EASA Annual Safety Conference

Overview on in-flight icing research

Prepared by
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AIRBUS

Overview on in-flight icing research
Content

- Context
- Icing R&D Roamap & Status
- Conclusion & Way Forward

Overview on in-flight icing research
Content

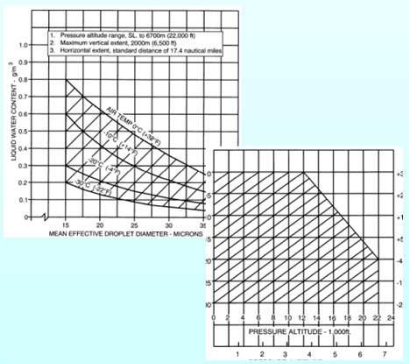
- **Context**

- *Icing R&D Roamap & Status*
- *Conclusion & Way Forward*

Overview on in-flight icing research
Context

- Current Ice & Protection Functions

App. C



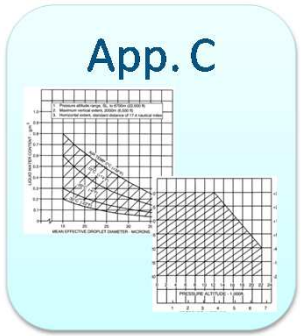
Wing (Slats 3 4 5) **Handling Quality** protection: bleed anti-ice

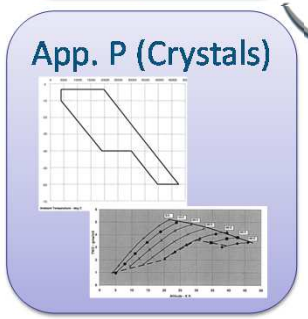
ATA30 cockpit systems
Probes protection
Advisory Ice Detection System

Nacelle inlet cowl **Foreign Object Damage** protection: bleed anti-ice

Overview on in-flight icing research
Context

- Future A/C Ice & Protection Functions





HTP/VTP
Handling Quality (HQ)
protection TBC

ATA30 Cockpit systems
Probes protection
Primary detection system

Pylon & Nacelle
FOD protection

Radome ice shedding

Inboard Wing
Engine **Foreign Object Damage** protection TBC

Outboard Wing
Handling Quality protection

Overview on in-flight icing research
Context

- Evolution of **icing regulation** (SLD, Glaciated & mixed phase icing conditions,…)
- Development and integration of **new and disruptive technologies** (eWIPS, PFIDS,…) to enable new A/C configuration, bleedless A/C,…
- Development and validation of **capabilities** to support technologies development, integration and certification (Test facilities, M&T, processes,…)
- Development and securisation of **icing expertise** in Europe

…While maintening the highest level of **safety**

Overview on in-flight icing research
Content

- *Context*

- **Icing R&D Roamap & Status**
  - **WEZARD – WEather HaZARDs for aeronautics**
  - **Rulemaking**
  - **Capabilities**
  - **Technologies**

- *Conclusion & Way Forward*

Overview on in-flight icing research

Icing R&D Roadmap & Status / WEZARD – WEather haZARDs for aeronatuics

FP7 Call 4

•Coordination: Airbus Operations SAS
• Topic: AAT.2011.7-23 - Technology support for crisis coordination for the air transport system following major disrupting events

Top Level Objectives

•Set-up an interdisciplinary and cross-sectoral network.
• Compile a list of the potential large scale, high impact **weather hazards and their technical** consequences on the aircraft (failures, damage, etc.).
• Perform a **state of the art review of the** research actions related to aeronautical weather hazards, in particular volcanic ash and icing.
• Perform an in-depth analysis which will **identify the gaps in the available knowledge,** the **priority areas for improvements and** the type of activity needed to develop a safer air transport system and therefore help to limit the effects of large scale, high impact events.
• Provide a consolidated **recommendation and roadmap report validated by the main** stakeholders of the aeronautics community.

Duration & Budget

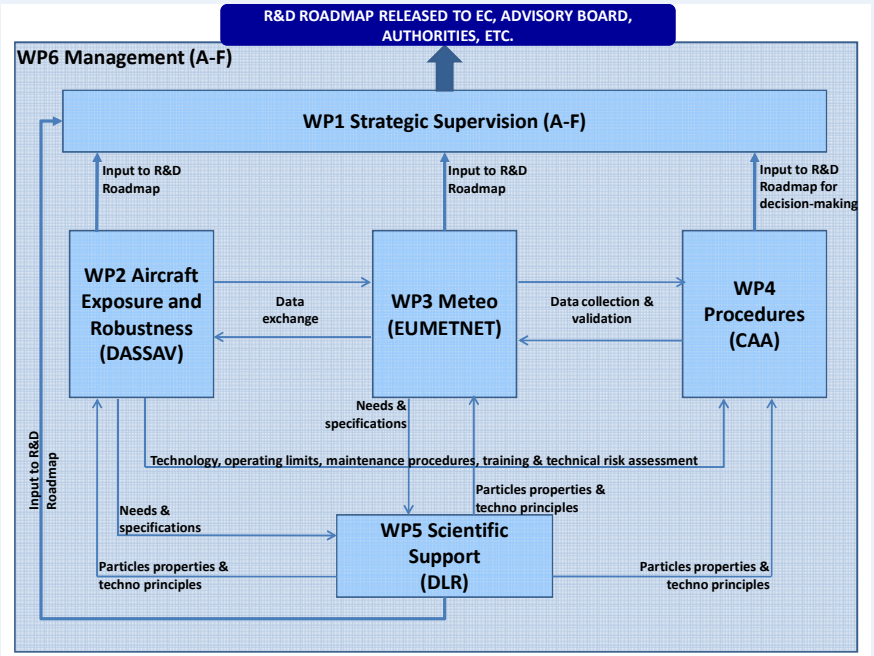
•Duration: **24 months** project / July 2011 – June 2013

