The SENS4ICE EU project - SENSors and certifiable hybrid architectures for safer aviation in ICing Environment

A project midterm overview - October 2021

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SAE AC-9C Aircraft Icing Technology Committee Meeting 21 OCT 2021

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 824253

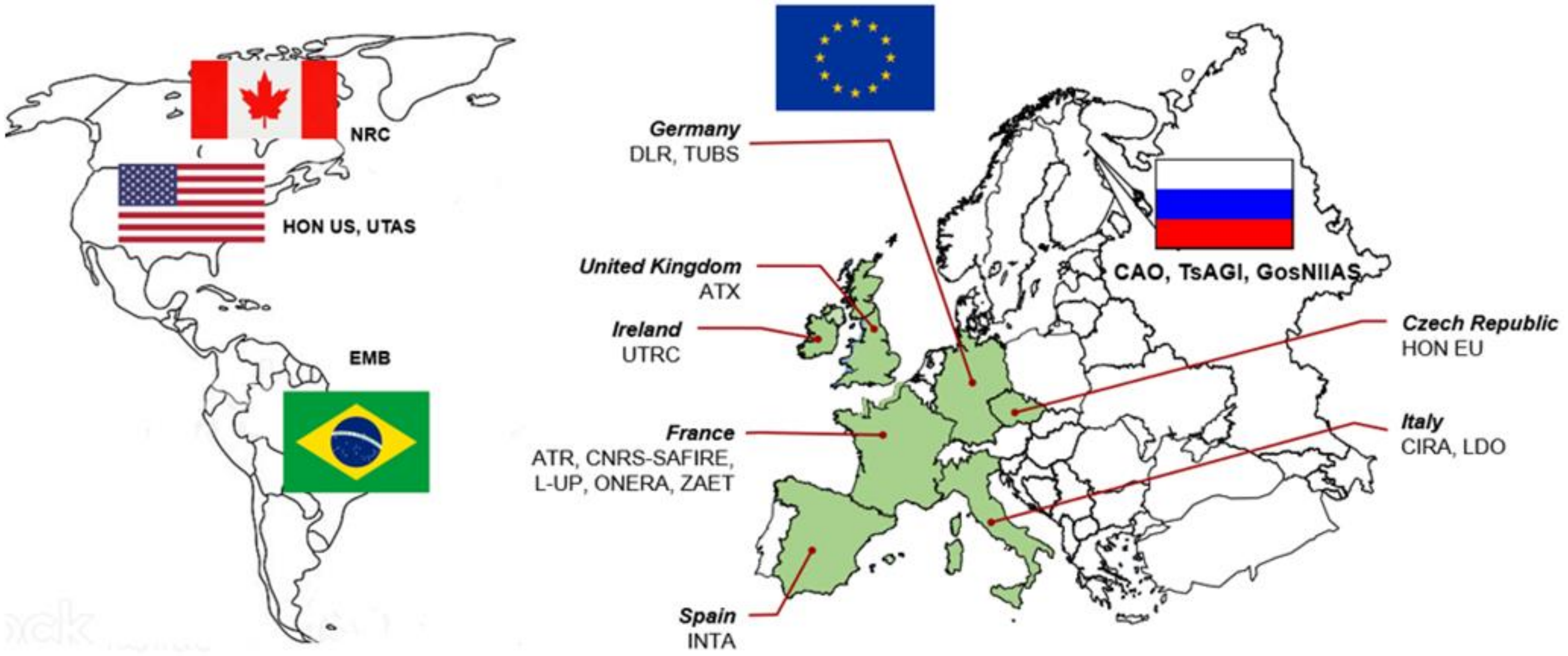
SENS4ICE Project Overview
SENSors and certifiable hybrid architectures for safer aviation in ICing Environment

- JAN 2019 - DEC 2022 (project extension expected)
- Coordinator: DLR
- Budget:
  - total estimated eligible costs 11.9 M EUR
  - max. EU contribution 6.6 M EUR
  - project effort in person-months approx. 1100 PM
- https://www.sens4ice-project.eu
- #sens4iceproject on LinkedIn

SENS4ICE Consortium Partners

1) DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT e.V. (DLR)
2) AVIONS DE TRANSPORT REGIONAL (ATR)
3) AEROTEX UK LLP
4) CENTRAL AEROLOGICAL OBSERVATORY
5) CENTRO ITALIANO RICERCHE AEROSPAZIALI SCPA (CIRA)
6) CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)
7) EMBRAER SA
8) STATE RESEARCH INSTITUTE OF AVIATION SYSTEMS
9) HONEYWELL INTERNATIONAL SRO
10) INSTITUTO NACIONAL DE TECNICA AEROESPACIAL ESTEBAN TERRADAS (INTA)
11) LEONARDO - SOCIETA PER AZIONI
12) L-UP SAS
13) OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES (ONERA)
14) FEDERAL STATE UNITARY ENTERPRISE THE CENTRAL AEROHYDRODYNAMIC INSTITUTE NAMED AFTER PROF. N.E. ZHUKOVSKY (TsAGI)
15) TECHNISCHE UNIVERSITAET BRAUNSCHWEIG
16) RAYTHEON TECHNOLOGIES RESEARCH CENTER
17) SAFRAN AEROTECHNICS
18) HONEYWELL INTERNATIONAL INC
19) COLLINS AEROSPACE
20) NATIONAL RESEARCH COUNCIL CANADA

