ICE GENESIS
Project Overview

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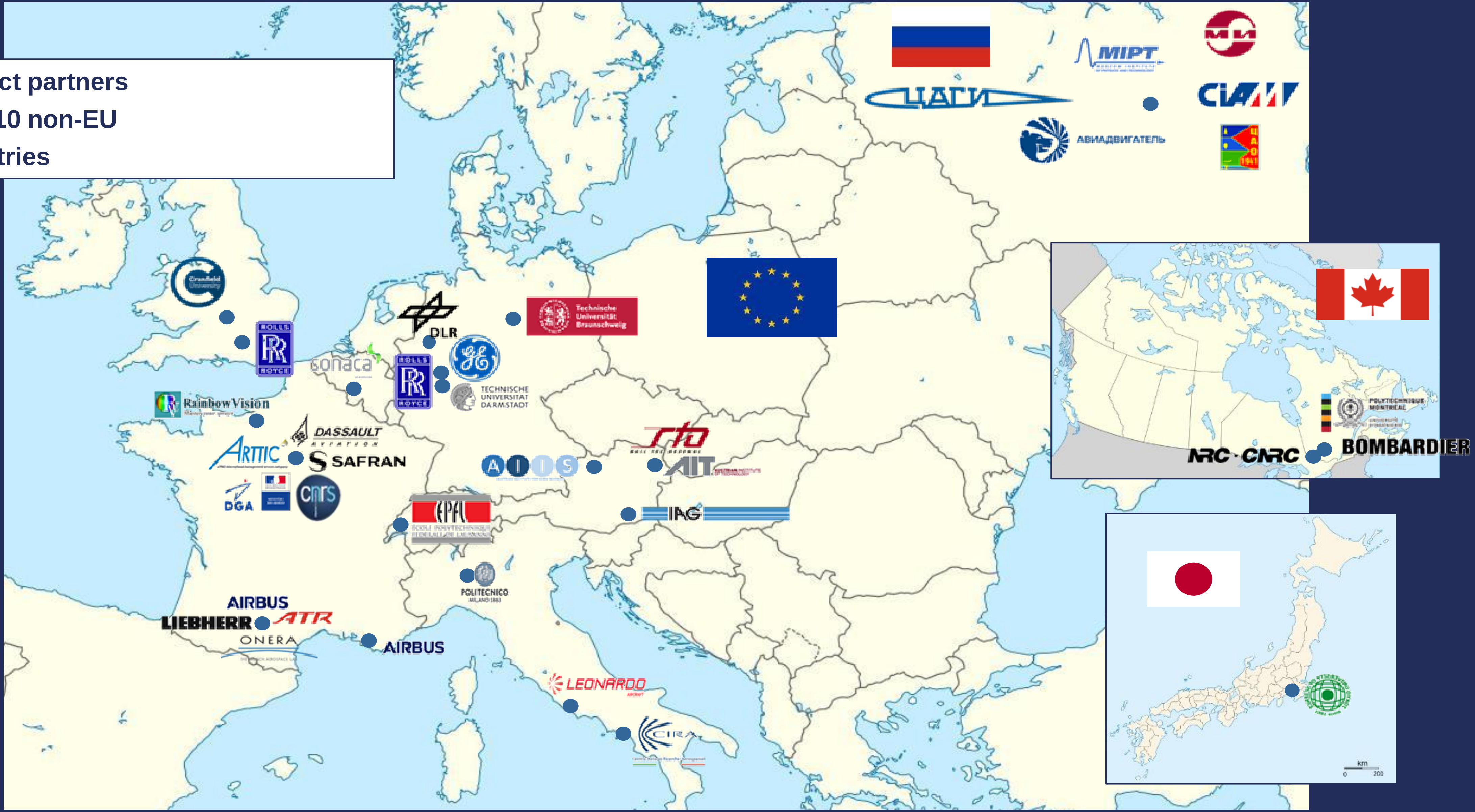
The Consortium

- 37 project partners
- 27 EU / 10 non-EU
- 10 countries



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ICE GENESIS project overview

Creating the next generation of 3D simulation means for icing

- **Duration:** From 1st January 2019 until 31st December 2022
- **Coordinator:** AIRBUS OPERATION SAS

- **Budget:**
  - Max EU Contribution: €11 964 300
  - Total Estimated Project costs: €21 984 549
  - Project effort in Person-months ~ 1858

- **Advisory board:** EASA, FAA, ADSE, AEROTEX, AIRBUS Defense&Space, CSTB, DAHER, EMBRAER,PIAGGIO, SAFRAN nacelles

ICE GENESIS project overview

Top level objective

The top level objective of the ICE GENESIS project is to provide the European aeronautical industry with a validated new generation of:

3D icing engineering tools
(numerical simulation and Icing Wind Tunnels capabilities)

addressing

Regulation CS25 Appendix C (well-known icing envionment)

Appendix O (SLD or Supercooled Large Droplet)

and snow conditions,

for safe, efficient and cost effective design and certification of future aircraft and rotorcraft.

Novelties in Europe : 3D ice scanning system
droplet temperature measurement
snow characterization and campaigns

ICE GENESIS project overview

Sub-objectives

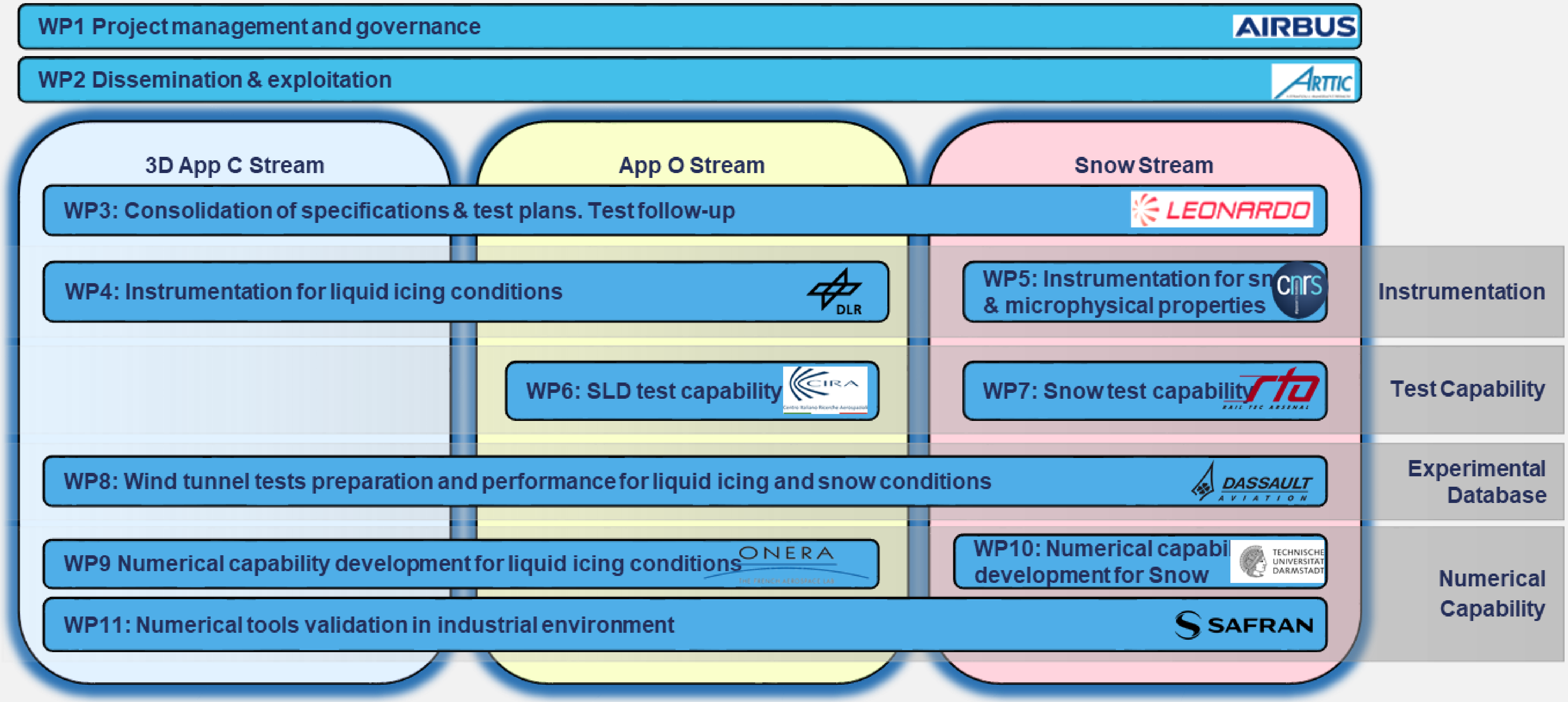
Obj#1: Improve and validate existing **3D numerical tools** to predict ice accretion in Appendix C, Appendix O and Snow conditions.

Obj#2: Upgrade and calibrate **icing wind tunnels** to allow reproduction of:

- **Supercooled Large Droplets (SLD) in FZDZ (Freezing drizzle) conditions**.
- **Snow conditions**
- Additionally, to **assess the potential of current icing wind tunnels to represent SLD in FZRA (Freezing rain) conditions**.

