ICE GENESIS
Project Overview

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824310.

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

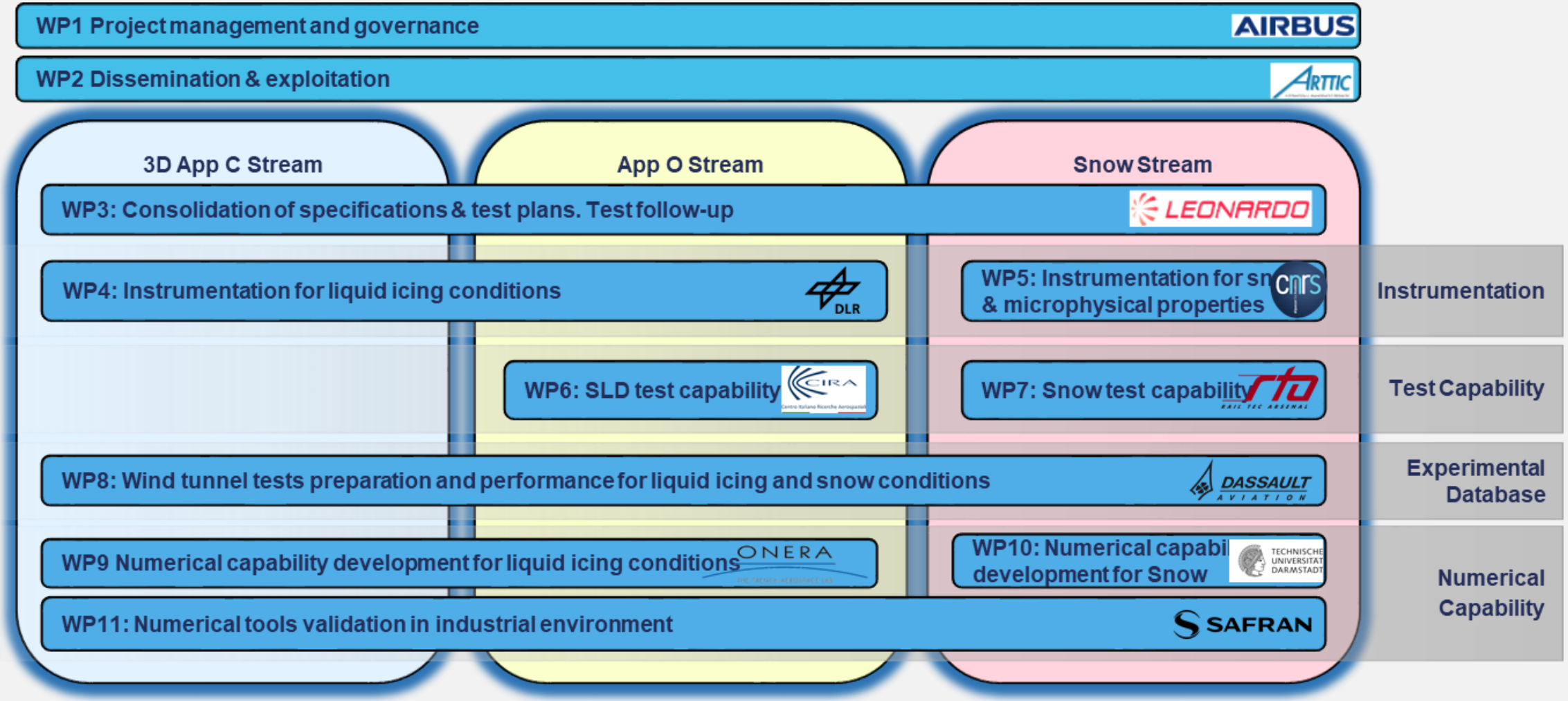
Obj#1: Improve and validate existing **3D numerical tools** to predict ice accretion in Appendix C, Appendix O and Snow conditions.

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**.

