Hybrid Ice Detection System

Development and Validation

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Outline

- Context and objectives
- HIDS development phases
- HIDS validation and laboratory tests
- HIDS aircraft flight test architectures
- Preliminary flight test results
- Conclusions and way forwards

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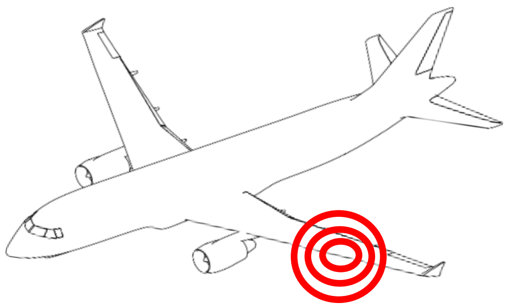
An overview of Hybrid Detection approach

Direct ice detection

Local detection (ice detector): presence of ice accretion/icing condition.



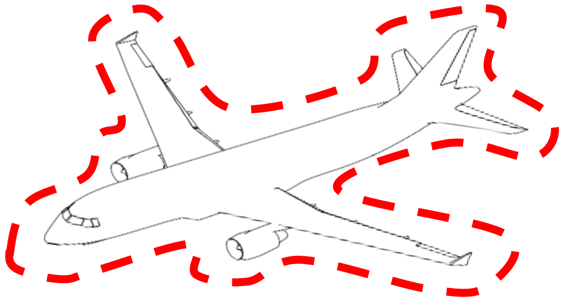
Hybrid ice detection

Combination of Direct and Indirect Detection.

- Flight safety increase.
- Better availability.
- False alarms reduction.
- Detailed information about the icing encounter.
- Continuous monitoring of A/C performance.
- Pilots better reaction.

Indirect ice detection

Global detection: effects of ice accretion.



SENS4ICE goals

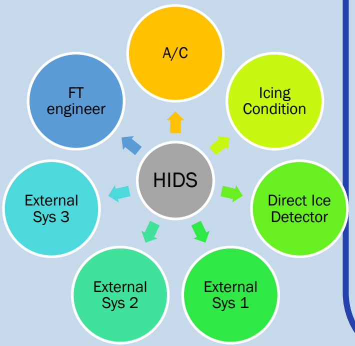
- To define the specifications and needs for Hybrid Detection approach
- To develop Hybrid Ice Detection System (HIDS) demonstrator for FT campaign

Outline

HIDS development phases

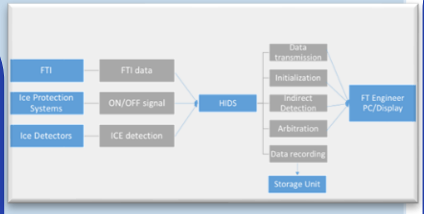
Model Based System Engineering (MBSE) approach