SENS4ICE international collaboration and cooperation



- InCo – international cooperation flagship: Aviation International Cooperation Flagship "Safer and Greener Aviation in a Smaller World"
- 20 project parties (11 countries)
  - 13 European/7 international
  - 9 research centers, 1 university, 9 industrial partners (OEMs and system developers), 1 consultancy partner
- Advisory Board (9 members)
  - aviation certification authorities (EASA, FAA, ANAC)
  - manufacturing (Bombardier, Gulfstream, Airbus DS, DAHER)
  - research (ITA, NLR)
  - operations (VC - *Vereinigung Cockpit*, German Pilot's Association)
- Coordination with EU icing projects ICE GENESIS and MUSIC-haic

SENS4ICE Goal/ Impact

Problem

- Detect icing conditions (including App. O/ SLD icing) – detection very challenging

Solution

- Hybrid approach – fusion of input data: sensor(s) and indirect detection

Benefits

- Operational benefits:
  - activate anti-/de-icing
  - avoid/ leave icing conditions
- Certification process benefits – flights in App. O/ SLD icing
  - safety risk due to severe and unknown aircraft icing
  - online evaluation of safety margins during flight tests/ certification flights

BACKUP

SENS4ICE
Scope and positioning

- SENS4ICE fills the gap of SLD icing detection (App. O)
  → hybridisation of different detection techniques
- Technology development, test, validation and maturation
  with specific regards to integration of hybrid system architectures
  → TRL 5 of hybrid system at the end of SENS4ICE
- Technology demonstration in relevant icing conditions:
  - icing wind tunnels
  - flight test

  → SENS4ICE will provide large data base of icing conditions
- Close cooperation with regulation authorities
  for development of new certifiable hybrid ice detection system
  → SENS4ICE will provide an acceptable means of compliance

→ SENS4ICE contributes to increase aviation safety in SLD icing conditions

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Expected impact

- Contribute to **increased flight safety**
  by fewer accidents and less in-flight events worldwide
- Contribute to **reduce costs** for all stakeholders
  by improved and internationally accepted certification rules, standards and means of compliance, covering all types of icing hazards
- Contribute to **decrease delays** in operations
  thanks to more efficient avoidance of icing hazards and to fewer damages in need of inspection and repair

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Layered Approach on Ice Detection

SENS4ICE will address this challenge of reliably detecting and avoiding App. O SLD conditions with a unique layered safety approach:

Strategic: flight planning based on **new enhanced weather forecast.**

Tactical: new nowcasting to enhance actual situational awareness in avoidance of hazardous icing conditions.

In situ: new hybrid detection of icing conditions and accretion to trigger IPS and safe exit strategy

Contingency: new detection of reduction in aircraft flight envelope (loss of control prevention)

→ Hybrid ice detection is central technology and key to this approach

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SENSors and certifiable hybrid architectures for safer aviation in ICing Environment
SENS4ICE

WP 1 – Direct and indirect ice detection for App. O
- Task 1.1 – Direct ice detection sensors
- Task 1.2 – Icing wind tunnel testing and evaluation of direct ice detection sensors
- Task 1.3 – Selection of sensor technology for hybridization & airborne demonstration
- Task 1.4 – Indirect ice detection
- Task 1.5 – Remote detection of icing conditions
- Task 1.6 – Maturation of sensor technologies for airborne demonstration

WP 2 – Hybrid ice detection architectures
- Task 2.1 – Hybrid ice detection system specification & requirements
- Task 2.2 – Means of compliance for certification
- Task 2.3 – Ice detection system implementation

WP 3 – Airborne demonstration and atmosphere characterization
- Task 3.1 – Specification for sensor integration
- Task 3.2 – HW and SW integration on ATR platform + flight test preparation
- Task 3.3 – HW and SW integration on EBM platform + flight test preparation
- Task 3.4 – Airborne demonstration in natural icing with ATR platform
- Task 3.5 – Airborne demonstration in natural icing with Embraer platform
- Task 3.6 – Flight test in natural icing with Yak-42 D platform
- Task 3.7 – Atmosphere characterization

WP 4 – Technology evaluation
- Task 4.1 – Individual technology evaluation and roadmap for future developments
- Task 4.2 – Evaluation of hybrid ice detection
- Task 4.3 – Overall evaluation of flight test campaigns
- Task 4.4 – Evaluation of project developments and results

WP 5 – Project management and international cooperation
- Task 5.1 – Project progress monitoring and interfacing with international partners
- Task 5.2 – Administrative, financial and quality management

WP 6 – Communication, dissemination and exploitation
- Task 6.1 – Dissemination activities and Action Plan
- Task 6.2 – Communication
- Task 6.3 – IPR, exploitation and certification

