SENS4ICE

SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES
FOR SAFER AVIATION IN ICING ENVIRONMENT

Hybrid Icing Detection: study and demonstration

SAE Symposium

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Three main topics to be addressed in the project SENS4ICE:

1. Hybrid ice detection system specification

2. Certification programme for hybrid ice detection system

3. Hybrid ice detection system modelization, design & assembly

1. Hybrid ice detection system specification
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HIDS specifications

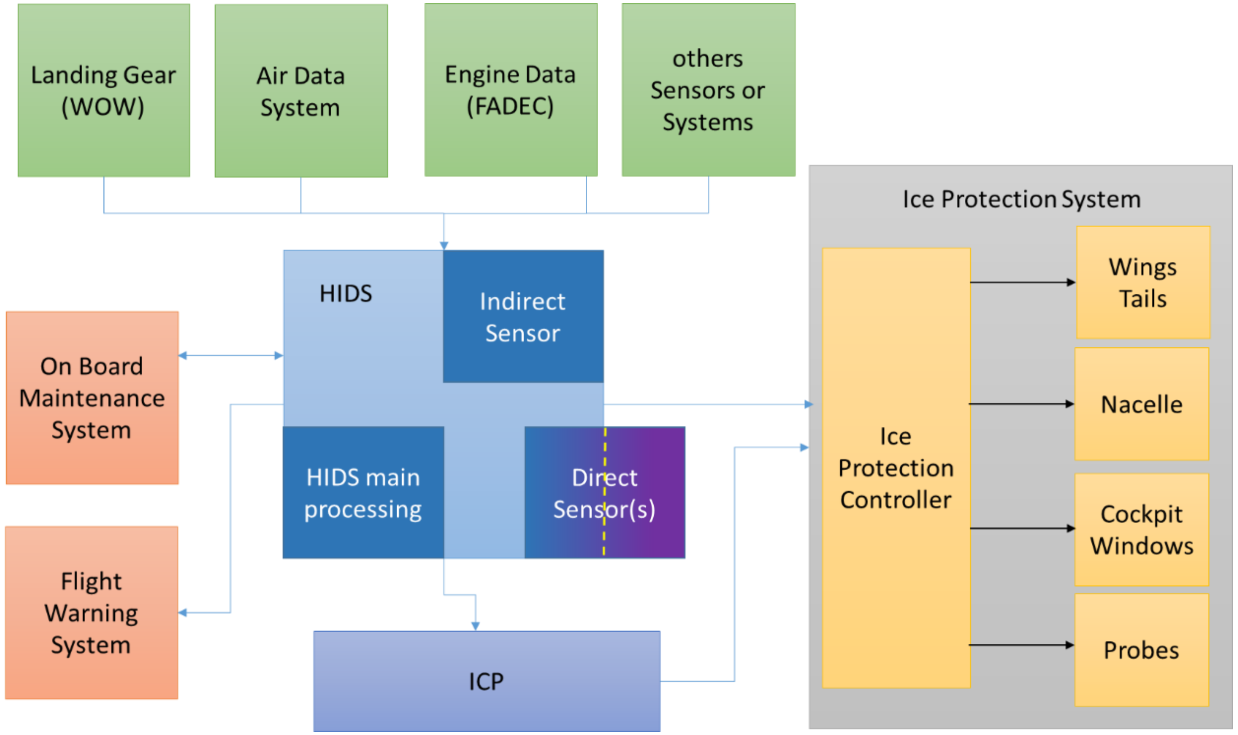
Hybrid ice detection architectures specification & requirements

The purpose of the HIDS technical specification is to provide the requirements of the Hybrid System in terms of functionality and system architecture to meet the terms of the desired assurance level.
Leonardo has been responsible for collecting:

- Definition of HIDS requirements for generic platform (environmental, electrical, interface)
- Definition of sensor location requirements
- Data to be recorded

The modifications shall not jeopardize ice protection certification following App. C or the equivalent Ice envelope.

HIDS specifications



Ice Protection System architecture for PRIMARY HIDS

The HIDS includes direct sensor(s) combined with indirect techniques in which the change of aircraft characteristics with ice accretion on the airframe is detected.

The direct sensor(s) can be a sensor detecting atmospheric conditions and/or ice accretion on the airframe.

