ICE GENESIS
Project Overview

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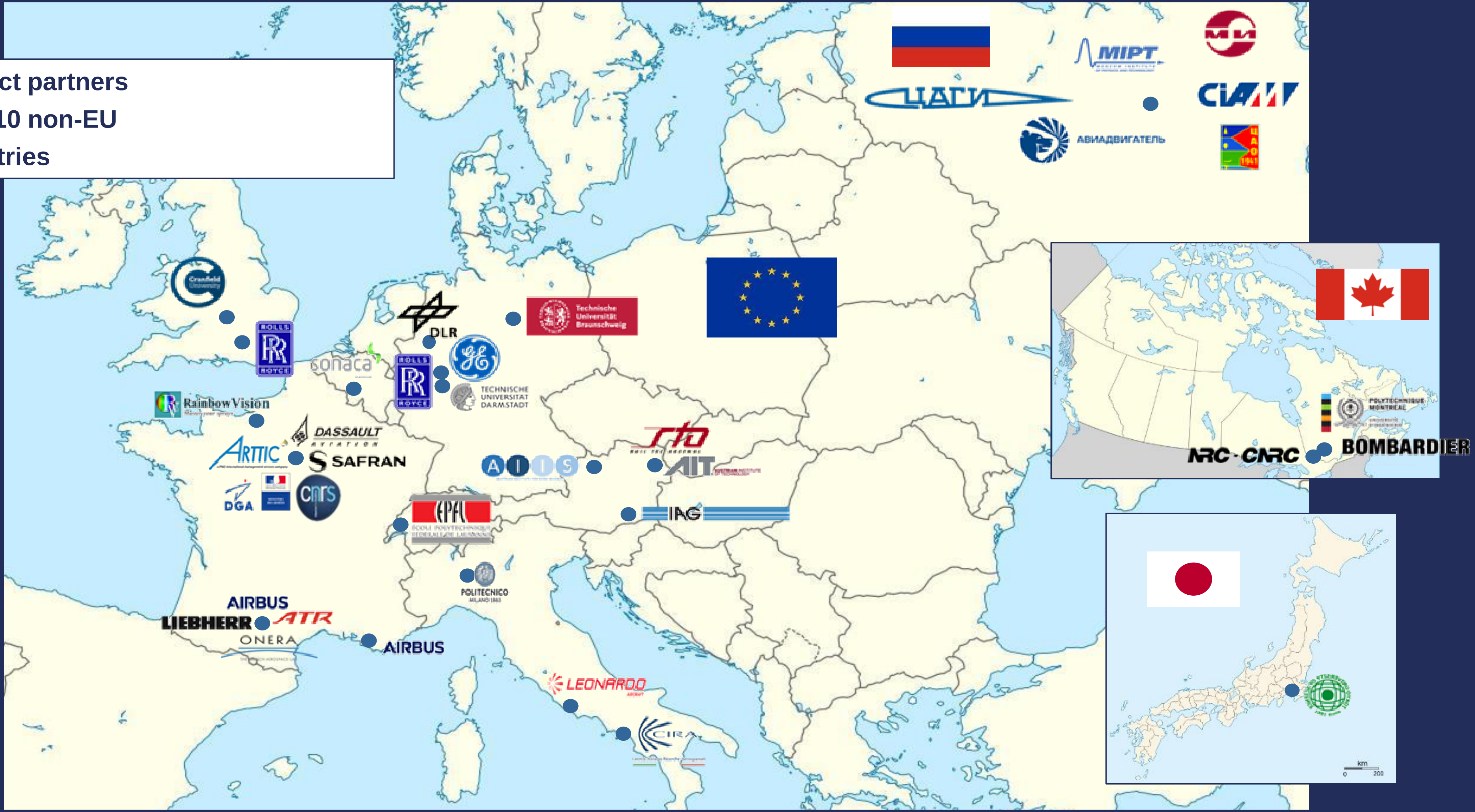
The Consortium

- 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

WP1 Project management and governance

WP2 Dissemination & exploitation

3D App C Stream

App O Stream

Snow Stream

WP3: Consolidation of specifications & test plans. Test follow-up

WP4: Instrumentation for liquid icing conditions

WP5: Instrumentation for sn
& microphysical properties

Instrumentation

WP6: SLD test capability

WP7: Snow test capability

Test Capability

WP8: Wind tunnel tests preparation and performance for liquid icing and snow conditions

