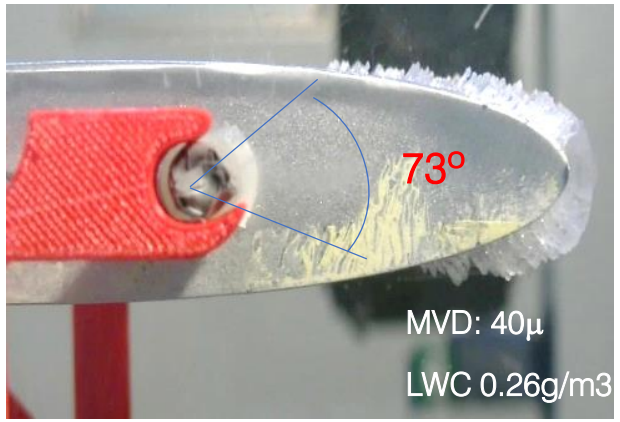


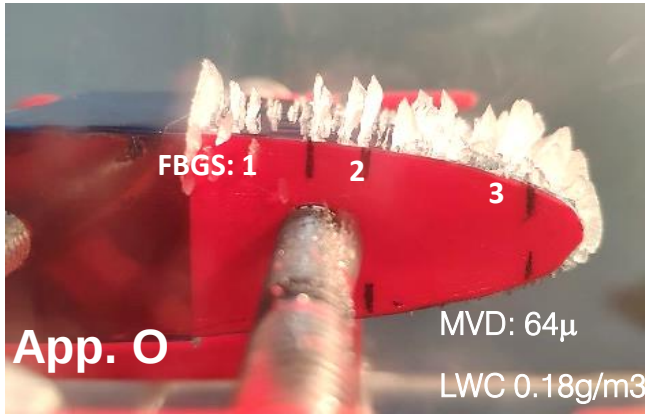
Thermographic video

NACA0012 in IWT

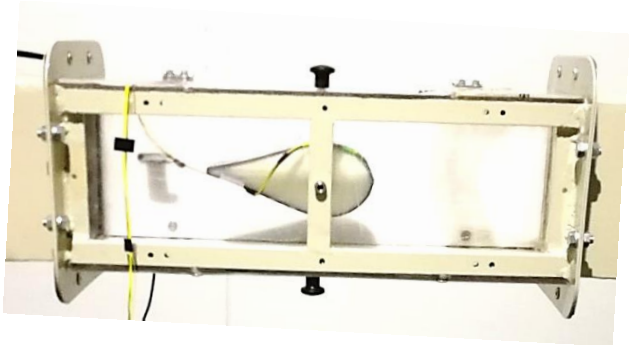
Differentiate between App C and O







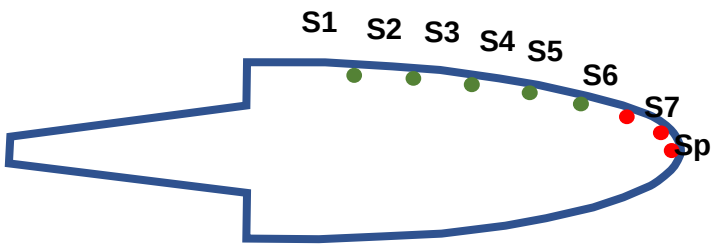
Aeronautic profile: NACA0012

