Icing Wind Tunnel tests in the framework of a Wing Ice Protection system certification process

AirTN-NextGen Workshop on Virtual testing,
towards virtual certification

Amsterdam (NL),
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OUTLINE

- The Wing Ice Protection system certification roadmap
- Icing wind tunnel test campaign requirements
- Icing wind tunnel tests – Typical results
- Lessons learnt and way forward

What should be demonstrated

- Capability to fly safely in adverse conditions (continuous maximum and intermittent maximum)
- Efficiency of the ice protection systems
- Identify the impact of ice accretion on the aircraft flight operations

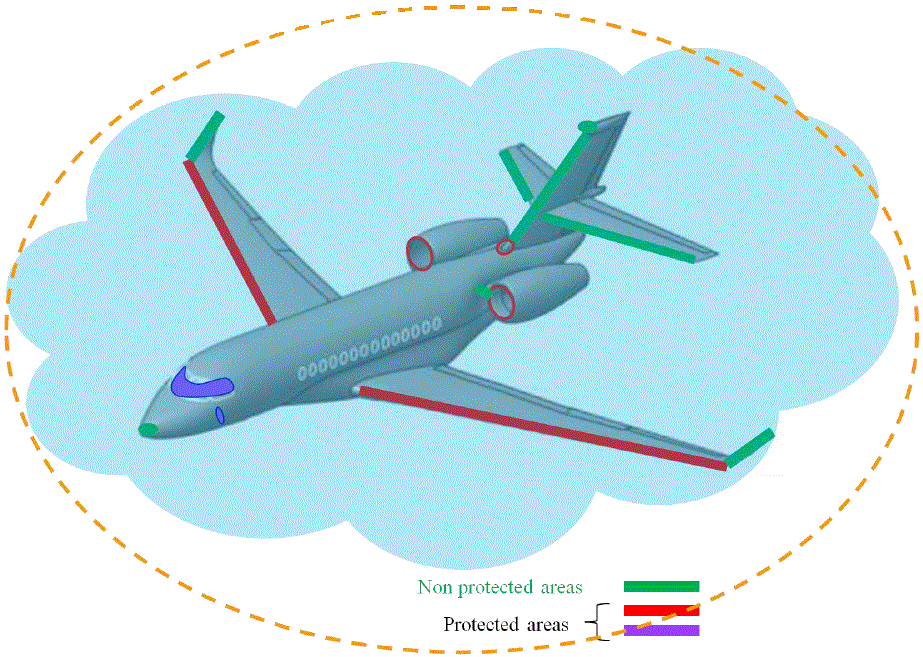
Regulations basis

- CS-25 Certification Specifications for Large Aeroplanes (EASA)
- FAR-25 (FAA)
- New regulations (App O and App D/P)
- Means of Compliance