•Gross budget: **600k€**

Partnership

AIRBUS, DASSAULT AVIATION, BOEING, EADS, THALES, Rolls-Royce, DGA, Civil Aviation Authority, SAFRAN Snecma, ONERA, DLR, imaa istituto di metodologie per l'analisi ambientale, EUMETNET

Concept & WBS



Overview on in-flight icing research
Icing R&D Roadmap & Status / Rulemaking

Status

•An **international HAIC/HIWC field campaign** planned in Darwin in Q1 2014 (2 months campaign / 200F/H incl. ferry flight)

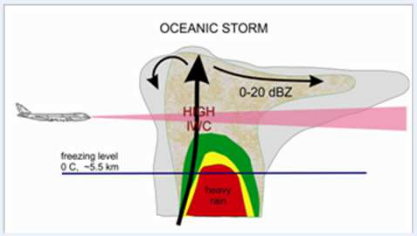
•Primary objective is to provide **99th percentile total water content statistics**, as a function of distance scale, to industry and regulators for assessment of App D/P

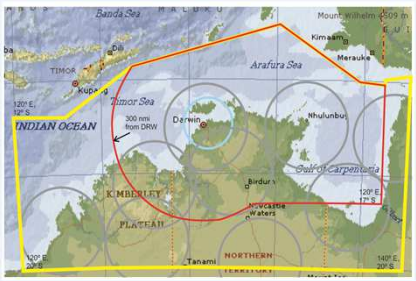
•**Two types of convection** for sampling :
- Oceanic convection (primary focus)
- Continental convection (secondary focus)

•**Three flight levels** for sampling:
- -50°C: a typical cruise altitude for commercial jet aircraft
- -30°C: a mid-altitude with possibly intermediate particle size
- -10°C: a low flight level to sample the cloud just above the melting layer

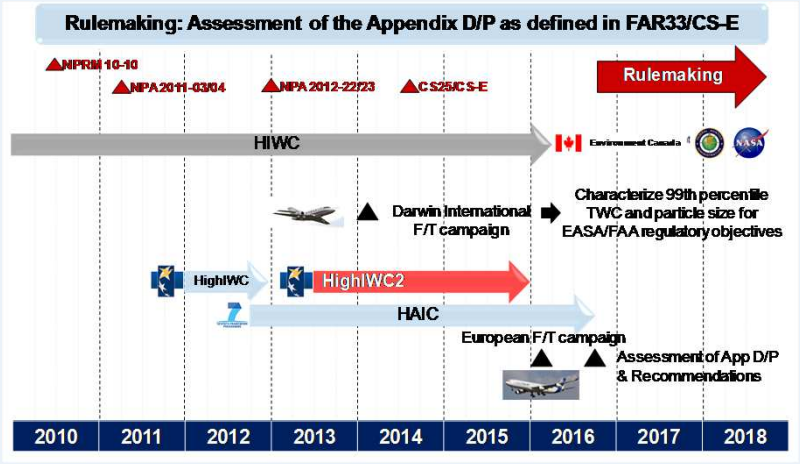
• **Projects**: HAIC, HIWC, EASA-HighIWC
• **Funding:** FP7, FAA, EASA

Illustration





Roadmap



Overview on in-flight icing research

Icing R&D Roadmap & Status – Capabilities / Performance Degradations

Status

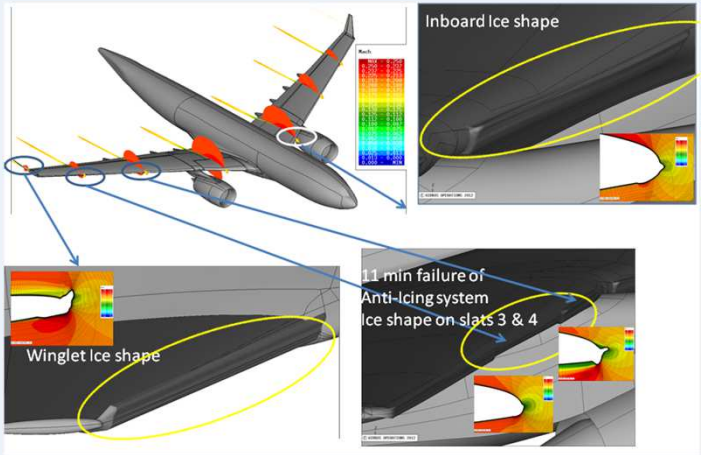
• **Goal:** Develop **RANS CFD capability** for prediction of perfomance degradations due to ice & Improve **Aerodata process for icing** which today rely on past A/C experience, engineering judgement and low Reynolds number testing.