Figure above illustrates the concept of the HIDS with a high-level system architecture – in this case, the HIDS is acting as a primary ice detection system and directly interacts with the ice protection system.

HIDS specifications

Following main concepts have been included and covered with Technical Specification:

- Interface identification- Input/Output Signal
- System Architecture
- Main Function Overview such as:
    - ✓ Measure condition or/and accretion of ice (sensor reading, …)
    - ✓ Detect condition or/and accretion of ice (indirect and direct sensors processing, …)
    - ✓ Possible discrimination between Appendix C and Appendix O icing conditions
    - ✓ Internal management (internal states and modes, NVM…)
    - ✓ Providing information to the Ice Protection System for the activation/deactivation and control of the de-icing systems
    - ✓ Communications (digital bus, discrete Input/output)
    - ✓ Advise the pilot and the Ice Protection Controller with warning messages in case of any system component failure/registered problem
    - ✓ Advise if any software update is available
    - ✓ Arbitration in case of conflict between Direct and Indirect detection
- Requirements for HIDS Operational Envelope
- Physical Requirements : Structure Interface/System Interface & Installation
- Qualification

HIDS specifications

<u>The HIDS can be described as a hybridization of 3 domains:</u>

- ✓ The direct ice sensor(s) measure icing conditions or ice accretion.
- ✓ The indirect ice sensors available on the A/C system which allow to measure in-flight A/C main parameters.
- ✓ The HIDS calculator, hosting the processing unit which will check A/C main parameters degradation during flight and correlate this information with (potential) icing of the A/C surfaces.
- ✓ The arbitration function inside the calculator will provide a validated alert to the pilot (or directly to a de-icing system).

1. Hybrid ice detection system specification
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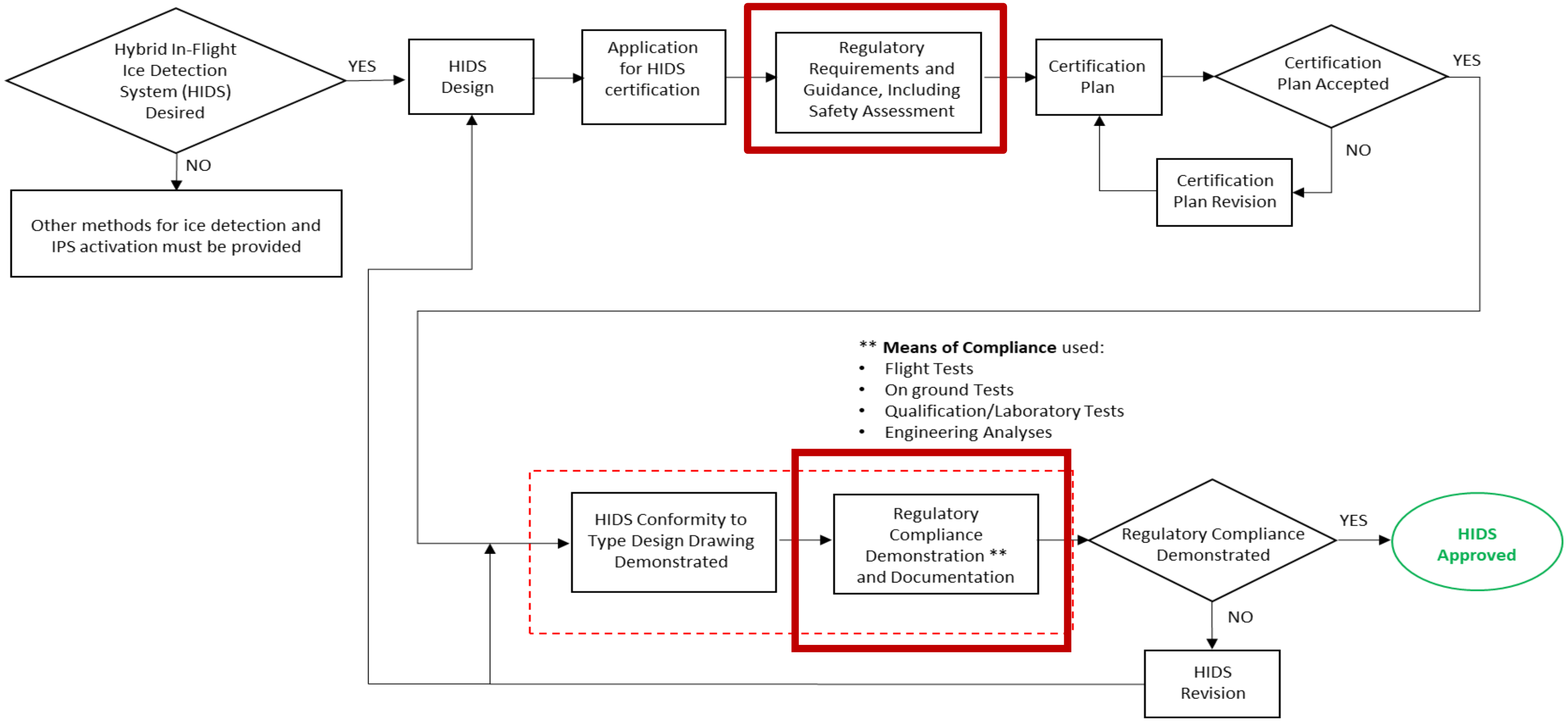
HIDS certification process