Experimental Database

WP9 Numerical capability development for liquid icing conditions

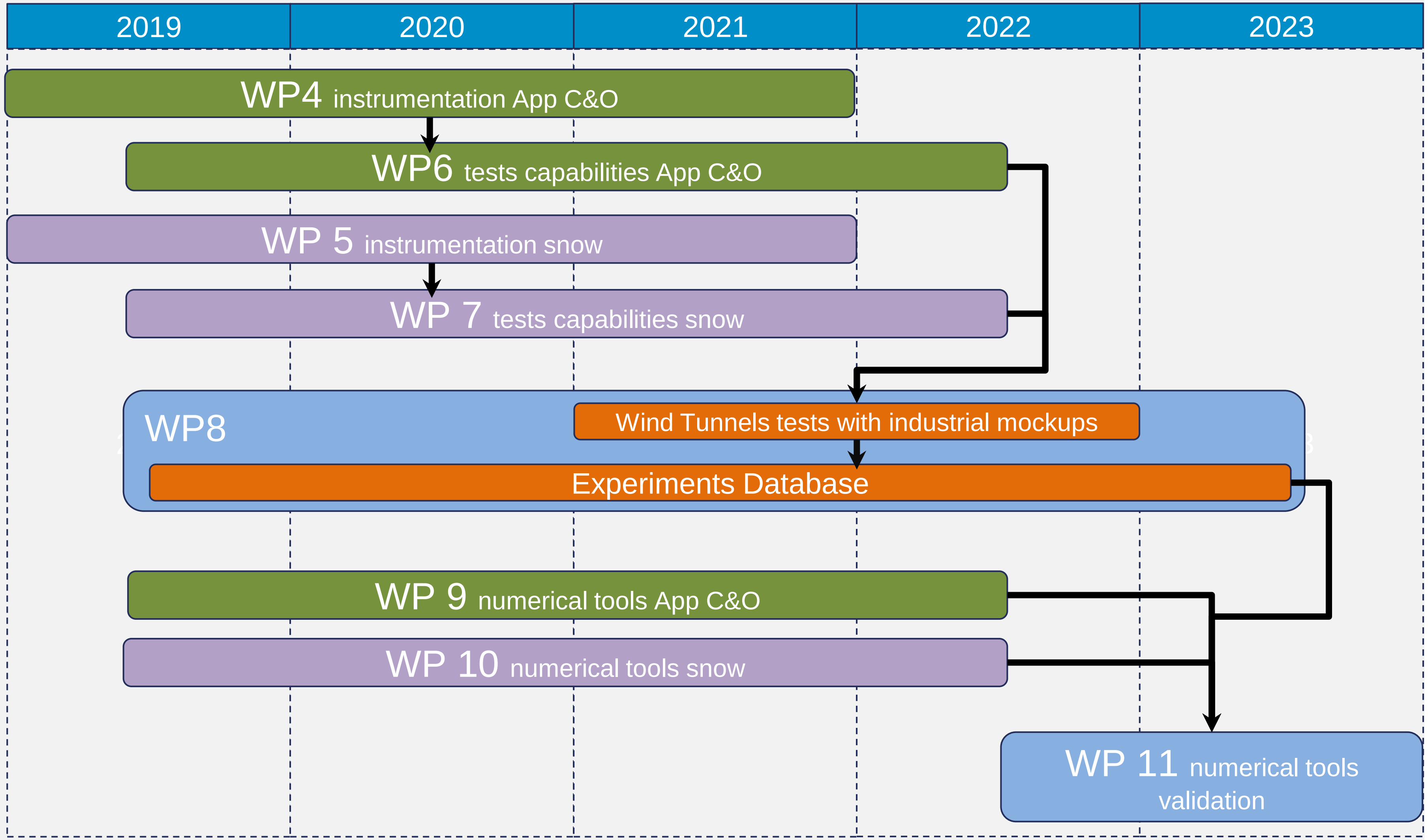
WP10: Numerical capabi
development for Snow

WP11: Numerical tools validation in industrial environment

Numerical Capability

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



Liquid conditions

Numerical tools improvements

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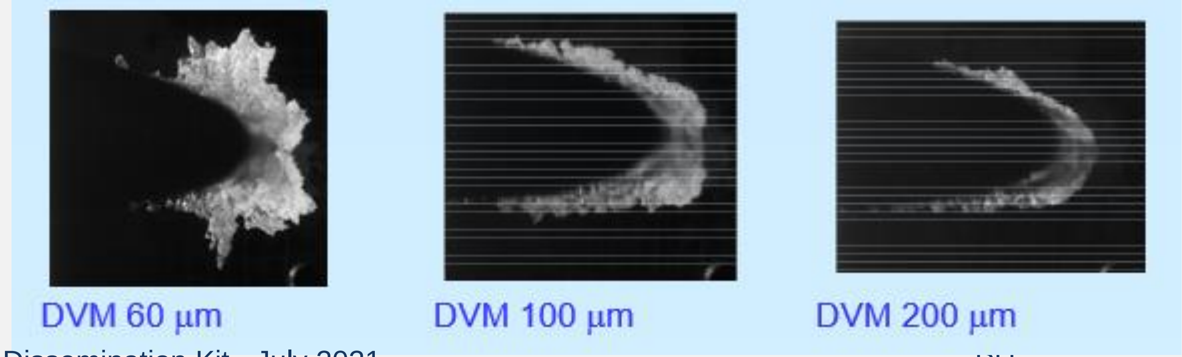
Objectives