Technical Work Packages Interrelation

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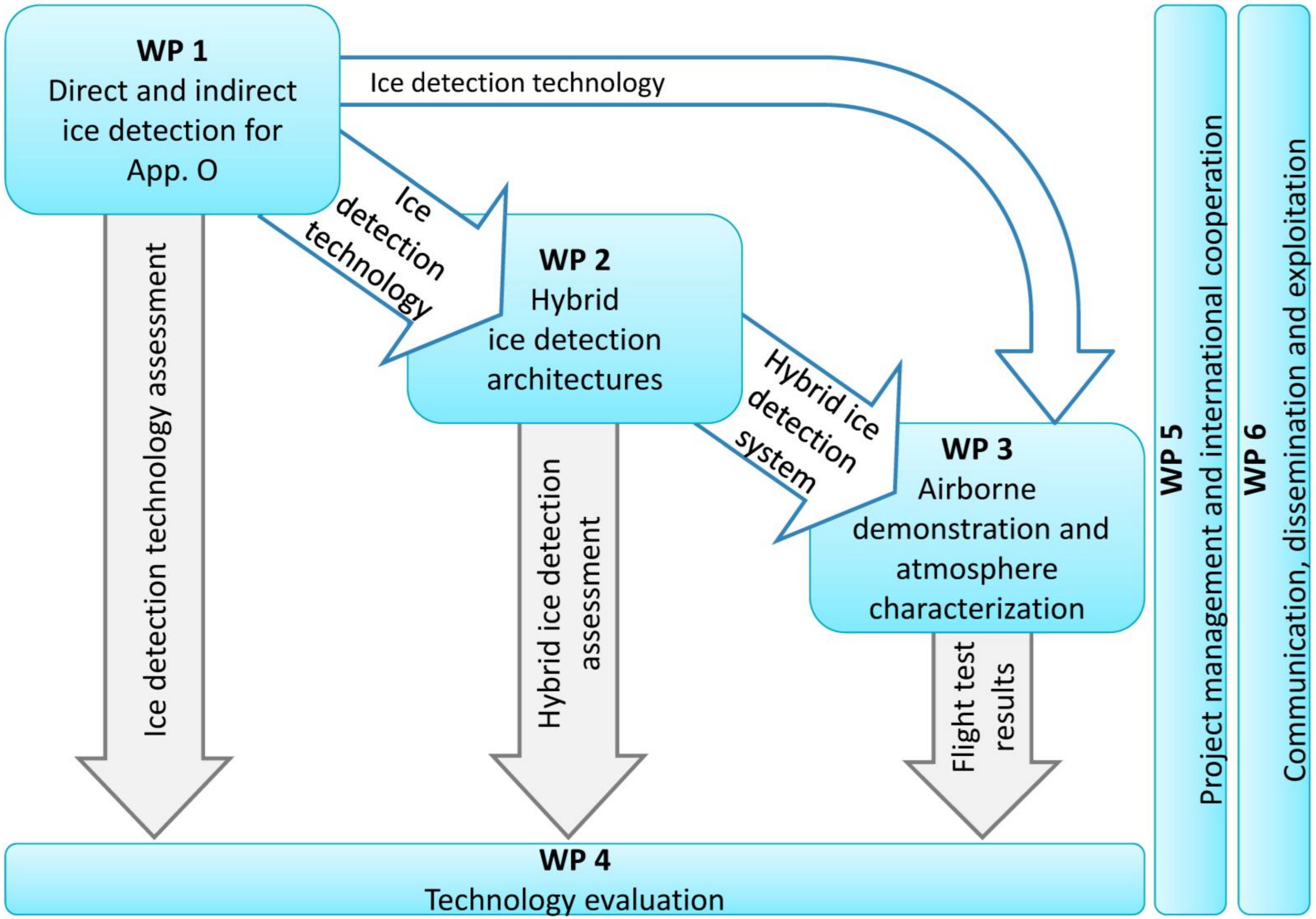
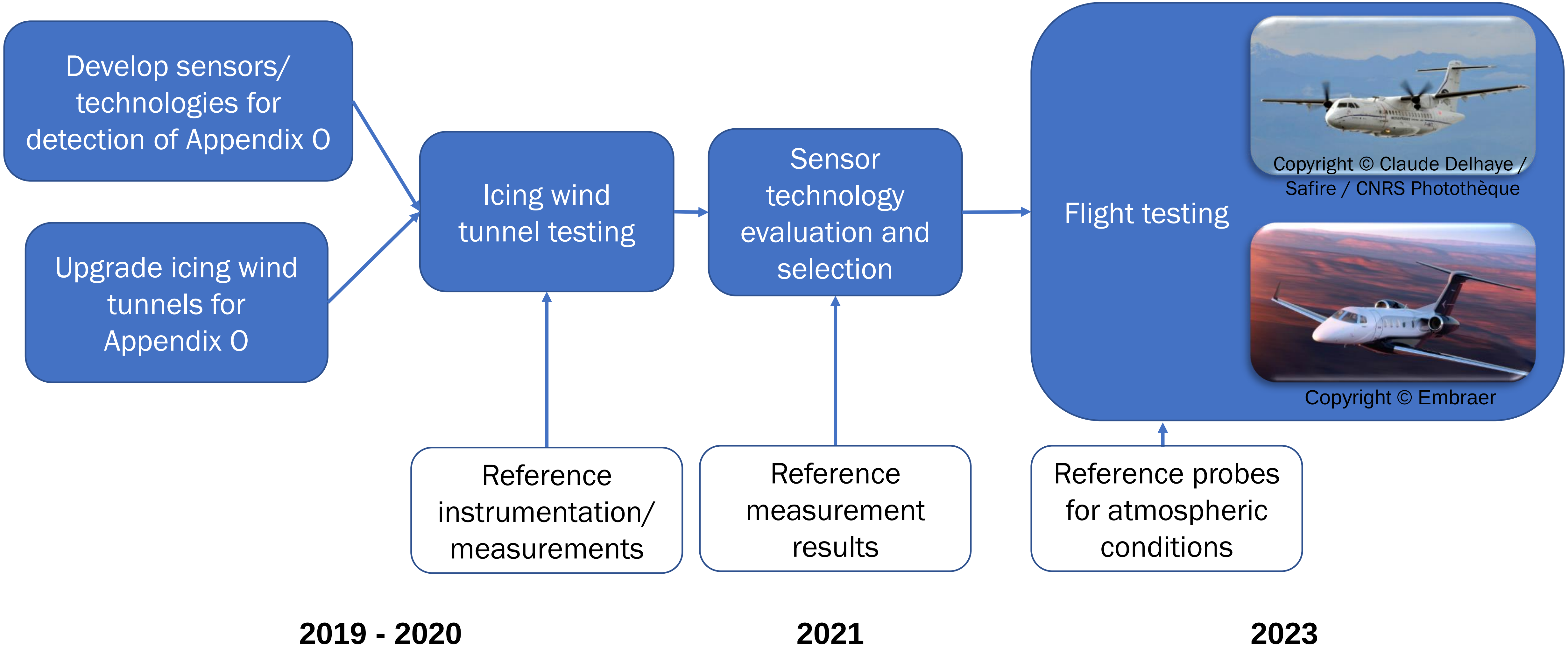