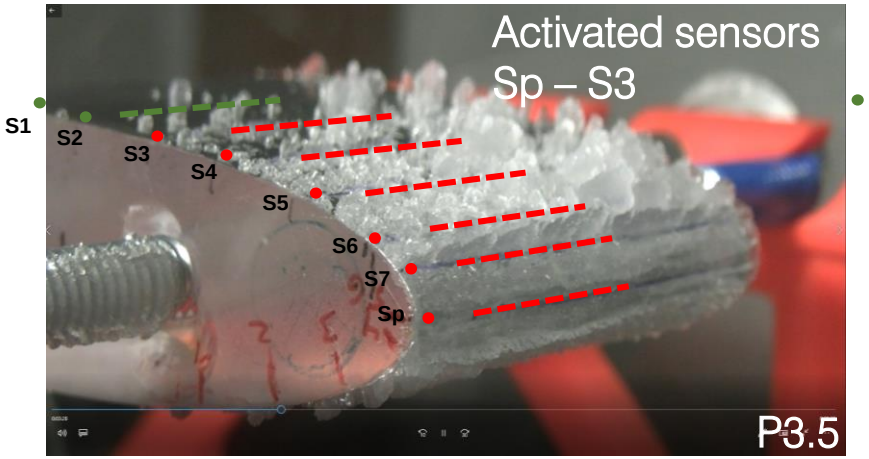


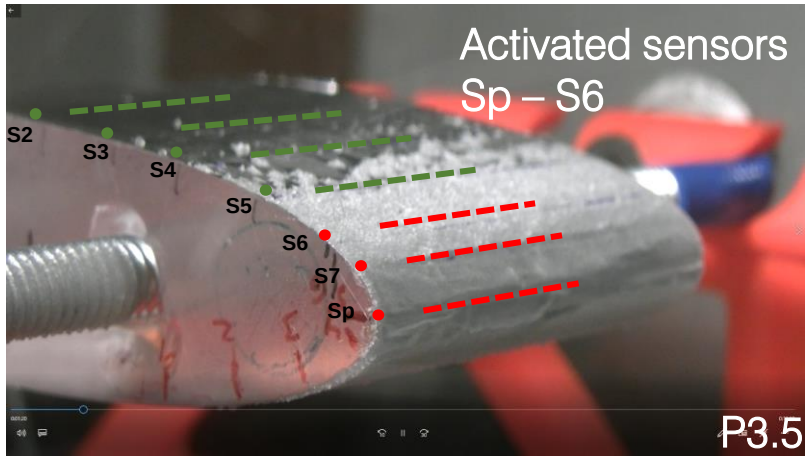
INTA IWT

Differentiate between App C and O

New FOD detectors during IWT tests







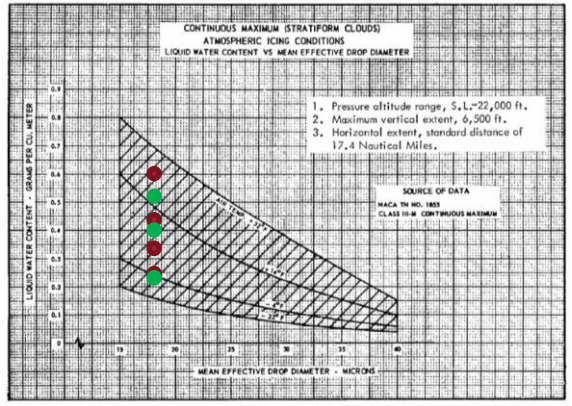
FOD Sensor head design
8 FBGS the along chord