Main task objectives

- To define guideline for future HIDS certification
- To identify possible certification issues and showstoppers



HIDS as a **primary** and **automatic** system (DAL A) for future commercialisation

- more robust and accurate detection based on dissimilarity (direct and indirect detections)
- improving detection in Appendix O
- increasing flight safety by proving a continuous monitoring on A/C performances

Within the SENS4ICE project, it was decided to focus the maturation of such a new ice detection approach on **fixed-wing aircraft**

- CS-25/14 CFR Part 25
- CS-23/14 CFR Part 23
- 14 CFR Part 121

HIDS certification basis and Means of Compliance

	Means of compliance									
Regulations	MOC0	MOC1	MOC2	MOC3	MOC4	MOC5	MOC6	MOC7	MOC8	MOC9
CS-25/ 14CFR Part25										
§ 25.863		x						x		x
§ 25.869(a)		x						x		x
§ 25.1301		x						x	x	x
§ 25.1302		x						x		
§ 25.1309	x	x		x		x	x	x		
§ 25.1322		x			x			x		
§ 25.1324	x				x		x			
§ 25.1326		x			x		x	x		
§ 25.1353		x	x				x			x
§ 25.1355		x	x				x			x
§ 25.1357		x	x				x			x
§ 25.1363		x	x				x			x
§ 25.1419(e),(g),(h)		x			x		x	x	x	
§ 25.1420		x			x		x	x	x	
§ 25.1585(a)		x		x						
Subpart H		x		x				x		
CS-23/ 14CFR Part23										
§ 23.1301		x						x	x	x
§ 23.1309(b)(c)(e)	x	x		x		x	x	x		
§ 23.1365		x	x				x			x
§ 23.1419(d)		x			x		x	x	x	
§ 23.1585(j)		x		x						
14CFR Part 121										
§ 121.321		x								

MOC list from *AMC and GM to Part 21*:

MOC0: compliance statement, design documents …
MOC1: design review
MOC2: calculation analysis
MOC3: safety assessment
MOC4: laboratory tests (IWT)
MOC5: ground tests
MOC6: flight tests
MOC7: design inspection
MOC8: simulation
MOC9: equipment qualification

HIDS certification issues

Issues for certification in Appendix O conditions

- Low probability to find Appendix O conditions during flight tests
- Actual lack of engineering tools (IWT, laboratory tests and simulations) to reproduce all Appendix O environment
- Validation of detection in Appendix O conditions
  - Appendix O reference probes do not meet ED-103revA standards

Issues for demonstrating MoC for Indirect Detection

- Definition of an accurate clean model
- AMC 25.1419 (d) Ice Detection, Compliance with CS 25.1419(e)(1) and 25.1419(e)(2)
  - How to demonstrate that the indirect method detects *"the presence of icing conditions or actual ice accretion under all atmospheric conditions defined in the relevant icing environment"* ?
  - How to define minimum and maximum detectability thresholds for indirect detection?
  - Only available MoC are Flight Tests: more certification effort will be required

HIDS possible issues

- Arbitration function shall take into account all the possible operation scenarios