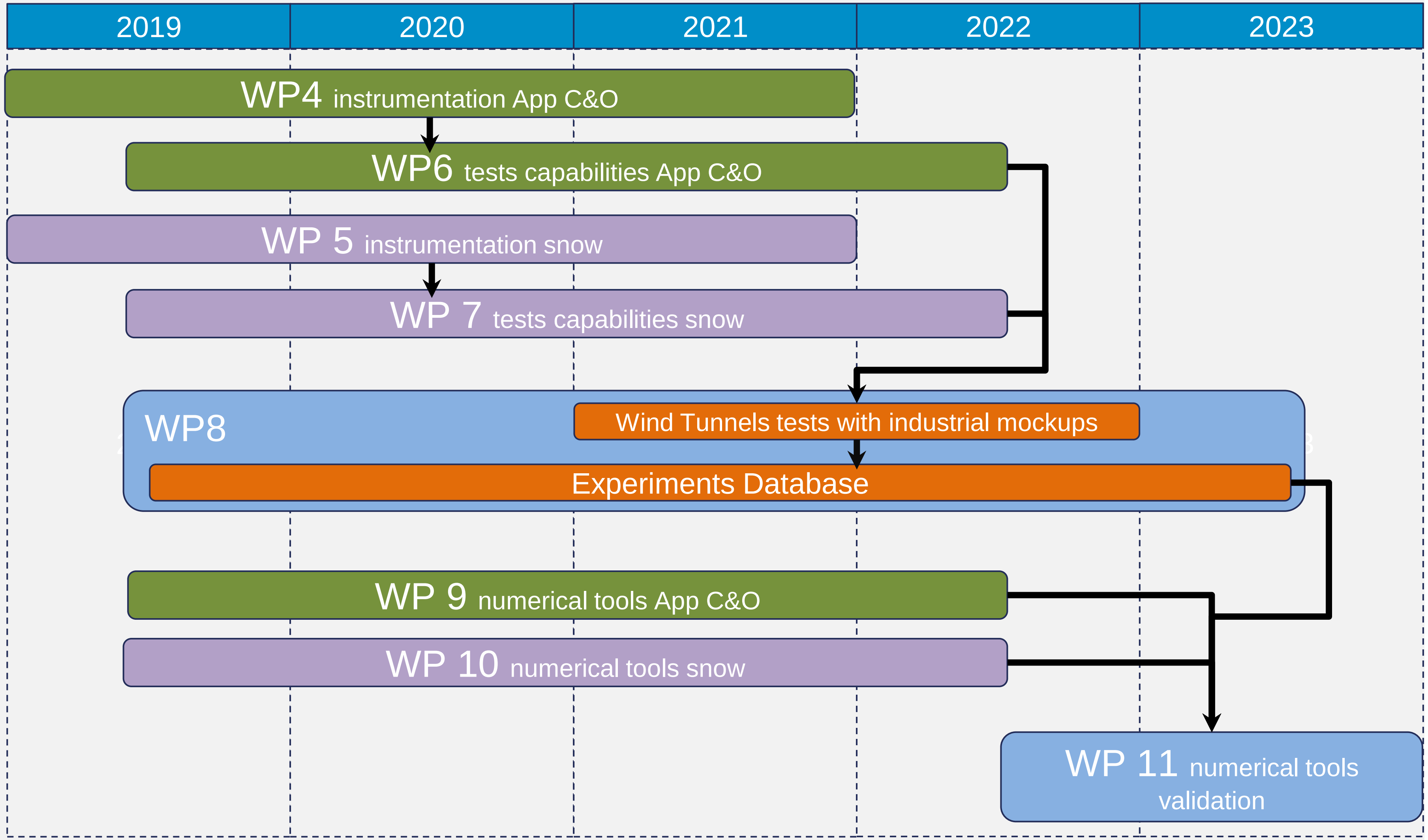
Obj#3: Build a **large scale experimental database** on representative 3D configurations to be used as a solid reference ("ground truth") for future numerical tools validation.

ICE GENESIS Organisation



WP DEPENDENCIES

- Perform wind tunnel tests in liquid icing and snow conditions, in industrial environment (IWT and mockups)
- Provide searchable database of experimental results for validation of numerical tools



SLD Test Capability

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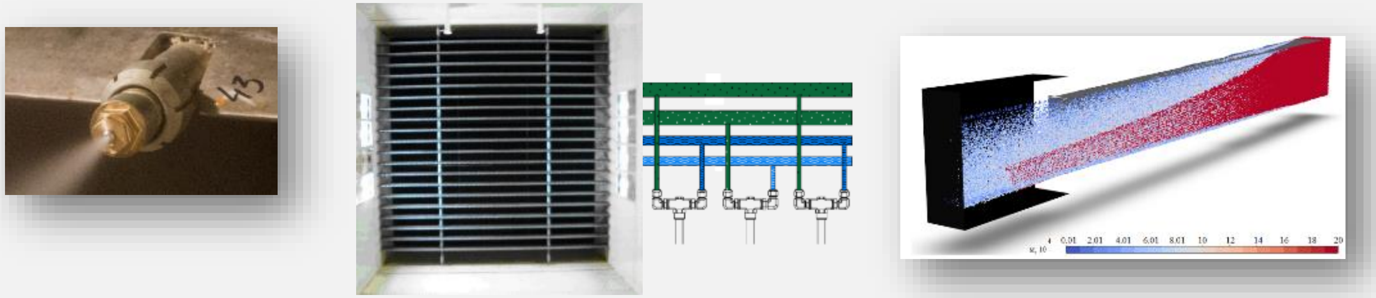
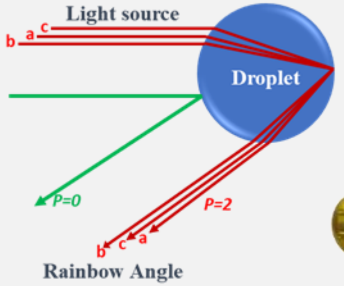
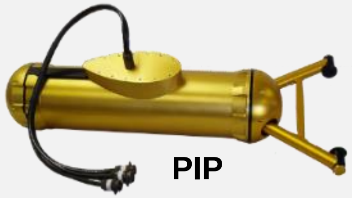
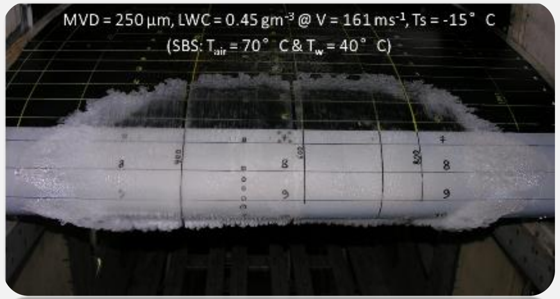
SLD Test capability - Objectives









SLD
Calibration Method

WP4 Instrumentation

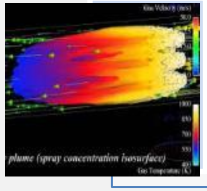
FZDZ
Improve Test capabilities

SLD Test Capability

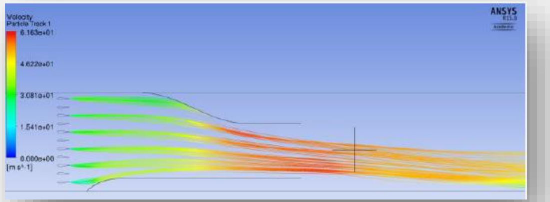
FZRA
Assess potential

WP4 Instrumentation

SLD Test capability - Calibration Methodology



Definition of the active spray nozzles layout on the SBS



Cloud homogeneity check

Check for potential spray nozzles malfunctionality and/or spray plume overlap effects on IG/CYLs

LWC measurements at the centerline of the t/s and in its reference cross-section

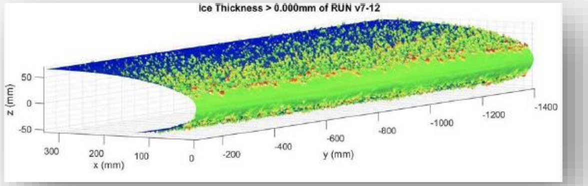
Perform the LWC measurements for the full envelope of spray nozzles water/air pressures ratio and assess the LWC cloud homogeneity

PSD/MVD measurements at the centerline of the t/s and in its ref. cross-section

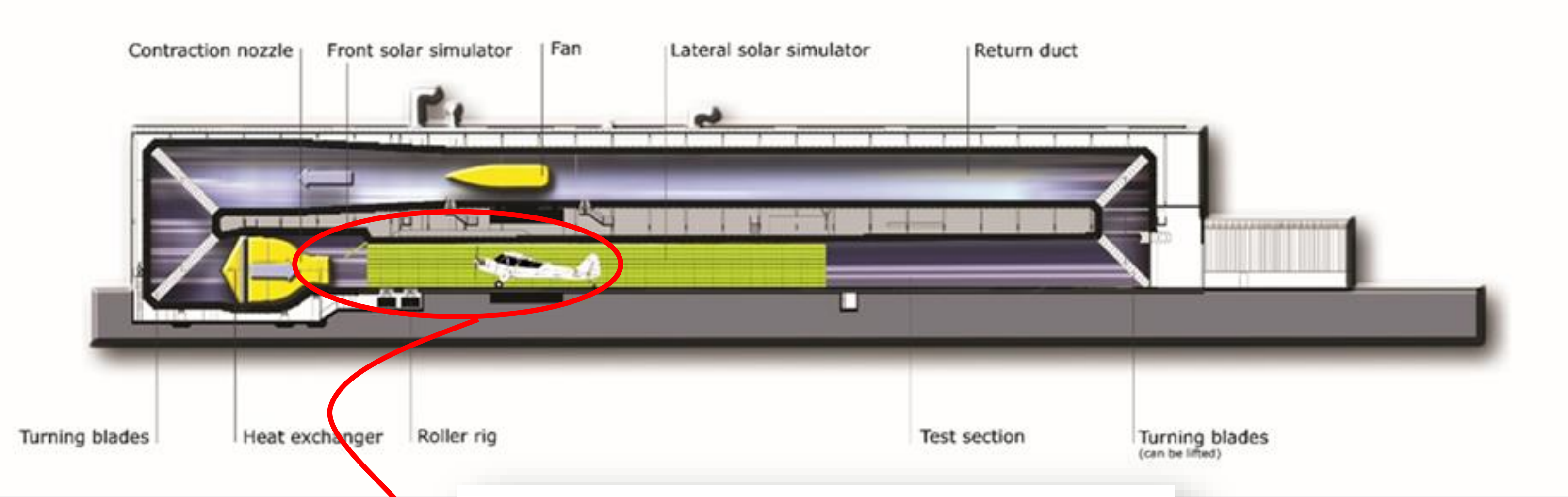
Perform the PSD/MVD measurements for the full envelope of spray nozzles water/air pressures ratio and assess the PSD/MVD cloud homogeneity.

