ICE GENESIS

SENS4ICE Final Dissemination Event

29 November 2023

Directorate-General for Research and Innovation of the European Commission, Brussels

E. LAINE (AIRBUS)
Project Coordinator

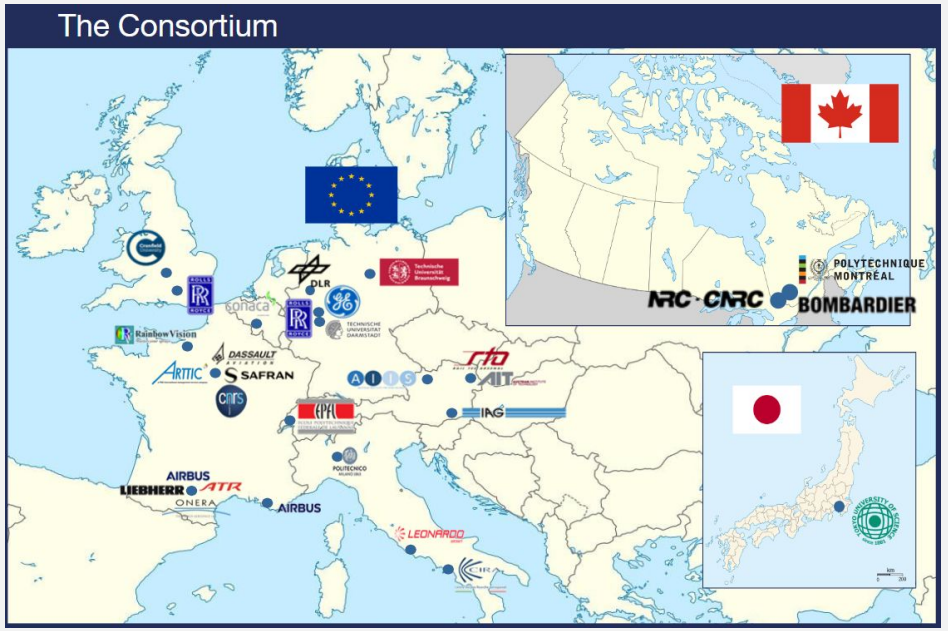
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824310.

OVERVIEW

Top level objective: To provide the European aeronautical industry with a validated new generation of **3D icing engineering tools** (numerical simulation and test capabilities), addressing **supercooled liquid water** (Appendices C & O) **and snow conditions**, for safe, efficient and cost effective design and certification of future aircraft and rotorcraft.

Technical objectives

1. Improve and validate existing **3D numerical tools** to predict ice accretion in Appendix C, Appendix O and Snow conditions.
2. Upgrade and calibrate **icing wind tunnels** to allow reproduction of:
   - Supercooled Large Drops in Freezing drizzle conditions.
   - Snow icing conditions
   - Additionally, to assess the potential of current icing wind tunnels to represent Supercooled Large Drops in Freezing rain conditions.
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



- Grant agreement ID: 824310
- Start date : 01/01/2019 - End date : 31/12/2023
- Total cost : € 12 352 417
- EU contribution : € 11 964 300
- 30 Partners, 26 EU / 4 non-EU, 9 countries
- Website : https://www.ice-genesis.eu/

FZDZ = Freezing Drizzle ; FZRA = Freezing Rain ; SLD = Supercooled Large Drops

Supercooled Liquid Water - Outcomes & Gaps

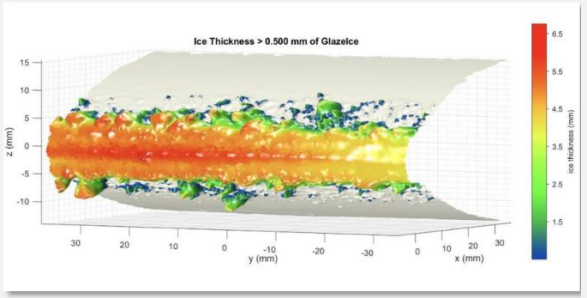
OUTCOMES

- **Icing Wind Tunnel Tests :**
  - **upgraded capabilities** in **FZDZ** (CIRA & RTA)
  - **preliminary capability** for **FZRA** (RTA)
  - preliminary droplet temperature characterization, 3D scanning of ice shapes
- **Methods & Tools :**
  - **some capabilities** demonstrated **in FZDZ** :
    - drop impact and mass deposit (splashing)
    - droplet re-emission
    - 3D capability: new methodologies for remeshing or multi-step processes
  - **new experimental observations** to be implemented in future models
  - validation in progress by industrials
- **Common experimental database :** https://www.icing-database.eu/