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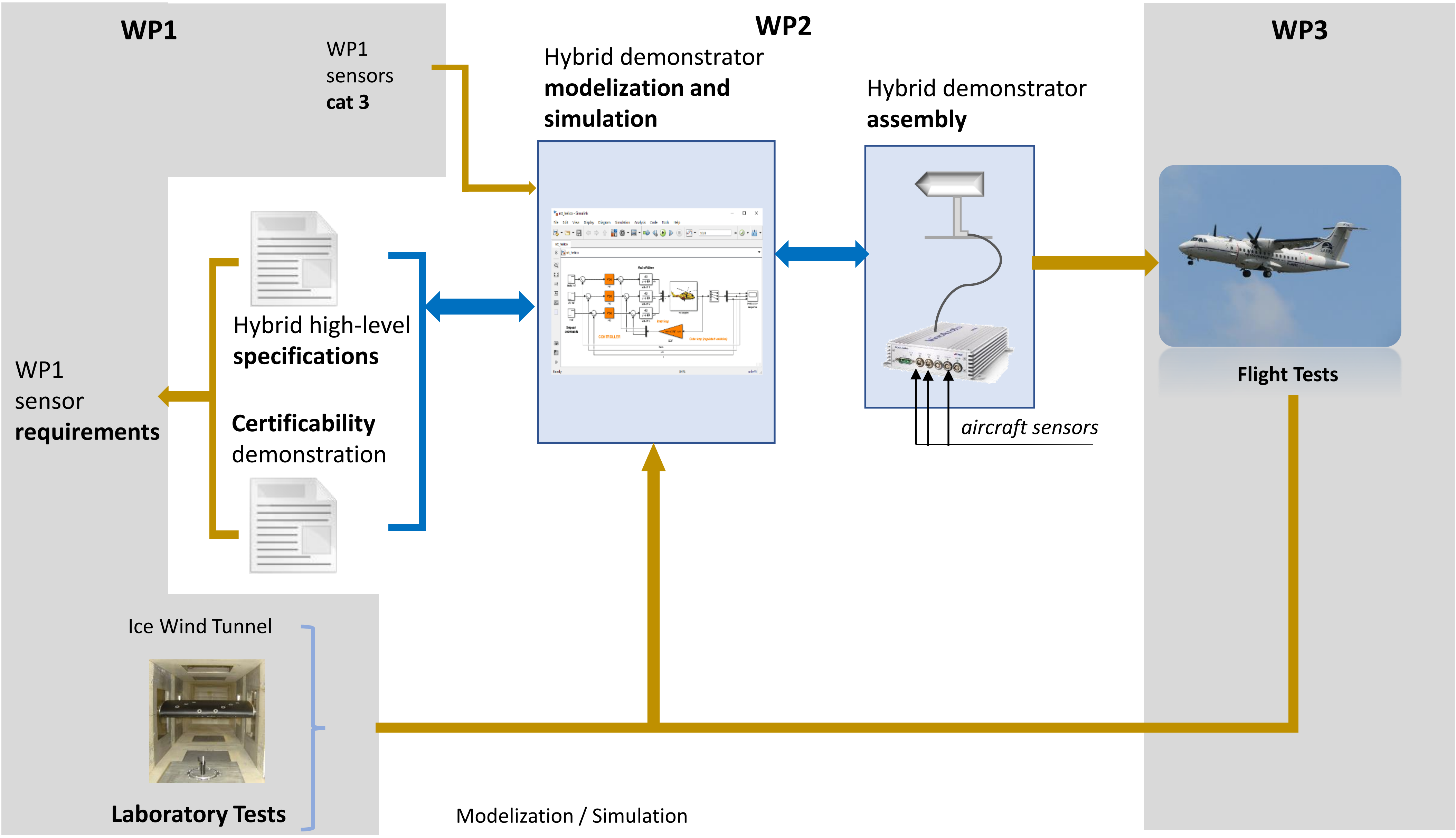
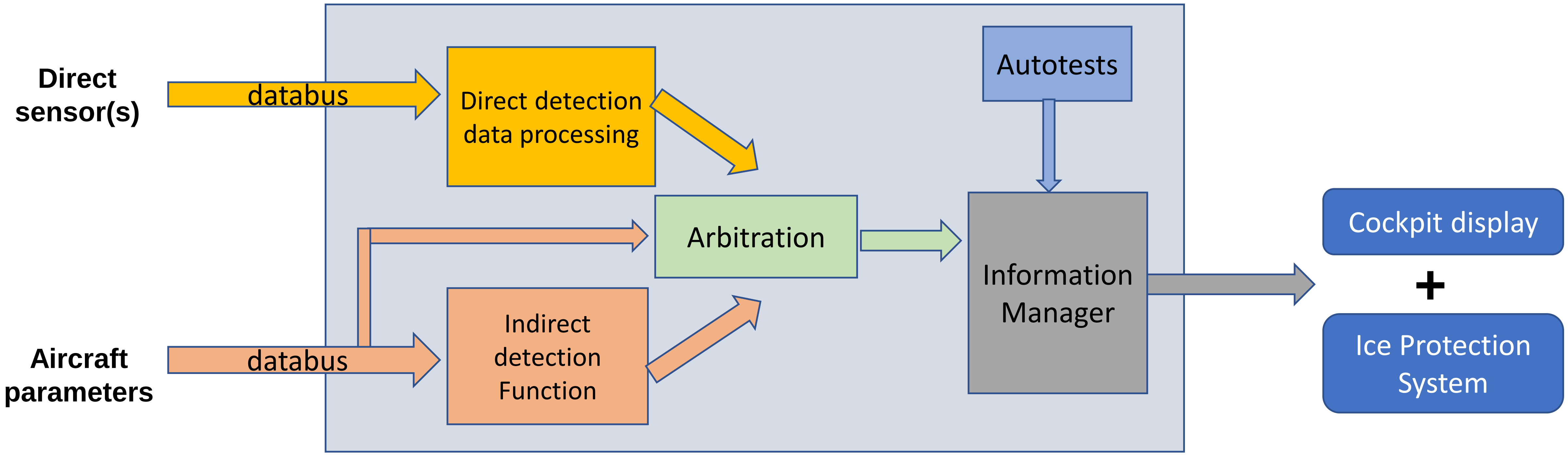
SENS4ICE WP2- workflow