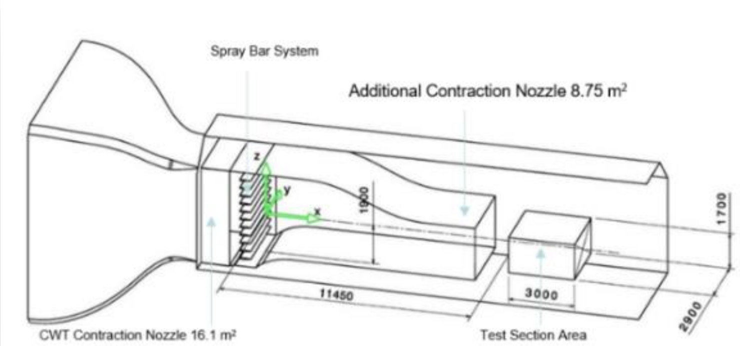
Collect ice accretion shapes on reference NACA 0012 wing section

Scan the reference ice accretion shapes for LWC checks and generate the facility SLD database after each calibration.



SLD Test capability – icing wind tunnels RTA (1/4)

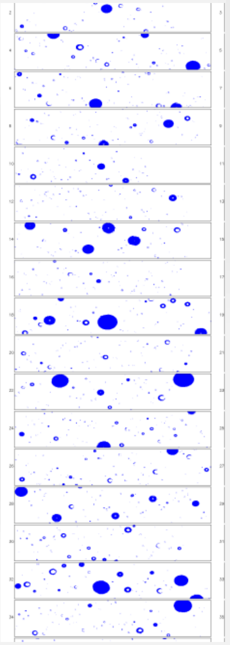


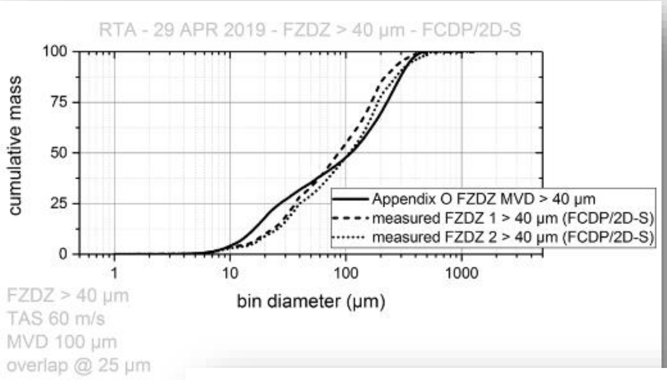


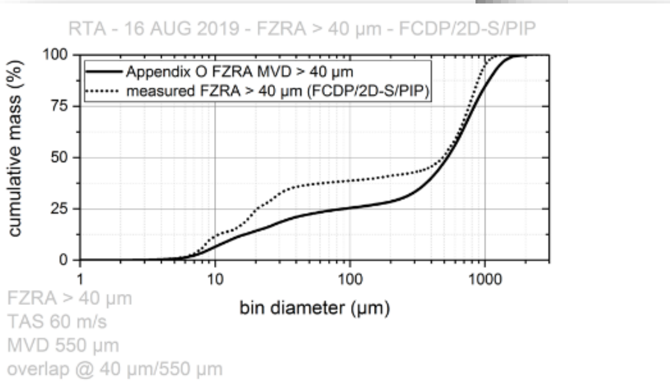
Test section	Size H (m) x W (m) x L (m)	Airspeed (m/s)	SAT (°C)	Altitude (m)
Reduced cross section	3.5 x 2.5 x 90.0 (1.7 x 2.9 x 3.0)	20 to 80	-2°C to -30°C.	sea level

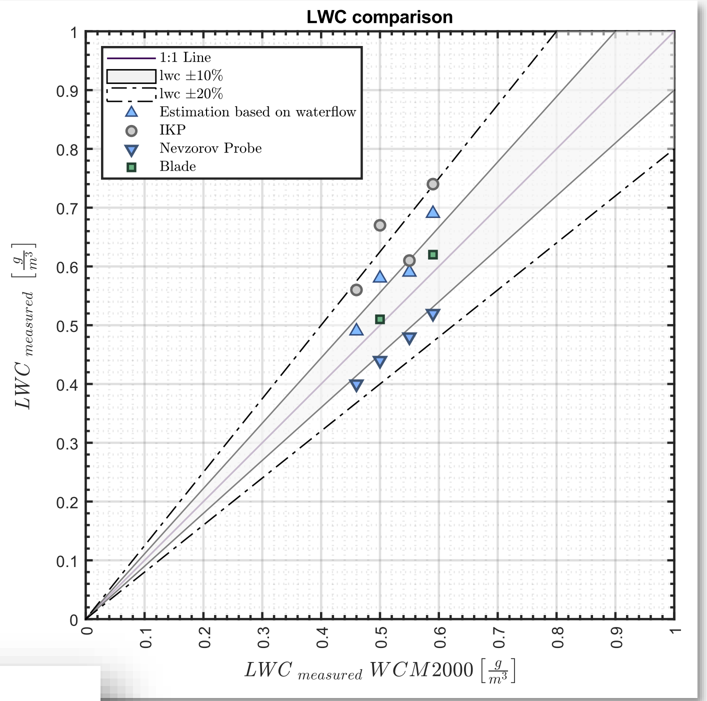
SLD Test capability – icing wind tunnels
RTA (2/4)

- **Definition of icing wind tunnel calibration methods**
  - Three experimental test campaigns in Appendix O conditions using different instrumentation → intercomparison
  - **PSD** and **LWC** measurements in cooperation with **DLR**, **CU**
    - Malvern Spraytec, 2D-S / FCDP, PIP, CAPS
    - WCM-2000, Nevzorov Probe, CU-IKP





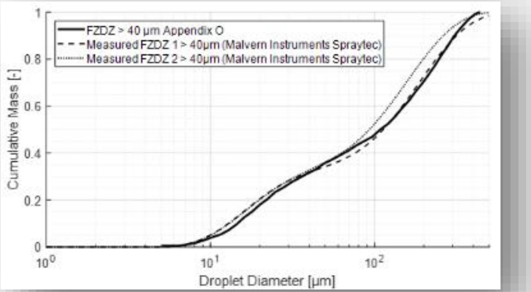


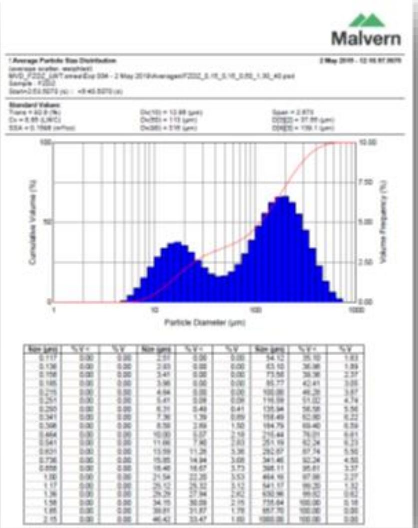


Example PSD results for FZDZ and FZRA conditions (left) and LWC measurement comparison (top)

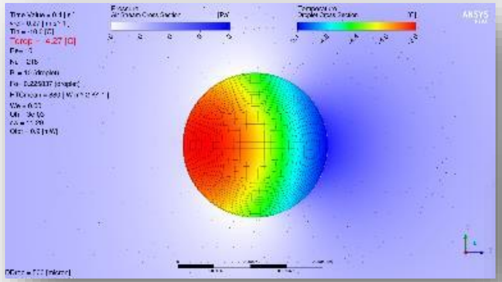
SLD Test capability – icing wind tunnels
RTA (3/4)

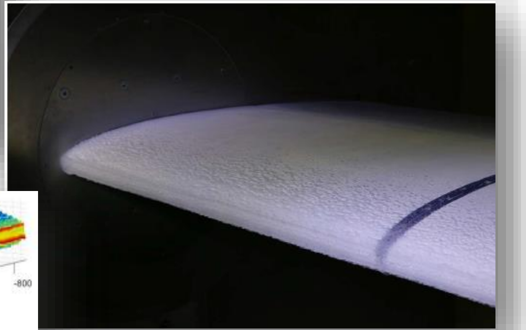
- **Improvement of experimental capability for FZDZ**
  - Investigations on achievable **LWC** and experimental testing of LWC reduction technologies
  - Investigations on achievable **PSD**
    - Modifications, upgrades and adjustments on spray bar system and required settings
    - Measurements and experiments in IWT and with spray nozzle test rig
  - Numerical and experimental investigations on **supercooled state** of large droplets
    - CFD simulations and experimental testing with NACA0012 wing
  - Numerical and experimental investigations on cloud **uniformity**
    - Particle tracking CFD simulations and experimental tests with NACA0012 wing section
    - Uniformity measurements using the ice accretion grid