SENS4ICE Timeline



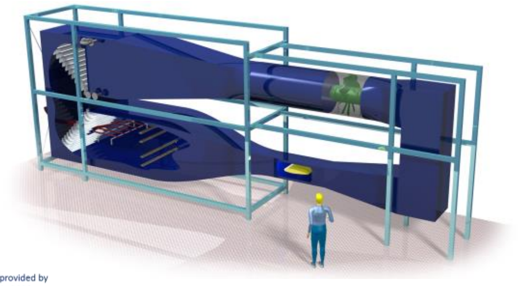
WP1: Direct and indirect ice detection for App. O High Level Objectives

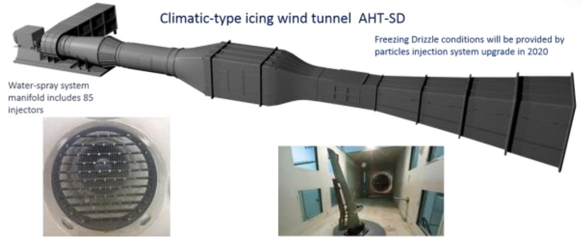
Main Objective: Develop technologies capable of detecting App. O icing conditions using a three-pronged approach:

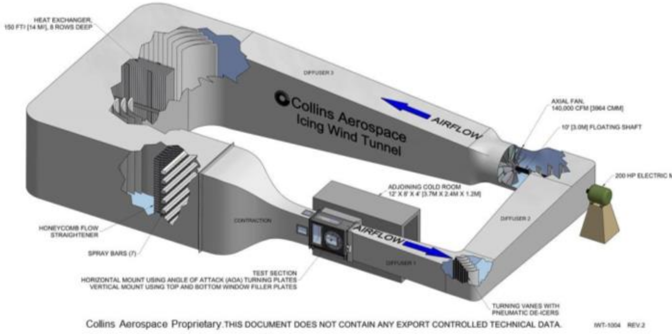
- Direct detection: development of *in situ* sensors capable of ice detection
  - 10 technologies under EU-funded development representing a variety of physical detection principles
  - Evaluation in icing wind tunnel tests under simulated App. O conditions – four tunnel facilities/total of 28 weeks testing time
  - Two-stage evaluation/selection process to ensure most promising sensors advance to flight test (WP3)
- Indirect detection: utilising existing sensor information and aircraft performance reference data for early detection of airframe icing
- Remote detection: development of methods to detect App. O conditions before the aircraft enters the hazard area
  - Detection and Nowcasting: development of algorithms that combine meteorological factors retrieved from satellite data to detect and forecast (very short-term range) icing threats in App. O conditions
  - Polarimetric weather radar: development of algorithms to classify icing threats and identify App. O conditions

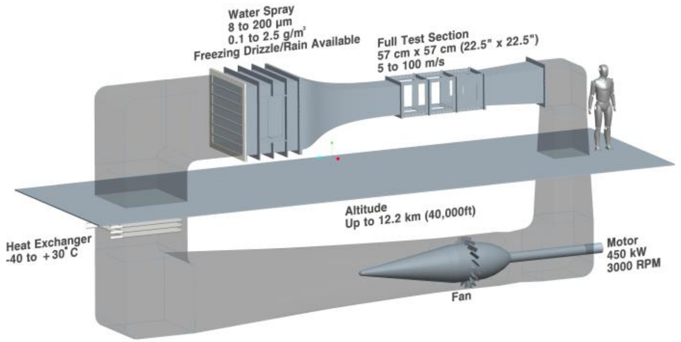
SENS4ICE research facilities: Icing Wind Tunnels

- TU Braunschweig
  - SLD capabilities available and enhanced during SENS4ICE
- TsAGI AHT SD and EU-1:
  - SLD capabilities developed during SENS4ICE
- Collins Aerospace
  - SLD capabilities available and enhanced during SENS4ICE
- National Research Council Canada
  - SLD capabilities available during SENS4ICE
- Total testing time: 28 weeks
- Planned time frame: NOV 2020 – MAR 2021



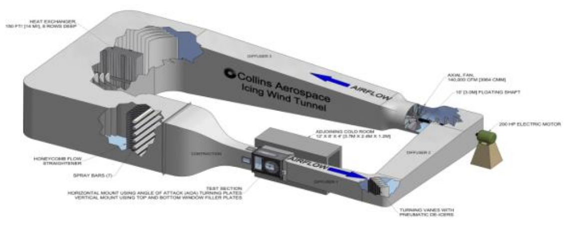






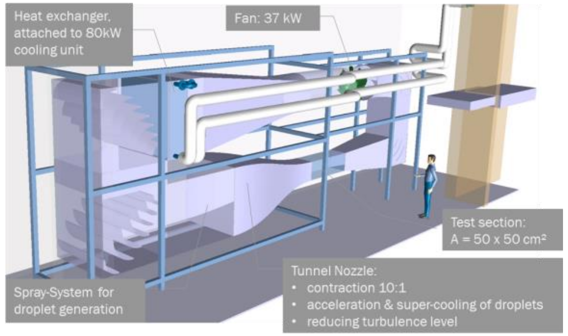
Overview of SENS4ICE IWT Capabilities

Collins Aerospace, USA



- 5-147 micron droplets
- LWC between 0.1 and 3 g/m3
- Temperature 0°C to -30°C
- Sustained speed 13-103 m/s
- Test section: 152×56×112 cm3
- Calibrated per SAE ARP 5905
- Compliant with AS9100C
- Controls and power supplies can simulate aircraft controls