HIDS architecture



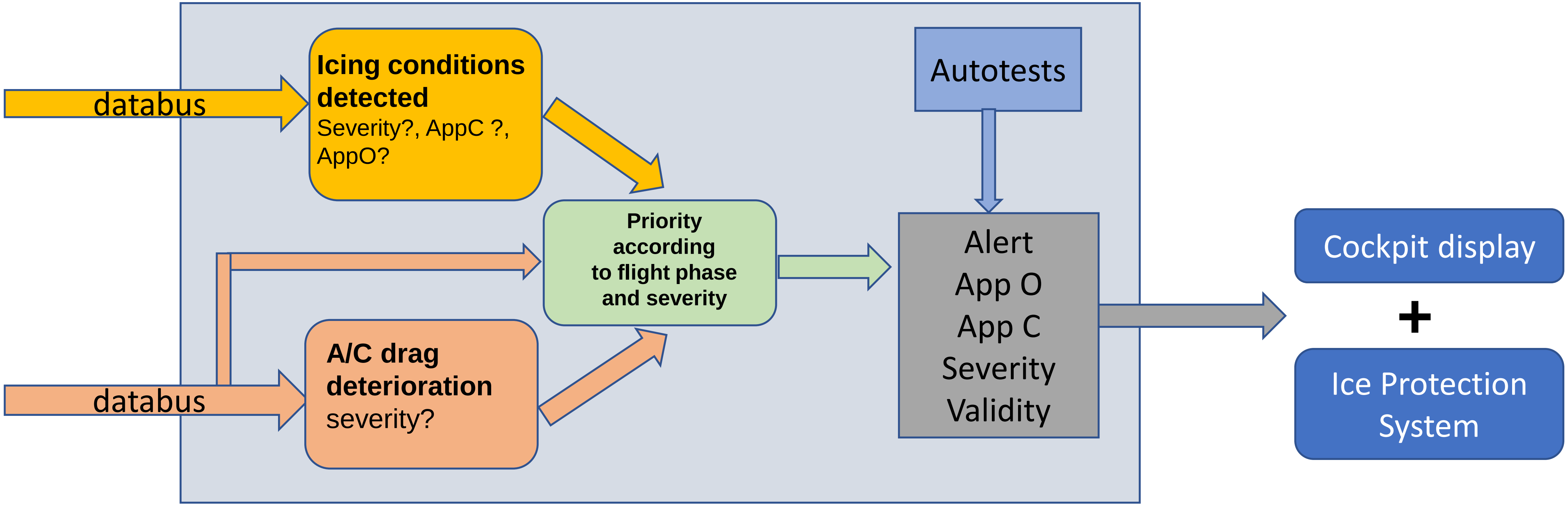
HIDS data

Direct Sensor(s)