• **Key Results**
- Turbulence modeling
- Advanced, modular and robust mesh generation concept (DGAC – NECTS1/2)
- Preliminary 3D capability assessment

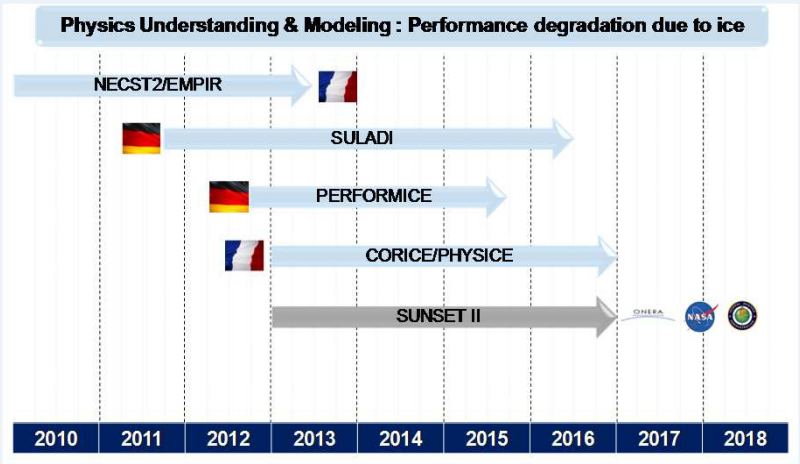
•**Challenges / Next steps:**
- **3D experimental database** for CFD capability assessment/validation
- **Advanced turbulence modeling**
- Implementation into **Aerodata Process for icing**

•**Project:** NECST1/2, SULADI, PERFORMICE, CORICE, PHYSICE, SUNSET2
•**Funding:** DGAC, LUFO, ONERA, NASA, FAA

Illustration



Roadmap

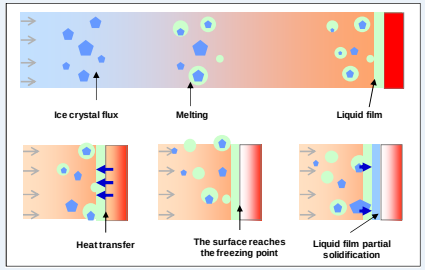


Overview on in-flight icing research
Icing R&D Roadmap & Status – Capabilities / Ice Crystals

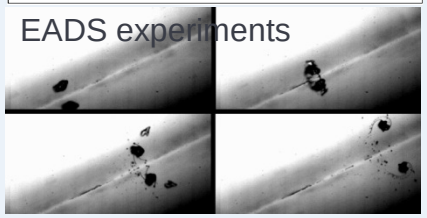
Status

- **Goal:** Develop **Acceptable Means of Compliance (AMC)** wrt the new glaciated and mixed phase icing conditions certification requirements (FAR33/CS-E App D/P),
- **Key Results:**
  - M&T: Specification, Literature review and Initiation of laboratory tests
  - IWT: Specification, Literature review and ice crystals generation improvement
- **Challenges / Next Steps:**
  - **Proof of concept** (TRL3) for icing test facilities planned en 2013 and calibration
  - **Proof of concept** (TRL3) for numerical capability planned mid 2014: A unique European model for ice particle trajectory, impingement and accretion
  - **Standardisation** through update of SAE ARP5905
- **Projects**: HAIC
- **Funding:** FP7

Illustration

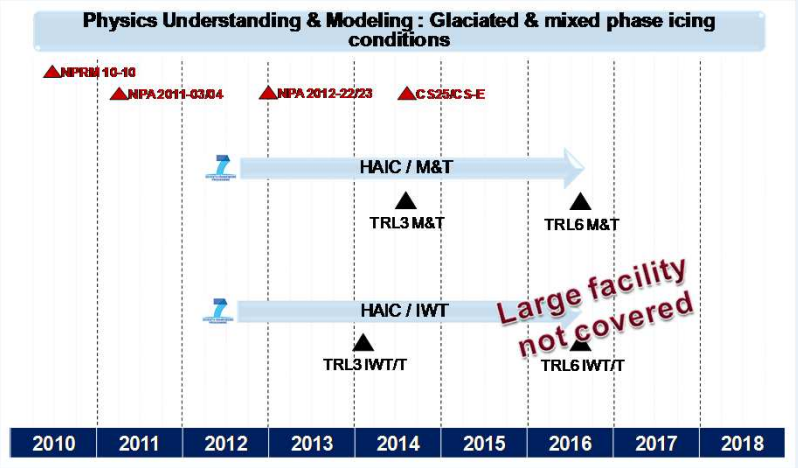


EADS experiments



EADS/TUD experiments

Roadmap



Overview on in-flight icing research
Icing R&D Roadmap & Status – Capabilities / SLD

Status

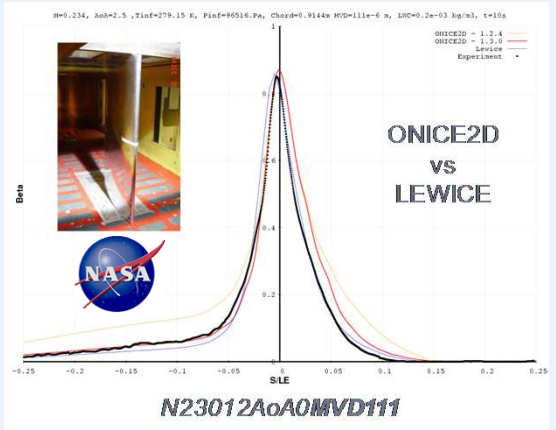
•**Goal:** Develop **Acceptable Means of Compliance (AMC)** wrt the new SLD certification requirements (FAR/CS25 App O),

