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

A project midterm overview

Carsten Schwarz – DLR Institute of Flight Systems

6th International Conference "Prospects of Civil Avionics Development", online / Moscow, Russia, GosNIIAS, July 22, 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)
(Calendar, add dates)

侉 Coordinator: DLR
(Calendar, add names)

侉 Budget:
(Calendar, add numbers)
- max. EU contribution: 6.6 M EUR
- total estimated eligible costs: 11.9 M EUR
- project effort in person-months approx.: 1100 PM

(Calendar, add projects)

(Calendar, add websites)

(Calendar, add social media)

(Calendar, add dates)

(Calendar, add places)

(Calendar, add names)

(Calendar, add projects)

(Calendar, add websites)

(Calendar, add social media)
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 AEREOESPACIAL 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 UNIVERSITAT BRAUNSCHWEIG
16) RAYTHEON TECHNOLOGIES RESEARCH CENTER
17) SAFRAN AEROTECHNICS
18) HONEYWELL INTERNATIONAL INC
19) COLLINS AEROSPACE
20) NATIONAL RESEARCH COUNCIL CANADA

SENS4ICE, EU-funded project, Grant Agreement No 824253

July 2021
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
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:
  - testing facilities
  - 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
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.
SENS4ICE will address this challenge of reliably detecting and avoiding App. O SLD conditions with a unique layered safety approach:

- **Hybrid ice detection** is central technology and key to this 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.
Technical Work Packages Interrelation

WP 1: Direct and indirect ice detection for App. O

WP 2: Hybrid ice detection architectures

WP 3: Airborne demonstration and atmosphere characterization

WP 4: Technology evaluation

WP 5: Project management and international cooperation

WP 6: Communication, dissemination and exploitation
SENS4ICE Timeline

Develop sensors/technologies for detection of Appendix O

Upgrade icing wind tunnels for Appendix O

Icing wind tunnel testing

Sensor technology evaluation and selection

Flight testing

Reference instrumentation/measurements

Reference measurement results

Reference probes for atmospheric conditions

2019 - 2020

2021

2023
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
- 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 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%.
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

WP1: Direct & indirect ice detection
- selected direct sensors
- WP1 sensor requirements
- Icing Wind Tunnel Tests
- Laboratory Tests

WP2: Hybrid Ice Detection Development
- Hybrid high-level specifications
- Certifiability demonstration
- Modelling/Simulation

WP3: Airborne demonstration
- Hybrid demonstrator model assembly
- Hybrid demonstrator model
- Flight Test

Copyright © Claude Delhaye / Safire / CNRS Photothèque
Copyright © Embraer
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
Embraer Phenom 300
CAO Yak-42D Roshydromet

Copyright © SAFIRE/JC Canonici
Copyright © Embraer
Copyright © TsAGI/CAO
SENS4ICE Timescale (simplified Gantt – original/ 4 years)

<table>
<thead>
<tr>
<th></th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Direct detection sensor development

Gate 1

Indirect detection development

Sensor F/T prep

Remote detection development

IWT tests

Hybrid: spec. & req.

MoC for certification

Hybrid ice detection system implementation

Gate 2

F/T prep

F/T Yak-42 D

F/T install

F/T

F/T preparation: ATR & Embraer

Technology evaluation

July 2021
This project has received funding from European Union’s Horizon 2020 research and innovation programme under grant agreement n° 824253.

https://www.sens4ice-project.eu

https://www.linkedin.com/company/sens4ice-project