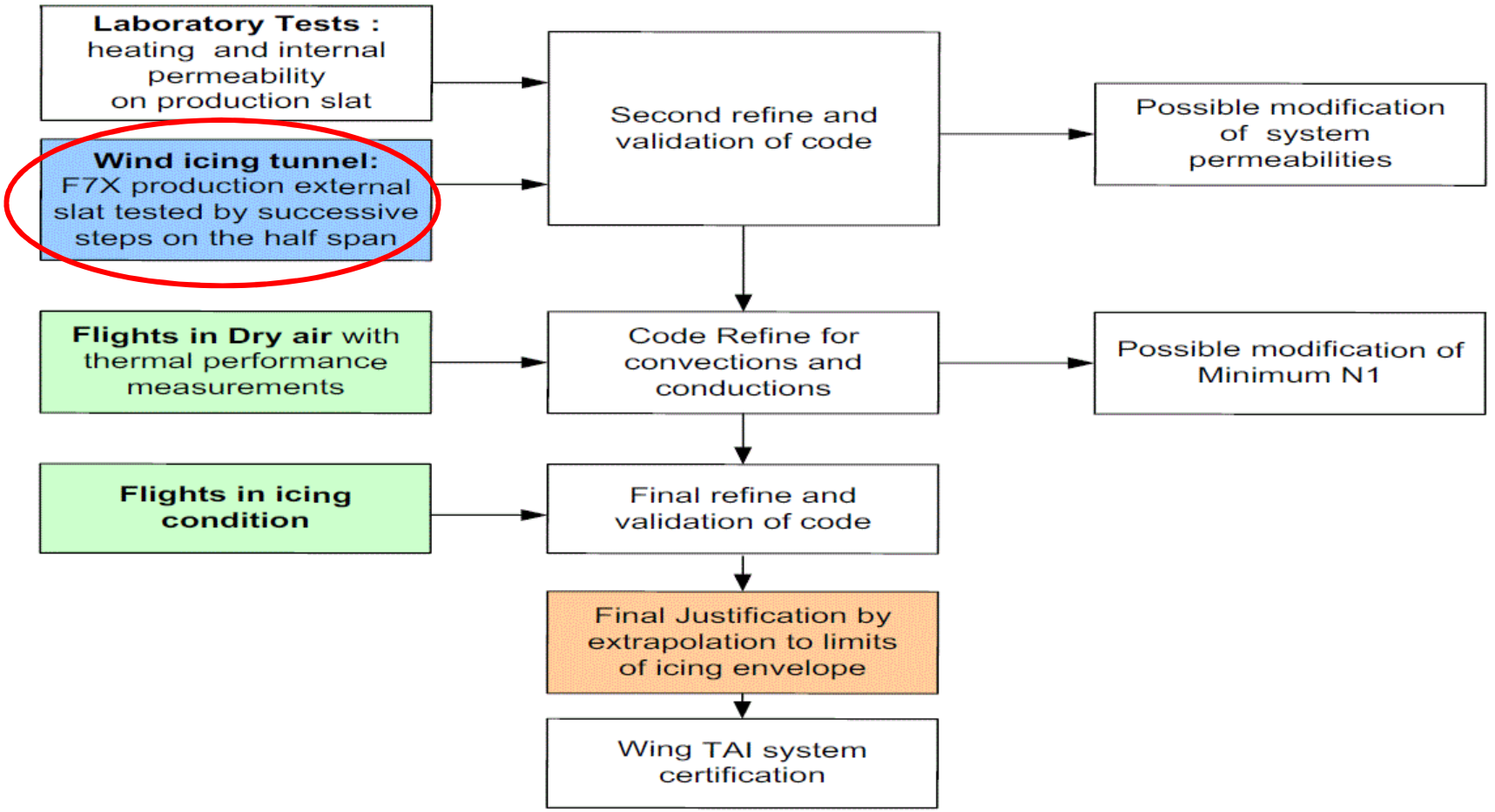
Means of compliance

- Simulation tools and/or analysis
- Ground tests (Laboratory and/or icing wind tunnels)
- Flight tests (Dry air and flight in natural icing conditions)