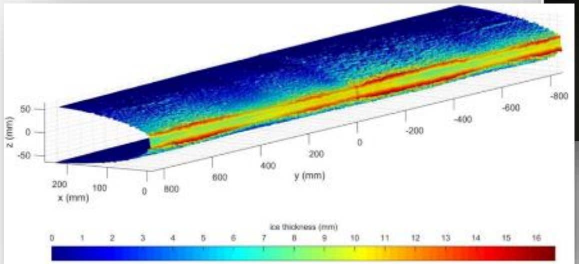




Preliminary PSD results for FZDZ MVD > 40 µm



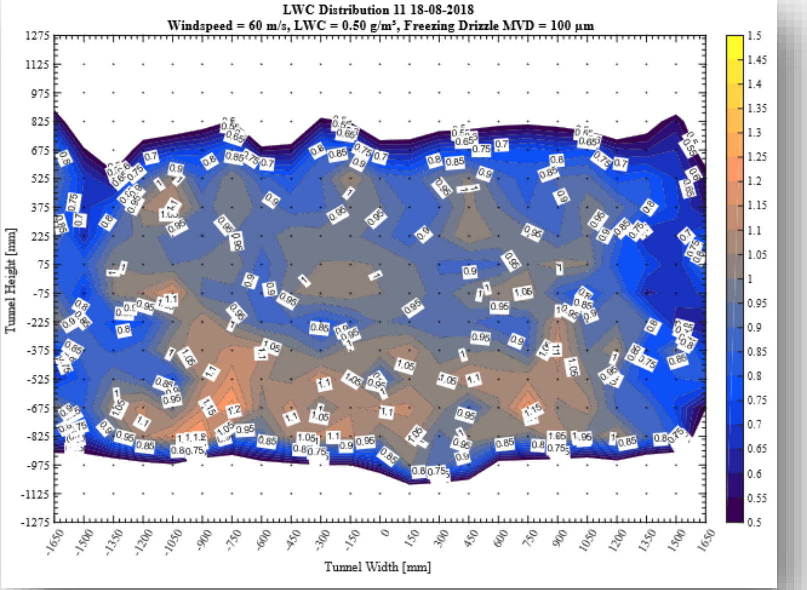


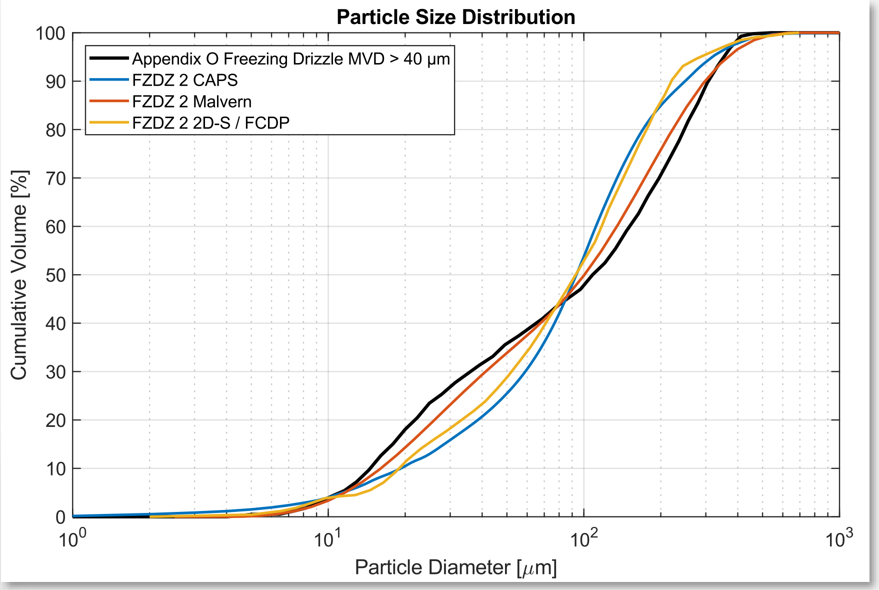


Droplet temperature and uniformity investigations

SLD Test capability – icing wind tunnels
RTA (4/4)

- **Test capability calibration in FZDZ conditions**
  - Centreline **PSD** Measurements using the **CAPS (DLR)**
  - Droplet temperature measurements with **RV**
- Final **SLD calibration** test slot is scheduled for June 2021
  - Centreline PSD & PSD uniformity investigations
    - CAPS
  - LWC, LWC Uniformity
    - WCM-2000, (Nevzorov Probe)



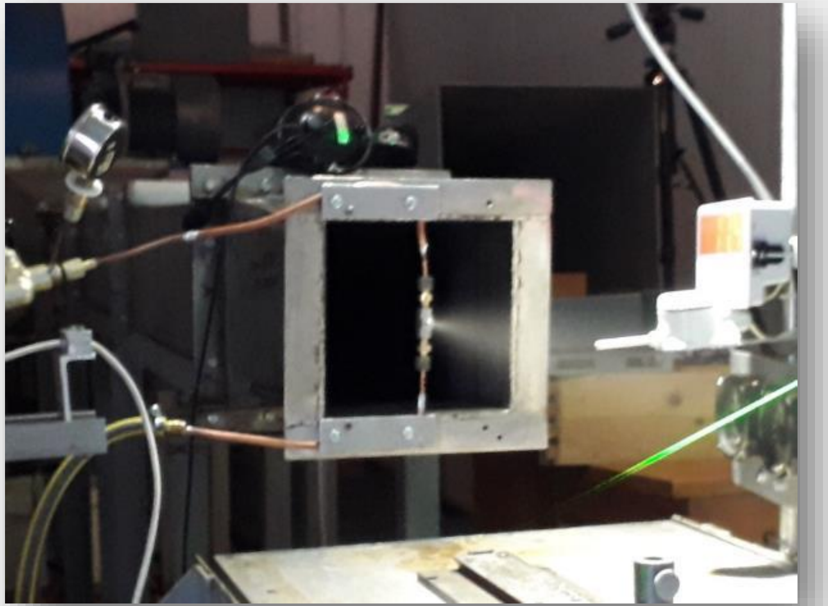


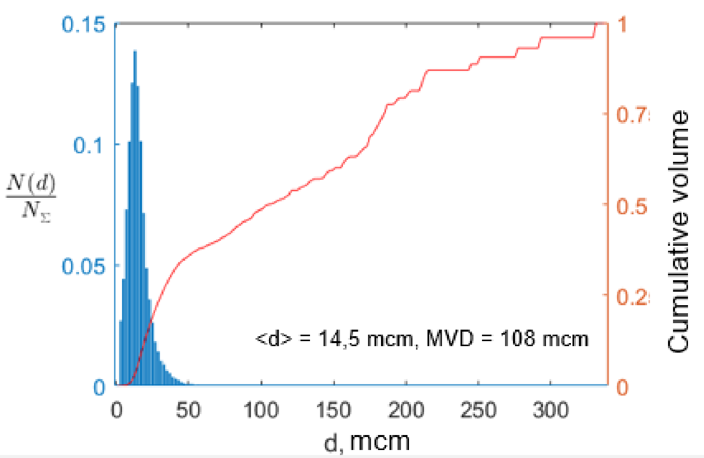
SLD Test capability – icing wind tunnels
TsAGI AHT-SD (1/4)

Test section	Size H (m) x W (m) x L (m)	Airspeed (m/s)	SAT (°C)	Altitude (m)
Main	1.00 x 1.00 x 3.00	Up to 150	Up to -35	sea level

SLD Test capability – icing wind tunnels
TsAGI AHT-SD (2/4)

❑ Spray nozzles selection and IWT performance improvement





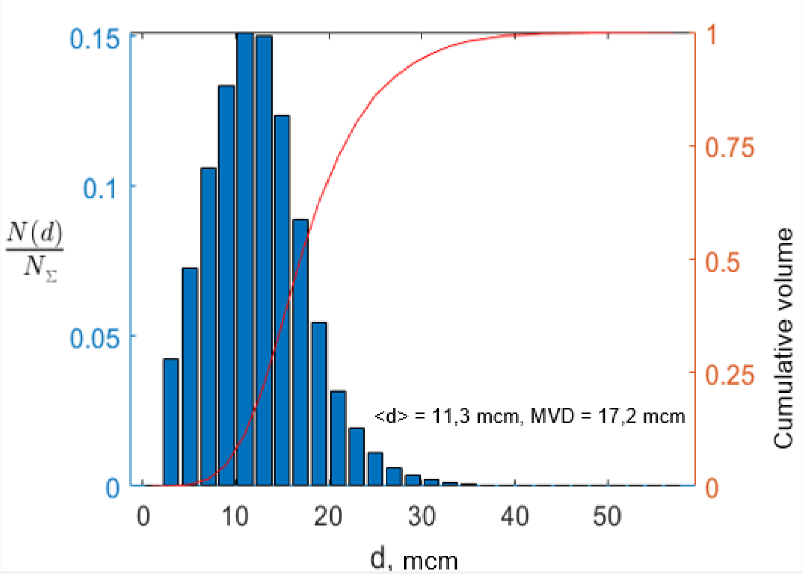
Example of the PSD measured

- 7 types of nozzles were investigated, and corresponding PSDs were measured.
- On the basis of comparison with the regulatory requirements, SU12J Spraying Systems Co. nozzles were selected for:
  - the modernization of the AHT SD and
  - the update of the EU-1 water spraying systems.

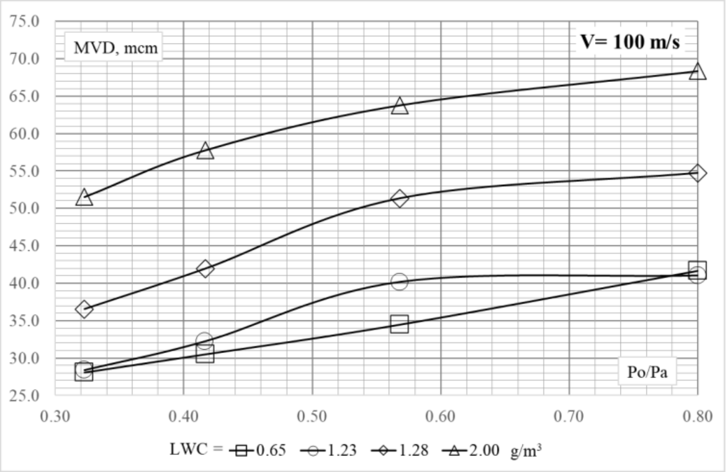
SU12J SS nozzle adapted to the AHT SD water spraying manifold

SLD Test capability – icing wind tunnels TsAGI AHT-SD (3/4)

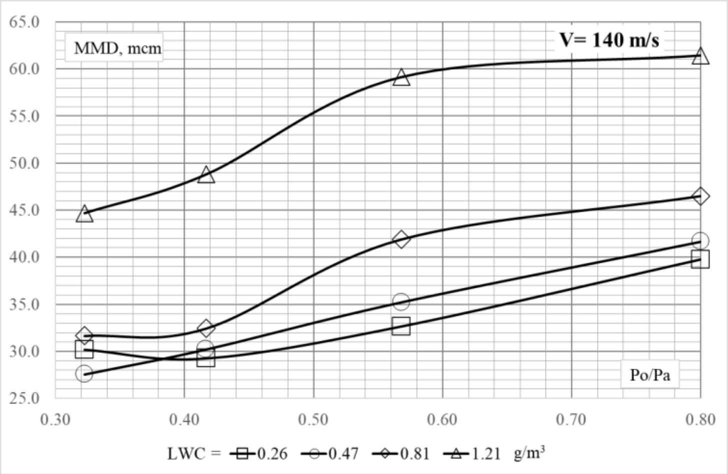
- AHT SD Calibration results (App.C)



