Deliverable D6.6c – Final publishable summary report

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Table of contents

List of figures

List of tables

I. Executive summary

Over a seven-day period in April 2010, air travel in most of northern Europe suddenly and unexpectedly came to a halt. A cloud of volcanic ash accompanying the eruption of the Eyjafjallajokull volcano grounded over 100 000 flights, stranded 10 million passengers and cost industry over USD 5 billion.

The EU-funded project 'WEather haZARDs for aeronautics' (WEZARD) is developing a research and development (R&D) roadmap leading to reliable air transport in the face of natural atmospheric hazards. The focus is on icing and volcanic ash.

Launched in July 2011, WEZARD consortium consists of air frame and engine manufacturers, meteorological offices, research centres, a systems supplier, a test facilities provider and a civil aviation authority. Together, they established an advisory board of expert representatives. These were selected from international organisations (e.g. the European Aviation Safety Agency (EASA) and the Federal Aviation Administration (FAA)), working groups, research projects and aircraft operators.

In May 2012, WEZARD organized a first workshop to present preliminary R&D roadmap and to assimilate advisory board opinions and recommendations on specific topics, including observation and prediction, on-board systems and research instrumentation and test and numerical capabilities development. The preliminary WEZARD roadmap spawned three proposals for Seventh Framework Programme (FP7) funding with active participation by the WEZARD consortium.

Identification of the need to anticipate regulatory changes and develop effective means of compliance led to submission of the proposal for the 'High Altitude Ice Crystals' (HAIC) project. This was successfully funded and is investigating mixed phase and glaciating conditions, in particular as related to heated probes and engines. WEZARD identified an additional topic on this subject related to supercooled large droplet (SLD). This initiative should lead to the submission of the proposal for the 'EXTreme ICing Environment II' (EXTICE II) project in the framework of HORIZON2020. The complexity, costs, and skills required to address current SLD research requires international partnerships and coordination of resources. The FAA stated "*We have a unique opportunity with EU and North American funding and skills/expertise/facilities to address major gaps in SLD engineering tools and methods development over the next few years by working together*"

WEZARD identified an additional three high priority topics. These consist of developing an integrated observation system to monitor distal volcanic ash clouds and an onboard volcanic ash detection and avoidance system. In addition, enhanced knowledge and tools for accretion and shedding are deemed critical for maintaining robust air transport under icing conditions. Two more proposals have been submitted to address these issues. The proposal for the ''efficient ice protection Systems and simulation Techniques Of ice Release on propulsive systems' (STORM) project was successfully funded and is investigating the development and validation of advanced simulation methodologies and ice protection concepts for aero propulsive systems. The remaining proposals for the 'Volcanic Ash Detection & Awareness System' (VADAS) project and the 'EUropean Volcanic ash Observing NETwork' (EUVONET) project will be submitted in the framework of HORIZON2020.

In June 2013, WEZARD organized a second workshop to present the final R&D roadmap and capture final recommendations from the advisory board. Eight workshop sessions were organized to present the main findings of the project. Another workshop on supercooled large droplet was also organized to prepare the EXTICE II project proposal and strengthen exchange with North America.

WEZARD outcomes could serve as a foundation for a consistent multi-year research plan addressing relevant priorities and gaps. As such, WEZARD aims to contribute to the next generation of icing and volcanic ash air transport protection systems through focused input to and guidance of related research projects.

II. Context & Objectives

On April 14th, 2010, the eruption of the Eyjafjallajökull volcano in Iceland and the accompanying cloud of volcanic ash forced most countries in northern Europe to shut their airspace between 15 and 20 April 2010, grounded more than 100,000 flights and affected an estimated 10 million travellers. This event revealed to what extent our society and economy rely on the availability of a safe and efficient air transport system and how fragile it still remains when faced with the complexity of atmospheric conditions.

Natural hazards that can severely impact the air transport system are not restricted to the results of volcanic eruptions as they also include other natural hazards involving particles such as icing (Supercooled large droplet, mixed phase and glaciated icing conditions).

The WEZARD project (CSA-SA WEather haZARDs for aeronautics, FP7, 4th call) aims to support and contribute to the preparation of future community research in the field of air transport system robustness when it is faced with weather hazards with particular focus on volcanic ash and icing (Supercooled Large Droplet, mixed phase and glaciated icing conditions).