Icing Areas



Stepwise approach of means of compliance



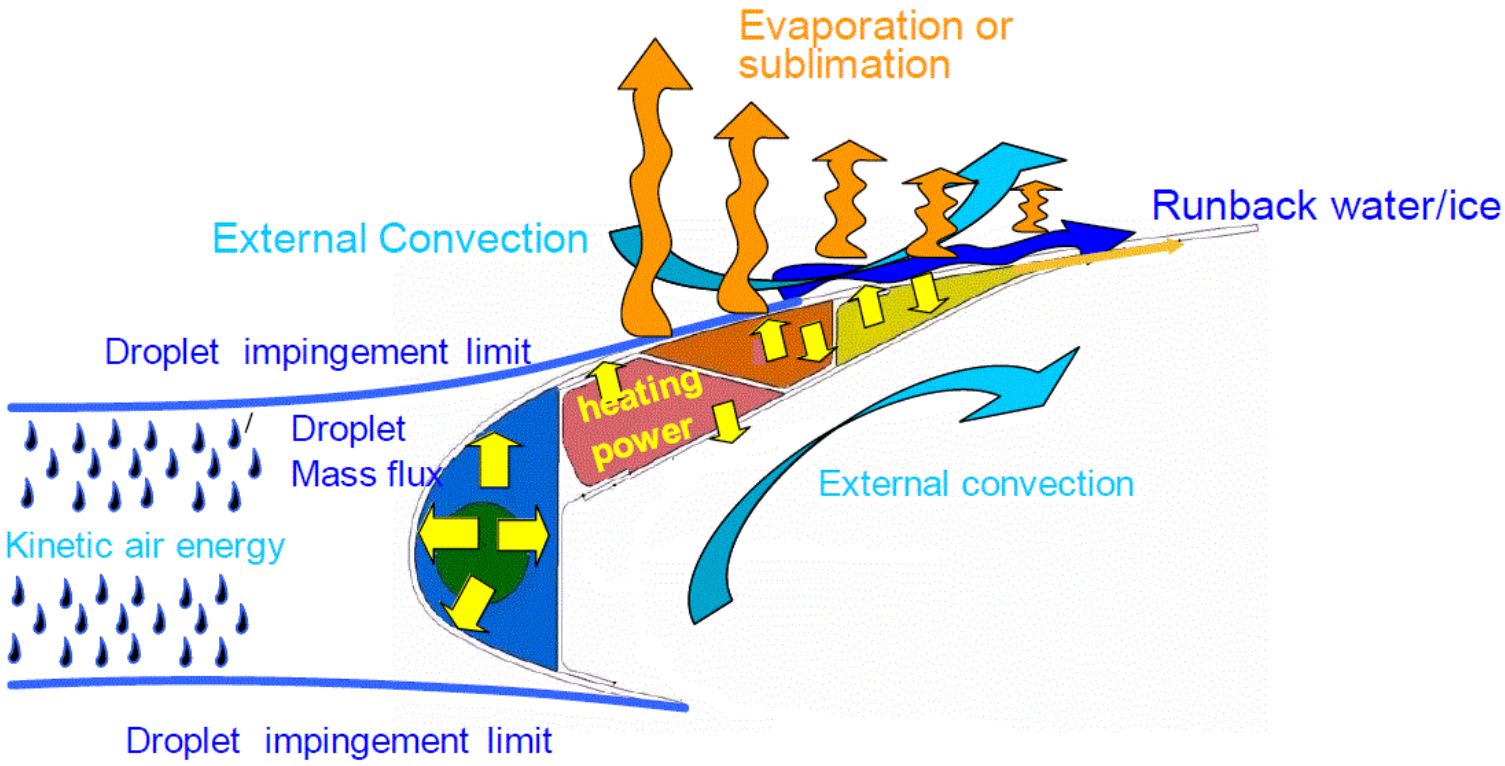
Icing Wind Tunnel Tests is a crucial tool for:

- System performance efficiency evaluation
- Certification demonstration (most severe conditions)
- CFD codes validation
- Characterize the ice shapes to evaluate the aerodynamic degradations