- Objectives: improve and validate current 2D/3D numerical tools with respect to Appendix C and Appendix O conditions, so that they can be used for both design and certification of aircraft, rotorcraft and engines
- Decomposition into 4 Tasks
  - Task 9.1: Basic experiments to provide missing data for model development
  - Task 9.2: Model improvements and implementation in 2D tools for calibration and preliminary validation
  - Task 9.3: Model integration in 3D numerical tools and preliminary validation
  - Task 9.4: Improvement of 3D ice accretion numerical methodologies
- Supercooled Large Droplets (SLD) are met in Freezing Drizzle and Freezing Rain conditions. Why is it so important to work on these conditions? => because large droplets do not behave as smaller ones… They are more inertial…

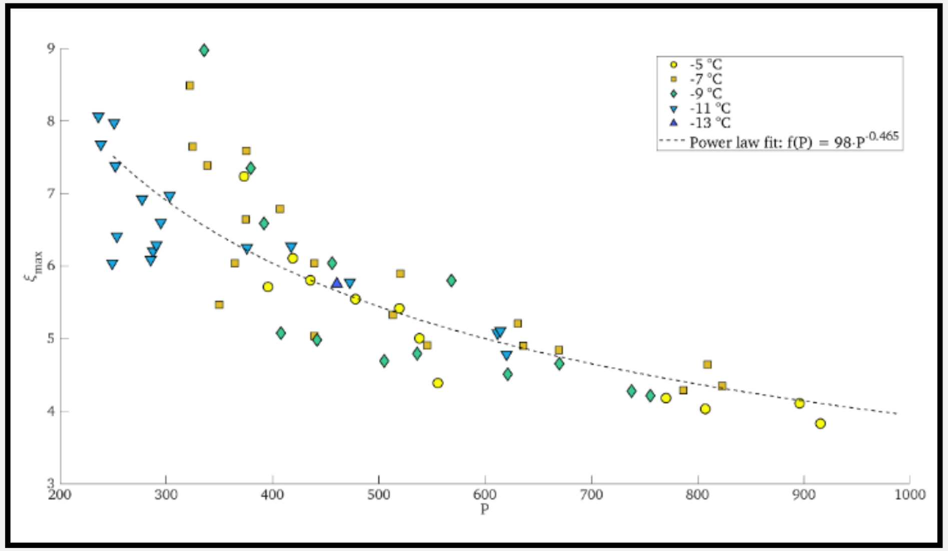


DROP IMPACT (T9.1)

- Objectives: extending/filling the gaps for SLD
- Characterization of the splashing regimes (CU, MIPT, ONERA, TUDA, TsAGI)
  - Low to medium velocity range: TUDA / medium to high velocity range: CU, ONERA
  - Considering various types of surfaces, # air temperatures and velocities, # surface temperatures, # droplet diameters

Example of drop impact

Ice accretion



Corona splash width

$$\xi_{max,Cor} = \frac{D_{max,Corona}}{D_0} \approx 98P^{-0.465} \quad \text{with} \quad P = \frac{Re^2}{We^{3/2}}$$

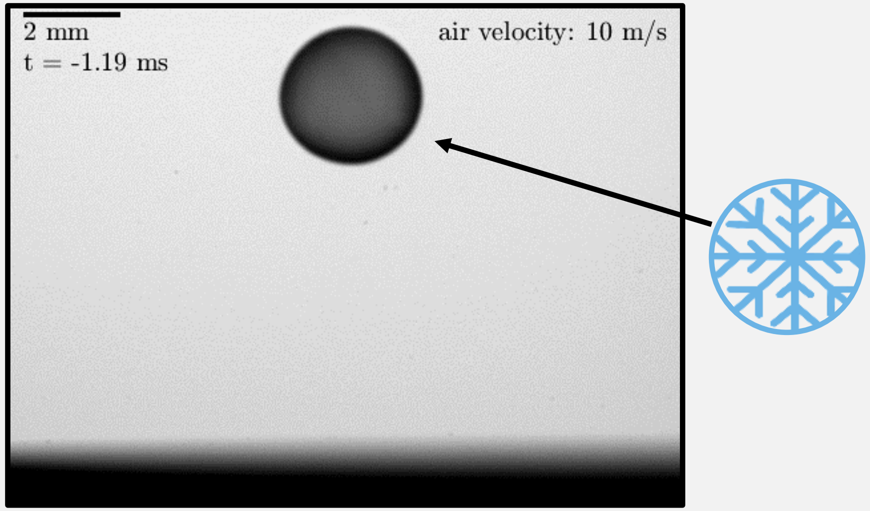
DROP IMPACT (T9.1)