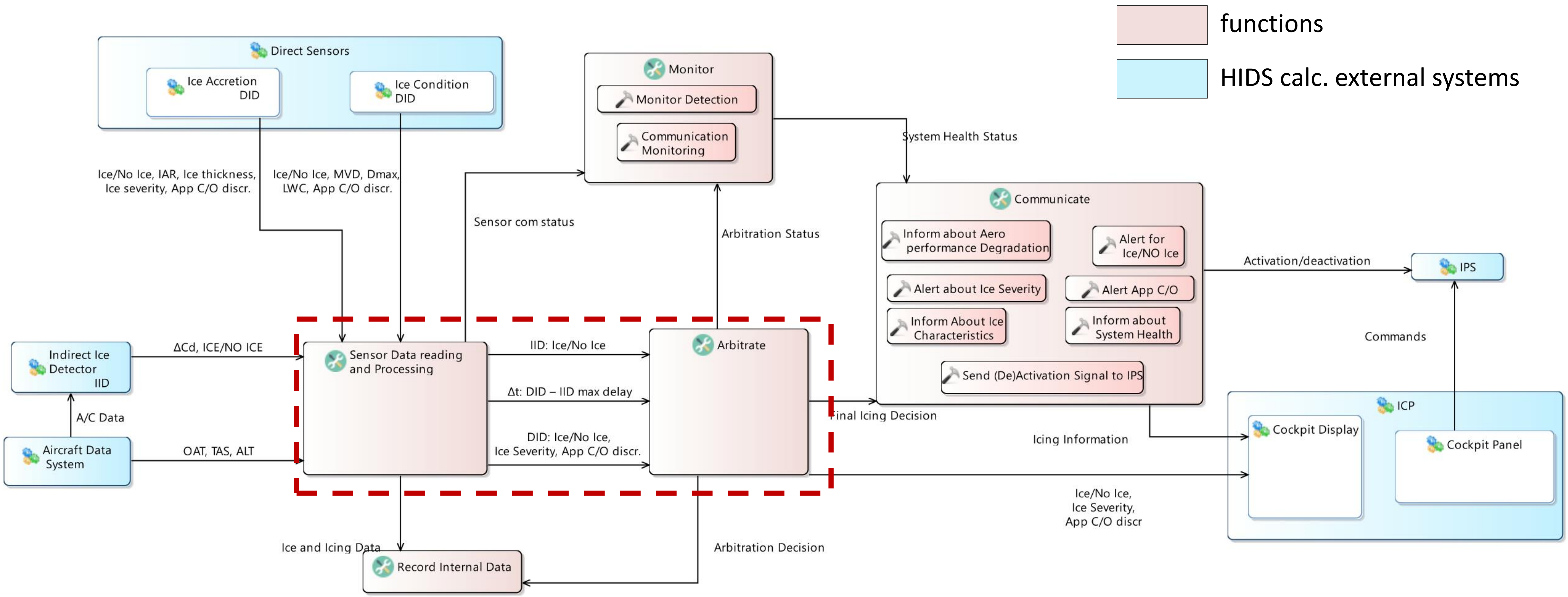
MVD
LWC
Ice thickness
Ice detection
App O detection
App C detection
TAT
Acretion rate