The detailed objectives of WEZARD are to:

- Set-up an interdisciplinary and cross-sectoral network (comprising expertise from observation and measurement, the aeronautics industry, aircraft operators, network managers, risk management specialists, scientists, etc.);
- Compile a list of the main weather hazards such as hazards which can be spread over very large areas (e.g. volcanic ash clouds) or severe atmospheric conditions (e.g. icing: SLD, mixed phase or glaciated ice conditions);
- Compile the technical consequences of these hazards on the aircraft (failures, damages, etc.);
- Compile an inventory of recent and ongoing R&D activities within relevant areas, and financed through different programmes at EU (FP5/6/7, environment, space/GMES, aeronautics, etc.) as well as at national level, and within relevant institutions;
- Compare, analyze and validate the results of relevant projects and activities in a structured peer review process, and to propose the most mature and relevant new developments for concepts and methodologies, data sources and models, etc. for take-up in risk detection, assessment and risk management. In particular, WEZARD will propose and promote technological solutions for realistic on board integration in term of weight, cost, availability, performance, etc.;
- Develop on this basis a coherent approach to the validation of the relevant input data, models, etc., targeted for the specific purpose of risk management in air transport;
- Finally, provide a R&D roadmap on further R&D and validation activities including priorities, impact analysis and consequence on decision making.

Finally, WEZARD will contribute to the definition of the next Aeronautic and Air Transport Work Programme by identifying and proposing activities and topics to be investigated by relevant projects in the FP7 and H2020 work programmes. Such a multi-year plan will ensure the sustainability of the

WEZARD network at mid and long term and then will contribute to secure and re-enforce the European expertise on atmospheric hazards.

III. Main S & T results/foregrounds

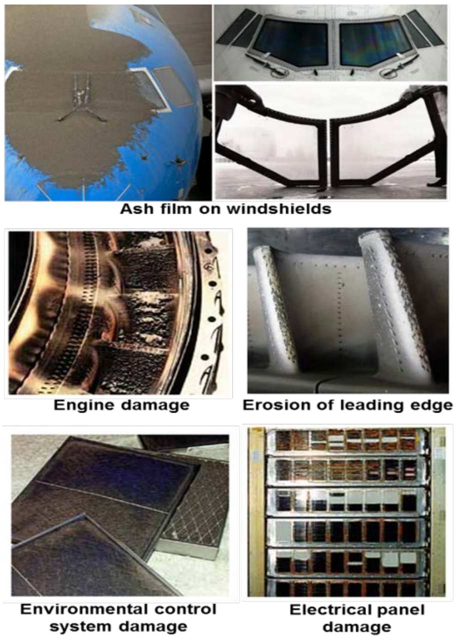
The WEZARD project (CSA-SA WEather haZARDs for aeronautics, FP7, 4th call) aims to support and contribute to the preparation of future community research in the field of air transport system robustness when it is faced with weather hazards with particular focus on volcanic ash and icing (Supercooled Large Droplet, mixed phase and glaciated icing conditions).

A. Volcanic Ash

On April 14th, 2010 the eruption of the Eyjafjallajökull volcano in Iceland and the accompanying widely dispersed cloud of volcanic ash (VA) forced most countries in Northern Europe to shut their airspace for safety reasons.

Decisions were taken based on potential threats to aircraft (A/C) considering:

- Clogging of orifices, probes, sensors and instruments leading to erratic measurement of the flight conditions (airspeed, total pressure, angle of attack, etc.);
- Damage to A/C exterior e.g. windshields, wing leading edge, landing lights;
- Ingestion into the engine leading to:
  - Power loss, multiple engine flameouts
  - Slow or no engine restart
  - Risk of loss of most electrical, hydraulic and pneumatic components with flight control problems and cabin pressurization failure;
- Blasting/erosion/corrosion of A/C components reducing A/C lifetime due to:
  - Degraded integrity of composite structure
  - Abrasion of fan-blades, engine inlet and compressor blades;
- Impaired vision caused by ash film on windshields.



As a consequence, **more than 100,000 flights were grounded by authorities during April 15-20**. This was considered the worst global travel interruption since World War II, **with severe social and economic impacts for a six day period**:

- **10 million travellers affected**, the majority of which experienced job disruption ;
- **81% of the Western European air freight brought to a standstill** with:
  - Food shops/restaurants facing shortages of perishable products ;
  - Production suspended due to interruptions in the supply chain (e.g. BMW and Nissan halted production of 7,000 and 2,000 cars, respectively) ;

  - o Imports of medications (vaccines, biological products, transplants) jeopardised or postponed, putting patients' lives at risk.
- **Ambulance flights and search and rescue services not able to operate**
- **€ 3.8 billion loss resulting in a 0.05% decrease in European Gross Domestic Product (GDP)**

This reveals to what extent our society and economy rely on the availability of a safe and efficient air transport system and how fragile it remains when faced with natural hazards such as volcanic eruptions and the ensuing complexity of atmospheric conditions.