TU Braunschweig, Germany

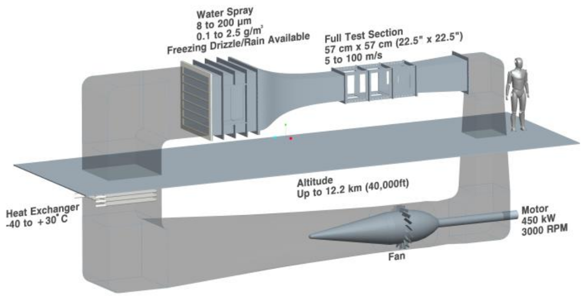


- MVD 9-60 micron droplets
- LWC between 0.1 and 1.5 g/m3
- Temperature 30°C to -20°C
- Sustained speed 10-40 m/s
- Test section: 150×50×50 cm3
- Calibrated per SAE ARP 5905
- Short spray transients ~ 15s
- Bi-modal SLD and mixed phase capability

TsAGI, Russia

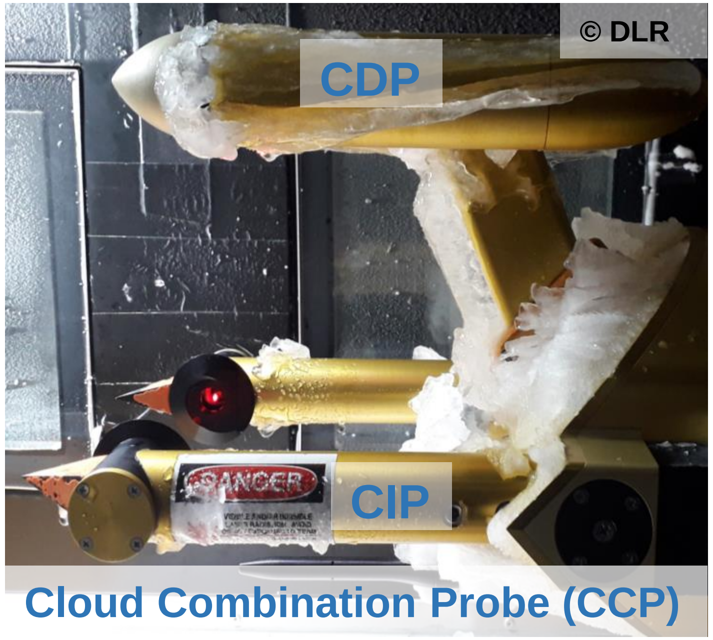
- 10-90 micron droplets
- LWC between 0.5 and 6 g/m3
- Temperature down to -40°C
- Sustained speed up to 150 m/s
- Test section: 300×100×100 cm3
- PDI Artium 2D PSD calibration
- LWC calibration with EIV-2K
- High speed camera with long-focus microscope

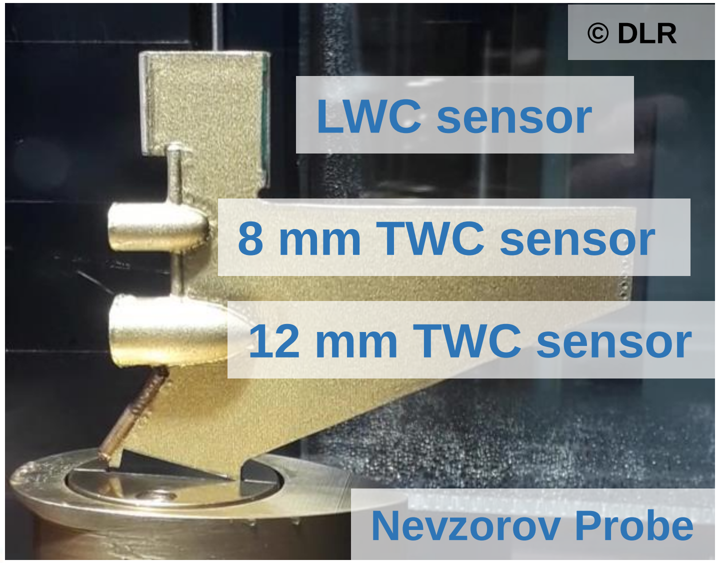
NRC, Canada



- 8-200 micron droplets
- LWC between 0.1 and 2.5 g/m3
- Supercooled Water: 10 to > 200 µm (incl. SLD bi-modal)
- Temperature +30°C to -40°C
- Sustained speed 5-100 m/s
- Test section: 57×57 cm2 (52x33 cm2 with insert)
- Sea level < Altitude < 40,000ft
- Calibrated per SAE ARP 5905