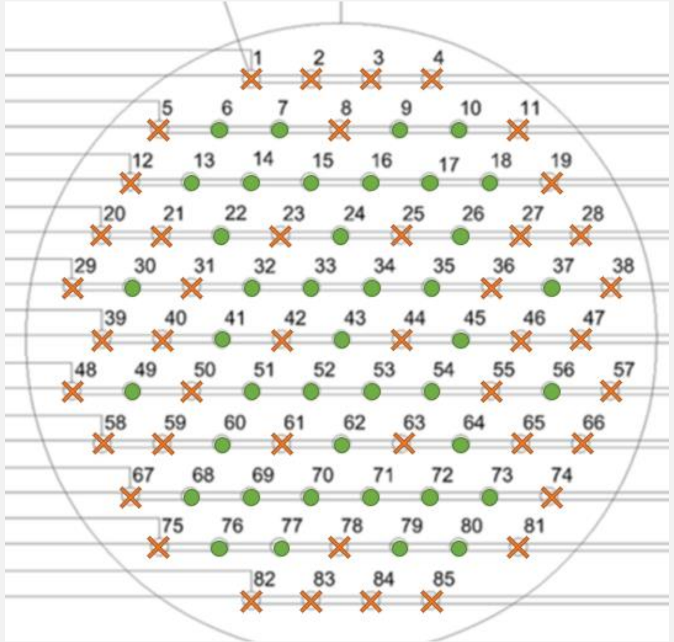
Example of the particles sizes distribution



MVD dependence on the pressure ratio for different LWC values



SLD Test capability – icing wind tunnels
TsAGI AHT-SD (4/4)

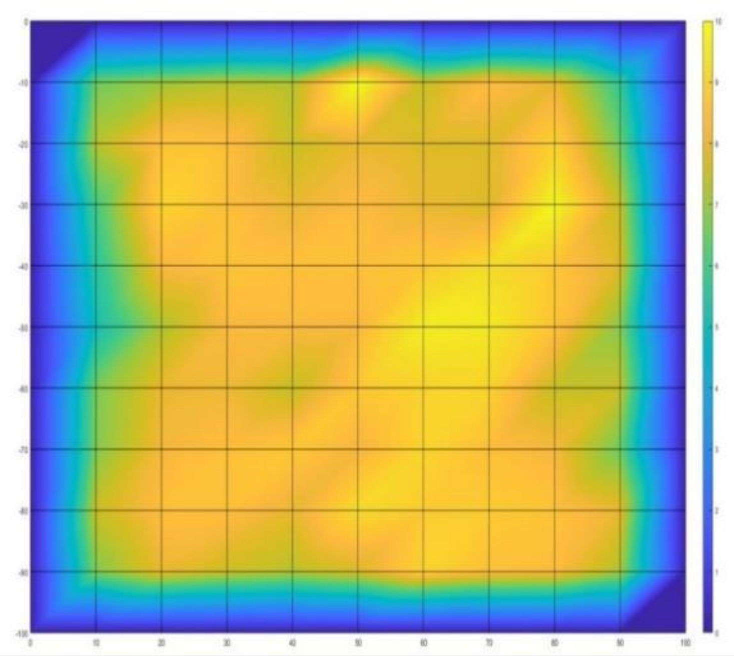


⇒ injectors off

⇒ injectors on

❑ LWC uniformity check

Icing grid

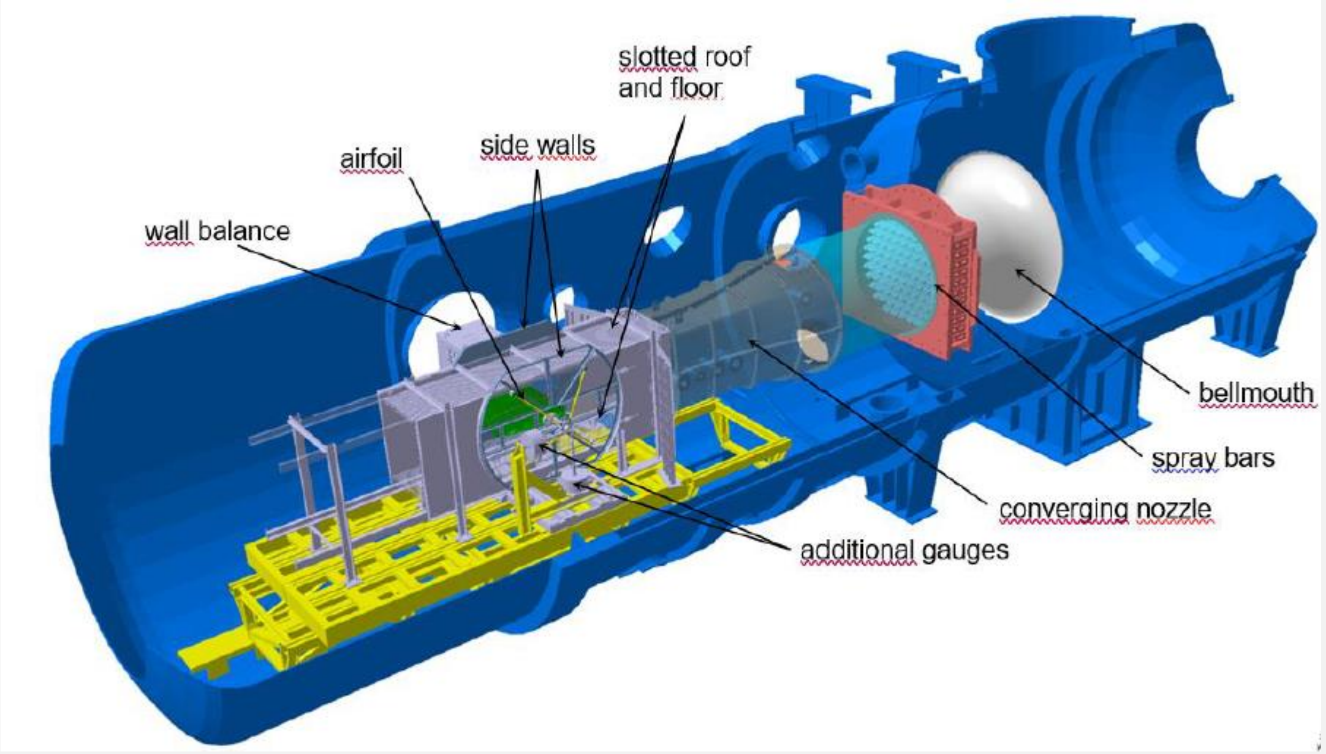


Icing intensity field – core with LWC variation less then 15%

❑ Way forward

- March 2021 => AVI nacelle / AVI splitter tests in App. C conditions
- March 2021 => LDO rescue hoist tests in App. C conditions
- April 2021=> AHT SD Calibration for App. O conditions
- Winter 2021-22=> Second step of the test campaign.

SLD Test capability – icing wind tunnels MinDef S1-ATF (1/3)

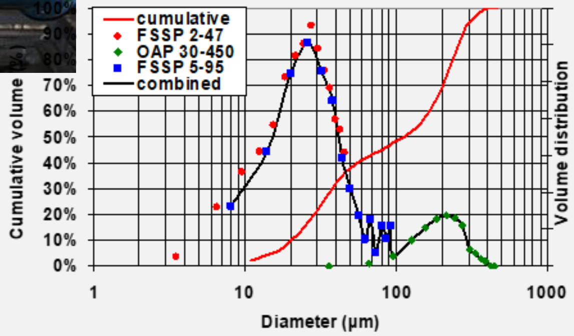


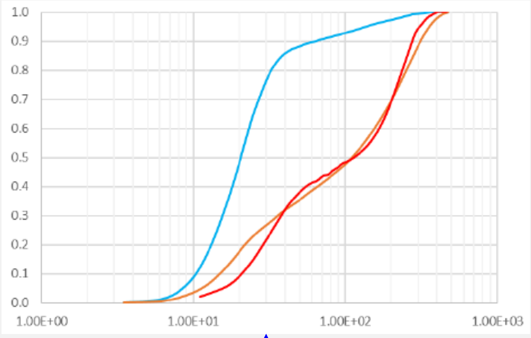
Test section	Size H (m) x W (m) x L (m)	Airspeed (m/s)	SAT (°C)	Altitude (m)
Omegga	0.82 x 0.7 x 3	10 - 250	-65 - 15	s.l. - 10000

- No improvements on the facility performance have been executed during the ICE-GENESIS program.
- The calibration methodology has been reviewed, in agreement with the program requirement.