The Eyjafjallajökull crisis cost airlines approximately €150 million per day, representing 30% of the total economic loss during that time. Such a loss might endanger the profitability and therefore continuity of an airline. If during the crisis only 30-50% of flights could have been operated safely at the border of the ash cloud or during days of limited ash proliferation to central Europe, the airlines' deficit would have been significantly reduced, medical air transport possible and the supply chain to the industrial sector via air freight secured, resulting in an acceptable societal and economic impact.

It is important to highlight, however, that in the case of the Eyjafjallajökull eruption European operational air traffic was impaired for only up to six days depending on geographical location, and that a future event might last much longer.

Although explosive volcanic eruptions on the scale witnessed in Iceland are not an everyday occurrence in air transport, **eruptions producing VA that can be a hazard to A/C occur on average about once per week somewhere over the globe**. It is also important to keep in mind that the Eyjafjallajökull eruption is considered by volcanologists as a very modest eruption[1]. More, geologists warn that much more powerful events of this type could occur in the not too distant future. As an example, an eruption of Katla, a very active Icelandic volcano, is expected to be ten times stronger than the 2010 Eyjafjallajökull eruption. There are 16 documented Katla eruptions between 930 and 1918, every 60 years on average. After 94 years, another Katla eruption is long overdue[2]. Worldwide, **70 volcanoes are currently known to be active** (see Figure 1 below).

1 Atlantic Conference on Eyjafjallajökull and Aviation (15-16 Sept. 2010 – Keflavik Airport, Iceland)

2 Thordarsson, Th. and Höskuldsson, A.: ICELAND (Classic Geology in Europe 3), Terra Publishing (Januar 2002), pp. 109-110; Sturkell, E. et. al., Volcano geodesy and magma dynamics in Iceland, J. of Volc. and Geoth. Res. 150 (2006) pp.14- 34

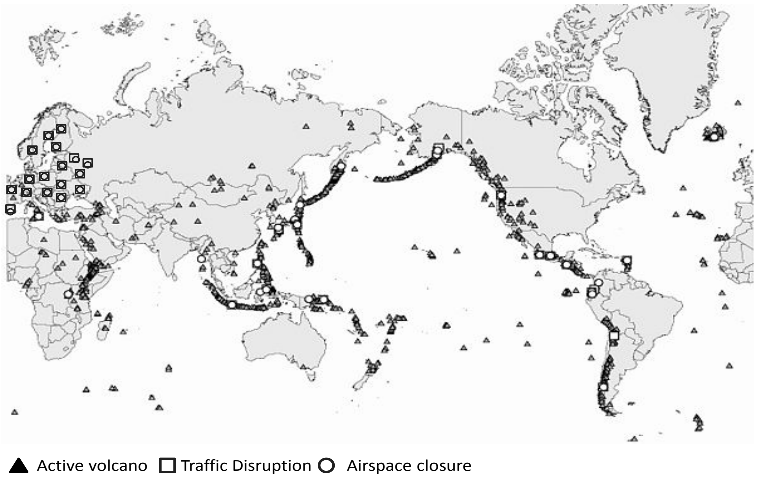


Figure 1: Active volcanos location with observed impact of eruption on air travel[3]

In case of volcanic explosive eruptions, several cubic kilometres of water vapour, halogen compounds, corrosive/hazardous gases (carbon dioxide (CO_2) and sulphur dioxide (SO_2)) and VA (glass particles and pulverized rock, i.e. small, solid particles) are widely spread by wind circulation into the atmosphere from few days up to several months. This potentially poses a threat to A/C and air traffic at large. A series of life threatening encounters of A/C with ash-loaded volcanic clouds in the 1980s highlighted the risk of volcanic emissions to aviation (see Figure 2 below).