and support the flight tests campaign preparation

Three main elements address the test campaign requirements definition:

- Physical phenomenon to be observed
- Icing atmospheric conditions
- Flight phases in icing conditions

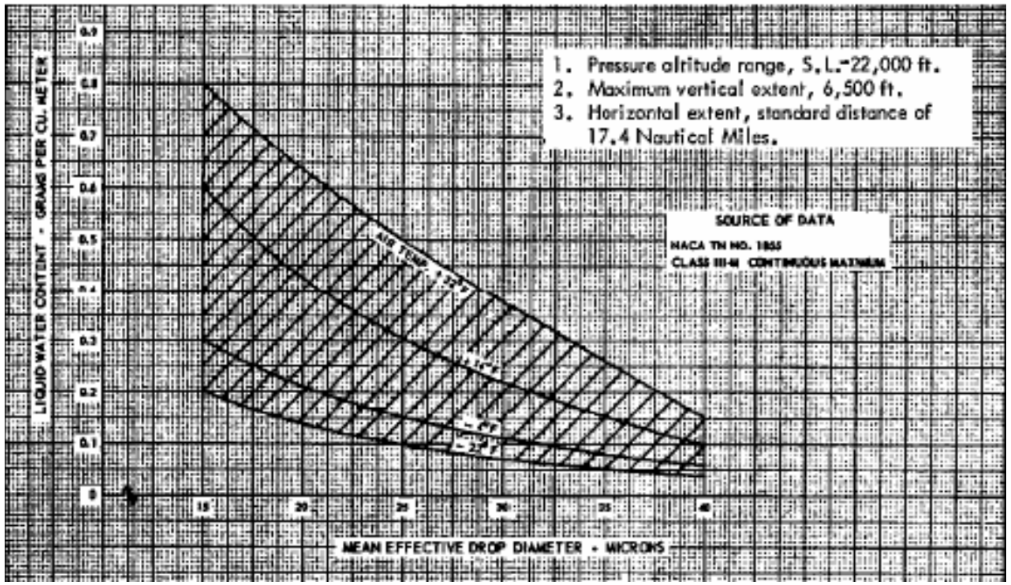
1. Physical phenomenon – ice protection system features