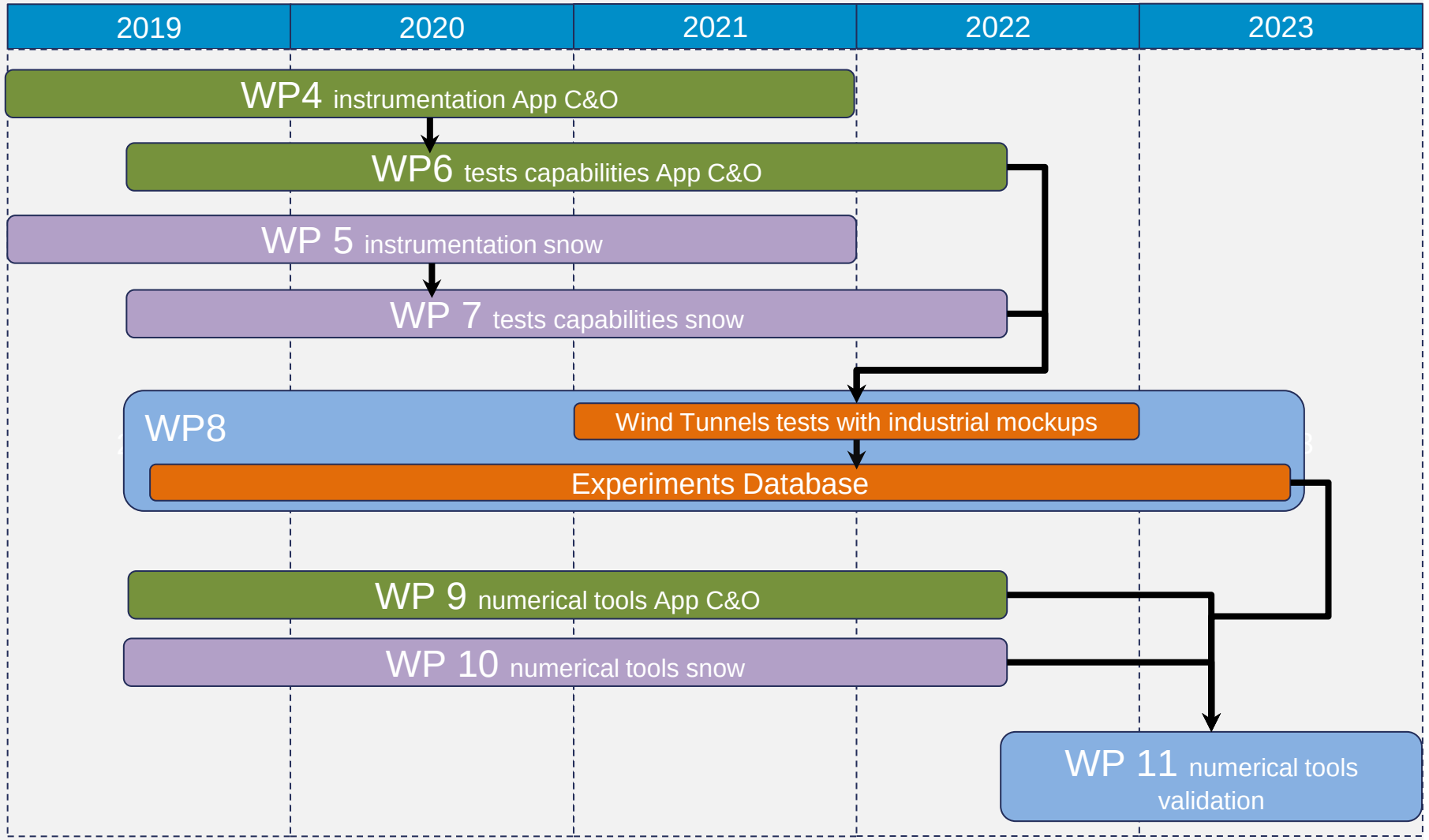
Obj#3: Build a **large scale experimental database** on representative 3D configurations to be used as a solid reference (“ground truth”) for future numerical tools validation.

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



Snow IWT improvements

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824310.

WP7 Overview

*To secure future program development and certification, there is a **need to develop snow test and numerical capabilities** to de-risk power plant system design before in-flight demonstration*

- Difficulty to find the right conditions. Advisory Circular (AC29-2C) defines **minimum information on the temperature range** and a **visibility criterion** representative of snow water content (1/4-mile or about 0,9g/m3).
- Manufacturers certify that each engine and its air inlet system can operate throughout the flight power range of the engine in **falling and blowing snow**, without adverse effect on engine
- There are **no validated engineering tools** (test facility and numerical tools) available
- Demonstration is performed at the end of the development during very challenging **certification flights.**
  - Flight tests in natural snowstorms, beside their intrinsic risk, are difficult to schedule
  - Any issue found at this stage of the development can lead to significant delay and costs

WP7 Overview

Objectives:

- Improve test capabilities for simulation of snow conditions close to natural snow properties
- Define a common calibration methodology
- Calibration of test facilities

Involved Partners:

- RTA, AIH, CNRS, CU, IAG, TSAGI, NRC, (DLR, AIT)

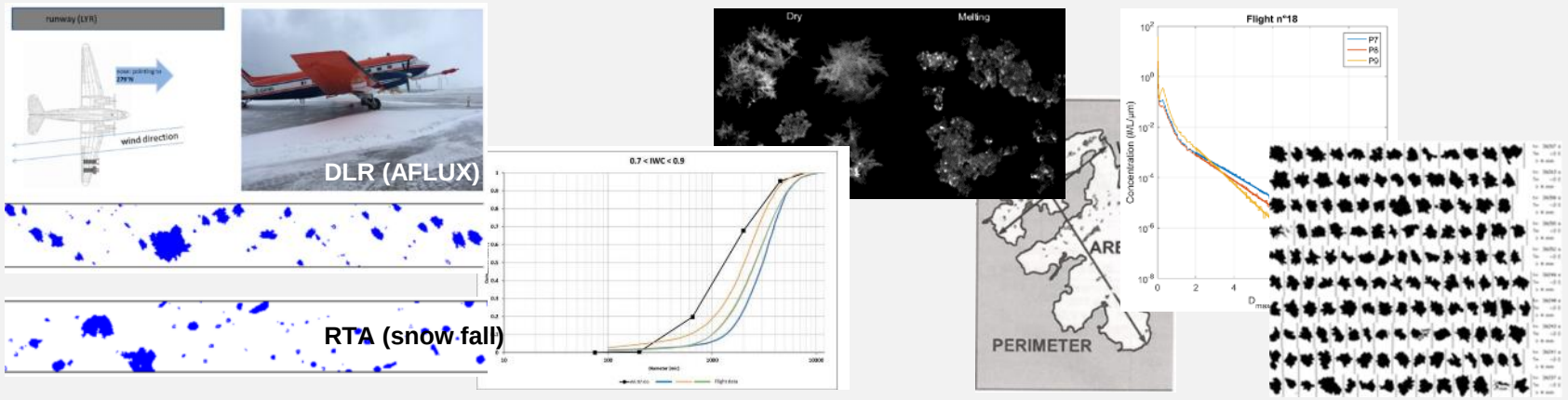
Tasks:

- *Task 7.1* – RTA Snow Test Capability Development
- *Task 7.2* – NRC Snow Test Capability Development
- *Task 7.3* – TSAGI Snow Test Capability Development
- *Task 7.4* – Test Facility Calibration

WP7 Snow Test Facility Specification

Close cooperation with WP5 (CNRS, DLR)

- Selection and improvement of most suitable **instrumentation** for calibration of **large-scale test facilities**
- **Initial specifications** were derived from existing data
- **Ground and flight tests** provide characterisation of snow precipitation microphysics and enable the definition of detailed specifications for test facilities
- Iterations are scheduled between these tasks so that outcomes of the tests are successively integrated in the engineering tools



Snow microphysical properties and test facility specification definition

WP7 Snow Test Facility Specification

Snow test capabilities requirements (in cooperation with WP3)

- Different snow conditions (falling / blowing snow), different snow types (wet / dry)

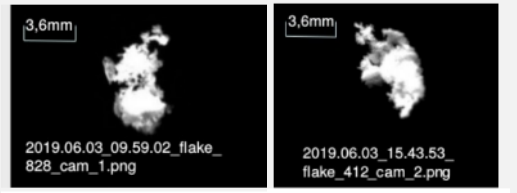
Requirement	Classification	Comment
Particle sizes [2000µm ≤ MMD_{max} ≤ 3000µm 50µm ≤ MMD_{max} ≤ 150µm]	**Essential**	Based on Airbus Helicopters F/T measurement, It is expected PSD for blowing snow to differ from falling snow: larger number of small particles (SP) with diameter ~ 100µm
Water content (solid phase only) [0.5 – 1g/m^3 0.5 – 3g/m^3]	**Essential**	Falling snow: Ice water Content up to 0.9 g/m^3 for H/C application (CS27/29) Blowing snow: Ice water Content up to 3g/m3 for A/C application (CS25)
Snow Bulk Density [40 kg/m^3 - 720 kg/m^3 570 kg/m^3 - 917 kg/m^3]	**Highly Desirable**	Varying snow bulk densities for falling / blowing and wet / dry snow
Velocity Range for H/C [0-150kts]	**Essential**	This requirement covers speed related to the following H/C flight phases and engines settings : Ground Operations, IGE Hover, Level flight, Descent and Landing
Temperature Range [-15°C ; +2°C]	**Essential**	As defined by regulation (different ranges for wet / dry snow)
Particle Mass/size distribution Particle morphology	**Highly Desirable**	Representative size distribution and particle morphology and in any case particle size distribution and particle morphology characterization from calibration
Test duration [0 – 60min]	**Essential**	up to 60 min according to AC29-2C

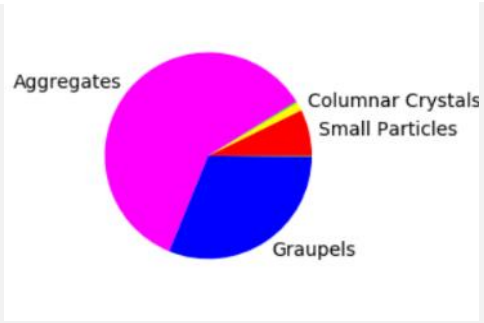
WP7 Snow Test Capability Development

- **What are the challenges?**
  - Generation of snow particles with PSD and morphology close to natural snow conditions
  - Transport of snow particles to the test section (breakup, morphology changes, …)
  - Uniform distribution of snow particles in over a large area in the test section (TWC, PSD, …)
  - Upscaling of the technology without major changes of snow quality

RTA Snow Test Capability Development

- In June 2019 first **laboratory tests** in the IAG climatic chamber were performed with the IAG **SnowFall** system
  - Investigation of the **snow characteristics** using the **MASC** (CNRS) and 2DVD (Joanneum Research) instrumentation were performed
  - Bulk snow **density and liquid water ratio** investigations
    - Measured densities from ~175 kg/m³ to ~415 kg/m³
    - Liquid water ratios from ~7.5% to ~48%
  - Snowflake **morphology** investigations
    - Dominated by aggregates and graupels
  - The SnowFall system showed its capability to produce **snowflakes** over a wide size and density range