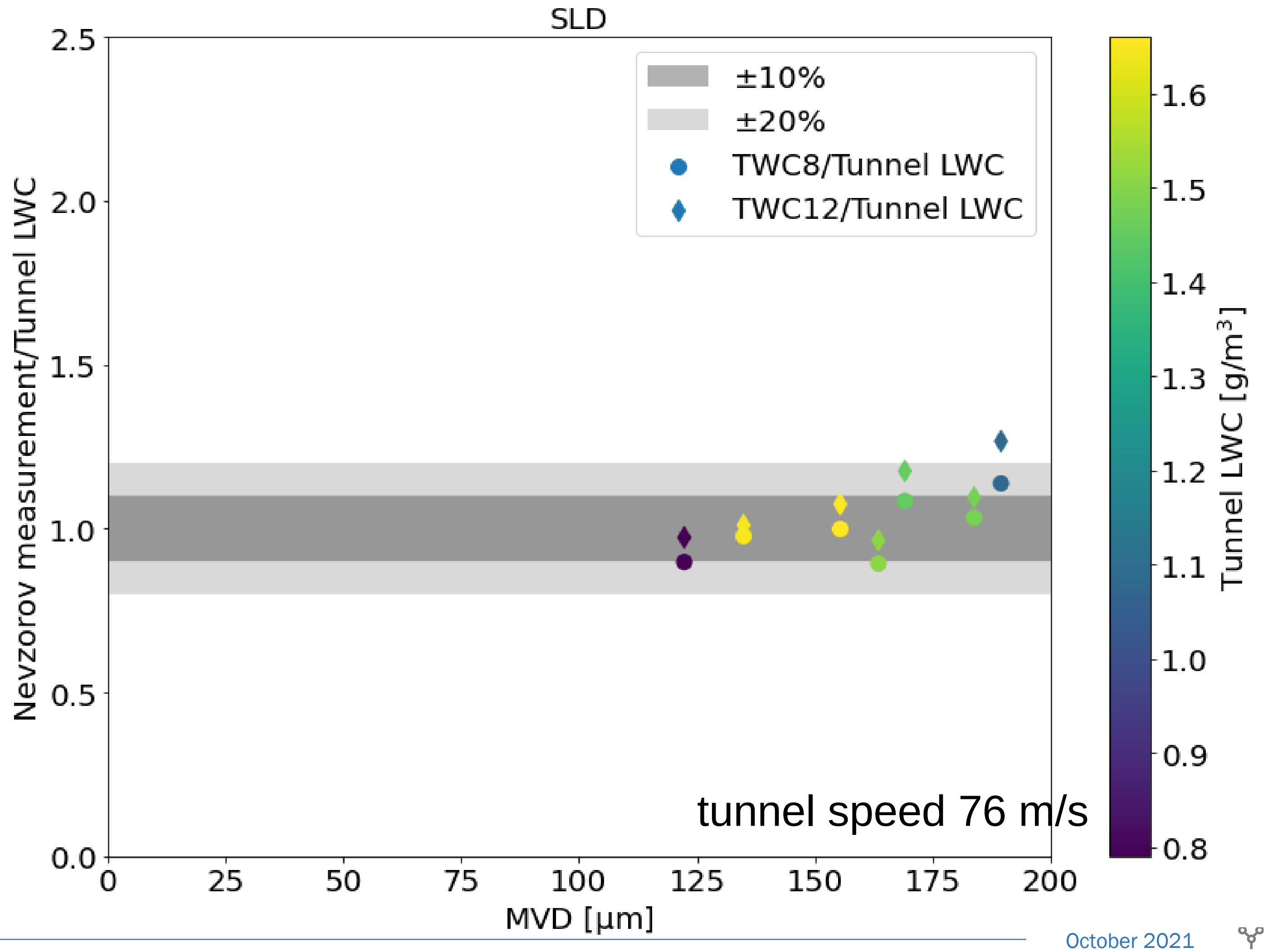
Reference Instrumentation & Measurements





Reference measurements (Nevzorov probe) in SLD conditions

- generally good agreement with tunnel LWC data (SEA probe)
- for MVDs < 180 um, Nevzorov and SEA probe agree within 20%



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WP2: Hybrid Ice Detection

Robust Hybrid Ice Detection:

different techniques for **direct sensing** of atmospheric conditions and/or ice accretion

+

indirect techniques to detect change of aircraft characteristics with ice accretion on airframe