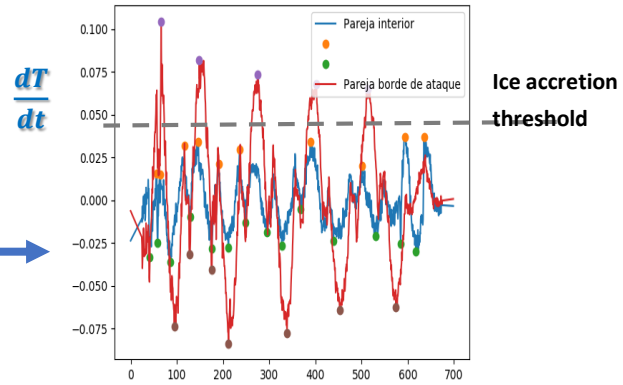
LWC=0,9g/m3
MVD=70 micron
-10°C, 1min

LWC=0,3g/m3
MVD=20 micron
-10°C, 1min

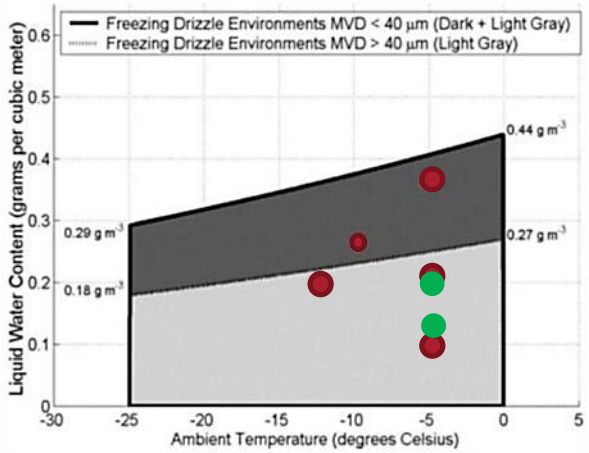
INTA Ice detection: tests performed

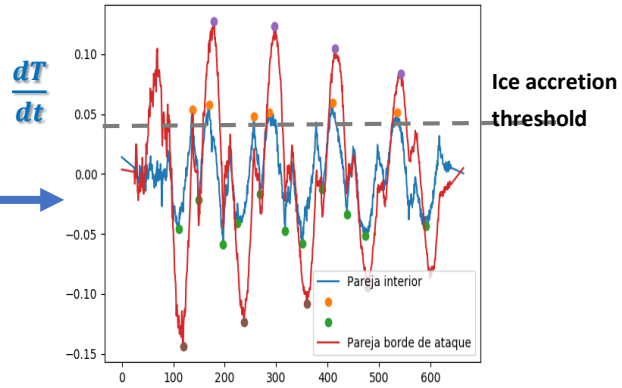
App C





App O





Icing conditions tested at INTA-IWT

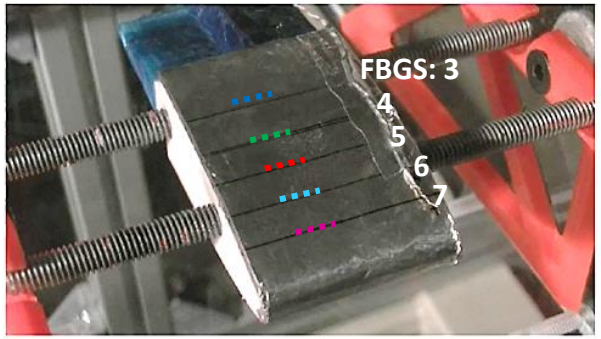
		MVD µ	LWC g/m3	T ºC	V m/s	Detected	Differentiated between App. C and App. O
App. C	Tubes_C1	20	0.25	- 18	50	✔	NA
	Tubes_C2	20	0.42	- 10	50	✔	NA
	Tubes_C3	20	0.55	- 5	50	✔	NA
	NGPDA_C4	20	0.25	- 5	70	✔	✔
	NACA0012_C4	20	0.25	- 7	70	✔	✔
App. O	NGPDA_O1	27	0.26	- 5	70	✔	✔
	NGPDA_O2	64	0.18	- 5	70	✔	✔
	NACA0012_O1	27	0.26	- 7	70	✔	✔
	NACA0012_O2	64	0.18	- 7	70	✔	✔

Example: IWT test

Stage 1

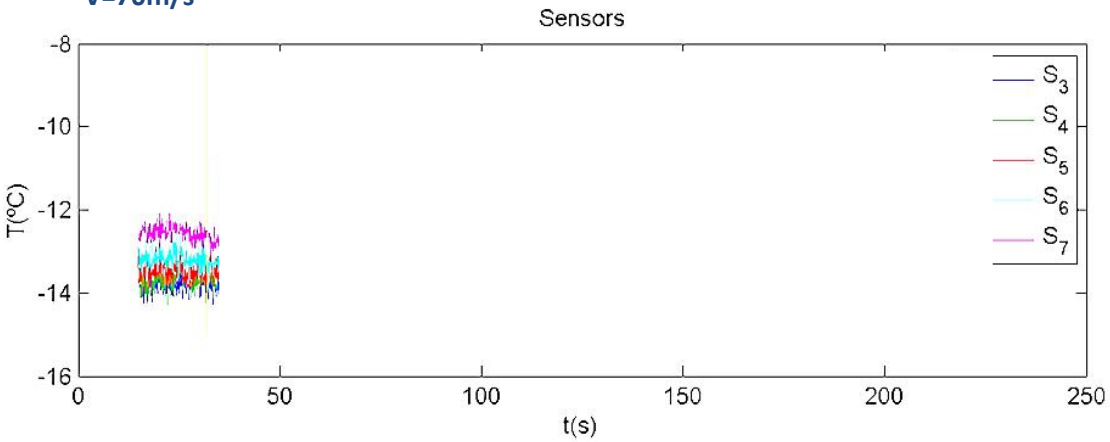
- IWT running at 70m/s and -14ºC
- No water spray