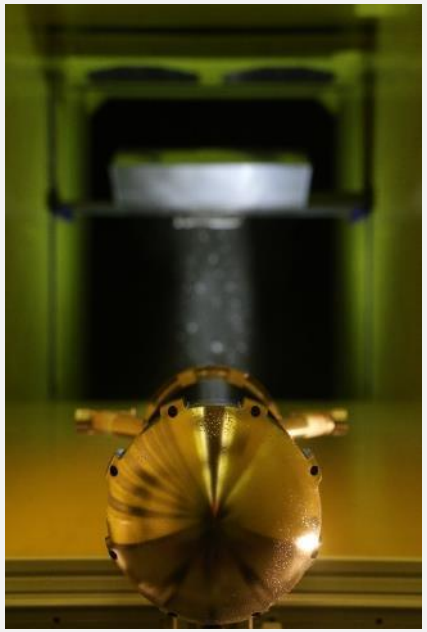




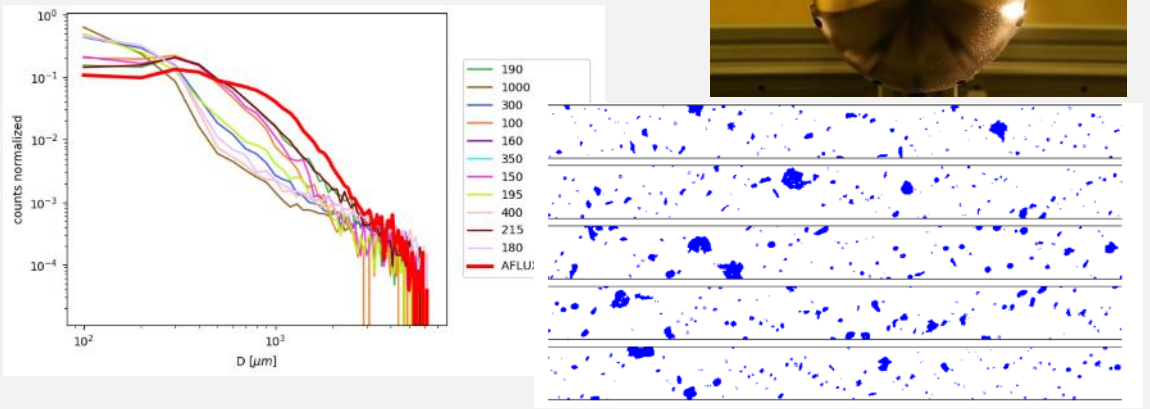
MASC measurements in the IAG climatic chamber

RTA Snow Test Capability Development

- **Experimental tests** in the RTA CWT were performed at test section airspeeds of up to 50 m/s and at a temperature range of 1°C to -4°C
  - Successful integration of the SnowFall system in the CWT
    - Modular approach – SnowFall unit can be mounted directly after the CWT contraction nozzle, an additional contraction can be attached
    - No effect on existing systems / capabilities
  - Snowflake transport to test section without significant breakup
  - Assessment of coverage area, snow accretion in test section



- **PIP Measurements** (by DLR)
  - Snowflakes with diameters of up to 6 mm were detected (at 50 m/s)
  - PSDs can be influenced with SnowFall settings
- **TRL2 assessment**
  - successfully passed in Dec. 2019

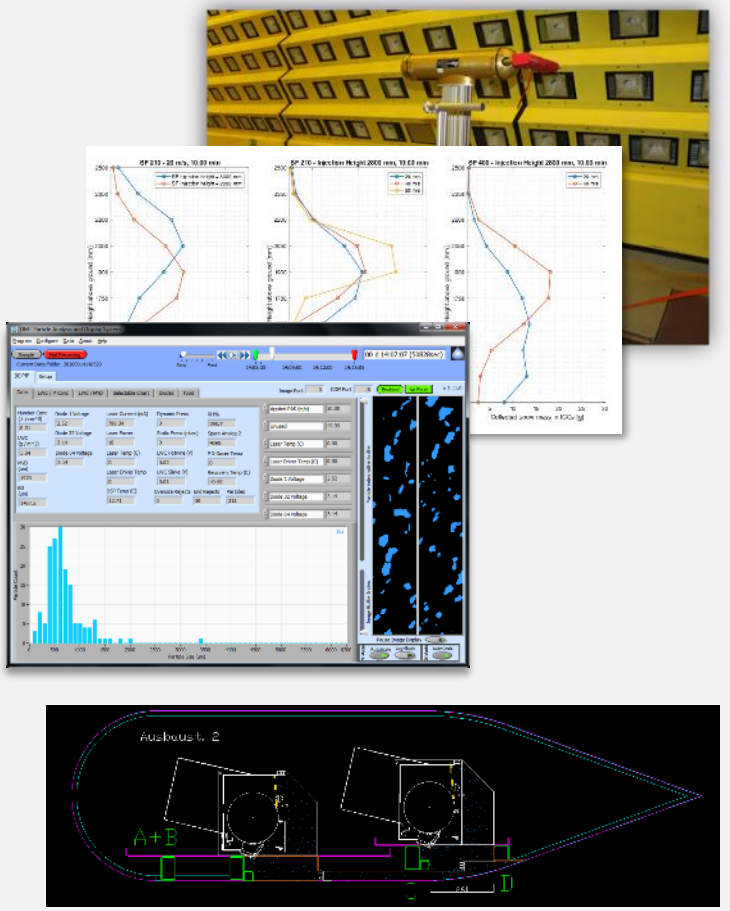


PIP measurements in the RTA climatic wind tunnel – number distribution (left), example images (right)

RTA Snow Test Capability Development

- Experimental testing with enhanced “small-scale” **Prototype 1C** were performed in September 2020
  - Better controllability of the snow coverage area
  - Tests at airspeeds of up to 60 m/s
  - Snow cloud **uniformity** assessment with “PIV” system supported by AIT and Ice Capture Cylinder tests
    - Uniform area with TWC ± 20% → ~550 mm x 400 mm
  - Further **TWC estimations** performed with ICCs
    - TWCs from 0.90 to 1.40 g/m³ were measured at 40 m/s
  - Snowflake size investigations with **PIP**, supported by CNRS
    - MMDs in the range of about 1 mm were detected (using B&L mass-size relationship) → has to be further verified due to issues with snow generation system during measurements

- An intermediate **TRL3** was successfully passed in December 2020 → **“GO”** for upscaled **Prototype 2A**
  - Experimental tests in the RTA CWT scheduled for May/June 2021