HIDS **environment** and **interfaces** definition

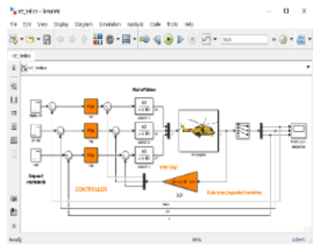


HIDS high-level **specifications**

HIDS **certification guidelines**

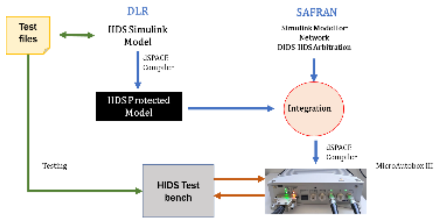


HIDS **architecture** definition



HIDS **modelling** and **software** development

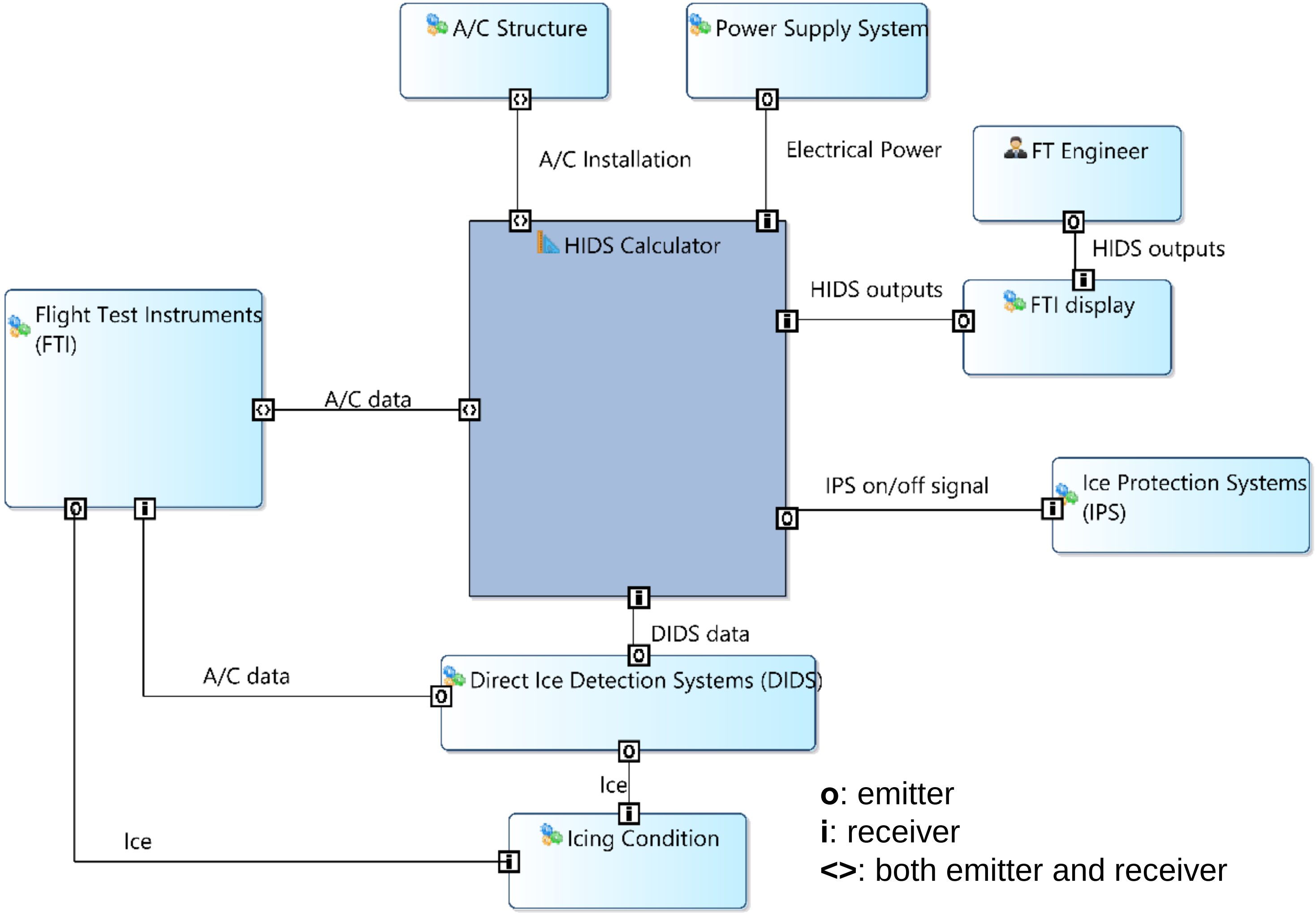
HIDS **hardware** definition



HIDS **validation** and **laboratory tests**

HIDS A/C **installation** and **integration**

HIDS environment



o: emitter
i: receiver
<>: both emitter and receiver

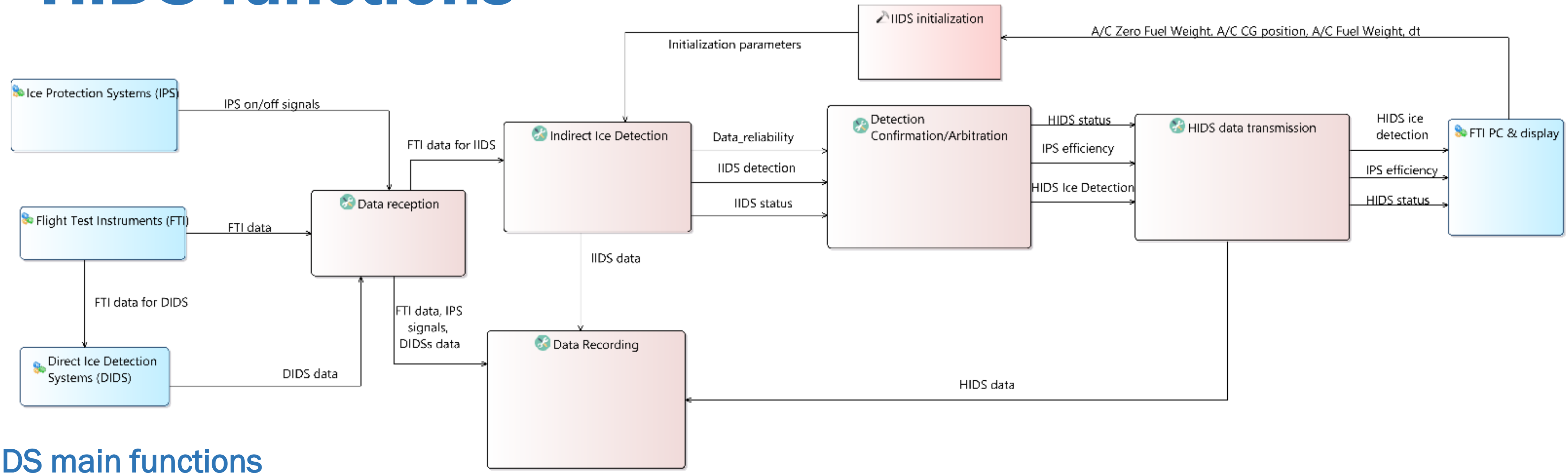
HIDS *Calculator* is composed of:

- DLR Indirect Ice Detection System (IIDS)
- HIDS specific functions for hybridization
- Communication functions

HIDS interfaces

- Aircraft power supply
- Aircraft systems (through FTI)
- Direct Ice Detection Sensors (DIDSs), up to 4
- FTI PC and displays
- Ice Protection Systems

HIDS functions

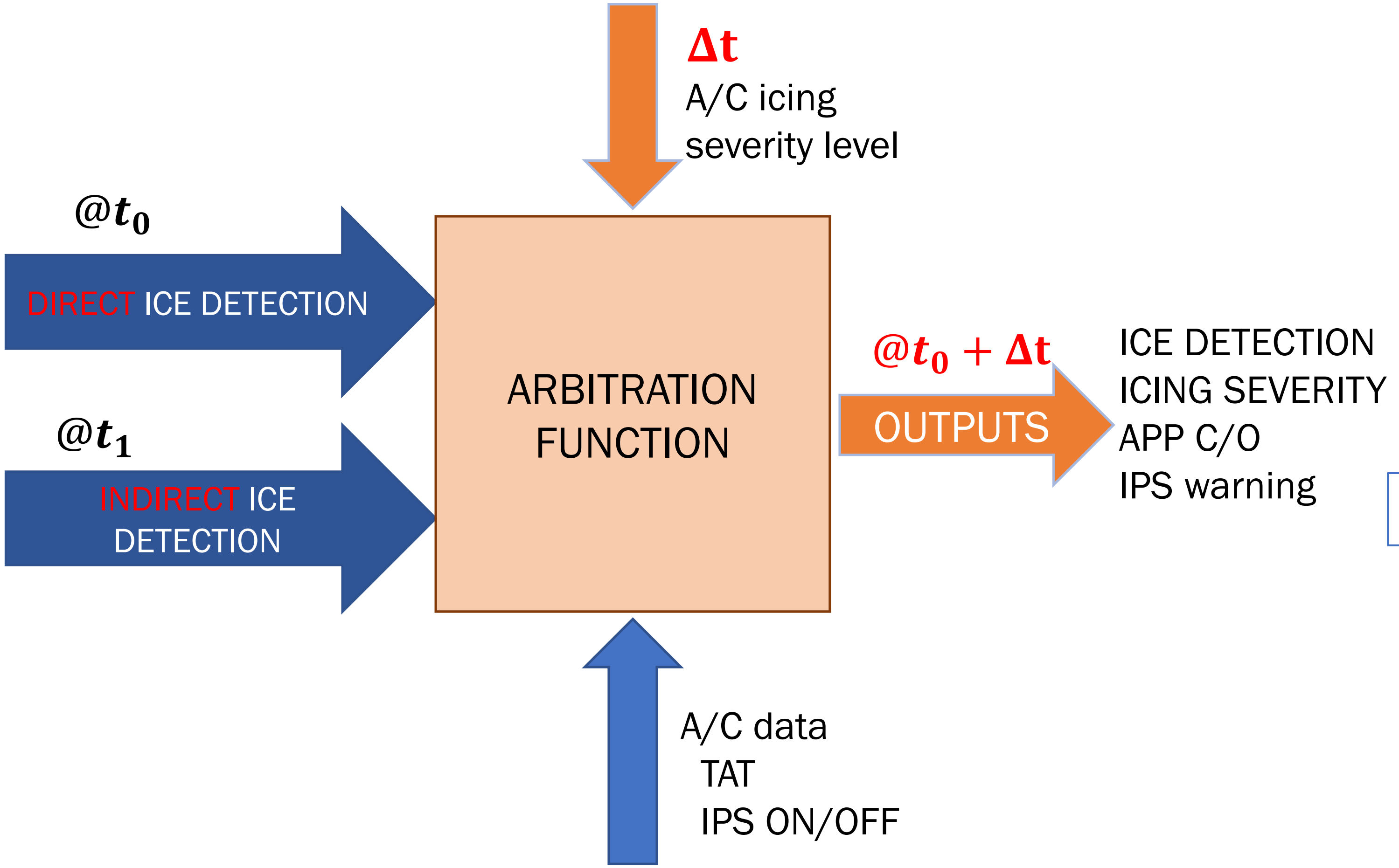


HIDS main functions

- **Data Communication**
  A/C and DIDSs data collection. HIDS outputs transmission.
- **Indirect Ice Detection** (DLR)
  INPUT: needed A/C data.
  OUTPUT: C_D factor, $\frac{\partial C_D}{\partial t}$, ICE detection, Reliability signal.
- **IIDS Initialization**
  To provide IIDS data not available via the A/C FTI (ZFW, ZFCG, TFW).
- **Arbitration**
  INPUT: Direct detection, Indirect detection, TAT, IPS on/off signal.
  OUTPUT: Synthetic and complete ice detection signal
- **Recording**
  To record all the public data on the network (requested only for SAFIRE ATR42).