•**Key Results:**
- **Understanding and modeling of physical phenomena** related to SLD such as break-up, splashing and bouncing
- **IWT** capability development & 2D and 3D EXTICE **SLD experimental database for FZDZ**
- **Preliminary Assessment** of 2D and 3D M&T capabilities

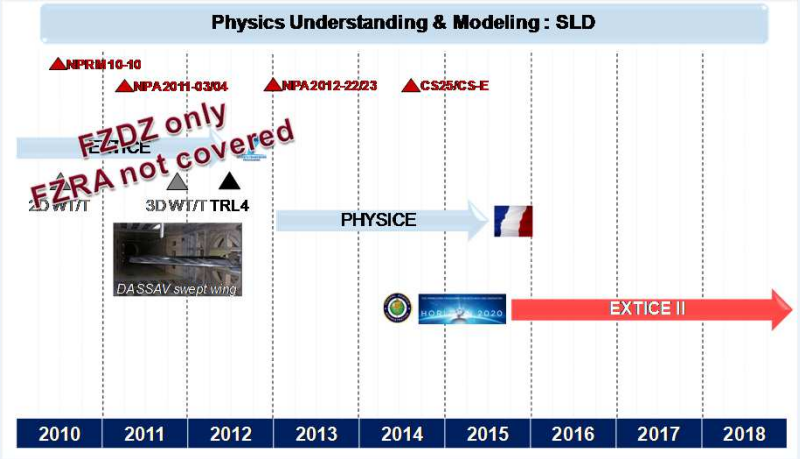
•**Challenges / Next Steps: EXTICE2**
- **IWT** improvement & calibration
- **Numerical tools** improvement (splashing)
- **Freezing Rain (FZRA) ??**
- **Standardization**
- **International Collaboration**

• **Projects**: EXTICE, PHYSICE, *EXTICE2*
• **Funding:** FP7, DGAC, *H2020, FAA*

Illustration



Roadmap



Overview on in-flight icing research
Icing R&D Roadmap & Status – Capabilities / Ice Accretion

Status

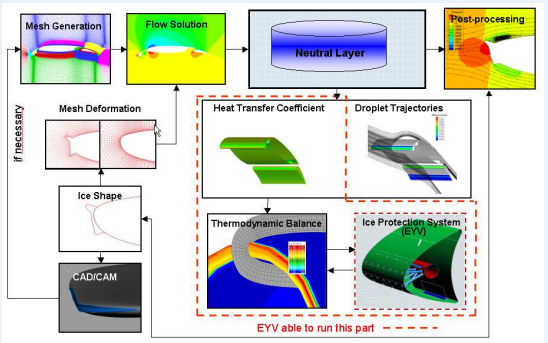
•**Goal:** To improve **2D and 3D Ice accretion prediction capability** to support design and certification of future products**.** The changes to be delivered by the current activities are:
- Enhanced 2D ice accretion capability (High-lift)
- 3D ice accretion capability & methodology

•**Key Results:**
- 3D capability development (ECLIPPS, ICECREMO,...)
- Preliminary 3D capability integration incl. Mesh deformation
- Preliminary 3D Capability Assessment

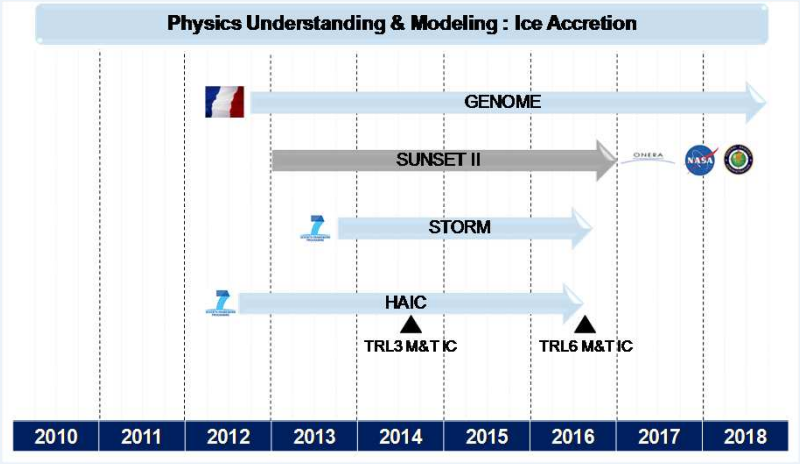
•**Challenges / Next Steps:**
- Capability improvement & Integration into industrial CFD environment (GENOME)
- 3D Ice accretion methodology
- 3D validation database & Capability assessment/validation (SUNSET2)

- **Projects**: GENOME, SUNSET2
- **Funding:** CORAC, ONERA, NASA, FAA

Illustration



Roadmap



Overview on in-flight icing research

Icing R&D Roadmap & Status – Capabilities / Ice Protection System

Status

•**Goal:** To develop **advanced capabilities for prediction of performances of eIPS** (ETIPS, EMIPS) as enabler for More Electrical A/C (MEA)