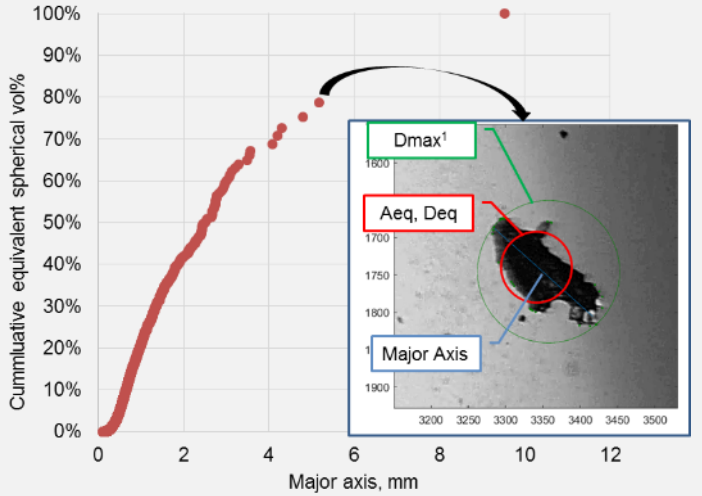


PIP installed in the RTA CWT (top), example PIP evaluation (middle) and uniformity assessment with ICCs (bottom)

NRC Snow Test Capability Development

- Preliminary testing of methods to produce **large snow like particles** have been completed
  - One method in particular found to be most effective in creating particles similar to the desired falling snow size and morphology
- Trials have also confirmed other **methods/instruments** to be effective:
  - Imaging of large particles for sizing
  - Compact iso-kinetic probe (CIKP) for snow concentration measurement
  - NACA0012 airfoil test article for accretion in glaciated and wet ice crystal conditions
- NRC Snow Maker test system capabilities aligned with test requirements:
  - Velocity*=10-90 m/s
  - Temperature=-20 to +5 ºC
  - TWC*=0.5-3 g/m^3
  - Test time: 1-120 minutes
  - Humidity: -40ºC dew-point to 100% RH

* With future tunnel enlarging

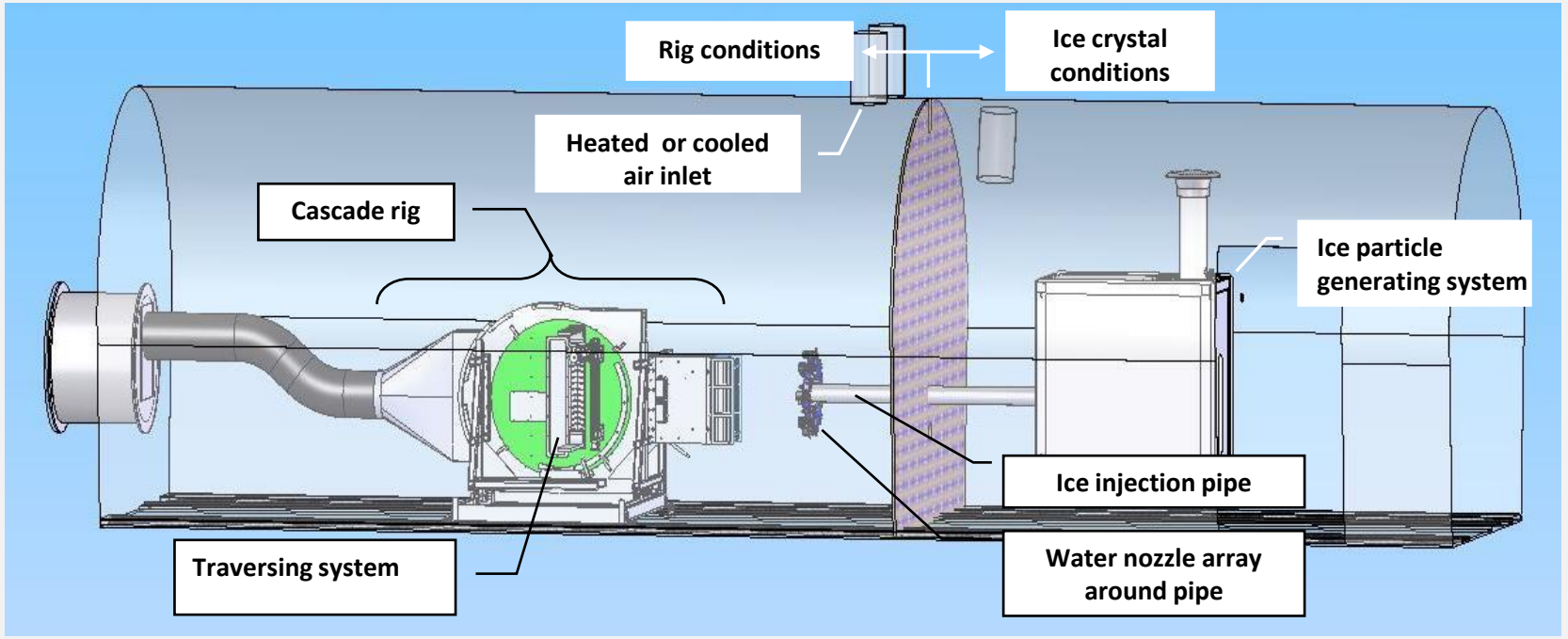


Snow particle imaging and size distribution data

NRC compact iso-kinetic probe in test tunnel for total water content measurement

NRC Snow Test Capability Development

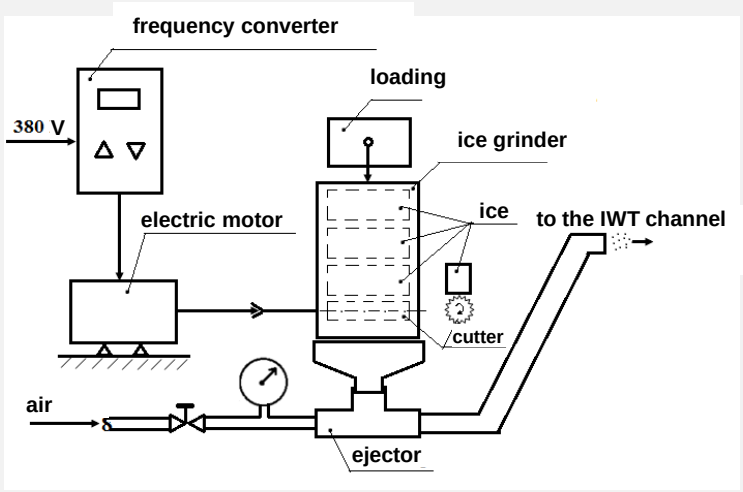
- Design and fabrication of new **full-scale Snow Maker system** is complete
- Will be installed and tested in the **NRC** altitude chamber this summer, 2021 for full scale testing