Insight on Arbitration function

Aim of Arbitration function: to extract a **single, consistent output** from Direct and Indirect detections!



DIDS → early detections

IIDS → need of a certain ice accretion on the airframe

Arbitration outputs provided after a certain delay $\boldsymbol{\Delta t}$ and if $\boldsymbol{TAT \leq TAT_{cr}}$

Definition of Δt

1. Fixed value
2. $\Delta t = \dfrac{(\tau_{MAX} - X\% \, \tau_{MAX})}{IAR_{DIDS}}$

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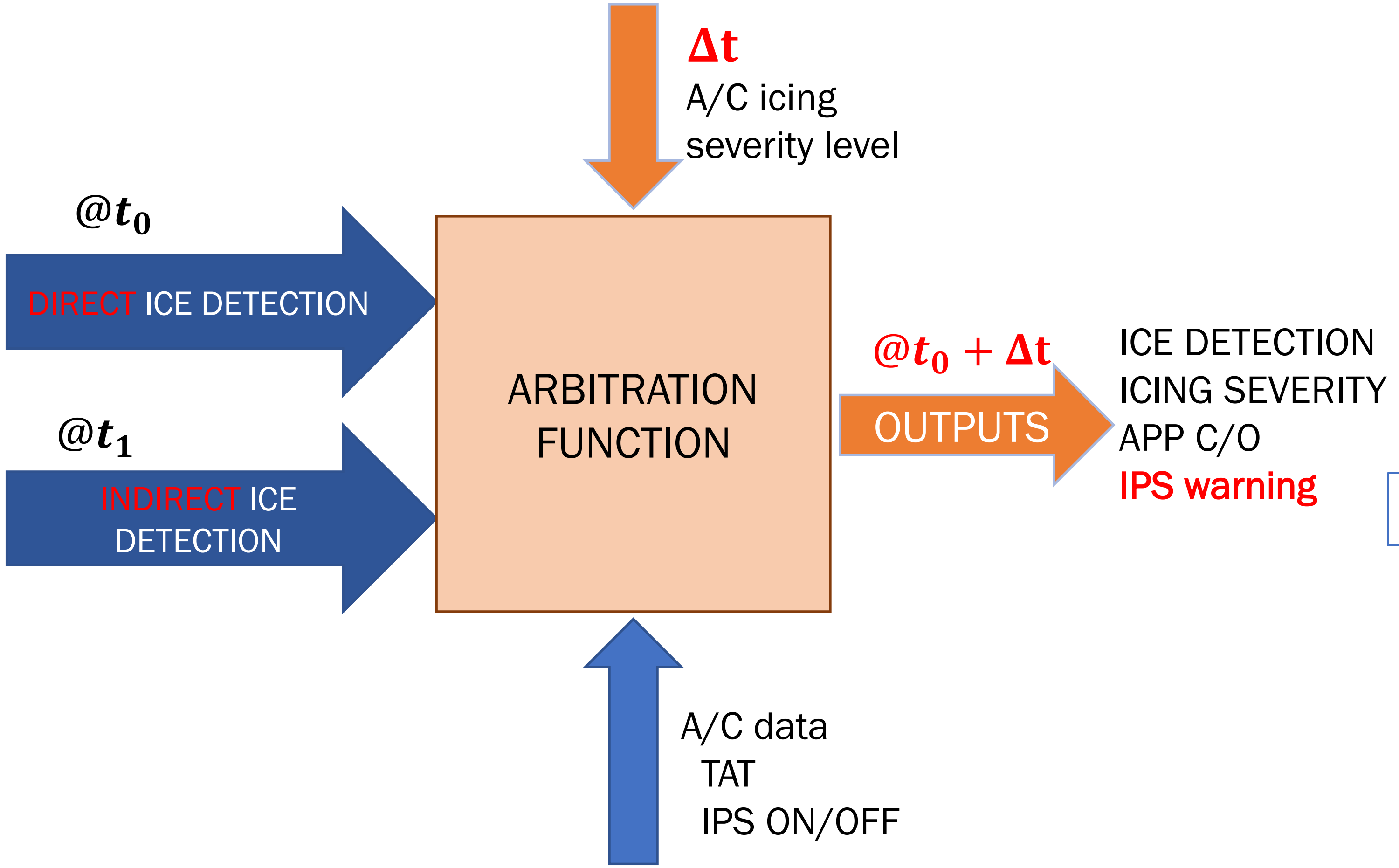

DIDS ➔ **early detections**

IIDS ➔ need of a certain **ice accretion** on the airframe

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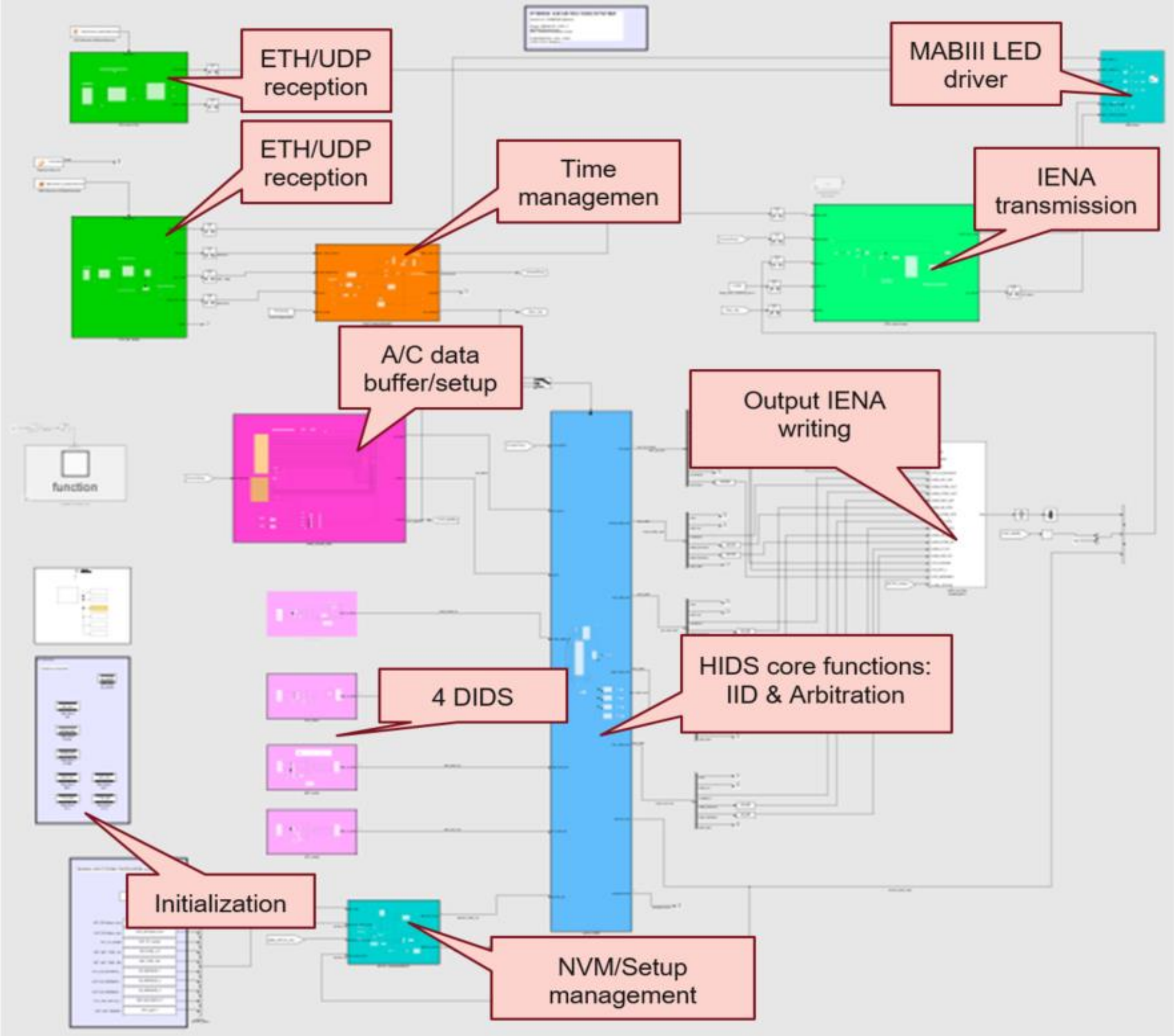
IPS warning if IIDS detects after IPS activation