Drop impact of dendritic droplets (TUDA)

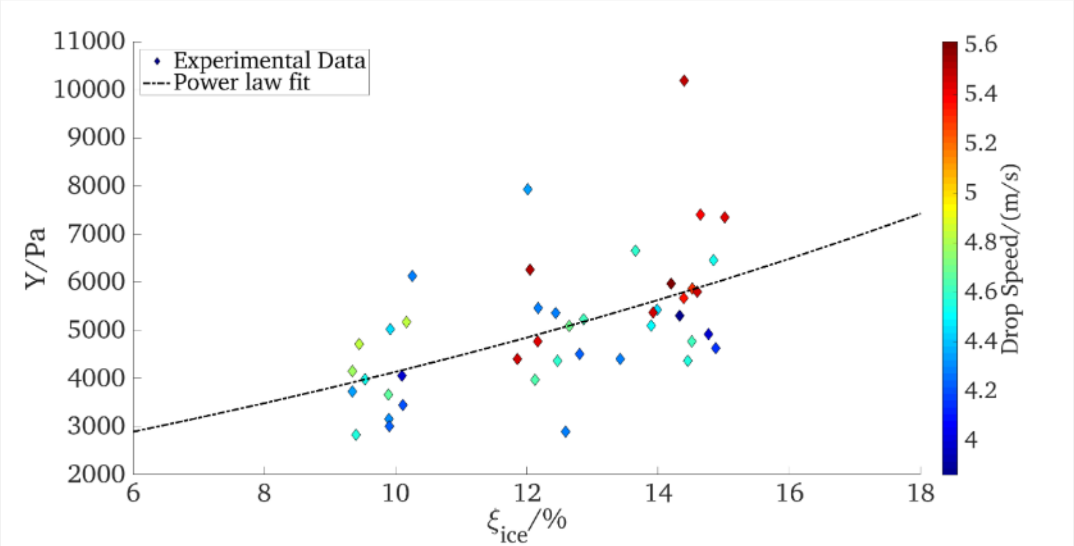
- Droplet containing dendrites prior to impact (Mushy Drop)
- Impact behaviour drastically changed
- Ice fraction determined from supercooling (Stephan number)
- Yield strength of mushy layer increases with ice fraction

$$\xi_{ice} = \frac{\rho_w c_{p,w} \Delta T}{h_w + \Delta T\left(\rho_w c_{p,w} - \rho_{ice} c_{p,ice}\right)}$$

ξ_{ice}: Mass fraction ice
ΔT: Initial supercooling
c_i: Heat capacity
h_w: Enthalpie of fusion
ρ_i: Density



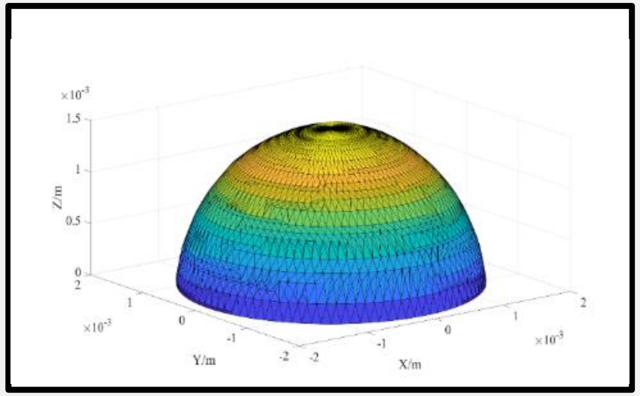
$T_{drop,0} = -11°\mathrm{C} \approx T_{surf}$; $v_{drop} = 4.9$ m/s
$D_{drop} = 3\mathrm{mm}$; $\xi_{ice} \approx 14$ %