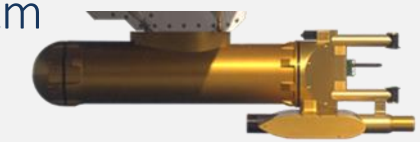
SLD Test capability – icing wind tunnels MinDef S1-ATF (2/3)

- PSD vs EXTICE program
  - FSSP 2 µm – 95 µm combine with OAP 30 µm – 450 µm





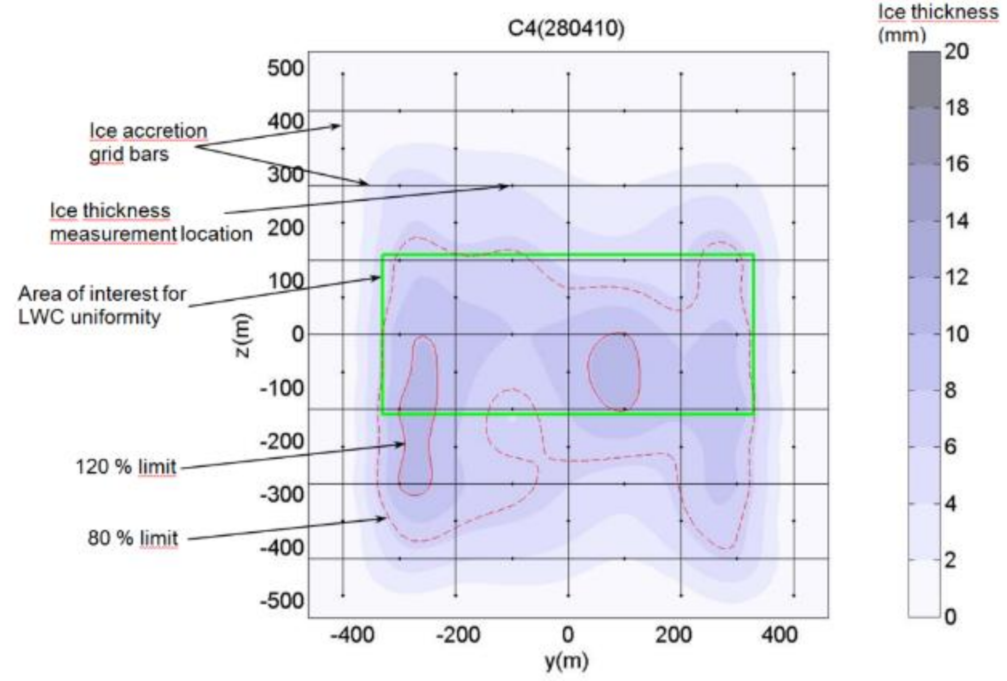
- PSD vs. ICE-GENESIS
  - CAPS-38 => CAS 0,5 µm – 50 µm + CIP 7,5 µm – 950 µm



- Droplets temperature
  - RambowVision technique

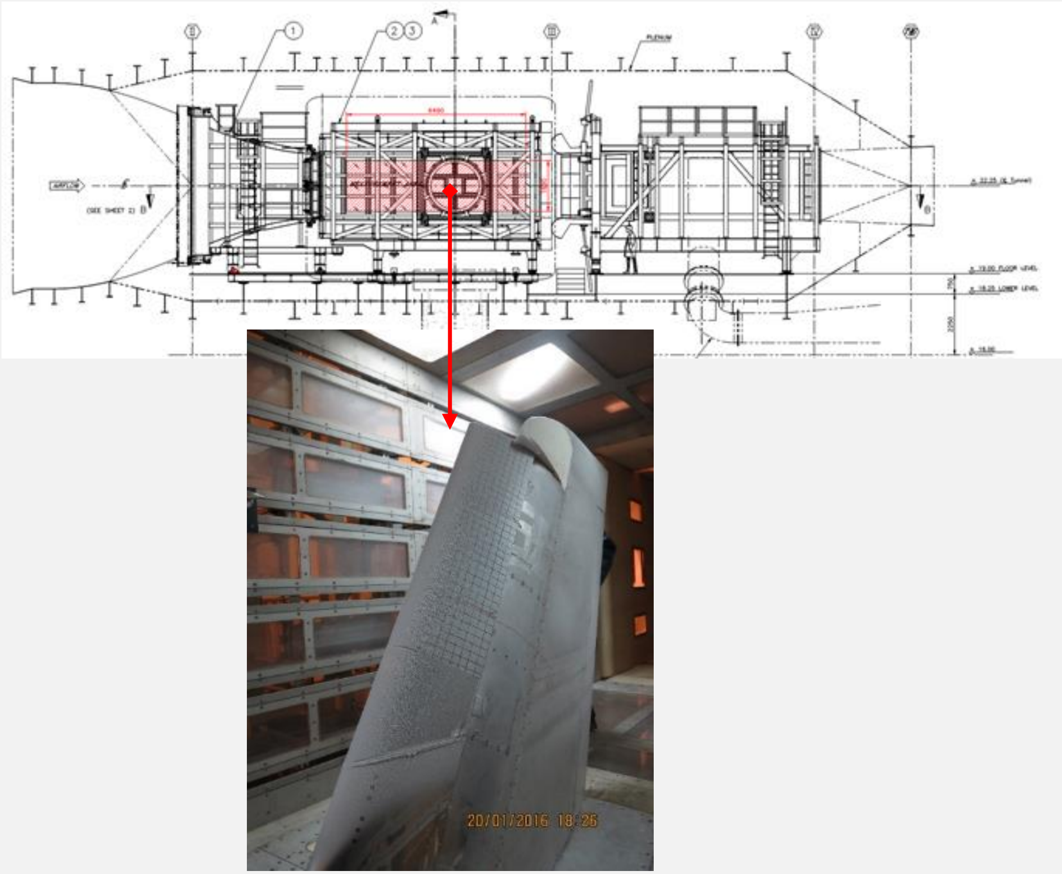
SLD Test capability – icing wind tunnels
MinDef S1-ATF (3/3)

- **Cloud homogeneity + LWC with icing grid vs. EXTICE program**



- **Cloud homogeneity vs. ICE-GENESIS**
  - Check the spray bar functionality with the Icing grid
  - CU-iso-Kinetic probe and/or Nevzorov 2cup hot-wire device
- **Cloud calibration activities scheduled on May 2021**

SLD Test capability – icing wind tunnels
CIRA-IWT (1/4)



- 20 STAINLESS STEEL BARS, 50 NOZZLES LOCATIONS FOR EACH BAR, MAX 500 ACTIVE NOZZLES
- ON/OFF SOLENOID VALVE AT EACH SPRAYING LOCATION
- AIR AND WATER PRESSURE CONTROL IN EACH BAR
- TWO AIR-WATER SPRAY NOZZLES:
  - STANDARD FOR APP. C
  - SLD MOD#1 FOR FZDZ

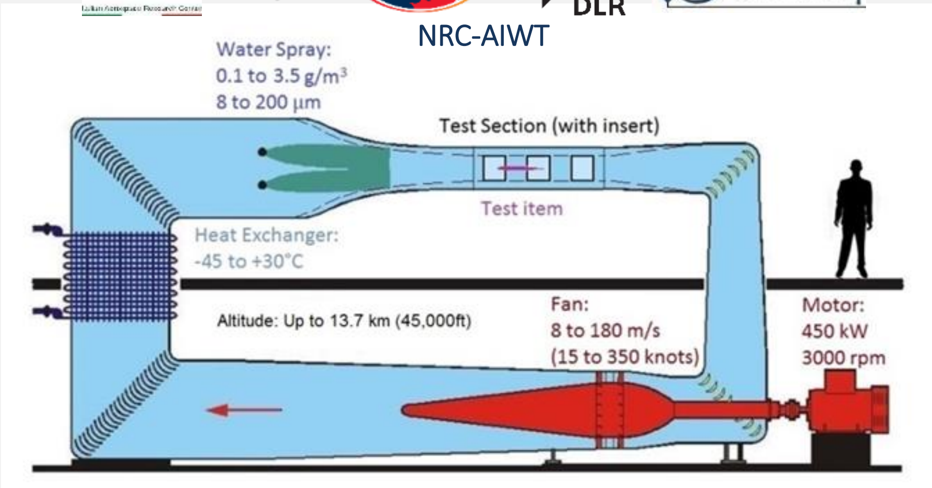
Test section	Size H (m) x W (m) x L (m)	Airspeed (m/s)	SAT (°C)	Altitude (m)
MTS	2.35 x 2.25 x 7.00	40 - 120	-35 – Amb.	s.l. - 6500

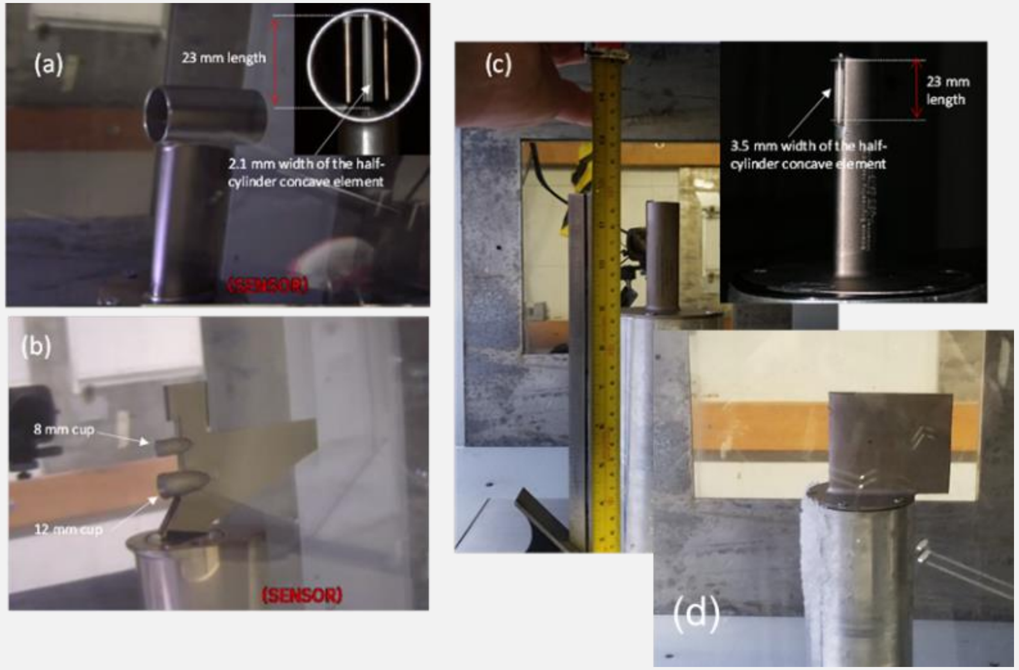
SLD Test capability – icing wind tunnels
CIRA-IWT (2/4)