Residual ice accretion

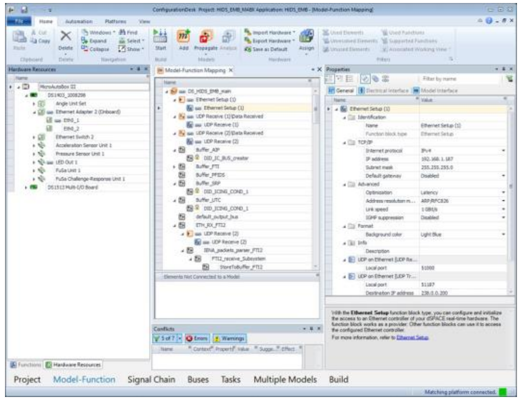
- Runback ice
- App O condition

HIDS Simulink model



Why SIMULINK?

1. **Easy** prototyping environment.
2. The **IIDS** model provided by DLR is a ***protected* Simulink model:** a compatible execution environment was required.
3. Simulink models are supported by **dSpace MicroAutobox** (hardware chosen for HIDS). **dSpace tools** allow to convert Simulink HIDS model into a ***real-time code*** by adding specific libraries **Ethernet UDP protocol**, chosen for FT data transmission.



dSPACE MAB III and Configuration desk (credit SAFRAN)

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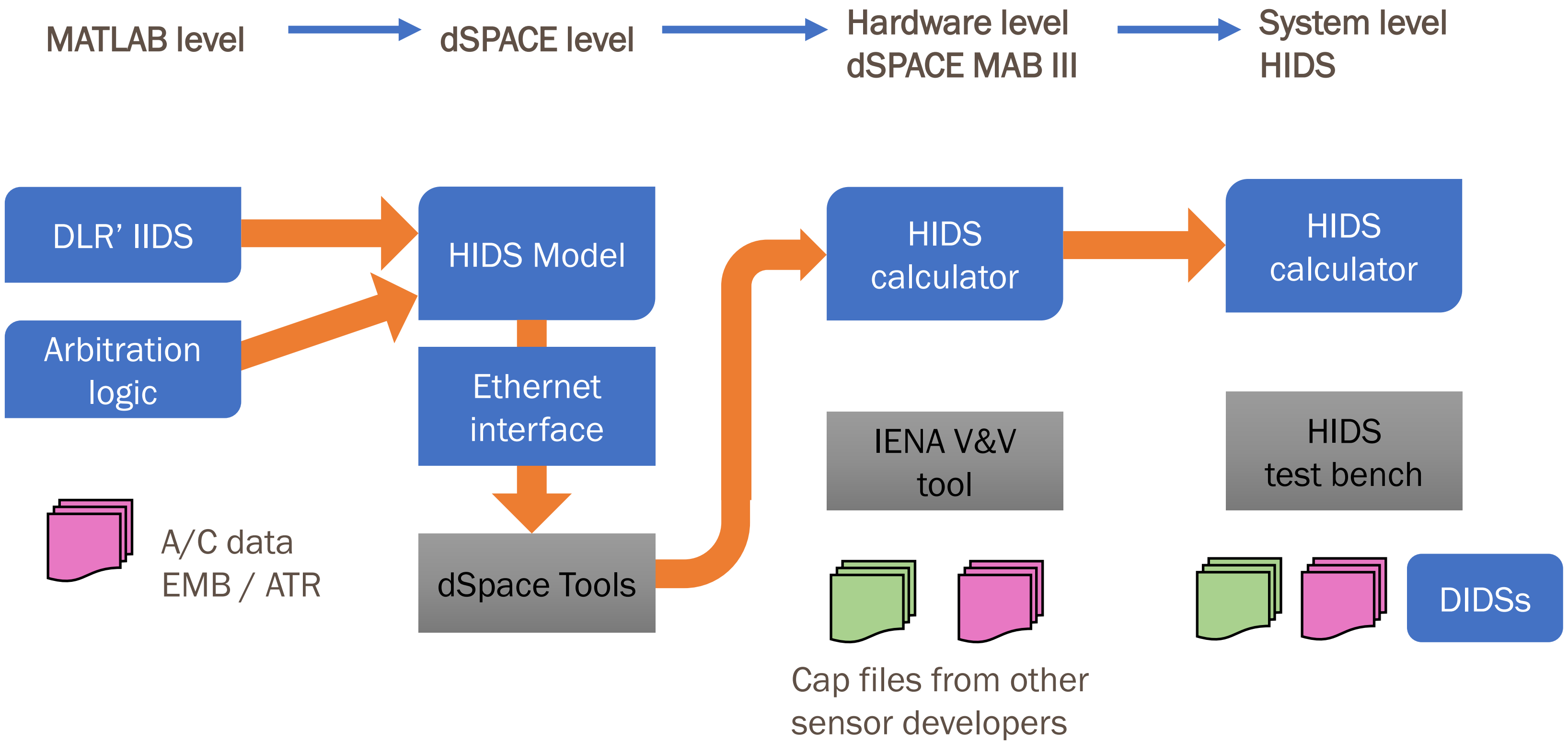
HIDS validation and laboratory tests



