1. PUBLISHABLE SUMMARY

1.1. SUMMARY DESCRIPTION OF THE PROJECT CONTEXT AND THE MAIN OBJECTIVES

Commercial aircraft have been experiencing in-service events while flying in the vicinity of deep convective clouds since at least the early 1990s. Heated probes and engines are the areas of aircraft most prone to mixed phase and glaciated icing threat. In anticipation of regulation changes according to mixed phase and glaciated icing conditions, the HAIC project will provide the necessary Acceptable Means of Compliance (numerical and test capabilities) and appropriate ice particle detection/awareness technologies to the European Aeronautical industry for use on-board commercial aircraft in order to enhance safety when an aircraft is flying in such weather conditions.

HAIC will also develop international cooperation and collaboration thanks to the involvement of key international organisations and companies as partners of the project or through the advisory board.

The main objectives of the HAIC project are to allow the European aeronautical industry to face challenges related to the evolution of regulation regarding mixed phase and glaciated icing conditions by characterising high ice water content environments and developing the Acceptable Means of Compliance (test facilities and numerical tools) to improve aircraft operation in such weather conditions by developing appropriate detection and awareness technologies to be fitted on aircraft and being able to alert the flight crew, thus continuously enhancing international flight safety.

This can be broken down into the following scientific, technical and dissemination objectives:

1.1.1. Scientific and Technical Objectives

- Characterise, optimise, enhance and select the most sophisticated cloud microphysics probes to measure mixed phase and glaciated icing conditions during flight tests and to calibrate icing wind tunnels
- Measure and characterise the microphysical properties of core or near-core regions of deep convective clouds, including cloud liquid and ice water contents, particle size distributions and particle shapes and provide 99th percentile total water content statistics as a function of distance scale to assess Appendix D and P diagrams representativeness vs real atmosphere
- Upgrade European icing wind tunnels to allow reproduction of mixed phase and glaciated icing conditions to allow the European Aeronautical industry to perform equipment qualification and generate a detailed experimental database to validate numerical tools
- Understand and model involved physical phenomena and develop numerical tools to simulate the impact of mixed phase and glaciated icing conditions on aircraft components (mainly engines and probes) for supporting both design and certification phases and perform an integrated cross-validation between in-flight measurements, wind-tunnel measurements and model predictions
- Develop and validate mixed phase and glaciated icing conditions awareness and detection technologies to alert the crew of flight in these particular icing conditions or to adapt the flight path well in advance in order to avoid such weather conditions

1.1.2. Dissemination Objectives

- Assess the proposed mixed phase and glaciated icing environment as defined in Appendix D and P in light of the analysis of the research flight tests performed as part of the HAIC project and provide recommendations to the regulatory bodies (EASA and FAA).
- Develop international cooperation and collaboration thanks to the involvement of key international organisations and companies as partners of the project or through the Advisory Board.

1.2. WORK PERFORMED SINCE THE BEGINNING OF THE PROJECT AND THE MAIN RESULTS ACHIEVED SO FAR

HAIC has achieved most of the objectives planned during the third year of the project.

As part of SP1 Instrumentation, the improvement of microphysical and bulk probes to be used in flight test campaigns and wind tunnel experiments was completed. New HSI (High Speed Imager) probe was also installed on NRC CONVAIR 580 during the HAIC/HIWC Cayenne 2015 campaign. The selection of the instrumentation of the HAIC A340 2016 campaign has been made. Finally, the instruments for wind tunnel calibration have been further developed and selected instruments have been integrated in the test facilities.

In SP2 High IWC Flight tests Campaigns, the 2nd HAIC/HIWC field campaign, aiming at completing the database to provide the 99th percentile total water content statistics as a function of distance scale to industry and regulators, was conducted out of Cayenne, French Guyanna from 9th May 2015 to 29th May 2015. . It involved three aircraft: SAFIRE Falcon 20, NRC/Environment Canada CONVAIR 580 and the Honeywell B757. This campaign is the results of an efficient and fruitfull international collaboration with the US lead HIWC project,the EASA-HighIWC project and with the additional support from the Ice Crystals Consortium. The third year of the project also focused on the preparation of the HAIC A340 2016 campaign with the definition of the installation concept and the launch of the working party in September 2015.

Regarding SP3 Space-borne Observation & Nowcasting of High IWC Regions, an updated version of the High IWC mask, built from concurrent CPP and A-Train products, and an operational RDT chain has been developed and successively tested during the HAIC/HIWC Cayenne 2015 campaign. Analysis is underway to evaluate their performances from the different in-situ measurements. Investigations are still underway to identify specific signatures of High IWC in visible, infrared and microwave observations/products of low orbit satellite missions. In addition a new algorithm based on neural network technique has been built from concurrent airborne RASTA and satellite MTSAT observations. The work performed as part of SP3 allows demonstrating TRL4 maturity. TRL5 is planned by end 2015.