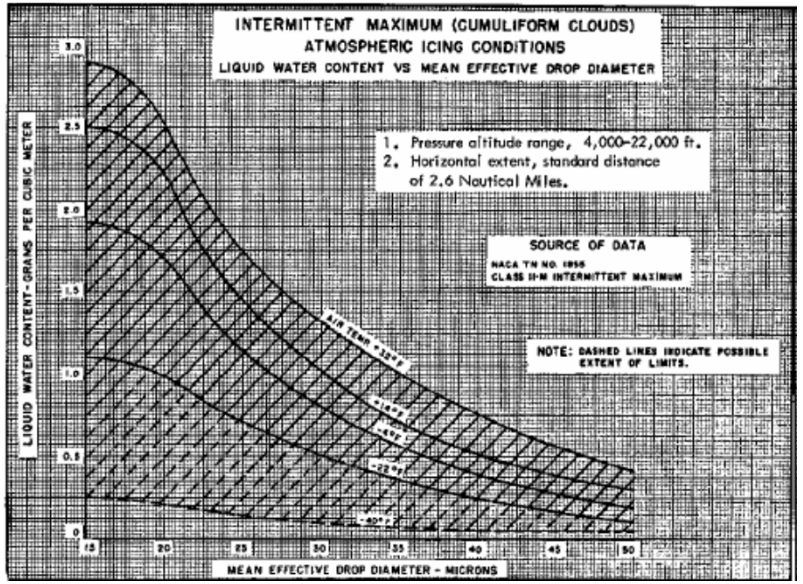
2. Icing atmospheric conditions

FAR-25, Appendix C, civil aircraft design envelopes

Continuous maximum



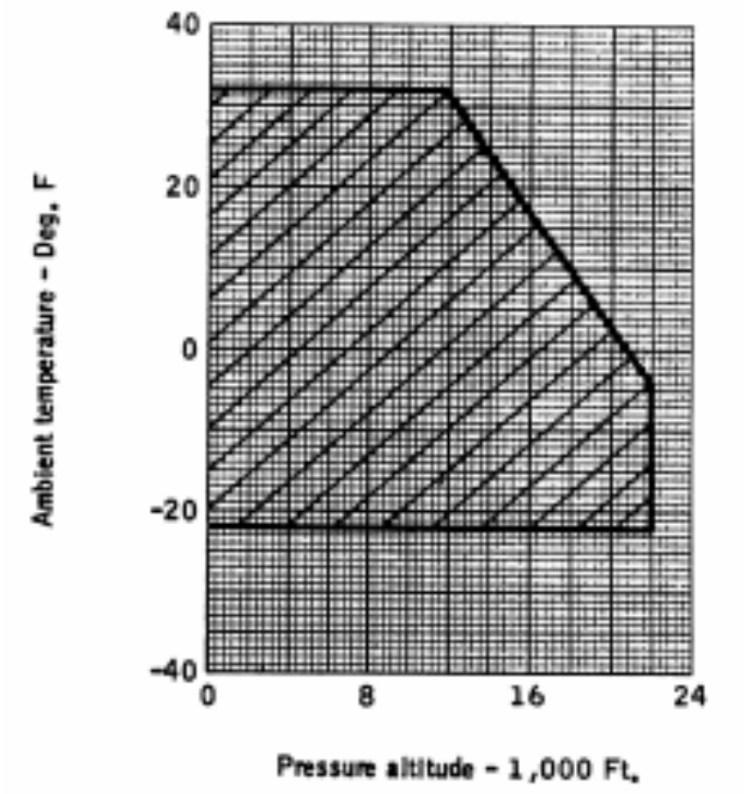
Intermittent maximum



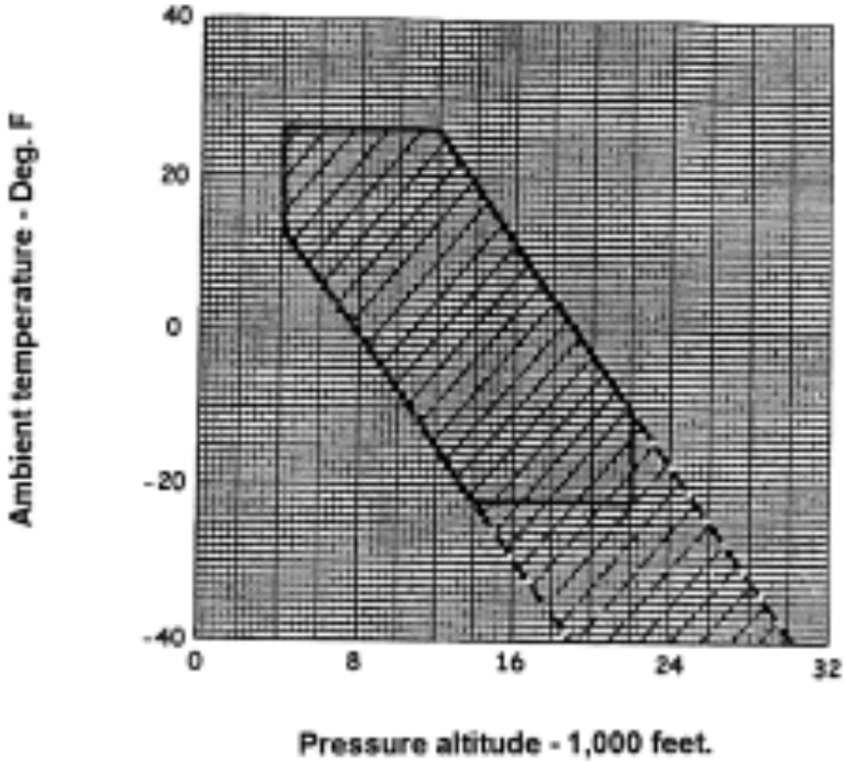
- Continuous maximum : stratiform clouds
- Intermittent maximum : cumuliform clouds

FAR-25, Appendix C, civil aircraft design envelopes (cont.)