•**Key Results:**

- **Experimental databases** (JTI-SGO, AEROMUCO) for assessment/validation of the capability

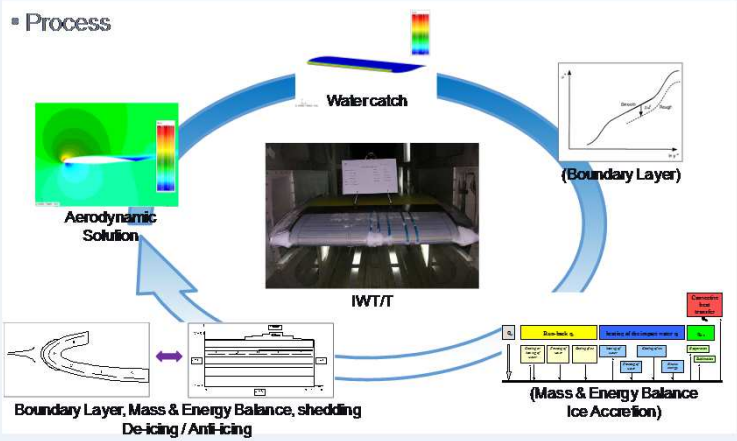
•**Challenges / Next Steps:**

- **Runback**
- **Ice shedding, ice mechanical properties** and ice block trajectory
- Capability assessment

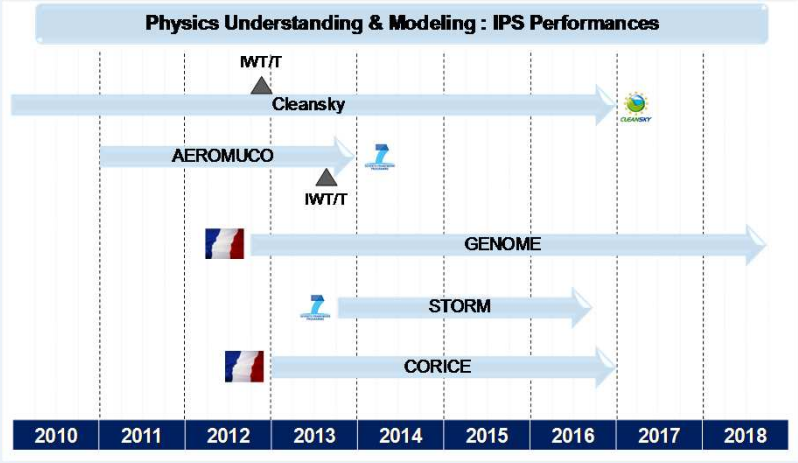
• **Projects**: JTI-SGO, AEROMUCO, STORM, GENOME, CORICE

• **Funding:** Cleansky, FP7, CORAC, DGAC

Illustration



Roadmap



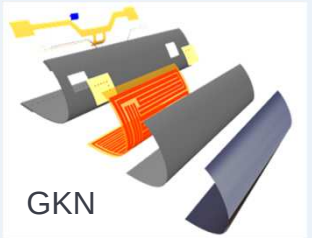
Overview on in-flight icing research

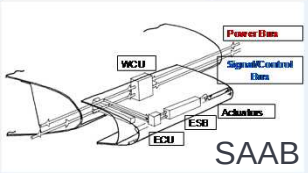
Icing R&D Roadmap & Status – Technologies / Ice Protection System

Status

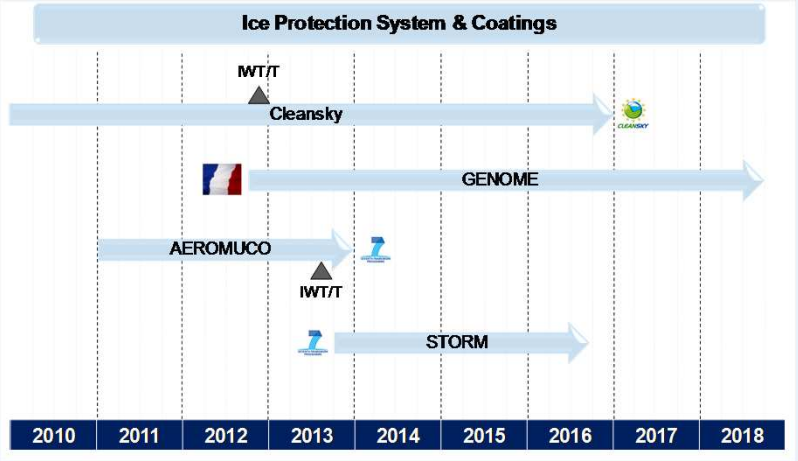
- **Goal:** To develop **e**lectrical **W**ing **I**ce **P**rotection **S**ystem (ETIPS, EMIPS) as enabler for More Electrical A/C (MEA) : Power consumption reduction and optimization, icephobic and hydrophobic coatings, Change from anti-ice to de-ice more for airfoil ice protection, integration
- **Key Results:**
  - **Experimental databases** (JTI-SGO, AEROMUCO) for assessment/validation of the eWIPS performances (TRL4)
- **Challenges / Next Steps:**
  - Icephobic and hydrophobic coatings for performance optimisation
  - F/T planned in 2016 (JTI-SGO, GENOME)
- **Projects**: JTI-SGO, JTI-SFWA, AEROMUCO, STORM, GENOME, INTEQ/AIWO
- **Funding:** Cleansky, FP7, CORAC, DTI