Video



T= -14ºC

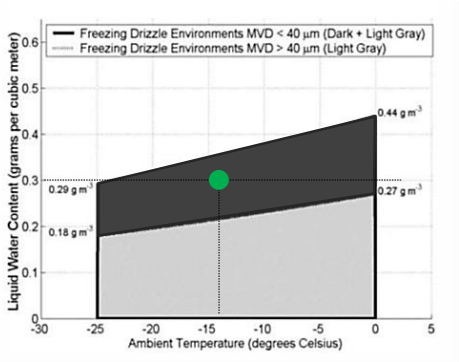
V=70m/s



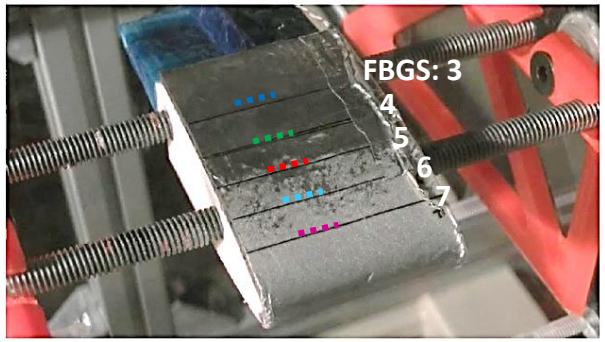
Example: IWT test

Stage 2

- Spray is on. Ice forms at sensor 7 close to leading edge, and sensor 6 and 5 .
- Rime ice
- App O
- No run-back water.