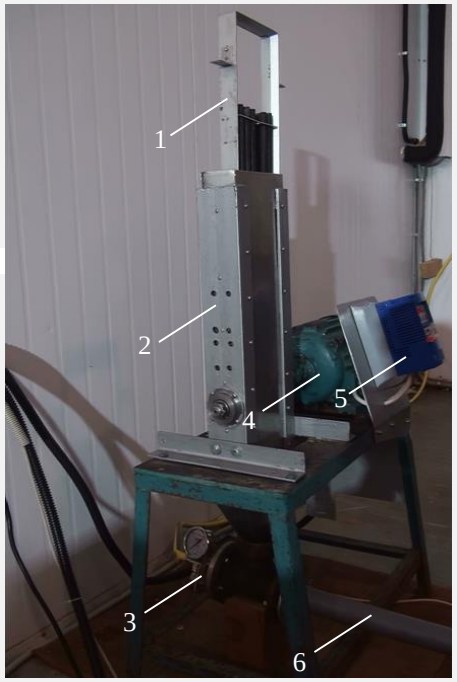
NRC Research Altitude Test Facility (RATFac) set up for ice crystal testing

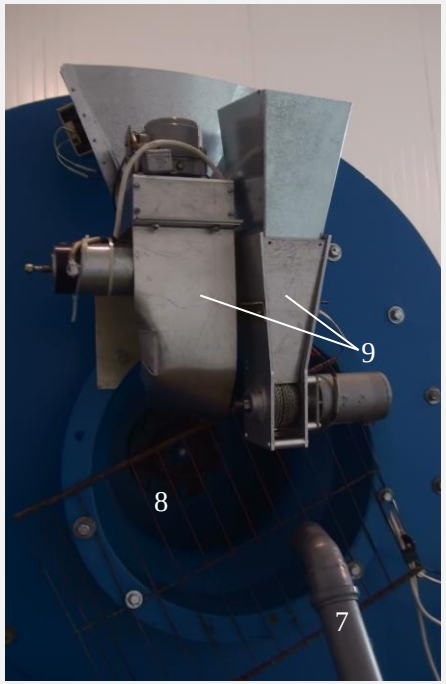
TSAGI Snow Test Capability Development - 1

An ejector system for crystals injection into the flow has been created and tested



The scheme of the ice crystals generation and transportation to the icing wind tunnel





1 - frame with replaceable loads, 2 - body of the ice-grinder, 3 - ejector, 4 - electric motor, 5 – frequency converter, 6 - pipe for transporting crystals, 7 - outlet section of the pipe 6), 8 - inlet of the fan, 9 - mechanical devices for crystals injection

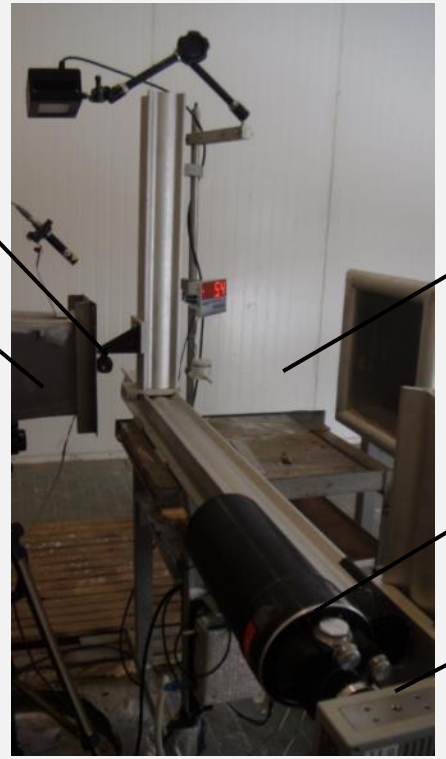
TSAGI Snow Test Capability Development - 2

An conveyor system for crystals injection into the flow has been created and tested

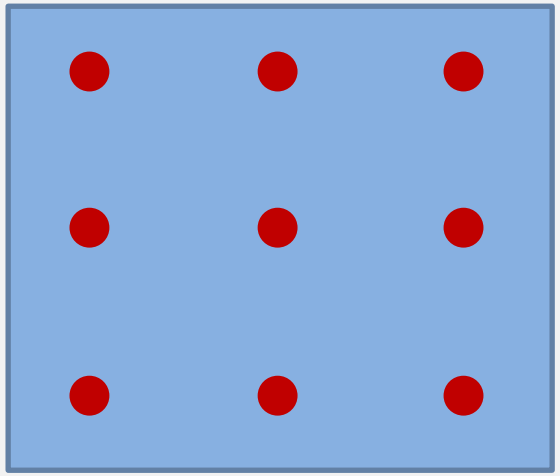
Conveyor system provides snow flow large LWC values from 5 to 20 g/m^3

EU-1 Calibration procedure

Shadow photography system for snow particles sizes, shapes and velocities measurements