Illustration





Roadmap



Overview on in-flight icing research

Icing R&D Roadmap & Status – Technologies / Icing Detection System

Status

•**Goal:** Develop **Detection & Awareness tehnologies**, including primary mode, able to detect, discriminate and characterise icing conditions (App C, O, D/P)

•**Key Results:**

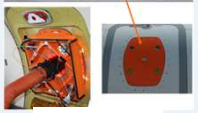
- **TRL4** achieved for PFIDS / App C (Cleansky, ON-WINGS) and **TRL2** for PFIDS / App O (GENOME)
- **TRL2** achieved for IDS and WXR / App D/P (HAIC)
- Initiation of standardisation process for IDS: ED-103 update as part of **EUROCAE WG95**

•**Challenges / Next Steps:**

- **TRL3** for ice crystals detection & awareness techno. planned end 2013 and F/T in 2016 (HAIC)

• **Projects**: DANIELA, NESLIE, JTI-SGO, JTI-SFWA, ON-WINGS, HAIC, CORICE, GENOME
• **Funding:** Cleansky, FP7, DGAC, CORAC

Illustration

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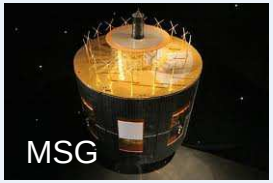
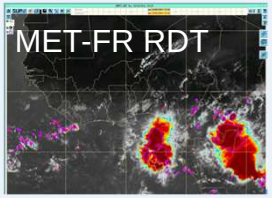
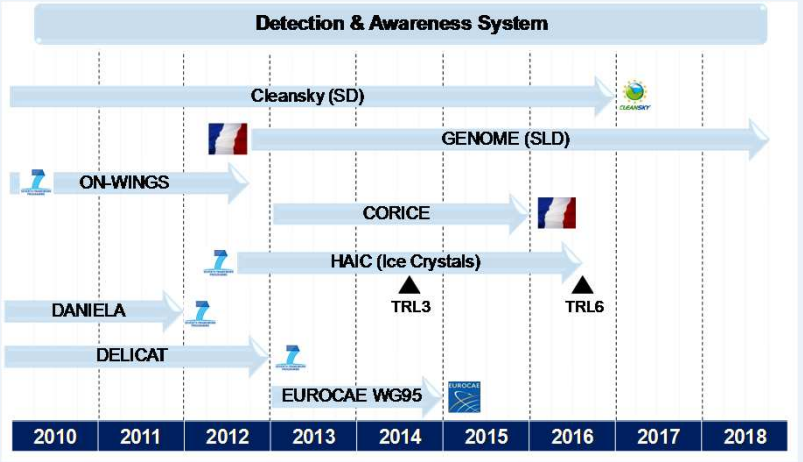




Roadmap



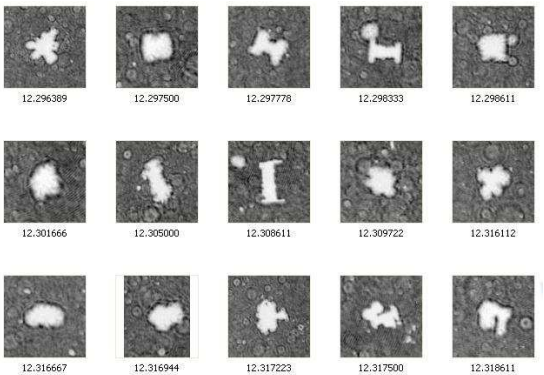
Overview on in-flight icing research
Content

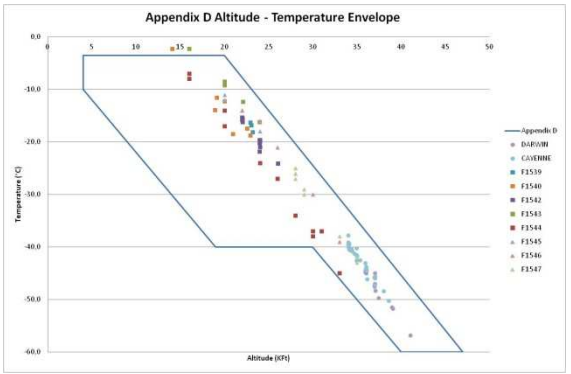
- *Context*
- *Icing R&D Roamap & Status*

- **Conclusion & Way Forward**

Overview on in-flight icing research
Conclusion & Way Forward

- Conclusion
  - An **interdisciplinary and cross-sectoral network**
  - A **streamlining of icing R&T related activities** through the definition of integrated R&T roadmap including identification of the gaps in the available knowledge and prioritization of areas for improvements
  - A large focus on **glaciated & mixed phase icing conditions**





Overview on in-flight icing research
Conclusion & Way Forward

- Way Forward
  - **Networking & Coordination**: To keep **momentum**, to ensure the **sustainability** of the WEZARD network for **prioritization and coordination** of weather hazards related actions of research at European level
  - **International Collaboration** has to be promoted to avoid gaps and/or overlaps, maximize benefit and efficiently face challenges related to evolution of regulation rules

Next challenges:

Conduct the **HAIC/HIWC international field campaign** at Darwin in Q1 2014 with the additional funding support of FAA and EASA

Set-up **EXTICE2** for the development of SLD Engineering Tools

AIRBUS
AN EADS COMPANY

Back-up – Technical Forcus

AIRBUS

Overview on in-flight icing research
EASA-HighIWC

EASA.2011.OP.28

•Coordinator: CNRS

• Topic: HighIWC — Ice Water Content of clouds at High altitude

Partnership

AIRBUS AN EADS COMPANY

Australian Government Bureau of Meteorology

CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

Top Level Objectives

The current project aims **to support the validation of the proposed mixed phase and glaciated icing environment as defined in Appendix D and P**.