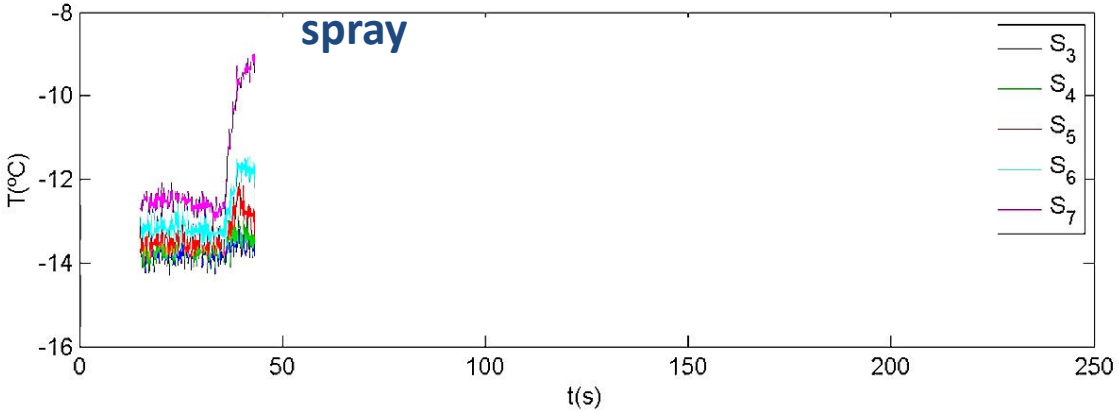


Video



T= -14ºC
LWC=0.3
MVD= 40 µ
V=70m/s

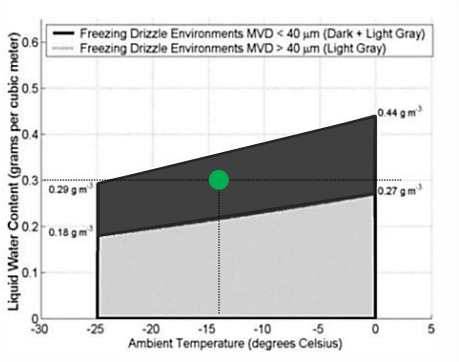
Sensors



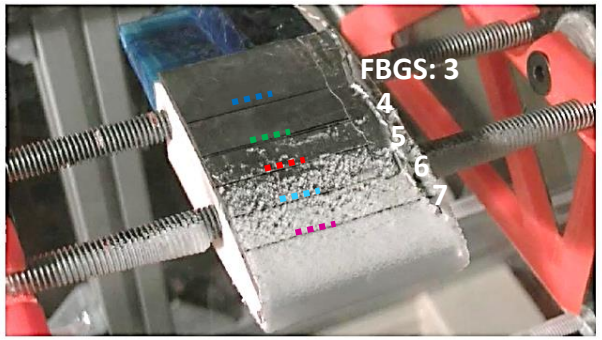
Example: IWT test

Stage 3

- Spray for 1 minute
- Ice is also forming and detected on S6 and S5.

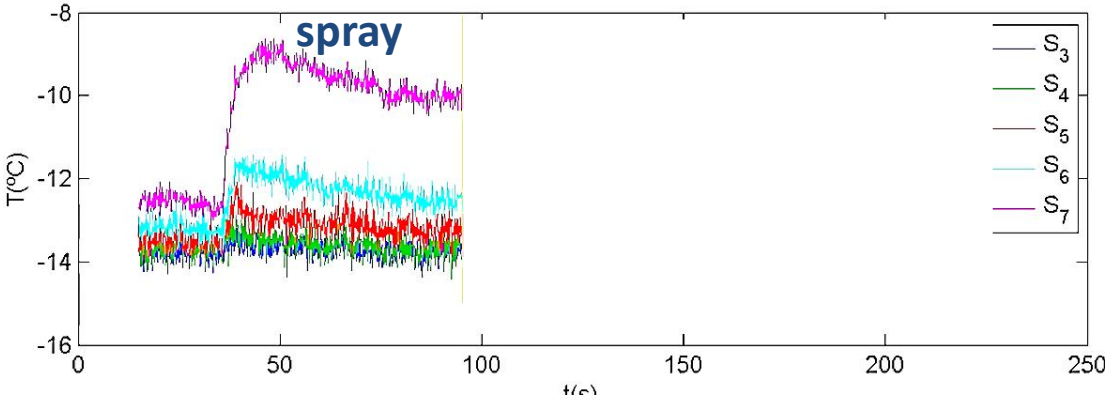


Video



T= -14ºC
LWC=0.3
MVD= 40 µ
V=70m/s

Sensors



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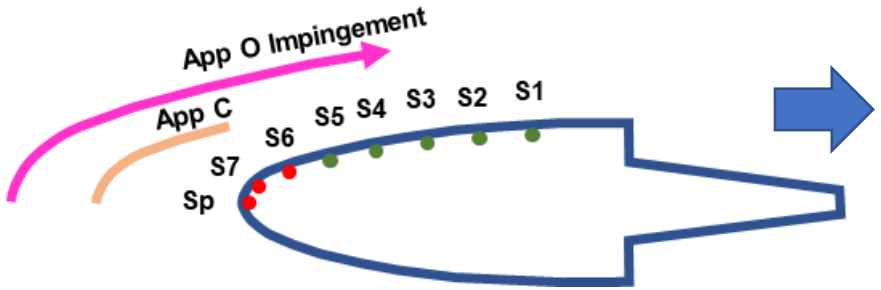
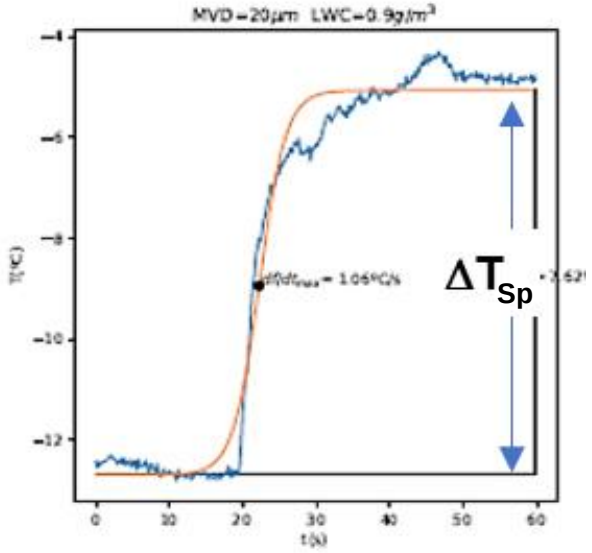
From individual sensor data to icing data