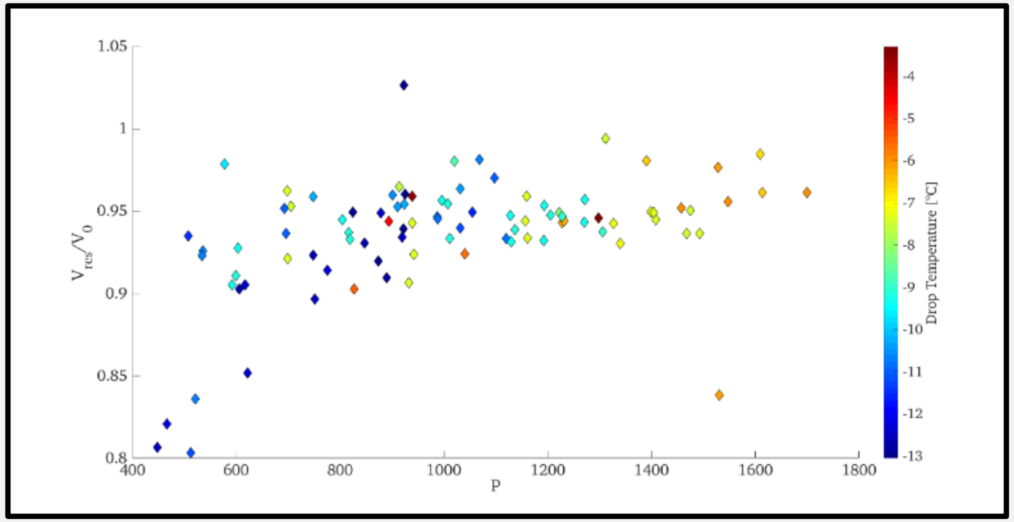
Yield strength Y increases with increasing ice fraction of drop

DROP IMPACT (T9.1)

- Characterization of the deposited mass ratio (TUDA)
  - Original measurement technique based on visual reconstruction



3D-Reconstruction of receding drop after impact

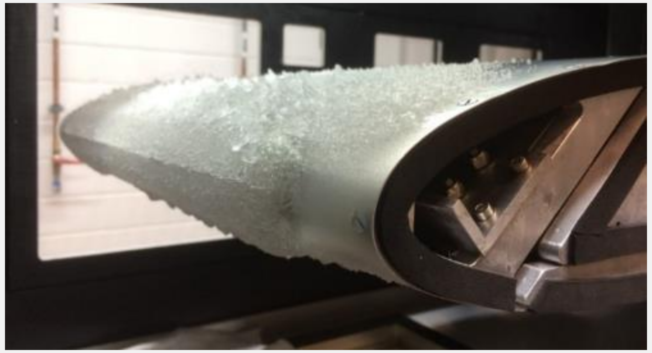


Reduced residual volume vs P dimensionless number

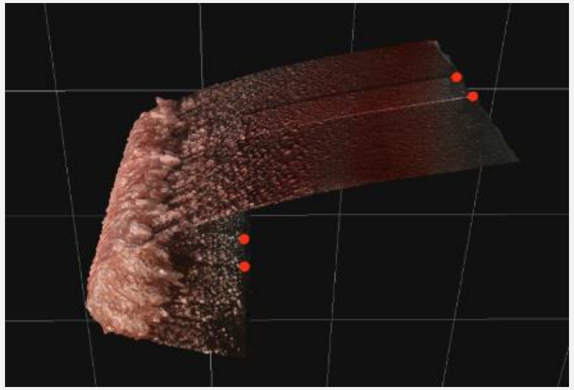
- Characterization of the re-emitted droplets/secondary droplets (CU, MIPT, ONERA, TsAGI, TUDA)
  - Measurement techniques based on either high-speed camera (CU) or Phase-Doppler-Anemometer (ONERA)
  - Data processing and experiments on-going

ROUGHNESS CHARACTERIZATION (T9.1)

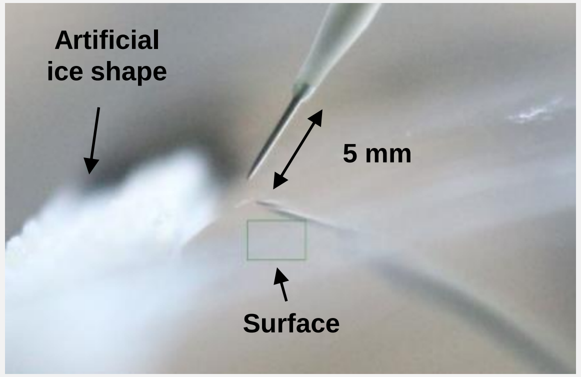
- Objectives (TUBS)
  - Acquire the geometry of the generated ice accretion with enough detail for roughness analysis
  - Perform boundary layer measurements to characterize the influence of roughness on the flow
- Description of work
  - Considering Appendix C and Appendix O conditions on airfoil
  - Acquisition done by the photogrammetry method + artificial ice geometry generated by 3D printing