The detailed objectives are to:

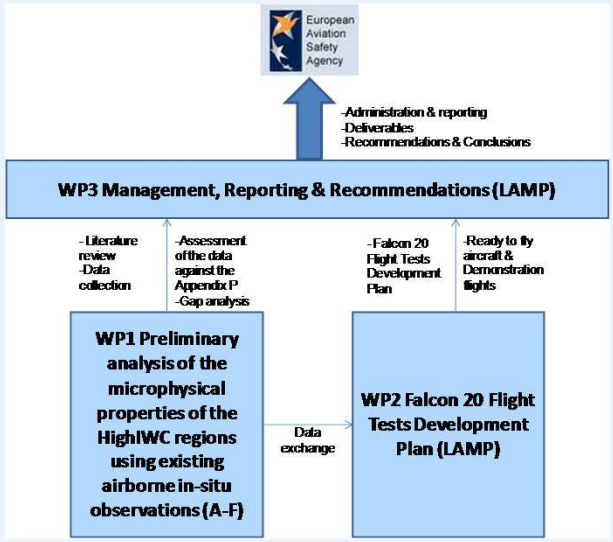
•**Assess the proposed mixed phase and glaciated icing environment as defined in Appendix D and P** in light of the analysis of the test flights conducted by Airbus over Darwin and Cayenne in 2010.,

•**Validate or propose modification of the mixed phase and glaciated icing environment as defined in Appendix D and P,**

•**Identify areas which require a further amendment,**

•**Define necessary actions for a more detailed flight test characterisation** with in particular the determination microphysical structure of cloud masses at high altitude with the appropriate precision.

Illustration & WBS



Duration & Budget

•Duration: **12 months** project – Jan / Dec 2012

•Gross budget: **298,5k€** (100% funding)

Overview on in-flight icing research
HAIC – High Altitude Ice Crystals

Top Level Objectives

•**To face challenges related to the evolution of regulation according to mixed phase and glaciated icing conditions** by characterising high IWC environments and developing the Acceptable Means of Compliance (test facilities and numerical tools),

•**To improve aircraft operation** by developing appropriate detection and awareness technologies to be fitted on aircraft and able to alert the flight crew when an aircraft is flying in and **to continuously enhance international flight safety**.

Duration & Budget

•Coordination: Airbus Operations SAS

•Duration: **48 months** project / Aug 2012 – July 2016

•Budget: 23M€

Technical Objectives

•**Characterize, optimize, enhance and select the most sophisticated cloud microphysics probes** to measure ice crystals conditions during flight tests and to calibrate icing wind tunnels.

•**Measure and Characterize the microphysical properties of core or near-core regions of deep convective clouds**.

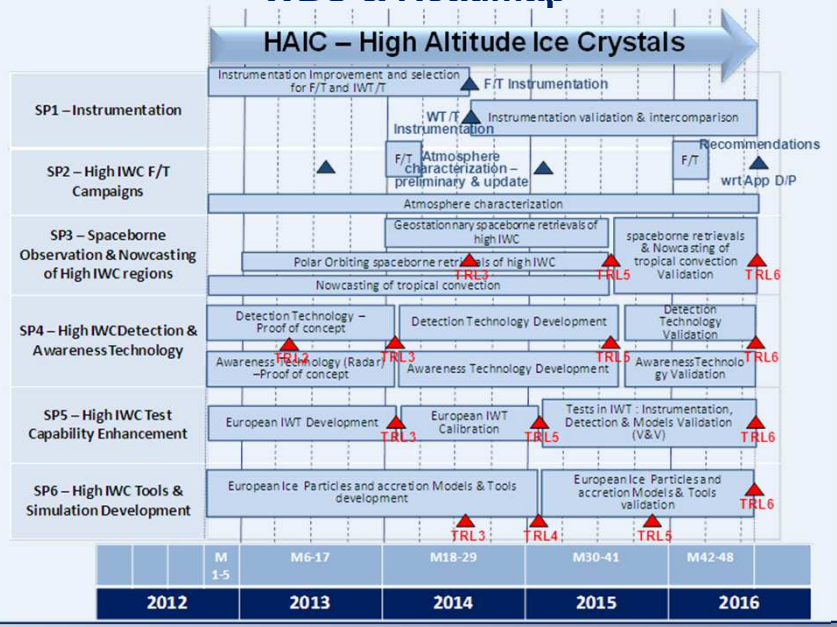
•**Upgrade European icing wind tunnels** to allow reproduction of mixed phase and glaciated icing conditions.