From individual sensor data to icing data



Sensor data



Raw output of each sensor

Icing data

$$LWC = f(\Delta T_{Sp}) \qquad ACC = f(\Delta T_{Sp})$$

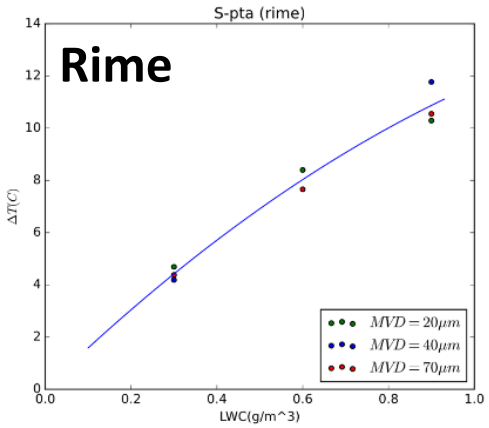
$$MVD = f(\Delta T_{Sp}, \Delta T_{S7} \dots \Delta T_{S2})$$

$$ACC\_O = f(\Delta T_{S7} \dots \Delta T_{S2})$$

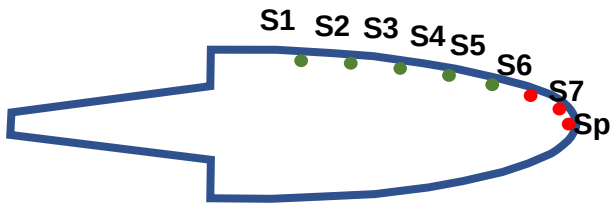
$$ACC_{THK} = \frac{LWC * e_b * TAS * t}{\rho_{ice}}$$

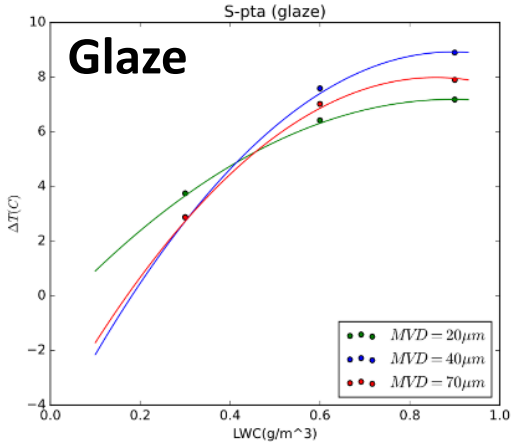
$$ACC_{RATE} = \frac{LWC * e_b * TAS}{\rho_{ice}}$$

From individual sensor data to icing data



$$LWC = f(\Delta T_{Sp}) \neq f(MVD)$$





		RIME P3.5 ΔT [ºC]							
LWC [g/m3]	MVD [micron]	S8	S7	S6	S5	S4	S3	S2	S1
0,95	70	7,75	6,98	4,33	2,5	1,15	0,76		
	40	9,08	7,98	4	2,14	1,2	0,39		
	20	7,62	5,72	2,37	0,97				
0,65	70	6,5	5,78	2,69	1,72	0,64			
	40	7,33	5,7	2,75	1,29	0,37			
	20	5,87	4,54	2,2	0,8	0,14			
0,35	70	3,22	2,78	0,69	0,46				
	40	3.36	2,45	0,62	0,26				
	20	3,74	2,54	0,63					