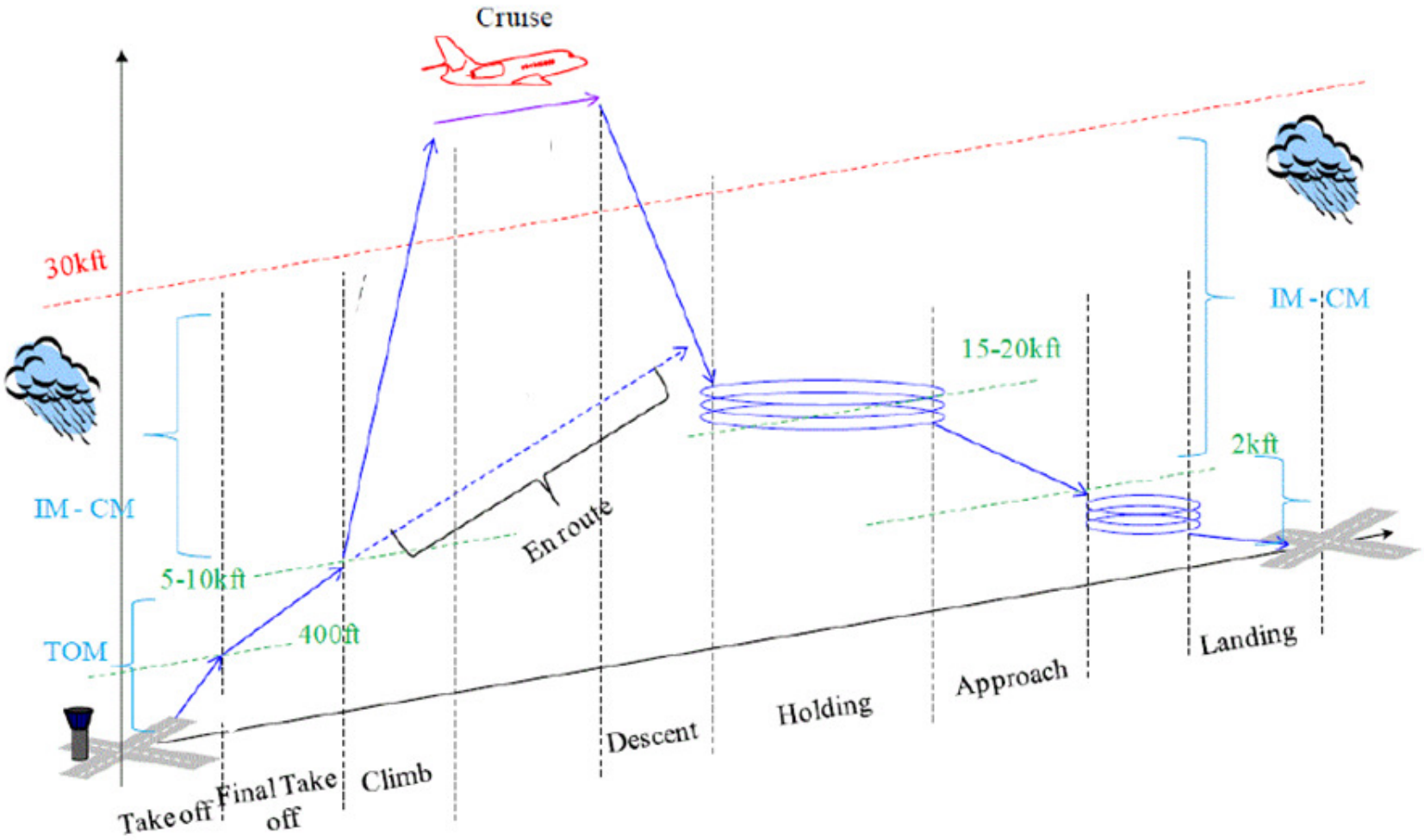
Continuous maximum



Intermittent maximum



3. Flight phases in icing conditions



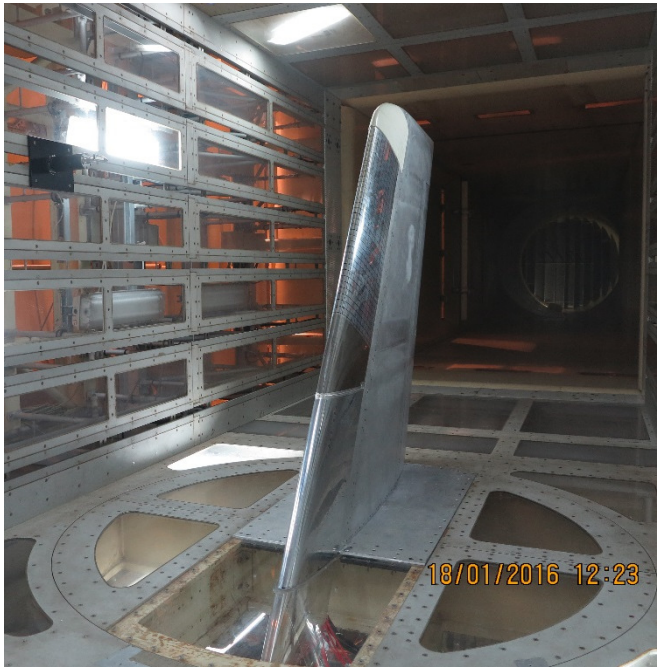
Crossing the three mentioned elements, the icing wind tunnel test campaign is designed in terms of:

- Set-up configurations (number of models, models configurations, etc.)
- Flight phases to be investigated in icing conditions (climbing, holding, cruise, etc.)
- Test matrix (number of tests, test conditions, cloud conditions)
- Test procedure
- Measurement techniques

ICING WIND TUNNEL TESTS – TYPICAL RESULTS

- In the framework of the development of the ice protection system for the Falcon 5X aircraft, in January 2016 CIRA completed an Icing Wind Tunnel test campaign committed by Dassault Aviation and aimed to the execution of the wing anti-icing certification tests.