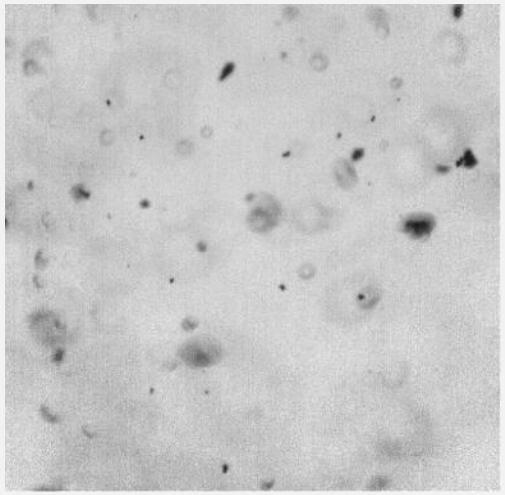


Flow shadow photos are used to calculate concentration and (on the basis of PSD) estimate IWC. Measurements were made in 9 points to confirm the IWC uniformity.



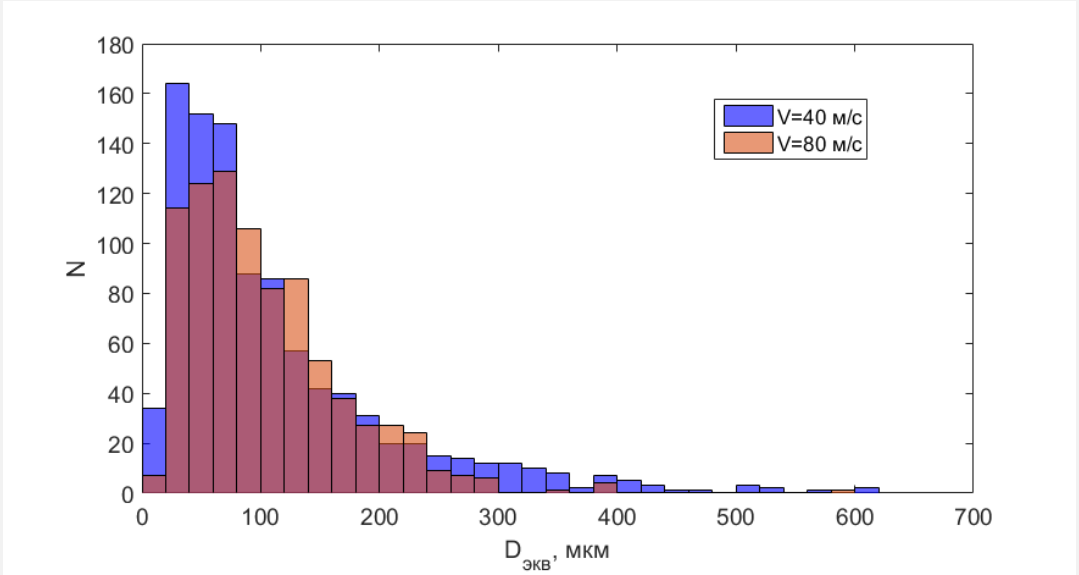
IWT working chamber cross section with measurement points (red)