Aircraft parameters

Altitude
Pressures
Speeds
Angle of Incidence
Engine RPM



SENS4ICE WP2- System Modelization

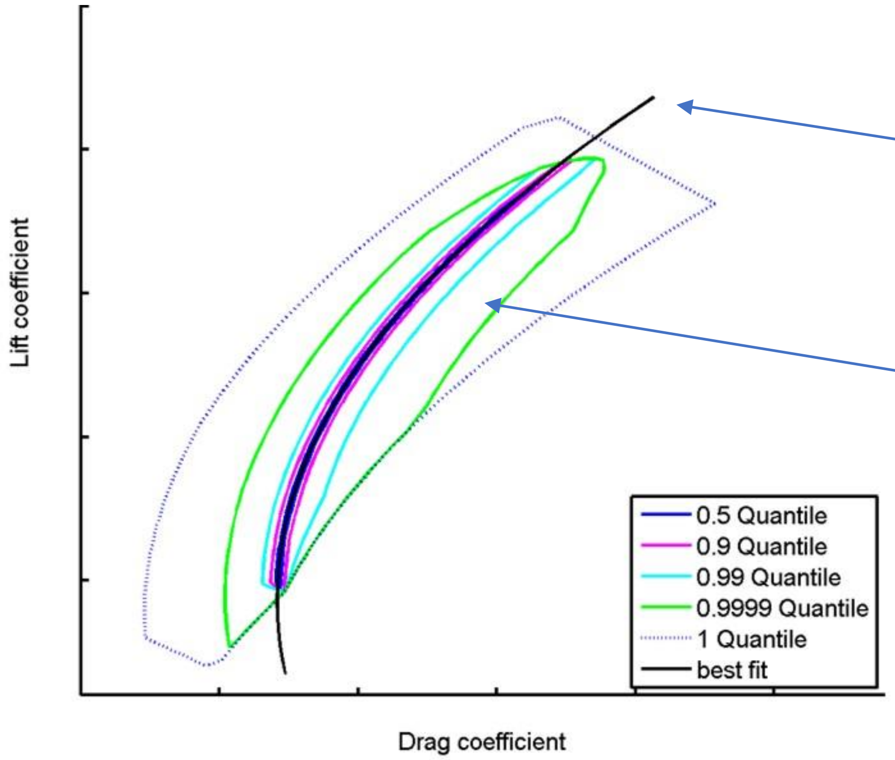


Direct detection sensors

Wide range of possible technology assessed within SENS4ICE :

Atmospheric Hydrometeor Detection based on ELectric measurement (AHDEL)
Adaptive Icing Probe (AIP)
AMPERA
Appendix O Discriminator (AOD)
Aircraft Flight Performance Monitoring (AFPM)
Cloud Multi Detection Device (CM2D)
Fibre Optic Ice Detector (FOD)
Local Ice Layer Detector (LILD)
Primary in-Flight Icing Detection System (PFIDS)
UT-Ice Detection System (UT-IDS)
Short Range Particulate Sensor (SRP)
Hotwire SLD Detector (HSLDD)

Indirect detection algorithm



Black line is the calculated drag polar, which could also be a reference polar or our reference model.

Quantile lines indicate which quantity of data lies within the given areas. (0.99 Quantile = 99% of data)

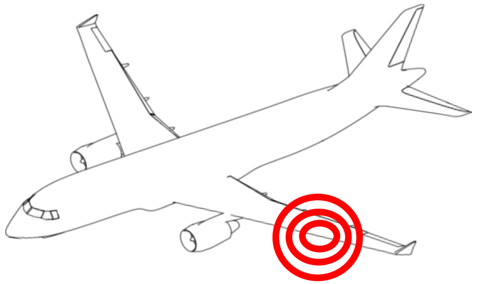
HIDS advantages

Direct detection

Hybrid detection

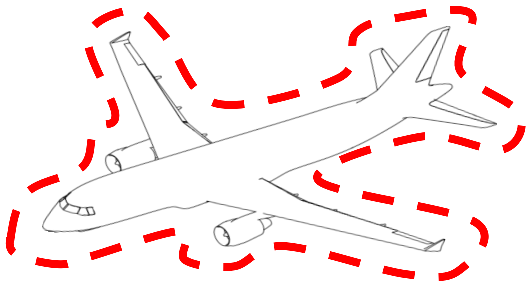
Indirect detection

local



> Cost effective redundancy with dissimilarity.
> Better availability.
> False alarms reduction
> Faster response time

global



> Sensitivity highly dependent on installation
(different for each aircraft model)
> Costly redundancy if needed
(2 sensors per aircraft ?)

> Multiple trigger sources
> Slow response time

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