Development, test, validation and maturation of different technologies for

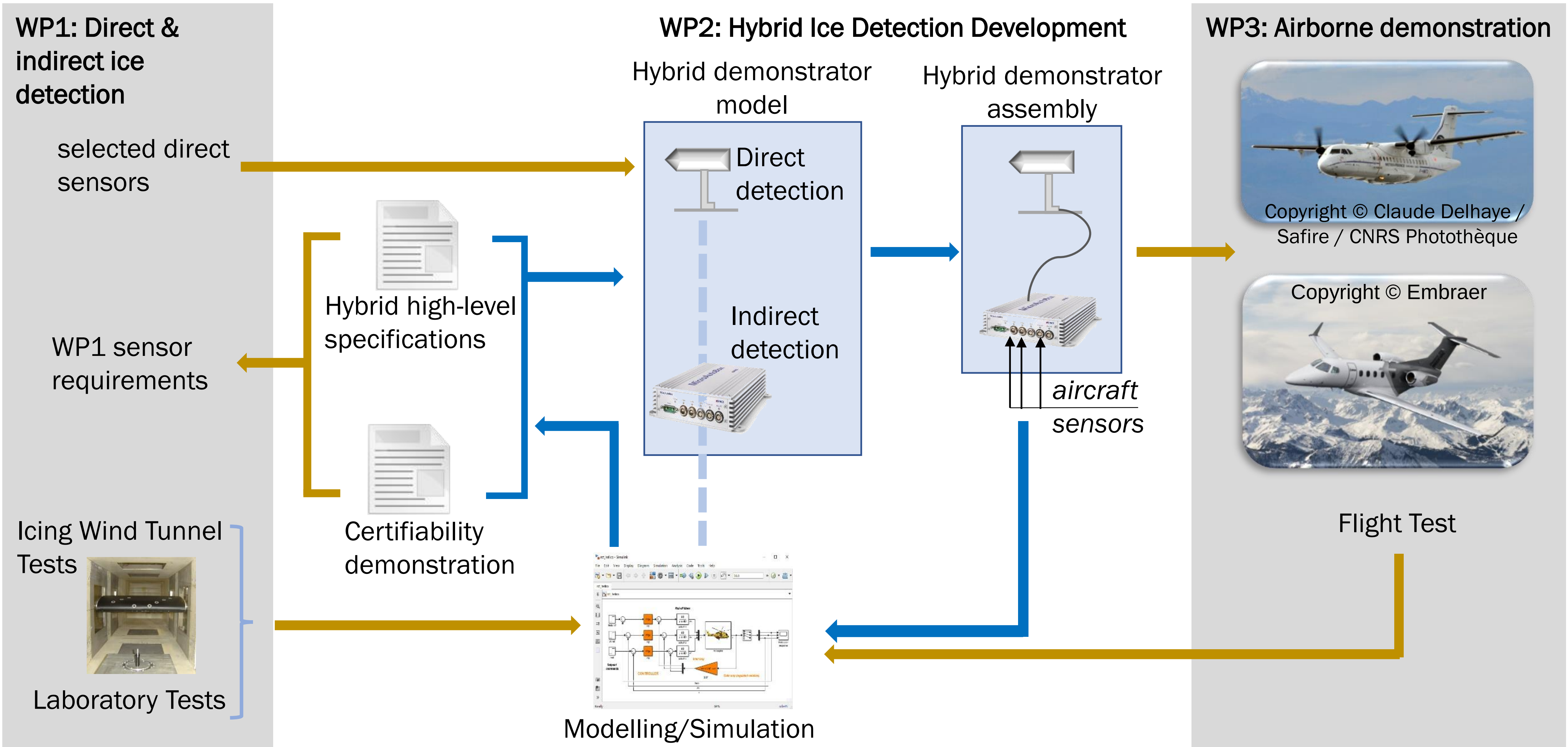
- direct ice detection
- indirect ice detection

Objectives for hybrid ice detection

1. Hybrid ice detection system specification
2. Certification programme for hybrid ice detection system
3. Hybrid ice detection system modelling
4. Hybrid ice detection design, build & assembly (+ TRL 5 review)

in **close cooperation with OEMs and certification authorities** during SENS4ICE

WP2: Hybrid Ice Detection – Development Workflow



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WP3: Airborne demonstration and atmosphere characterisation

dedicated to airborne technology demonstration in relevant icing conditions

Objectives

- Issue main requirements and constraints
  for integration of sensors and probes on flight test platforms
- Release flight test program
  for testing new individual and hybrid technologies in distinct icing conditions
- Perform airborne demonstration in natural icing conditions:
  - in Europe with CNRS/SAFIRE ATR-42
  - in North America with Embraer Phenom 300
  - in Russia with Yak-42D "Roshydromet"
- Characterisation of atmosphere from flight test campaigns in App. O conditions

Guidance by special Flight Test Committee (FTC) formed by platform providers and leaders of WP1, WP2 and WP4 to ensure harmonised preparation and execution of individual flight test campaigns

SENS4ICE research facilities:
Flight Test Platforms

- total flight test time: 125h in natural icing conditions
- planned main time frame: Q1/2022 *(delays due to Covid-19)*

SAFIRE ATR-42

Copyright © SAFIRE/JC Canonici

Embraer Phenom 300

Copyright © Embraer

CAO Yak-42D Roshydromet

Copyright © TsAGI/CAO

SENS4ICE Timescale (simplified Gantt – original/ 4 years)