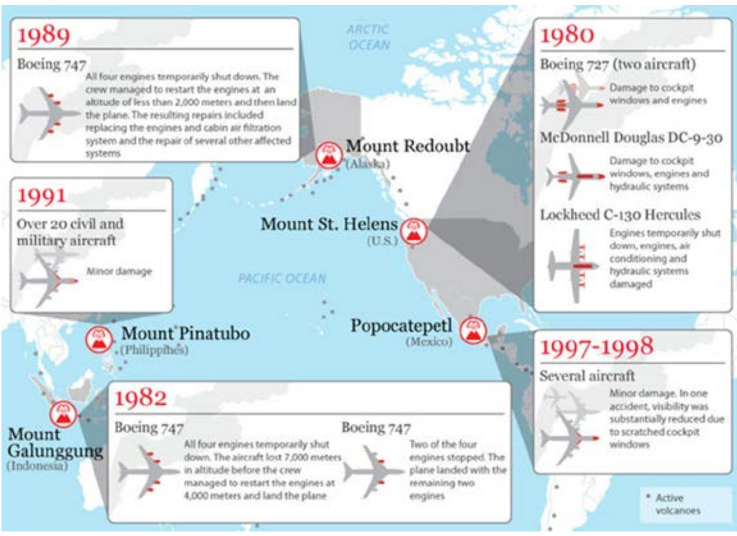


Figure 2: A/C and VA damage

Damages to A/C are usually due to clogging and accumulation of molten debris in the hotter part of the engine and consequent loss of power, resulting from the difference between the melting point of VA (≈1100 K) and the typical operational temperature (1400 K) of jet engines if thrust is above idle. For instance, during the Mt. St. Helens, USA eruption in 1980, a Lockheed C-130 lost two of its four turboprop engines, and in the 1982 eruption of Galunggung, Indonesia, two Boeing 747 lost engine

3 Guffanti, M. and Miller, E.K. (2002), Reducing the threat to aviation from airborne volcanic ash, 55th Annual International Air Safety Seminar, 4-7 Nov. 2002, Dublin, Ireland.

power at 11,300 m and 9,000 m above sea level (a.s.l.). Both airplanes landed safely at nearby airports, but only after descending several kilometres. In 1989, a Boeing 747 flew into the plume emitted by Mt. Redoubt, USA, resulting in a total loss of engine power (Casadevall, 1994). A successful restart of the engines less than 2,000m a.s.l. allowed for safe landing. These encounters resulted in significant economic losses, but fortunately no human lives were lost. Several minor events were recorded during the eruption of Mt. Pinatubo, Philippines in 1991, with damage to A/C estimated to exceed US$ 100 million (Miller and Casadevall, 2000).

Other effects include clogging of cooling mechanisms greatly reducing the engines' lifetime, and abrasion of engine parts, the outer hull of A/C, avionics systems (e.g. Pitot-static tubes) and windscreens (becoming opaque). Certain volcanic gases can also be hazardous to aviation, in particular SO_2 and sulphuric acid (H_2SO_4). Although they do not impair the airworthiness of A/C in such drastic ways as VA, prolonged exposure might reduce the lifetime of A/C systems and lead to economic loss (Bernard and Rose, 1990; ICAO, 2007).The example of a DC-8-72 NASA research A/C which flew into the plume of Hekla volcano, Iceland in February 2000 illustrates the problem: The presence of a volcanic plume was not perceived by the crew and only verified afterwards by the scientific instruments on-board the A/C. Although a first visual inspection of the engines revealed no damage, clogged cooling passages of turbine blades and SO2 in the engine oil were detected later on, potentially reducing the remaining lifetime of certain vital engine parts.

In the course of the Eyjafjallajökull crisis, the "no-fly-rule" stating that A/C are not allowed to fly through plumes of any VA concentration was replaced in the ICAO European and North Atlantic region (EUR/NAT) by conditional flying zones. This "No Fly Zone" comprises areas where VA (of any concentration) is observed and predicted to be, whereas in "Enhanced Procedures Zones" (as defined by the 2010 ICAO EUR/NAT VA contingency plan) forecast VA concentration contours of 2×10^{-4} (low contamination threshold), 2×10^{-3} g m^{-3} (medium contamination) and 4×10^{-3} g m^{-3} (high contamination) are used as a basis for informing the implementation of airspace restrictions. This more flexible and quantitative-based approach has been proven to keep larger areas of European air space operational, although the potential impacts of this approach in terms of the long-term damage to A/C components is still poorly understood. It should also be noted that the meteorological and volcanological community are working in coordination with the aviation industry to further improve and reduce uncertainties associated with the monitoring, observing and modelling of volcanic eruptions and plumes.

More recently, the International Volcanic Ash Task Force (IVATF) recognised the concept of "Visible Ash avoidance" (*volcanic ash that can be observed by the human eye*) as the main driver to maintain a good safety level in contaminated environment. Although this concept may replace in the future the existing concentration maps provided by the VAACs, the European Authorities still recommend that ash concentration charts provided by the European VAAC, for operations in European airspace, identify the three zones as described in the ICAO Volcanic Ash Contingency Plan EUR and NAT Regions (EUR Doc 019).