		GLAZE P3.5 ΔT [ºC]							
LWC [g/m3]	MVD [micron]	S8	S7	S6	S5	S4	S3	S2	S1
0,95	70	*4,25*	3,76	2,35	0,69				
	40	*4,3*	4,2	2,99	0,8				
	20	3,48	2,99	0,53					
0,65	70	2,8	2,59	1,1	1,16				
	40	4,37	4	2,21	0,35				
	20	4,63	3,38	1,03					
0,35	70	2,07	2,06	0,24					
	40	2,46	1,97						
	20	2,6	1,14						

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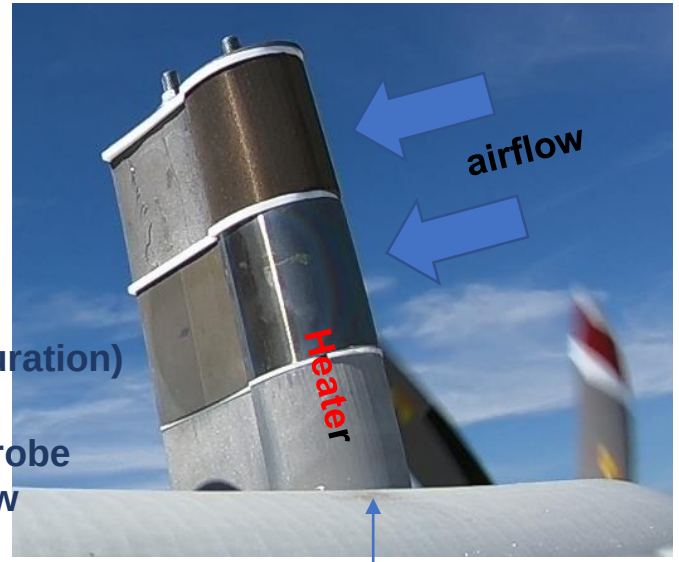
Fligh tests

INTA FOD performed flight tests

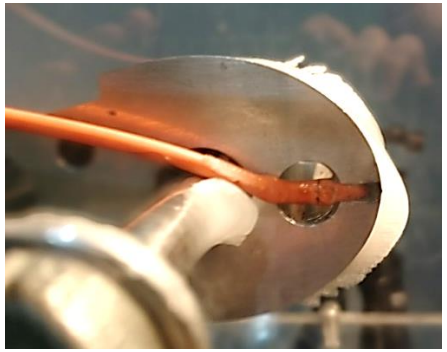
Optional second sensor probe

First sensor probe (SENS4ICE configuration)

Spacer to lift the probe into the free air flow

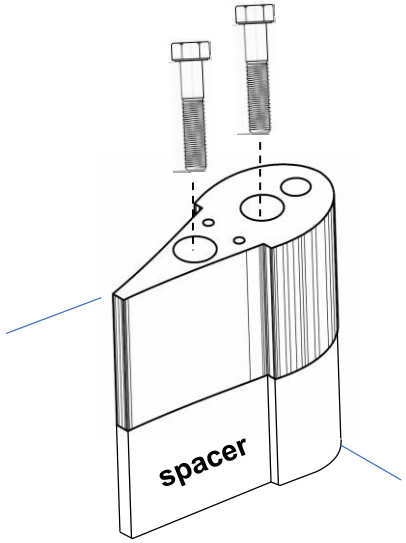


- **Sensor configuration from flight tests at INTA in C212 aircraft**

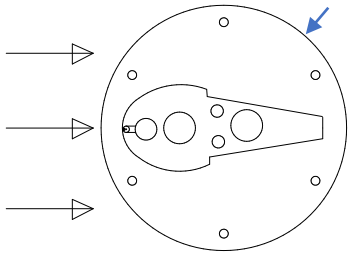


Al Sensor probe in IWT Heater (optional)