❑ Icing wind tunnel calibration methods – hot-wire LWC sensor selection

CIRA Met Analytics NRC CNRC Canada DLR SEA

NRC-AIWT





Test section	Size H (m) x W (m) x L (m)	Airspeed (m/s)	SAT (°C)	Altitude (m)
Full size	0.57 x 0.57 x 1.8	10 - 100	to -40	s.l. - 12000

1. Ext. Multi-Wire **(a)**
2. Nevzorov 2-cup **(b)**
3. Standard Nevzorov
4. Robust probe **(c)**
5. Ice Crystal Detector **(d)**

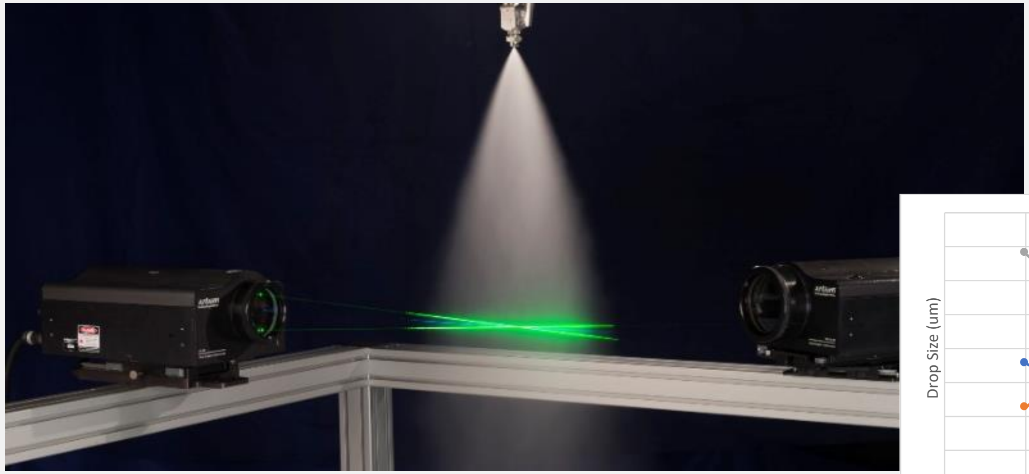
- × 30 spray conditions at -5 °C and three speed (40, 80, and 100 ms^{-1})
- × LWC sweep @ 20 µm, 100 µm and 250 µm
- × MVDs sweep @ 0,5 g m^{-3} and 0,2 g m^{-3}

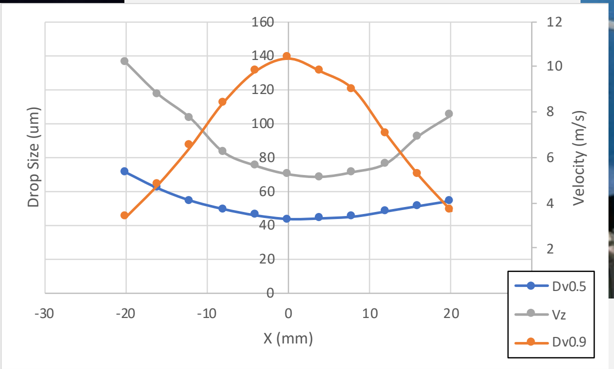
CIRA would like to acknowledge:

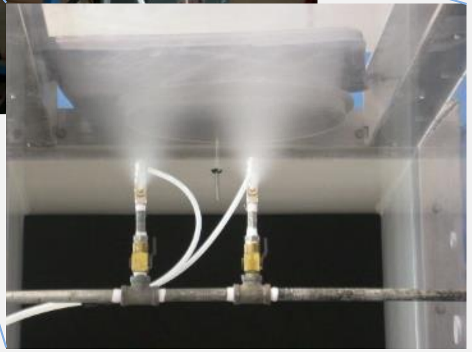
- ❑ *David Orchard and Gislain Chevrette (NRC-AIWT) for providing facility time-slot*
- ❑ *Mengistu Wolde, Natalia Bliankinshtein and Leonid Nichman, collected and organized data from all 5 sensors used in this analysis, shared the NRC's ICD and Nevzorov data and their initial analysis as part of the GLAZEICE project funded by the NRC APDC program*
- ❑ *Christiane Voigt and Johannes Lucke (DLR) for providing Nevzorov 2-cup and processing its data*

SLD Test capability – icing wind tunnels CIRA-IWT (4/4)

❑ Improvement of experimental capability for FZDZ and FZRA



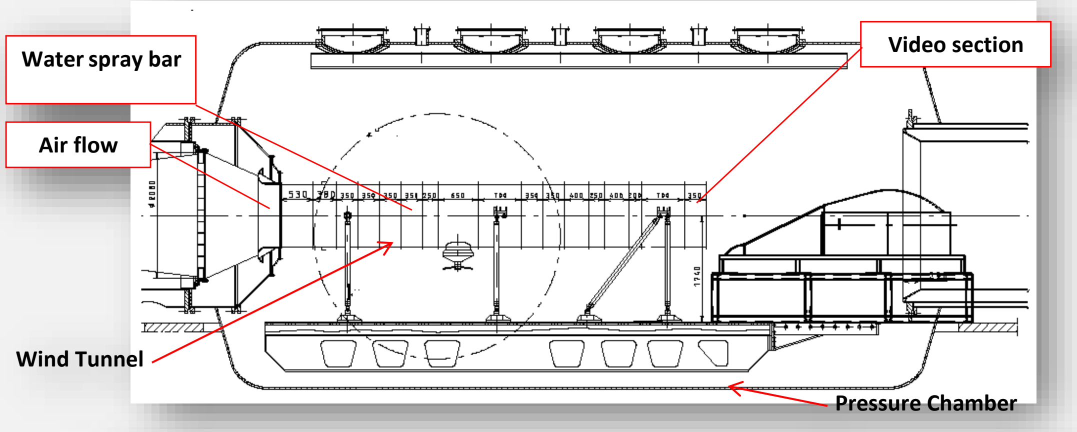


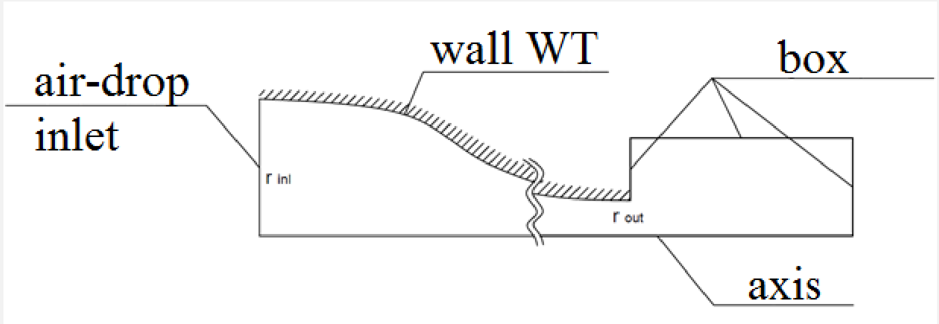


- 13 spray nozzles set ups have been investigated through PDI testing over a range of conditions including 3 prototype 3D printed nozzles.
- 3 candidate nozzle setups have been selected for FZDZ and FZRA cloud generation in CIRA-IWT. Preliminary wind tunnel tests are scheduled on week #19 (May 10 – 14, 2021).
- **CIRA-IWT full calibration (FZDZ + FZRA) scheduled in July - November 2021**

SLD Test capability – icing wind tunnels
CIAM C-2 (1/4)

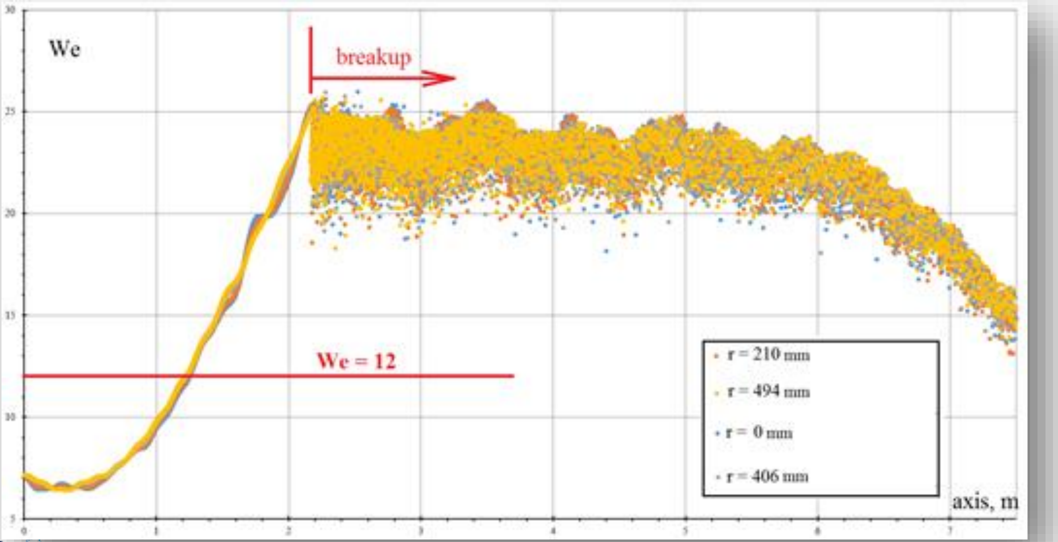
❑ 2D design numerical pre-analysis to determine the shape of the channel