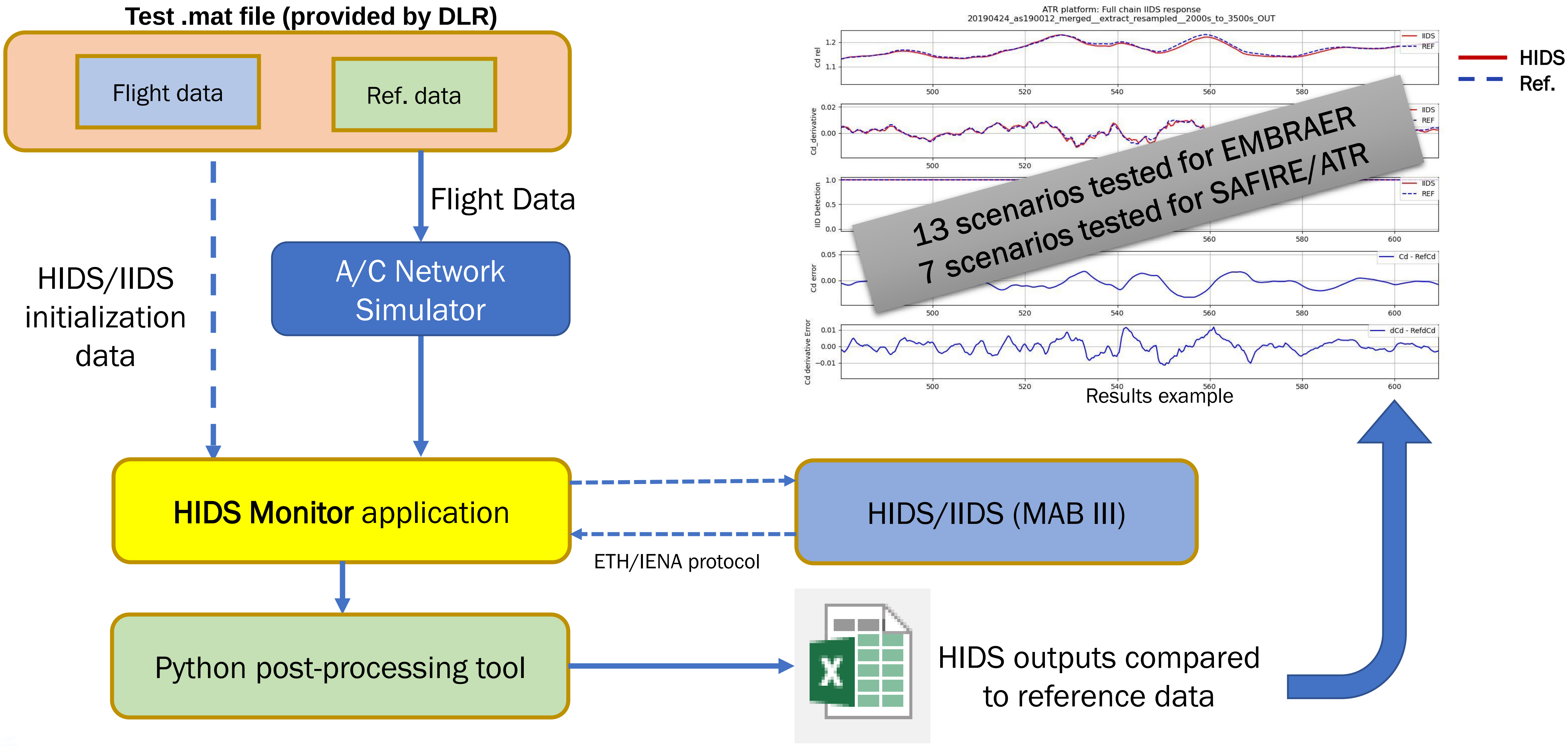
Main testing phases

1. Validation of HIDS/IIDS Simulink model
2. Integration of HIDS Simulink model into dSPACE environment
3. Validation of HIDS Calculator Ethernet interfaces
4. Validation of the whole HIDS demonstrator

Development of a specific **test bench**: the **HIDS Monitor** PC application!

(CVI, National Instrument)

HIDS validation and laboratory tests



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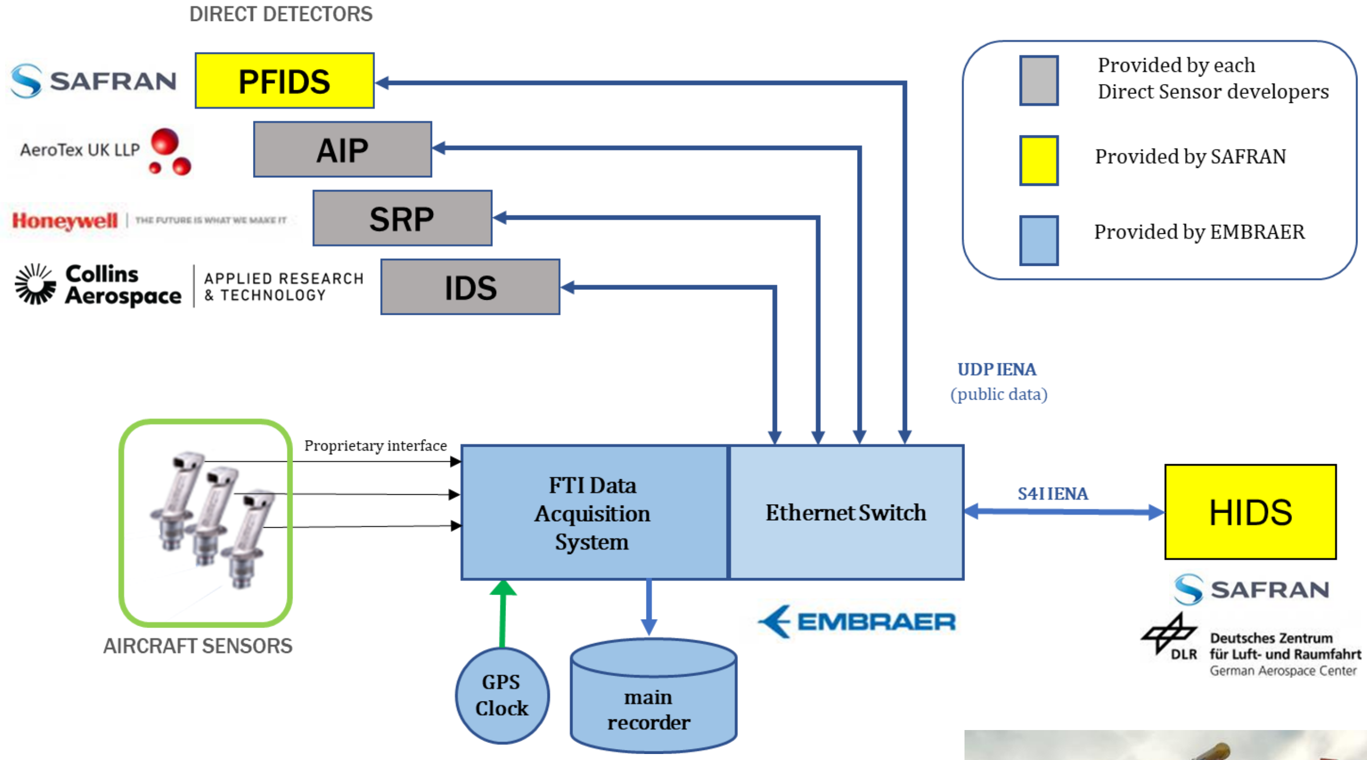
Embraer Phenom300 - HIDS FT architecture