Experiments



Geometry of the accreted ice
(Photogrammetry ~50 photos)



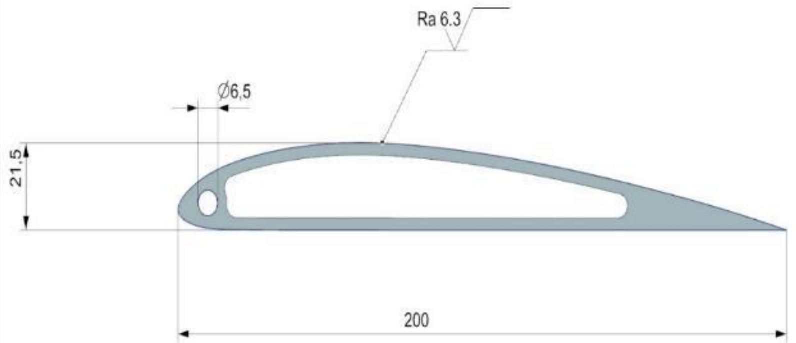
BL measurements

Investigation the influence of SLD conditions on thermal ice protection systems efficiency

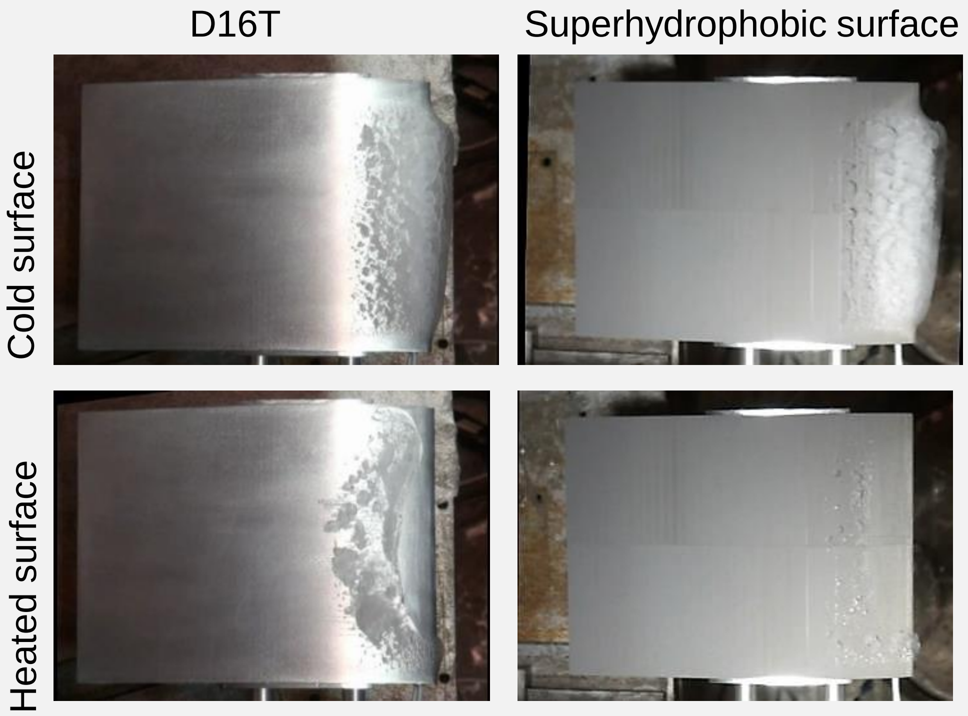
TsAGI investigates the influence of surface properties on wing model ice accretion in App. C and App. O icing conditions

Surface	Icing conditions	LE heating	V, m/s	Ta, C
D16T	App. C	Off	Up to 80	Down to -18
SH	App. C	Off	Up to 80	Down to -18
D16T	App. C	On	Up to 80	Down to -18
SH	App. C	On	Up to 80	Down to -18
D16T	App. O	Off	Up to 80	Down to -18
SH	App. O	Off	Up to 80	Down to -18
D16T	App. O	On	Up to 80	Down to -18
SH	App. O	On	Up to 80	Down to -18

2 wing models are used: with ordinary (duralumin) and superhydrophobic (θ ≈ 150°) surface



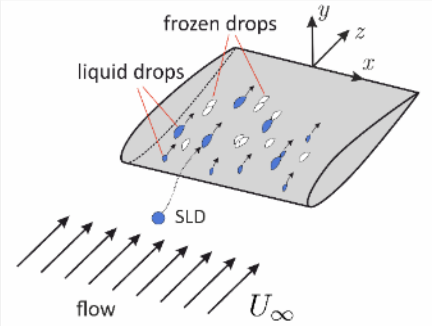
Ice accretion on wing model for cold surface and in run-back mode