- The test article was a wing tip, vertically installed inside the test section, characterised by a 1:1 scale leading edge slat and a wing box supplied of a flap (to guarantee on the model leading edge the targeted pressure distribution), and equipped with a pneumatic bleed air anti-ice protection system (“piccolo” tube).



ICING WIND TUNNEL TESTS – TYPICAL RESULTS

- Two wing slat configurations were tested: clean and high-lift
- A dedicated aerodynamic tests session (in both clean and high-lift configurations) was carried out before the icing tests
- Ice accretion tests (with protection system off) and anti-icing tests (with protection system activated) were both executed
- Preliminary tests were aimed at optimizing the performance of the ice protection system, in preparation of the certification tests performed just after the preparation test session, under the witness of the certification authorities.

ICING WIND TUNNEL TESTS – TYPICAL RESULTS

- The final purpose of the tests was to demonstrate the efficiency of the wing anti-ice system at selected certification points.
- Different operational conditions were simulated (approach, descent, holding, etc.) as well as several cloud conditions (both continuous and intermittent).
- Droplets diameter range from 20 to 40 microns
- Water concentration range between 0.14 and 1.82 g/m^3
- Altitudes range between 0 (sea level) and 17.000 ft
- Static temperature down to –30° C.

Ice accretion test result

V ≈ 110 m/s
T ≈ –25. 0 °C
h ≈ 5000 m

AoA ≈ 8°
flap angle = 0.0°
model configuration: high lift

MVD = 20.0 µm
LWC = CM condition
Spraying time < 10min

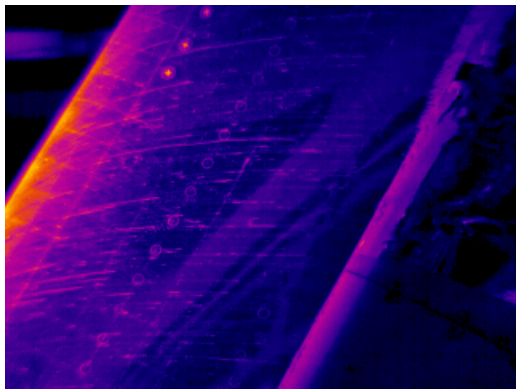
HADI OFF

Anti-icing tests result – preliminary tests

Run-back ice on the slat

Run-back ice measurements

Frozen water rivulets



Water rivulets & run back ice detected by IR camera

Lessons learnt

- Wind Tunnel Icing Tests is a tool in the framework of the (long and complex) icing certification process
- Being the tests executed in strictly controlled conditions, they represent the essential bridge between laboratory tests, CFD evaluations and flight tests
- Tests results are never to be taken for granted, even after extensive efforts in design, CFD and laboratory tests
- They are still the only mean to perform realistic simulation of complex phenomena involving bi-phase flow / aerodynamic / aircraft structure / ice protection system.
- Scaling laws, able to overcome wind tunnel limitations, are difficult to be applied in such cases, so a wide testing envelope, in terms of speed / temperature / altitude / droplet size / droplets concentration, represents a key asset in the experimental effort
- Experience gained in past Research Project (Extice, etc.) confirmed the significant benefit of integrated projects were both CFD and icing tests results are coupled to have clear understanding of the present state of the art of different means of compliance
- High accuracy and repeatability of the test/cloud conditions are, of course, necessary prerequisites for successful icing tests

Way forward

- Icing Wind Tunnels Operators must always be committed on the improvement of the icing tests quality
- The recent issuance of updated regulations for the icing certification (November 2014), imposes the need of significant technological updates to icing wind tunnels (and CFD), in order to be capable to cover the new specified cloud conditions (freezing drizzle, freezing rain, ice crystals, mixed phases)
- Technological updates efforts must be equally addressed to the development of both cloud generation systems and measurement techniques
- Presently, the capability of such new systems to generate the cloud conditions indicated in the new regulations is not obvious and significant gaps are expected.
- Presently, the accuracy and reliability of the available measurement techniques in characterizing the new cloud conditions is still an intense area of research
- Icing tests will remain in the next years a means of compliance in the framework of the icing certification. Nevertheless, integrated Research Projects can be a useful environment to understand how combining icing tests and CFD for an intelligent and optimized coverage of the new regulation envelope