Aircraft data provided by

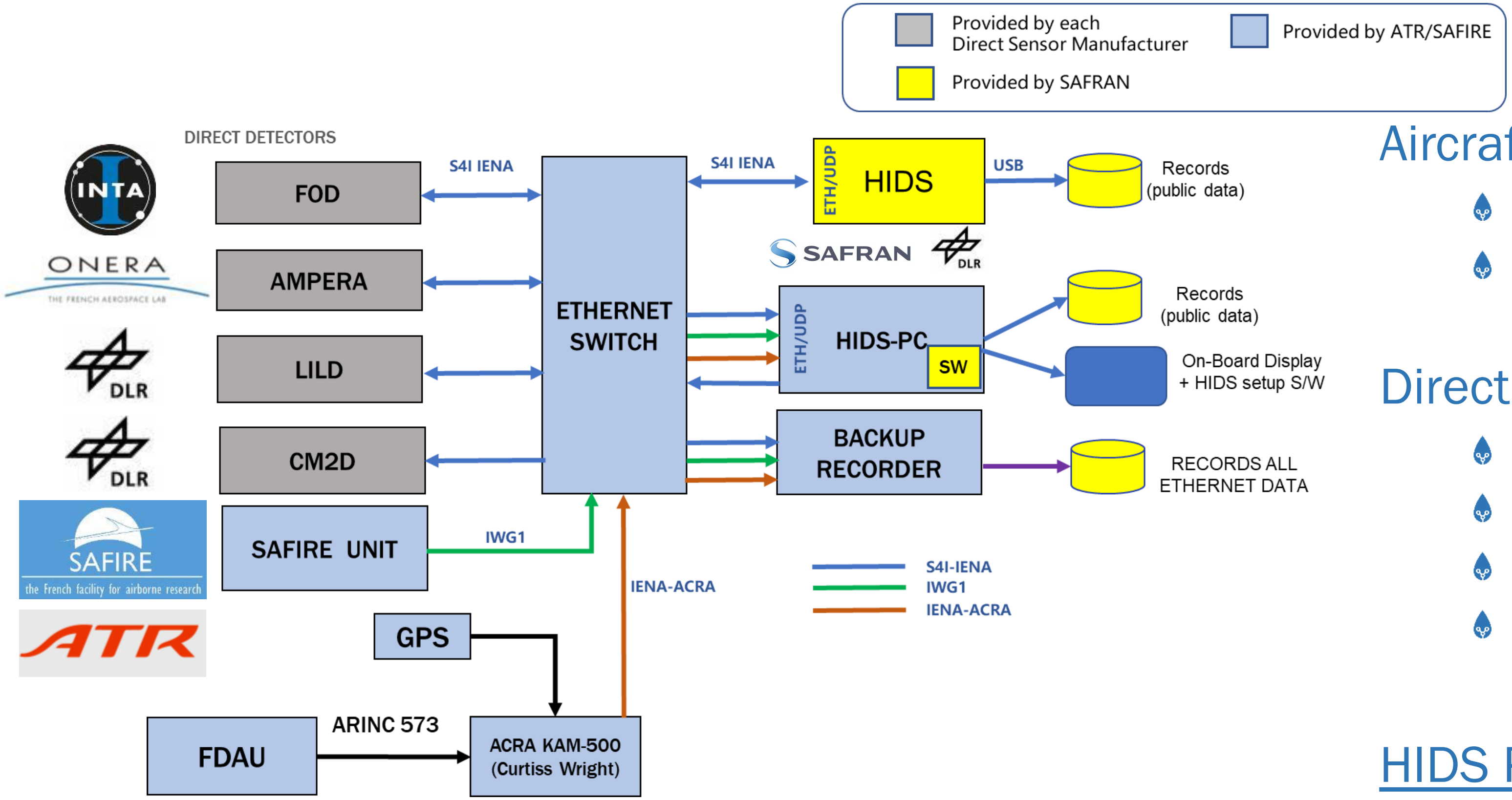
- FTI System (ETH/UDP, IENA S4I format)

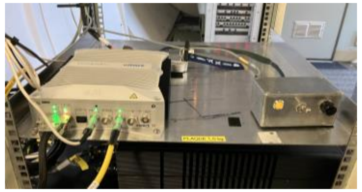
Direct Ice Detectors

- PFIDS (SAFRAN)– Ice Accretion Detector
- AIP (AEROTEX) – Icing Condition Detector
- SRP (HONEYWELL) – Icing Condition Detector
- IDS (COLLINS) – Icing Condition Detector

Embraer Phenom 300 used for US Flight Test campaign
(credit Embraer)

SAFIRE ATR42 - HIDS FT architecture






HIDS Calculator (on the left), HIDS PC tool (on the right).
(credit SAFRAN)

Aircraft data provided by

- SAFIRE FTI (IWG1 format)
- ATR FDAU (ARINC 573 converted into ETH/UDP by ACRA equipment)

Direct Ice Detectors

- FOD (INTA) – Ice Accretion Detector
- AMPERA (ONERA) – Icing Condition Detector
- LILD (DLR) – Ice Accretion Detector
- CM2D (DLR reference probe)

HIDS PC functions (*HIDS_ATR_FT* tool)

- To translate ACRA and IWG1 frames to S4I IENA format
- To enable HIDS/IIDS Initialization
- To monitor/display HIDS and DIDSs outputs
- To record all public data on network (backup)

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Quicklook on HIDS behaviour

US FT campaign

Location:

Period: Winter 2023 (February/March)

Flight hours: about 25

HIDS Communication:

HIDS/IIDS Initialization:

HIDS Ice Detection:

HIDS Recording: N/A

HIDS Monitoring: EMB FT Engineers

Credit Embraer

EU FT campaign

Location:

Period: Spring 2023 (April)

Flight hours: about 50

HIDS Communication:

HIDS/IIDS Initialization:

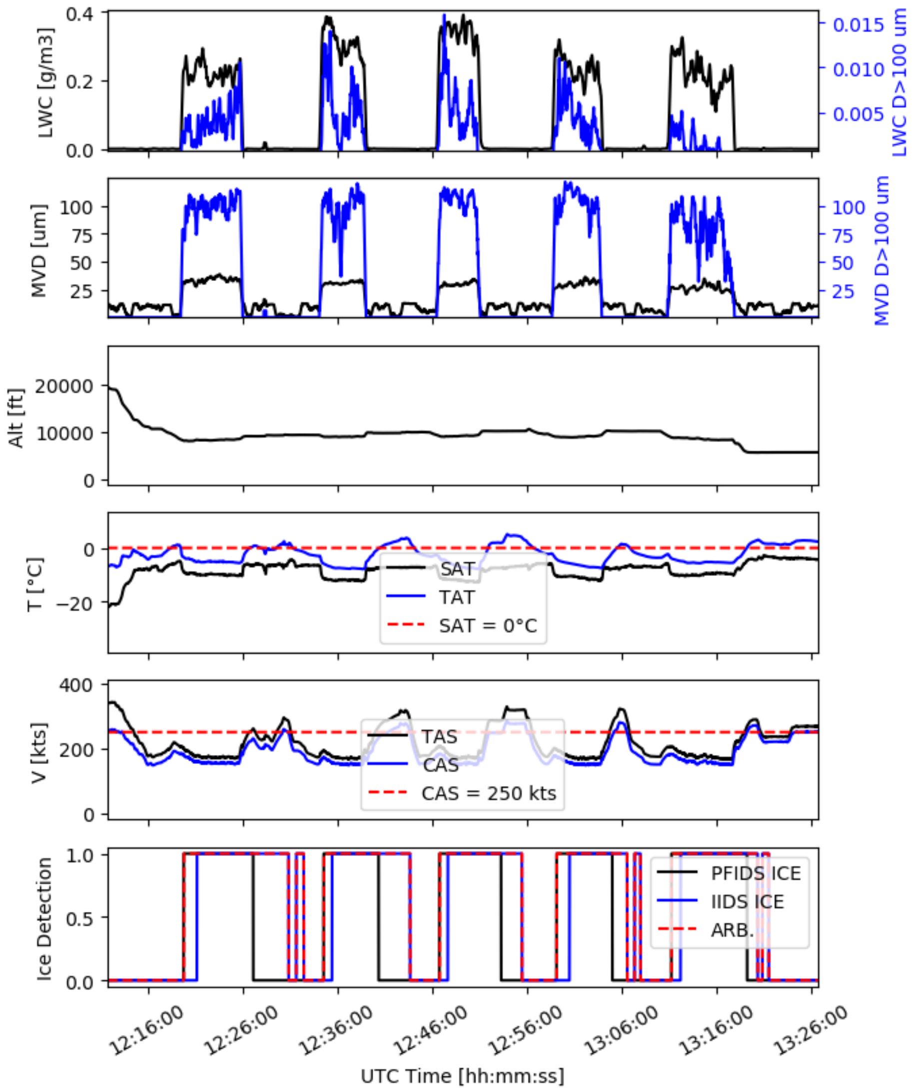
HIDS Ice Detection:

HIDS Recording:

HIDS Monitoring: SENS4ICE partners (In-Flight Mission Manager)

Credit SAFRAN

Preliminary Flight Test results



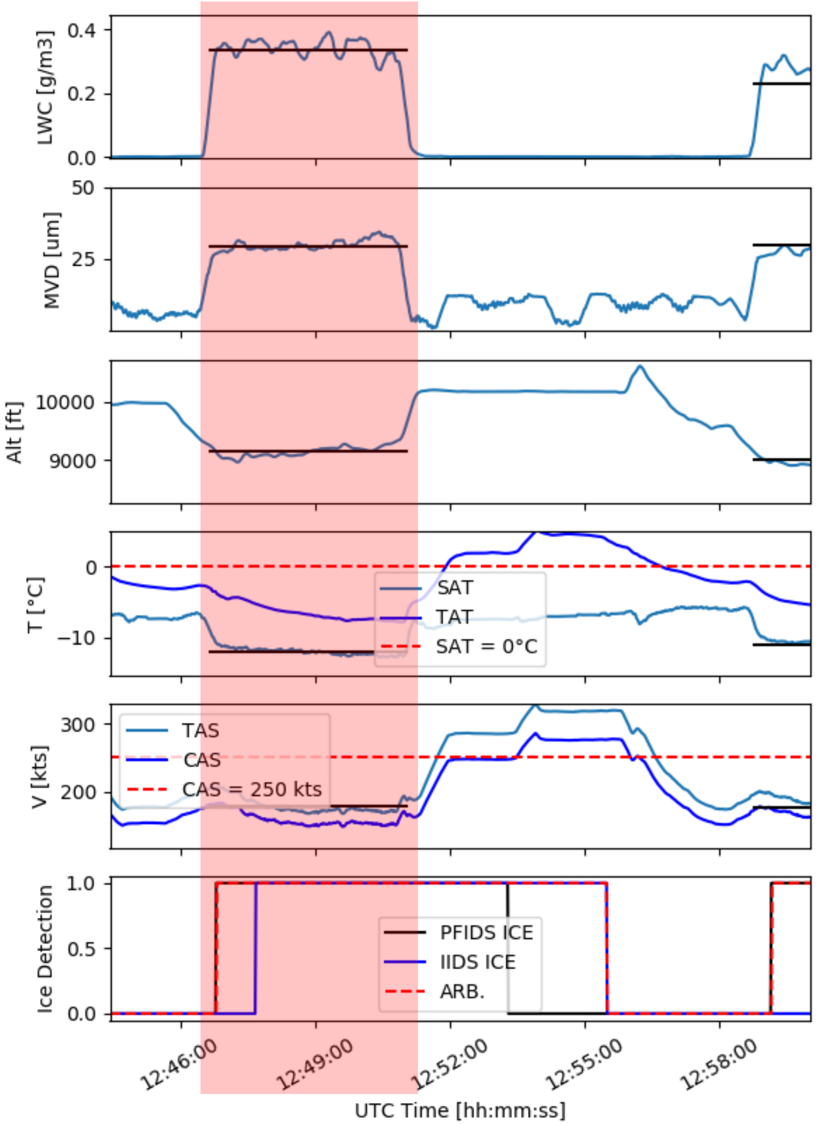
The Figure shows an example of PFIDS/IIDS Arbitration output for the FT#4 (25 FEB 2023) of US campaign

- Several **Appendix O conditions** encounters
- Both **Direct** and **Indirect** Ice detection
- **HIDS arbitration** output delay $\Delta t = 0s$

On going analyses

- Identification of icing condition encounters (IC)
- Evaluation of the average LWC, MVD, SAT, TAS, ALT
- Evaluation of ED103revB IAR and detection time
- Evaluation of IIDS and DIDSs detection time
- Arbitration logic optimization via FT scenario replay