EU-1 Calibration results



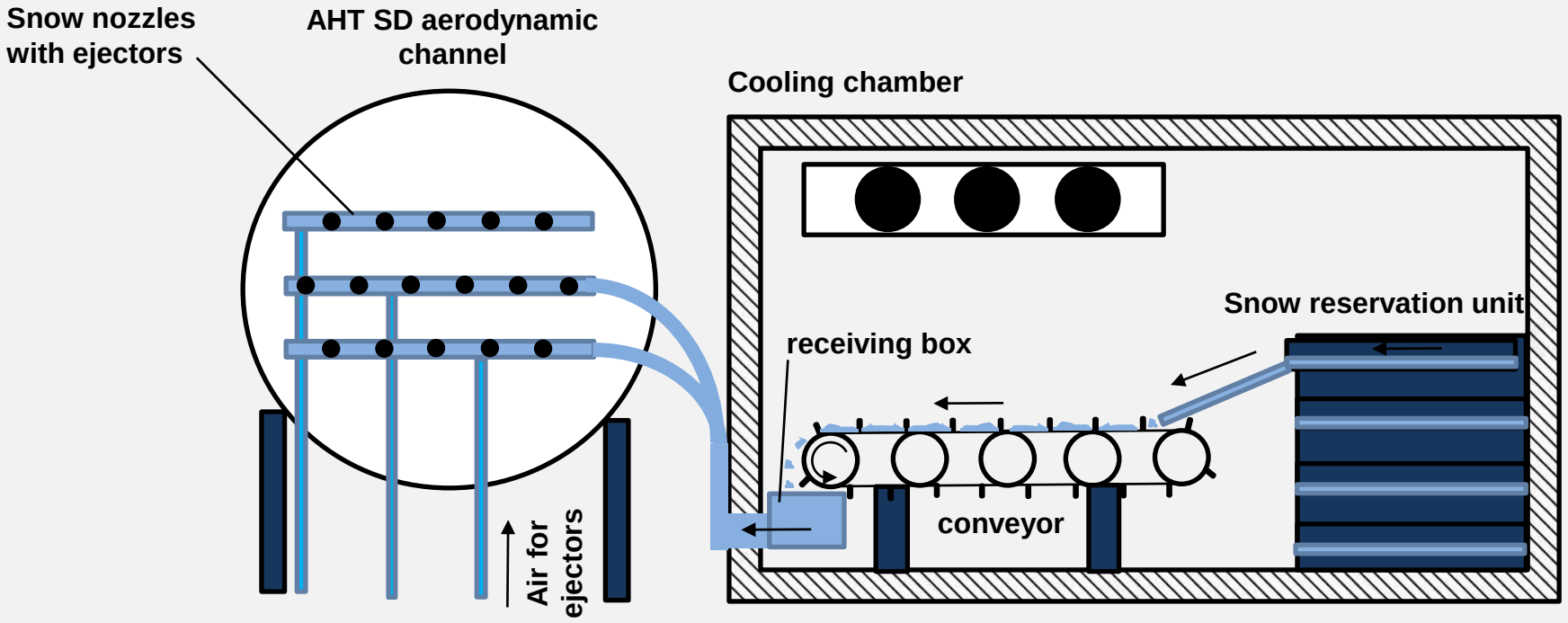
Example of crystals photo in the flow

Crystals sizes distribution for 2 different flow velocities



Preliminary concept of the SNOW Generator SYSTEM integration to AHT SD

- According to the EU-1/VSIO tests, only natural snow can provide the appropriate levels of the IWC
- The preliminary concept of the AHT SD snow generation system include as ejector as conveyor parts



Test Facility Calibration

- A **Workshop** for the preliminary definition of **calibration methodology** for snow test facilities was held at IAG / RTA in June 2019, with participation of all international partners including TSAGI, FAA & NRC
  - Close cooperation with WP5
  - Discussions on definitions, snow characterization, importance of different snow parameters and on common test article
  - Definition of the target requirements for snow test facilities
  - Calibration methodology for snow test facilities

Snow Workshop – SnowFall system demonstration in IAG climatic chamber

Test Facility Calibration

Calibration Procedure

- Reference document for the calibration of IWTs is the **SAE ARP 5905**, the basic procedure remains unchanged including size distribution, water content and cloud uniformity measurements → but with **adapted instrumentation and techniques**
- Revision required → features of snow clouds are different from small supercooled droplets in terms of size, shapes and density
- Relevant parameters and **acceptance criteria needs to be updated**
- A **continuity check test** is introduced as main acceptance criteria by testing a model (NACA0012 airfoil) to demonstrate the ability of the test facilities to reproduce snow accretion phenomena, & to allow facility intercomparison

Test Facility Calibration

Instrumentation (selection in cooperation with WP 5)

Particle size and Morphology

- Optical Array Probes (OAP) → **PIP,** CIP, 2D-S, HVPS
- High resolution imager (CCD) → HSI, CPI, PIV
- Scattering probes → CAS-DPOL, CDP-2, FCDP, BCDP

- Combination of different probes might be required
- PIP has shown good results → still some questions concerning the data evaluation

Total Water Content (TWC)

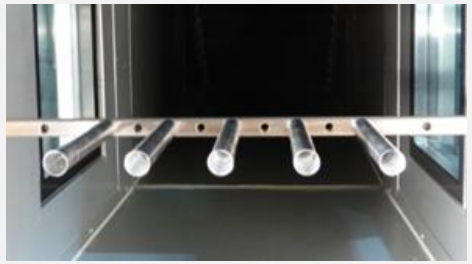
- Isokinetic evaporator probes → CU **IKP, IKP-2**
- Counterflow Virtual Impactor → CVI Snow
- Hot - wire probes → Robust Probe, Nevzorov Probe

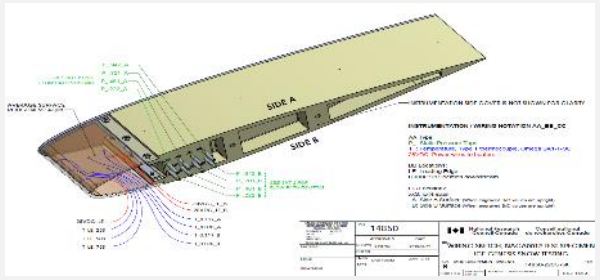
- **Ice Capture Cylinders (ICCs)** measurement have shown promising results → validation with e.g. IKP still open
- Isokinetic probes (IKPs) with large inlets are the preferred option, no measurements have been performed yet

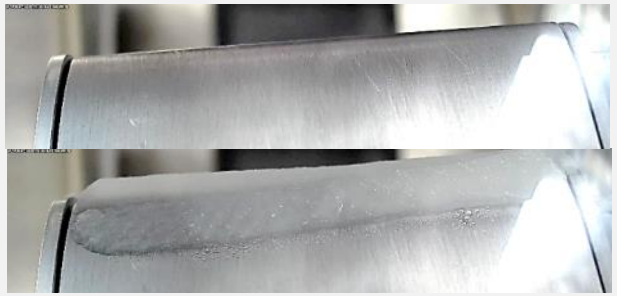
Precipitation Imaging Probe (PIP) in the RTA IWT (top), NRC Compact Isokinetic Probe CIKP (bot)

Test Facility Calibration

- **TWC Uniformity**
  - **ICCs** arranged in a grid in the test section have shown promising results
  - A „PIV“ setup with a laser sheet has also been tested
  - Traversing of **IKP**
    - might be difficult due to the heated lines → limited coverage area
- **Liquid Water Ratio (LWR)**
  - Bulk measurement → Calorimetry
- **Snow bulk density**
  - Collected in container and weighed
- **Continuity check**
  - The NACA0012 airfoil test article has been shown to be effective for accretion in glaciated and wet ice crystal icing (ICI) conditions
  - Three airfoils have been designed, fabricated and supplied to NRC, RTA and TUBS.







Ice Capture Cylinder arrangement at TUBS (top), NACA0012 common test article drawing (centre), oop view of NACA0012 test article LE in NRC ICI cascade rig (bot)

THANK YOU FOR YOUR INTEREST

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