In SP4 High IWC Detection & Awareness Technology, the development of the technologies has been pursued with a focus on the demonstration of the performances. In particular, icing wind tunnels tests have been initiated for detection technologies and weather radar has been flight tested during the HAIC/HIWC 2015 Cayenne campaign. This work led to the successful demonstration of TRL4 maturity for 3 out of 5 technologies considered as part of the project. Work also focused on the preparation of the HAIC A340 2016 campaign with the development of the prototypes and the convergence on architecture and installation concept.

In SP5 High IWC Test Capability Enhancement, improvement of European test facilities and associated commissioning tests have been completed allowing to demonstrate TRL3 maturity. Calibration has started with the support of SP1 but difficulties due to the availability of the instrumentation and the facilities delayed the achievement of the calibration and the associated TRL5 milestone. Finally, the campaigns for validation of detection technologies developed as part of SP4 have started.

Finally, SP6 High IWC Tools & Simulation Development achieved all laboratory experiments and a comprehensive set of models has been developed for ice crystal trajectory, impingement and accretion. The implementation of these models into numerical tools is almost achieved and validation activities are on-going. As far as the assessment of impingement and accretion models is concerned, the preliminary results are very encouraging and prove that a major progress, beyond the state of the art, has been done since the beginning of the project. This technostream is now well on track to demonstrate TRL4 maturity by end 2015.

1.3. EXPECTED FINAL RESULTS AND THEIR POTENTIAL IMPACTS AND USE (INCLUDING SOCIO-ECONOMIC IMPACT AND THE WIDER SOCIETAL IMPLICATIONS OF THE PROJECT SO FAR)

Operational safety related research activities are a major research topic which has been dominant throughout the ACARE Strategic Research Agendas 1 and 2 which provides the Aeronautics Research agenda up to 2020. “Flight path 2050” also emphases the importance of safety and the

mastering of all aeronautical aspects (Aircraft & operational safety, ATM, Infrastructures, Test and simulation facilities and certification) related to weather hazards.

The HAIC project will significantly contribute to this objective through the delivery of the following expected results:

- A characterisation of the microphysical properties of core or near-core regions of deep convective clouds based on a unique flight test dataset in deep oceanic convective storms
- 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) with improved representativeness of simulated mixed phase and glaciated icing conditions and covering the whole flight and icing envelope
    - A unique European 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 when an aircraft is flying in such weather conditions
    - A pre-operational space-borne remote detection and nowcasting application of glaciated icing conditions (TRL6) based on imagery of geostationary MSG-SEVIRI satellite observations, validated with space-borne active and passive cloud observations from LEO and GEO missions and integrated into a pre-operational application for detection of Rapidly Developing Thunderstorm (RDT) over the Tropical Atlantic
    - An upgraded on-board weather radar (TRL6), based on current state-of-the-art X-band airborne weather radar equipment, to raise awareness to the flight crew of the encounter of glaciated icing conditions
    - Two to four mixed phase and glaciated icing conditions detectors (TRL6) to alert the flight crew in these particular icing conditions
- An assessment of the representativeness 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 characterisation performed as part of the project

Indeed, HAIC will provide aircraft manufacturers with enhanced understanding, measurement and modelling capacities of near icing or icing conditions at high altitude. All these capacities will in turn permit the effective industrialization and integration of appropriate detection and awareness technologies on new aircraft products and possibly on existing aircraft fleet and the effective development and qualification of new air data probes and engines.

HAIC will also cover standardisation at international and European level through SAE or EUROCAE regarding pitot probes qualification requirements (SAE AS8006, EUROCAE ETSO C16a), test facility calibration methodology (SAE ARP5905) or operational performance for inflight icing detection systems (SAE AS5498).

These contributions will allow improving aircraft operation in such icing conditions and thus to enhance international flight safety.

Finally, HAIC is promoting cooperation with international working groups and international collaboration. HAIC and many of its partners, as members of several dominant international working groups, will disseminate much of the HAIC results to working groups such as the EIWG, EUROCAE WG89 and WG95 or SAE AC-9C. Also, on top of the HAIC/HIWC international collaboration to collect cloud data in deep convective clouds, five partners from Australia, Canada and the United States are directly involved in the project. Lastly, several US based organisations (FAA, Boeing, NASA, GE, Goodrich, etc) have accepted to join the HAIC advisory board.