Fiber optic Interrogator Si155 from Micron Optics 3kg/ 30W

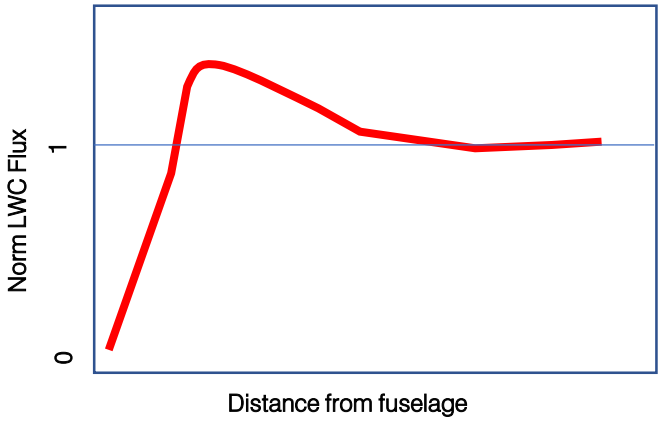


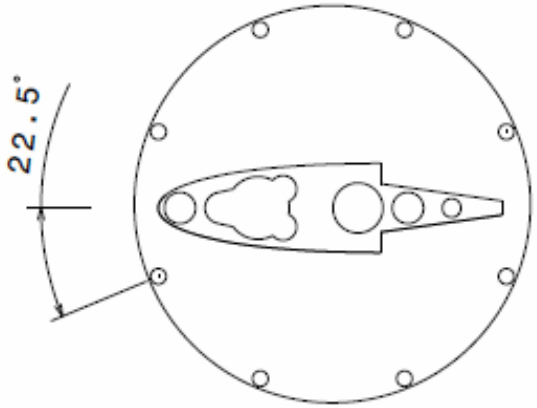
Actual sensor position

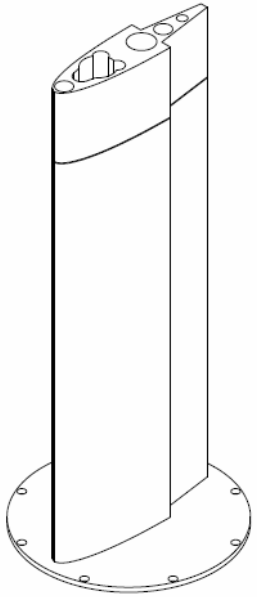


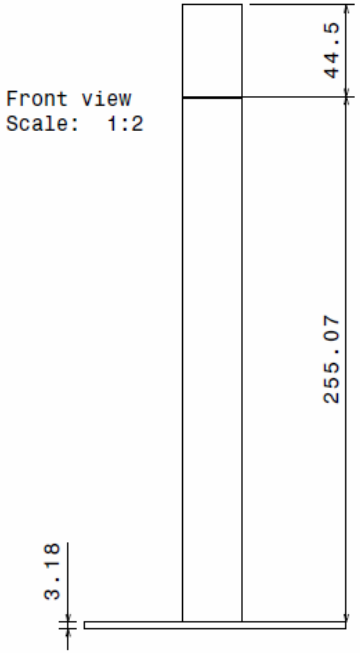
SENS4ICE IWT and Fligth testing

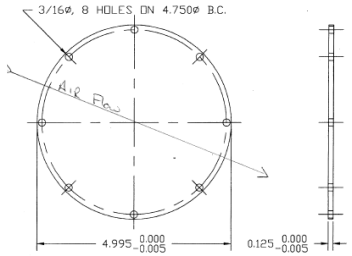
- Specific topics
  - Pairing: NRC AIWT
  - Pairing: EMBRAER Phenom 300











Impingement/free air flow definition to evaluate extension length

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Summary

Summary

- Fiber optic sensor FOD has a high potential for ice detection in A/C
  - Light weight, robust
  - Low consume
  - Electro Magnetic Interference (EMI) safe
- First App C and App O detection has been shown in INTA IWT tests
- Possibility for evaluation of:
  - MVD
  - LWC
  - Ice thickness/ accretion
- Very good detection in RIME, more complicated in GLAZE
- Future development
  - Characterization in critical App O condition (NRC IWT tests) with low LWC
  - Optimization of the evaluation software
  - Optimization of the sensor head development
  - Demonstration in flight tests

Thank you for your attention

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

Fiber optic based ice detector

frovelm@inta.es

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