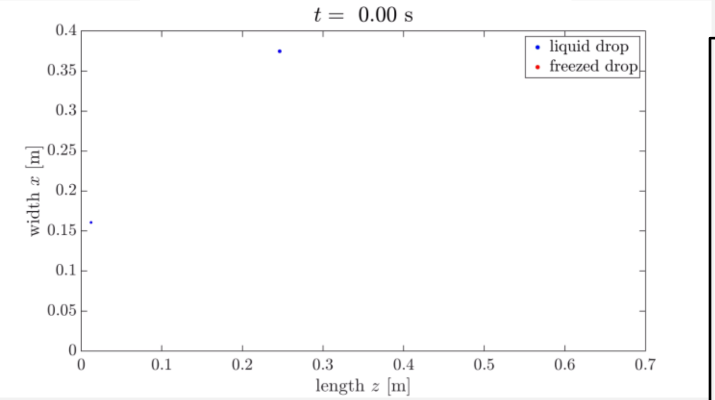


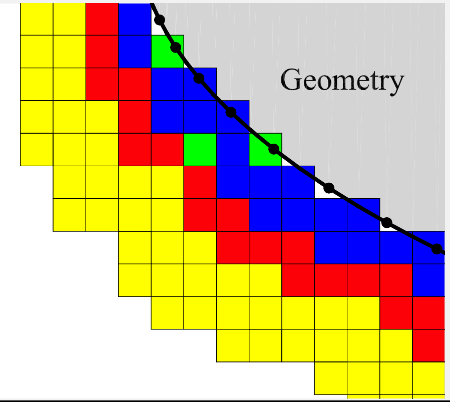
Tests output: run-back ice mass, mass of evaporated and blown-down water, surface temperature dynamics

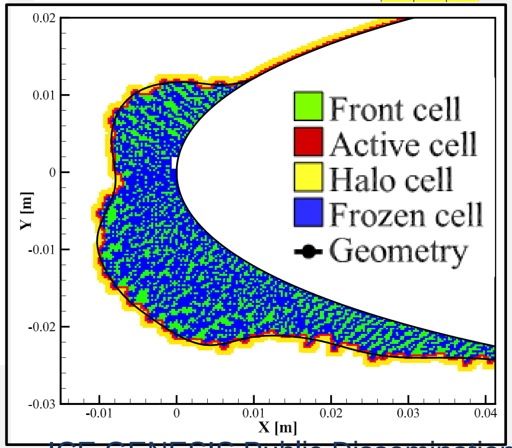
MODELLING ACTIVITIES (T9.2)

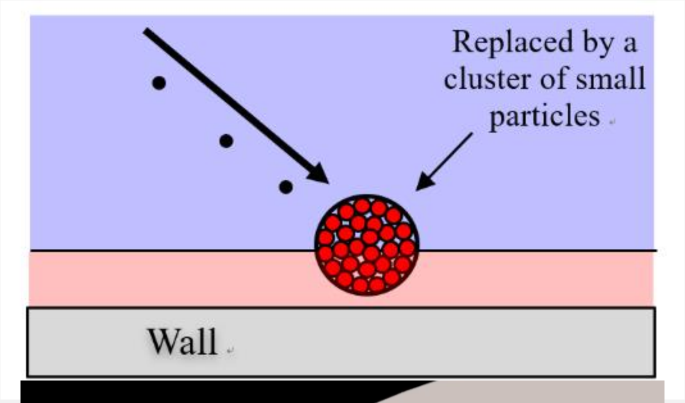
- Objectives
  - Developing or improving models for SLD and ice accretion roughness geometry
  - Implementing and assessing the models in 2D tools through numerical benchmarks