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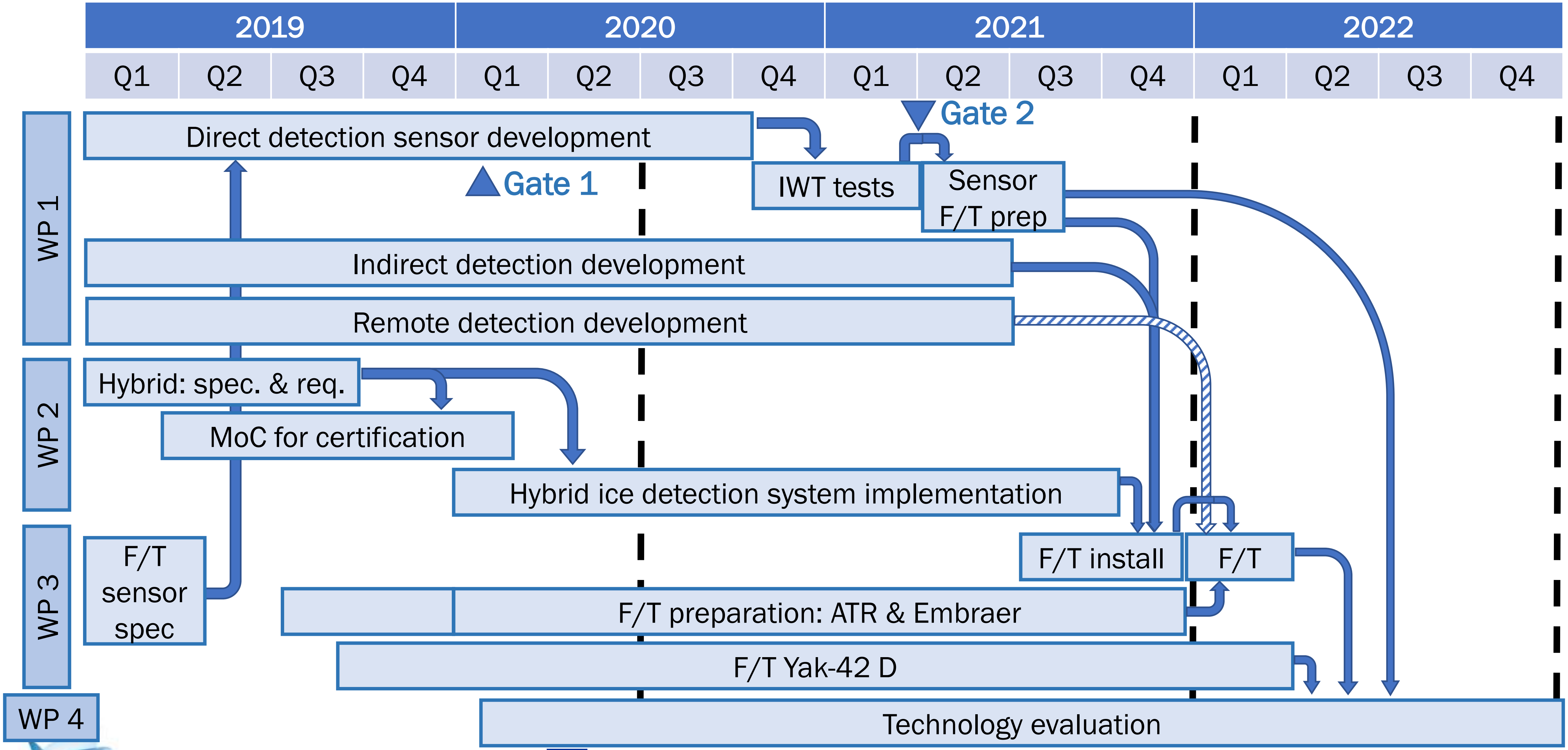
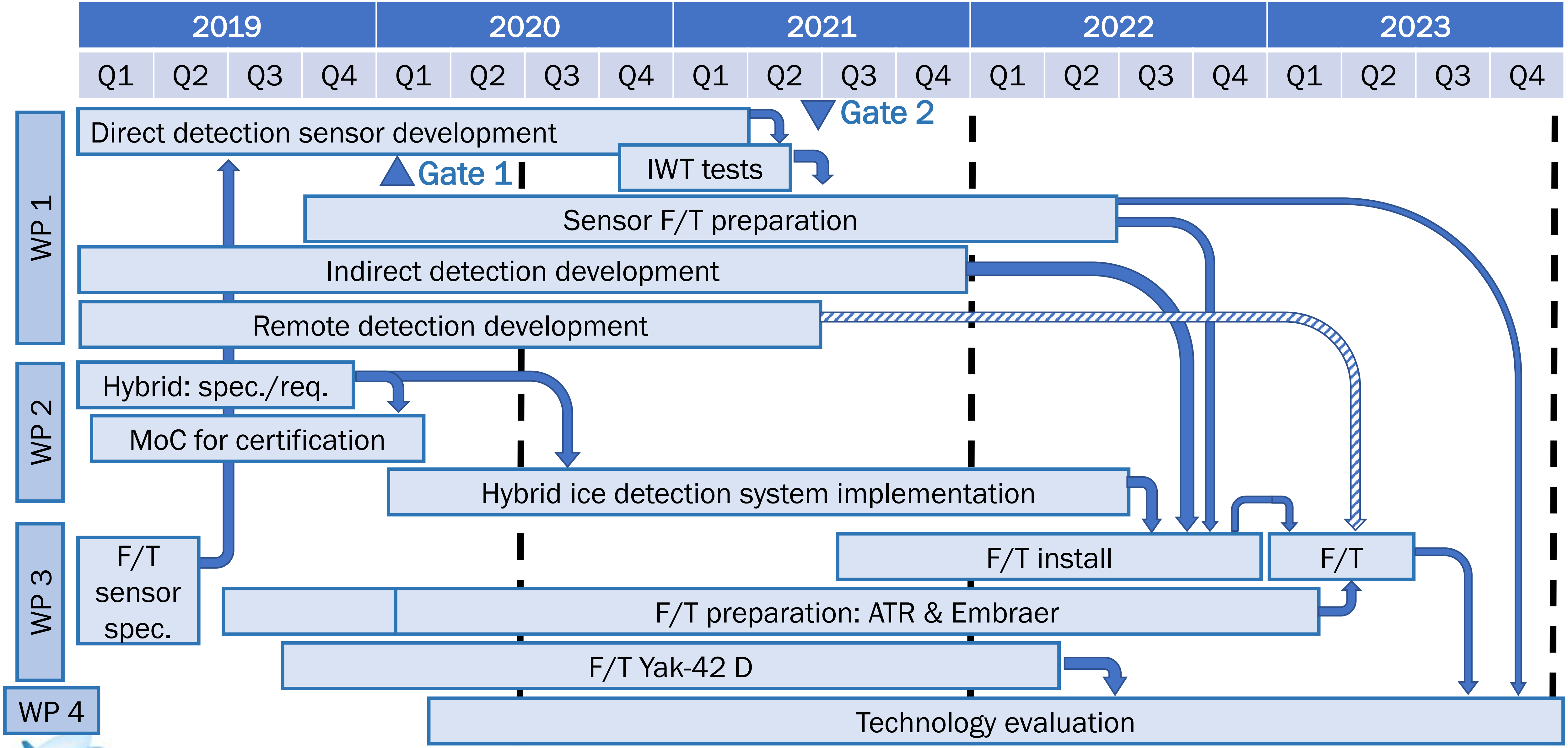


SENS4ICE Timescale (simplified Gantt – extended/ 5 years)



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