•**Understand and model involved physical phenomena** and **Develop numerical tools**

•**Develop and validate mixed phase and glaciated icing conditions awareness and detection technologies** to alert the crew

•**Assess the proposed mixed phase and glaciated icing environment as defined in Appendix D/P** and **provide recommendations to regulatory bodies.**

WBS & Roadmap



Overview on in-flight icing research
HAIC – High Altitude Ice Crystals

Results

- A **characterization of the microphysical properties of core or near-core regions of deep convective clouds**.
- A set of experimental and numerical capabilities as **Acceptable Means of Compliance (AMC)** for the qualification and certification of future aircraft products (mainly probes and engines)
  - **Four complementary upgraded European icing test facilities (TRL6)**,
  - A **unique numerical model** for ice particle trajectory, impingement and accretion and **mature research and industrial simulation tools (TRL6)**.
- A set of **awareness and detection technologies** to be fitted on aircraft and able to alert the flight crew.
  - A **pre-operational space-borne remote detection and nowcasting application of ice crystals conditions (TRL6)** based on imagery of geostationary MSG-SEVIRI satellite observations,
  - An **upgraded on-board weather radar (TRL6)**, based on current state-of-the-art X-band airborne weather radar,
  - **Two to four mixed phase and glaciated icing conditions detectors (TRL6)**, depending on selection performed as part of the project,
- An **assessment of the relevance of the proposed mixed phase and glaciated icing environment** as defined in Appendix D and P and a **set of recommendations** to regulatory bodies (EASA/FAA) in light of the atmosphere characterization performed as part of the project

Partners

International collaboration with North America (NASA, FAA, EC,...)

Darwin **HAIC/HIWC International Flight Test Campaign** for atmosphere characterization - planned in Q1 2014.

Back-up – H2020 Workprogram

Draft Abstract

H2020 Workprogram
EXTICE2 – Draft Abstract

- ACARE SRIA 2050 challenge: Ensuring safety and security
- Specific Challenges: Supercooled Large Droplets (SLD) have been incriminated as main contributors in noteworthy incidents and accidents, mainly for smaller aircrafts and turboprops, leading to an evolution of the regulation rules which should be applicable by 2014. The challenge to be addressed is the improvement of Engineering tools, to support future development and certification of new products.
- Content and scope: Research will target the development of measurement techniques and instrumentation for research purposes on Supercooled Large Droplet (SLD) icing conditions. This knowledge will be used to improve the representativeness of ground testing (wind tunnels) and modeling capacities.
- Selected icing tunnels should be modified to reproduce more faithfully SLD icing conditions and the computer based modeling will be refined to better include actual physical phenomena. An integrated cross-validation will be performed between wind-tunnel measurements and model predictions. Results will be analysed in the light of the current regulatory framework.
- Expected impact: The work should aim at providing aircraft manufacturers with enhanced understanding, modeling and simulating capacities of SLD icing conditions. The objective is to reduce the risk of incidents when an aircraft is flying in such weather conditions.
- Implementation and management: Cooperation with international working groups on this topic is encouraged as well as cooperation with North America

H2020 Workprogram
EXTICE2 – EXTreme ICing Environment

HORIZON 2020, Call 2

•Coordination: **Airbus Operations SAS** - TBC

Top Level Objectives

•**To face challenges related to the evolution of regulation according to SLD icing conditions** by developing the Engineering tools to support future development and certification of new products,

- •**Characterize, optimize, enhance and select the most sophisticated cloud microphysics probes** to calibrate icing wind tunnels.
- •**Upgrade European icing wind tunnels to allow reproduction of SLD icing conditions (FZDZ and FZRA)** to allow the Aeronautical industry performing qualification of equipments.
- •**Understand and model involved physical phenomena** and **Develop numerical tools** to simulate the impact of SLD icing conditions on aircraft components for supporting both design and certification phases.

•To continuously **enhance international flight safety**

•To promote **International collaboration** (USA, ...)

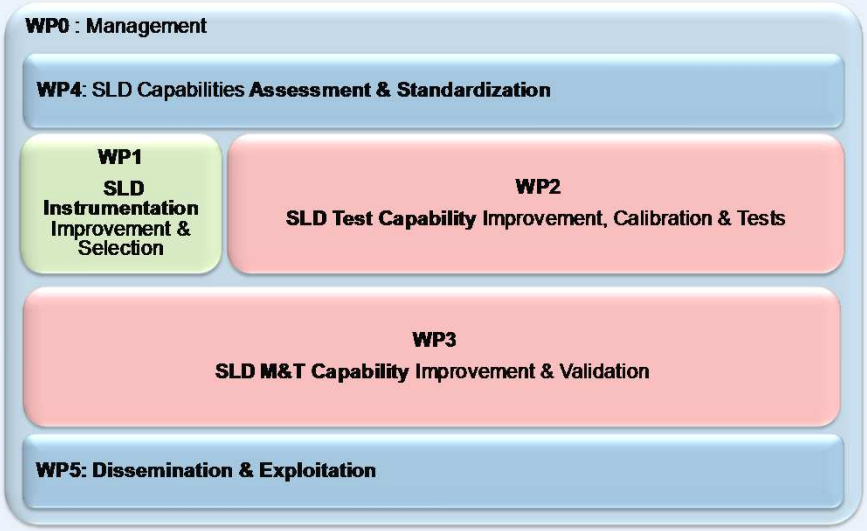
Duration & Budget

•Duration: **4 years (2015-2019)**
•Gross budget: **~7M€** + US contribution

Partnership

To be completed

WBS



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