mono-dp = 2 mm Voutlet = 180 m/s

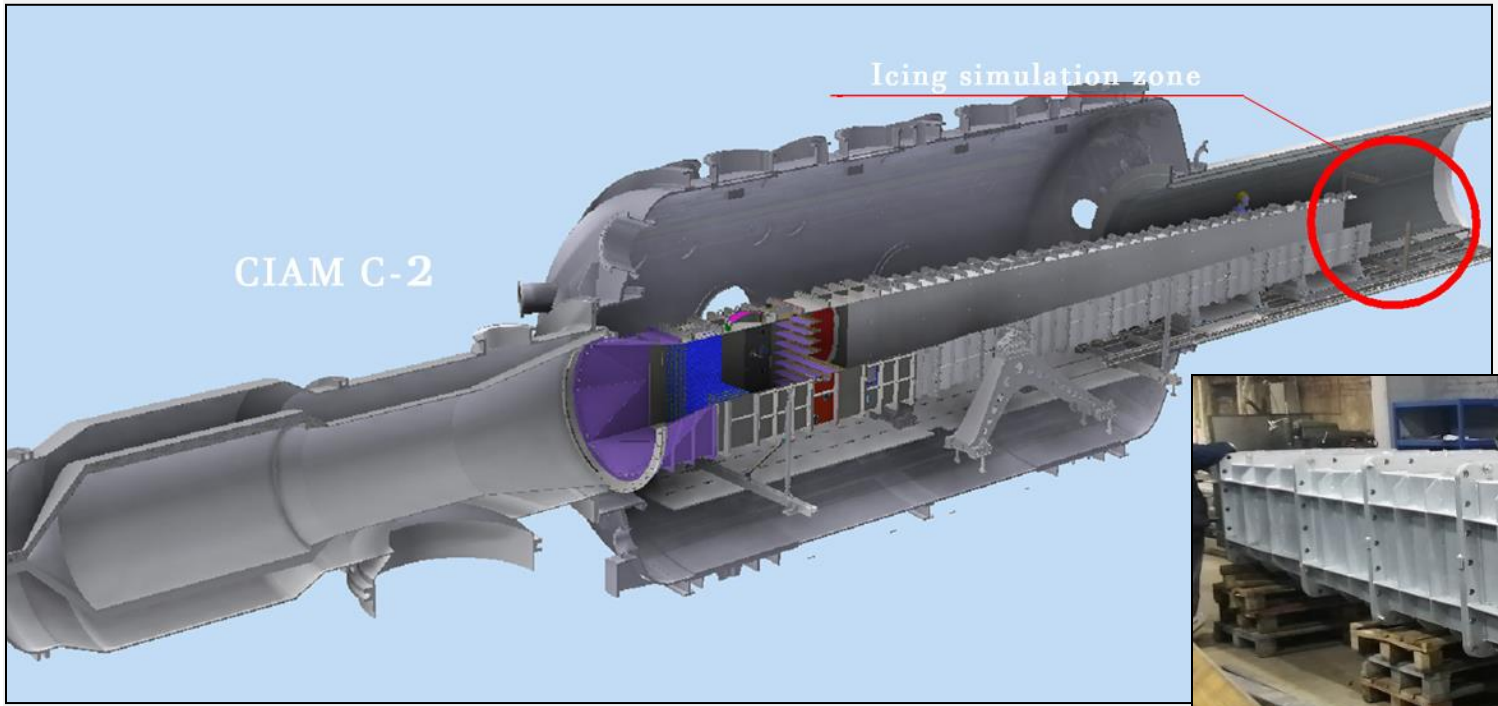
r inlet = 700 mm Tube length = 7500 mm (stand restrictions)



Multi-stage rectangular wind tunnel with stabilization sections

SLD Test capability – icing wind tunnels
CIAM C-2 (2/4)

- The layout scheme of the C-2 stand with IWT for SLD has been approved

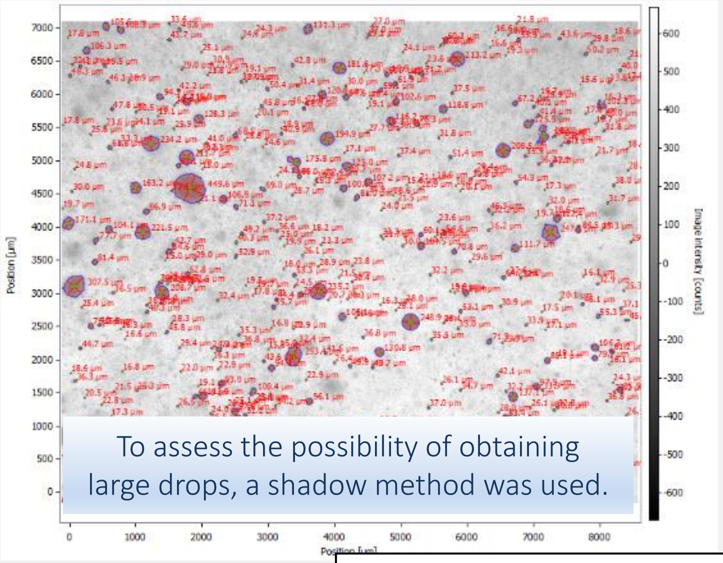


Mock-up assembly of the first sections of the IWT was made

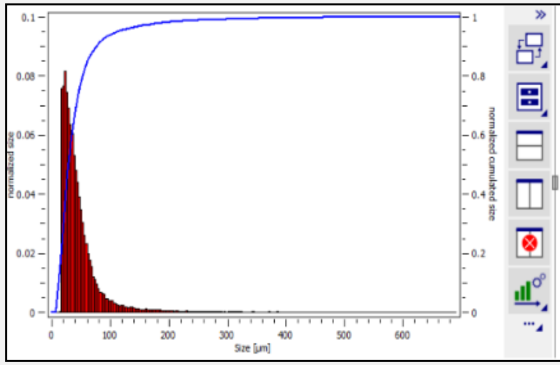
SLD Test capability – icing wind tunnels
CIAM C-2 (3/4)

- The unit for determining the flow characteristics of the injectors has been assembled

two types of air nozzles have been investigated

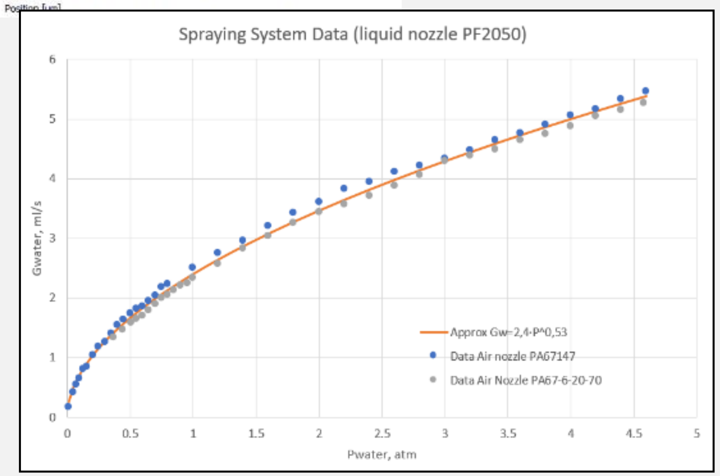


To assess the possibility of obtaining large drops, a shadow method was used.



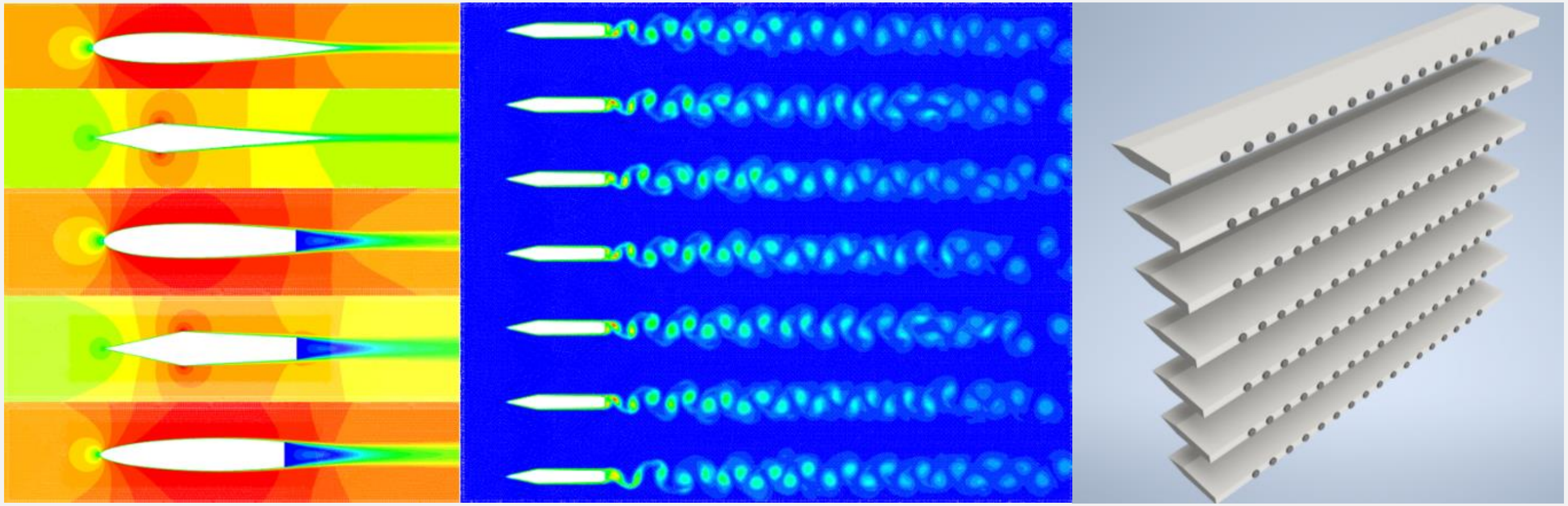
Cumulated statistics for 65585 particles:

	Statistic	Value
1	D10	33.2 µm
2	D32	95.7 µm
3	Dv10	41.3 µm
4	Dv50	161.2 µm
5	Dv90	465.1 µm
6	VP	---
7	VM	---
8	Mrel	---
9	Mabs	---
10	MVF	---



SLD Test capability – icing wind tunnels CIAM C-2 (4/4)

- Computational studies to determine the spray bar geometry. Evaluation of the influence of the pylon shape on the aerodynamic characteristics of the collector



- The aerodynamic losses of the flow pressure during the passage of a collector with different pylon shapes are estimated
- In a non-stationary calculation, the effect of the "cut" of the trailing edge on the increase in flow turbulence and the spread of droplets is checked. **This modification is justified only for drops with a diameter of up to 80 microns (only for Appendix C). For SLD, a pylon is used without a clipped trailing edge.**

THANK YOU FOR YOUR INTEREST

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