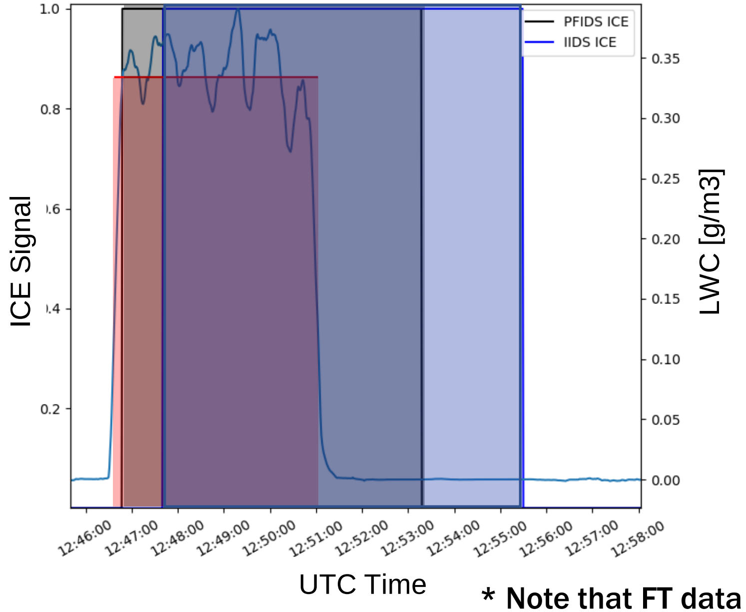
Preliminary Flight Test results



On going analyses

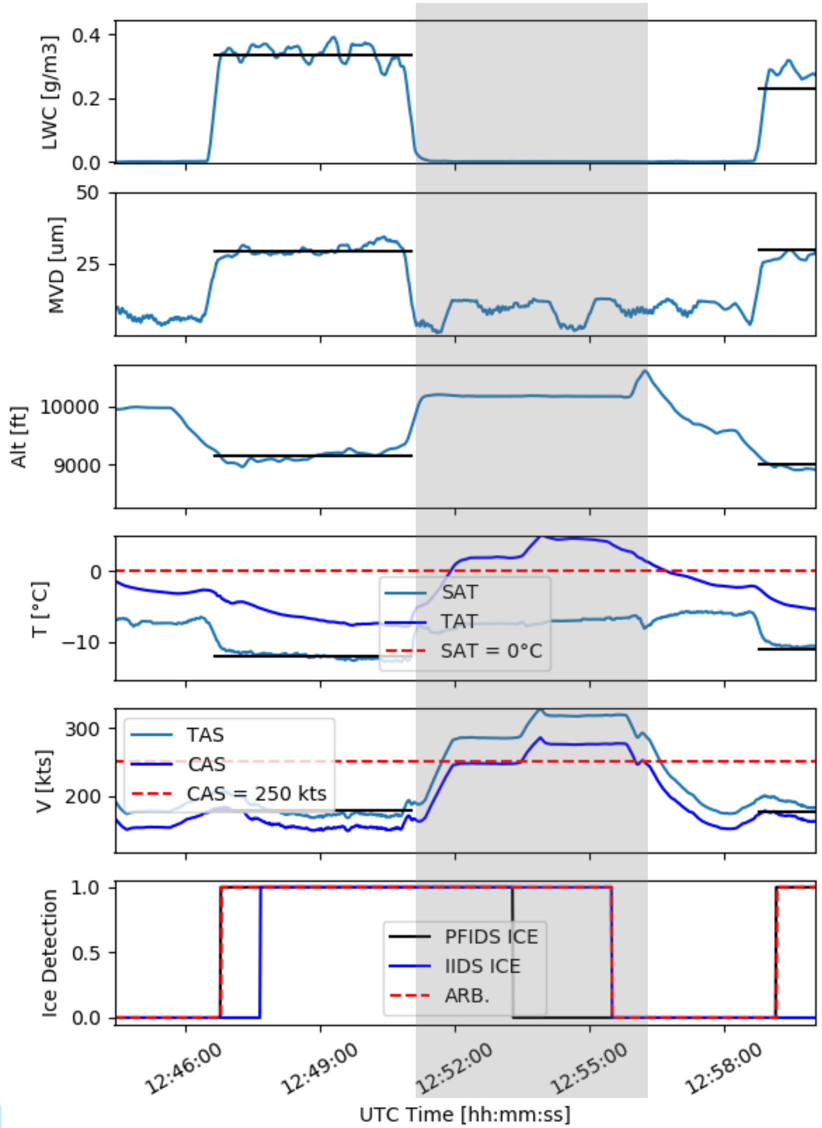
- Focus on one icing encounter
  - LWC = 0.33 g/m3; MVD ~ 29 μm (from DLR μPhysics data)
    Alt = 9155 ft; SAT = -12 °C; TAS = 180 kts
  - Detection times (ref. ED103 revB)
    - $t_{ED103_B} = 11s$
    - $t_{DIDS} = 10s^*$
    - $t_{IIDS} = 60\ s^*$

Importance of the association of the two different detection sources!



* Note that FT data are available @ 1 Hz rate!

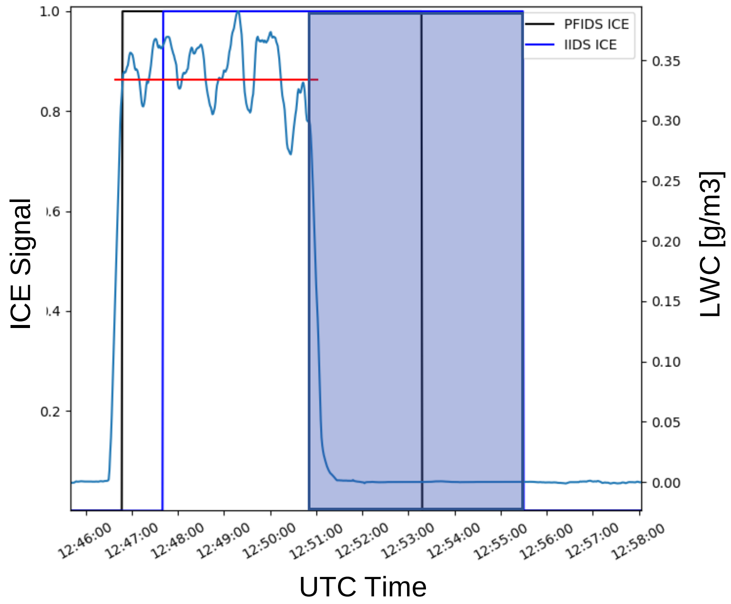
Preliminary Flight Test results



On going analyses

- Aircraft de-icing phase
  - exit from the cloud ➔ increase of Alt
  - increase of speed (CAS≥ 250 kts) ➔ increase of TAT> 0°C

- DIDS ICE signal drops 2 min after the exit from IC
- IIDS ICE signal is maintained during all the de-icing phase
  - Performance degradation due to residual ice (?)



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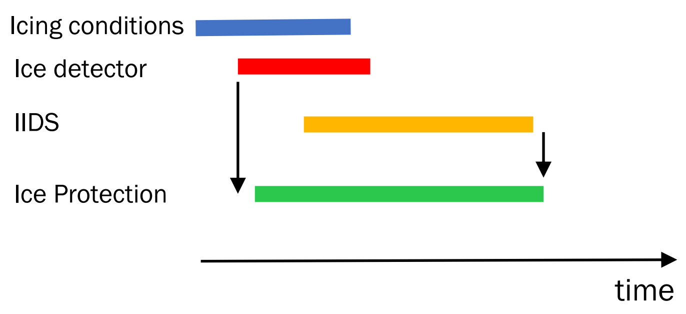
Conclusions and ways forward

- HIDS challenging development and testing
  - Large amount of different data to process
  - Strong dependency on the aircraft type and architecture

- Promising Flight Tests results
  - Good system behaviour during FT (communication, IIDS initialization, data recording)
  - Benefits of hybridization already observed
    - Early Direct Detection
    - Continuous monitoring of A/C performance (residual ice)
    - Possible optimization of Ice Protection
  - Further data post-processing needed to enable optimization of HIDS



- Challenges to be addressed
  - **HIDS outputs:** A tight collaboration with aircraft makers is needed to properly exploit the rich information provided by HIDS.
  - **HIDS airworthiness:** A new certification approach to be developed in collaboration with certification authorities.

Thank you all for attending !

Thanks to all SENS4ICE partners for the fruitful discussions during HIDS development process! ☺

Special thanks goes to

- DLR
- Embraer
- SAFIRE
- ATR
- ANAC & EASA
- Leonardo

Q&A session

For any further questions, please contact

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