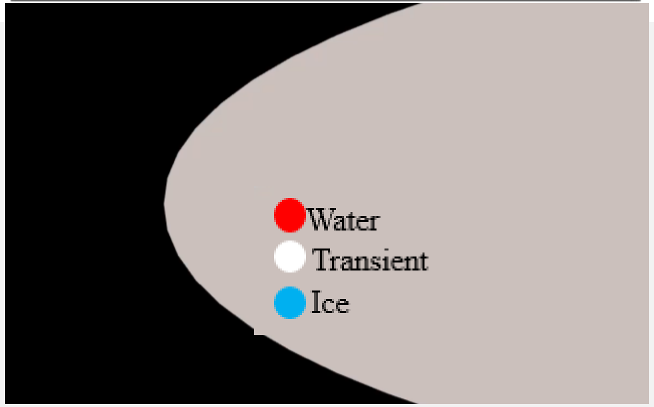






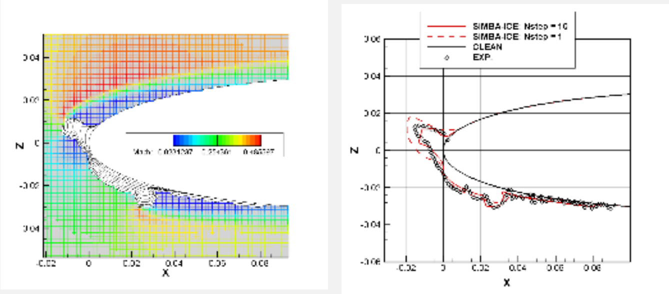




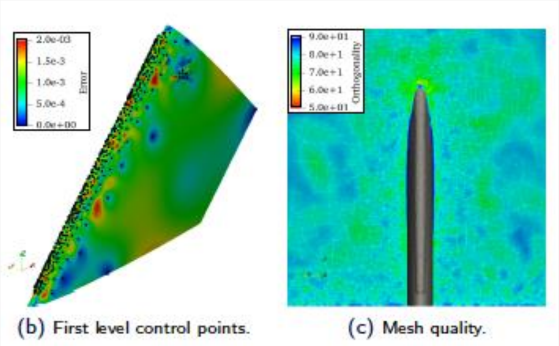


NUMERICAL APPROACHES (T9.4)

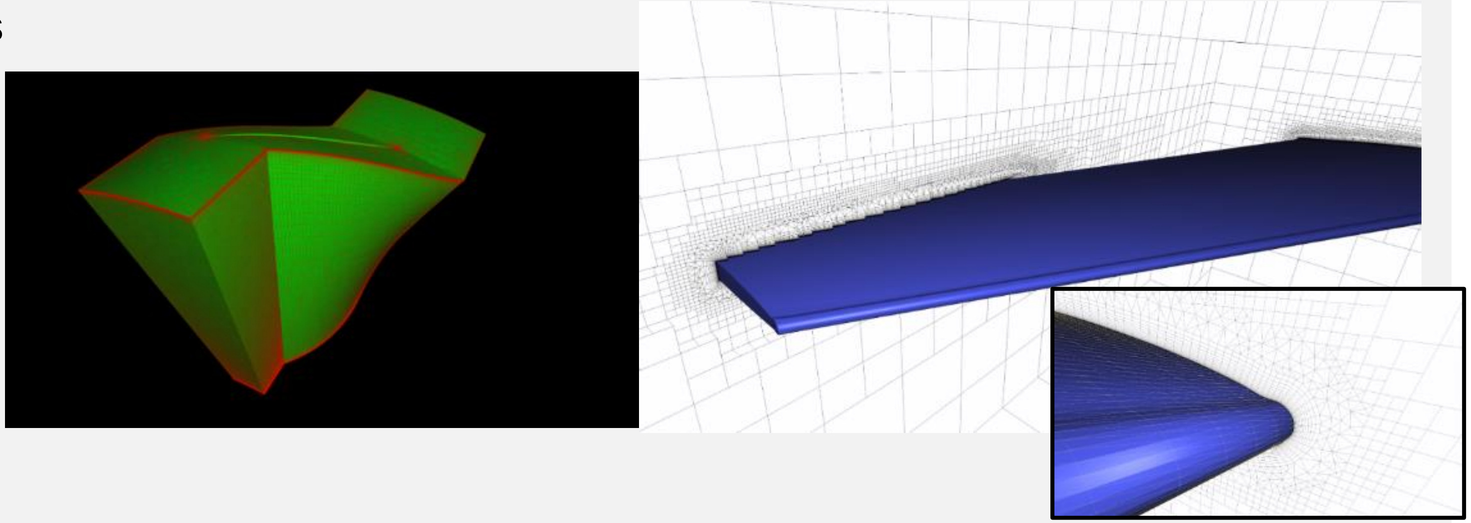
- Objective: improving 3D ice accretion numerical methodologies (AVI, BOMB, CIRA, MIPT, ONERA, POLIMI, POLYMO, TsAGI, TUS)
  - Automatic mesh adaptation, automatic re-meshing, Immersed Boundary Method
  - Predictor/corrector and multistep techniques



IBM calculations (CIRA)



Mesh adaptation – RBF method (POLIMI)



Automatic re-meshing – CASSIOPEE (ONERA)
Application to external and internal flows

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