GAPS

- **Icing Wind Tunnel Tests :**
  - missing **full FZDZ capability :** cloud uniformity, LWC too high, droplet temperature effect, instrumentation standardization for particle size distribution and LWC, **extend calibration** to the broad CIRA envelope
  - improve **efficiency** of the SLD set-up and App.C/O switching for industrial applications
- **Methods & Tools :**
  - missing **full FZDZ capability :** high speed effect/erosion, altitude effect
  - lack of reliable **experimental data** to properly assess the models
  - **industrialization** of the tools
- **In general : some efforts are needed to provide applicants for future A/C configurations the same level of acceptance for the Means of Compliance in Appendix O as it is in Appendix C**

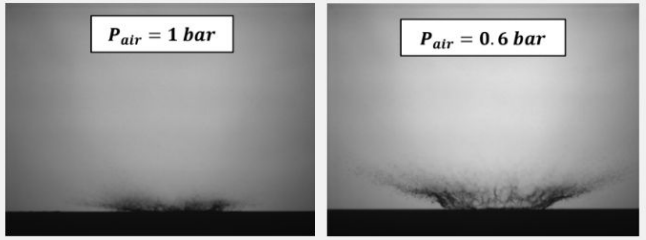
Supercooled Liquid Water TRL Status			
Icing Conditions		**Appendix C**	**Appendix O (FZDZ)**
Test Facilities	***RTA***	Already available	**TRL5**
	CIRA	Already available	**TRL4**
3D Numerical Tools		**TRL4** target **TRL5** (11/2023)	**TRL4** target **TRL5** (11/2023)



← 3D scan of an ice shape generated in icing wind tunnel (color is proportional to thickness)

$D_0 \approx 325\ \mu m\ ;\ V_{air} = 140\ m/s\ ;\ T_{air} = 15°C$

Experimental observation of the altitude effect on droplet impact →



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LWC = Liquid Water Content ; TRL = Technology Readiness Level

Snow - Outcomes & Gaps

OUTCOMES

- **Characterization of falling snow conditions** (field campaigns)
- **Icing Wind Tunnel Tests :**
  - Development of **snow generation systems** in RTA & NRC with the capability to change the particle melt
  - **Calibration of snow wind tunnel** test facilities
- **Methods & Tools :**
  - **Modelling of the physical phenomena** related to snow : drag, melting; preliminary model for sticking efficiency, erosion, accretion
  - Validation in progress by industrials

GAPS

- **Icing Wind Tunnel Tests :**
  - **Upscaling** to regulatory Total Water Content (TWC)
  - Validation database on **representative industrial configurations**
  - **Efficiency and operability** of the snow generation systems
- **Methods & Tools :**
  - Modelling: snowflake impact and accretion, heated surface, ice shedding, saltation
  - **Validation on complex 3D cases** (engine air inlet)

Snow TRL Status		
Test Facilities	***RTA***	**TRL4**
	NRC RATFac	**TRL4/5**
Tools	Transport : **TRL4**, target **TRL5** (12/2023) Accretion : **TRL3**, Target **TRL4** (12/2023)	

ATR42 Snow Field Campaign at Les Eplatures (Swiss Jura) - 01/2021

IAG SnowFall snow generation system into RTA Climatic Wind Tunnel and calibration

TRL = Technology Readiness Level ; TWC = Total Water Content

CONCLUSION & WAY FORWARD

CONCLUSION

- **Clear progress on wind tunnel test facilities** for the simulation of SLD and Snow conditions (FZDZ: TRL4/5, FZRA: Preliminary Capability, Snow: TRL4)
- **Improved understanding and modelling** of SLD and Snow conditions, though **some progress remains necessary on the new models** in order to use them as certification means of compliance
- **Beneficial international cooperation, to be continued**: enhanced impact, harmonization, orientation of fundings towards common targets, scientific excellence

CONTEXT

- **Climate evolution**: increasing weather hazards, need for disruptive aircraft and powerplant configurations to achieve CO_2 emissions reduction targets
- **Certification**: New stringent policies and certification requirements or increasing level of authorities expectations
- **No approved engineering tools** for use as workable direct means of compliance (free from excessive conservatism) → **the future clean and sustainable aviation products cannot be certified without further research**.

NEXT TARGET: Obtain workable means of compliance for Icing, Snow and Ice Crystals for application to future products design and certification at horizon 2030+

WAY FORWARD

- Necessary **improvements** for SLD, Snow and Ice Crystals simulation in test facilities and numerical tools **shall be addressed in future common research initiatives**.

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