The IAVWOPSG also approved the definition of "Discernible ash" (volcanic ash detected by: defined impacts on/in aircraft; or by agreed in-situ and/or remote sensing techniques) and recognised that it is the 'agreed in-situ and/or remote sensing techniques' that is used by the VAACs as a basis for producing their forecast advisories.

It has to be highlighted that the principles of a certification standard addressing airworthiness and susceptibility of aircraft and engines to volcanic ash was not endorsed at IVATF level.

Finally, **ICAO Document 9974 states that the airline is responsible for the safety of its operations**. The risk of an encounter with VA has therefore to be mitigated through airlines' safety risk assessment policies with necessary pre-flight planning and/or tactical in-flight re-planning. Reports and forecasts from the Volcanic Ash Advisory Centres (VAACs) are currently the only support to airlines safety risk assessment with regard to VA. They are produced based on information gathered and analyzed from remote observations (ground based and airborne) and satellite images based on which VAACs are using sophisticated trajectory/dispersion model forecasts.

The work performed by WEZARD has led to the issuing of the WEZARD R&D Roadmap for volcanic ash structured around 6 technology streams:

- Volcanic Ash Risk Assessment & Aircraft Susceptibility
- Volcanic Ash Observations & Dispersion Model
- Volcanic Ash Technologies Development & Integration
- Volcanic Ash Numerical Capabilities
- Volcanic Ash Test Capabilities
- Volcanic Ash Expertise & Sustainability of the WEZARD Network

In particular, two **High Priority Needs** were identified by WEZARD.

The first one is related to the "research and development of existing, new and evolving volcanic ash observing technologies and dissemination systems to underpin the future successful realisation of an integrated European volcanic ash observing network." This aims to address a key gap identified: that current systems cannot provide the information required for decision makers in the aviation industry on the geographical and vertical extent of volcanic ash and associated levels of contamination. It recognises that no single observing technology can provide a complete and fully resilient solution - all observational techniques have strengths and weaknesses. An enhanced observational network of complementary monitoring systems is needed to initialise, validate and verify volcanic ash dispersion model output and forecasts, focussing on distal monitoring. This is analogous to the principle of investing in a range of quality observational measurements of the atmosphere in order to improve the accuracy of weather forecasts, a tried and tested philosophy. The 'EUVONET' proposal for a European *integrated* observing system for volcanic ash would enable significant progress to be made in the area of improving observations and data usage. Moreover, EUVONET would also ensure continuation of the coordination of many international volcanic ash research and development efforts to ensure the effective pull through of science into operations.

The second high priority needs is related to the development of Volcanic Ash Detection and Awareness Systems. The associated proposal for a "Volcanic Ash Detection & Awareness System" (VADAS) would aim at assessing the feasibility and benefit of the development and integration of an advisory VA detection and awareness system into commercial A/C in order to provide airlines and pilots with necessary information to support strategic pre-flight planning and tactical in-flight re-planning for safe operation in VA conditions and real-time data to VAACs to improve ash dispersal forecasts. The proposal should demonstrate proof of concept (TRL3) for volcanic ash detection and awareness technologies development & integration. Capability to detect other weather hazards such as icing (SD, SLD, ice crystals) or SO2 will be a key factor in the assessment of the technologies.

B. Icing

Icing classically occurs when an aircraft flies through clouds in which **supercooled droplets** are suspended. A supercooled droplet is a small drop of liquid water with an ambient air temperature below freezing point. This is an unstable state for water, and any energy input will make the water turn to its stable phase: ice. Therefore, when the droplets impinge on the aircraft surfaces, they freeze, leading to ice accretion. Airframe icing can lead to a reduction of visibility, damage due to ice shedding, blockage of pitot tubes and static vents, reduced flight performance, adverse aerodynamic effects, etc. In order to comply with certification regulation rules, airframers have to demonstrate safe aircraft operation in icing conditions, as defined per CS25 and FAR25. This demonstration is performed through a combined use of theoretical studies, wind tunnel tests, simulated results and flight tests.

More recent aircraft incidents have highlighted the existence of icing cloud characteristics beyond the current certification icing envelope that is defined by the CS/FAR Appendix C. This envelope, defined as a function of altitude, temperature and Liquid Water Content, covers only supercooled droplet with diameters up to 50µm.

Among these icing conditions, **Supercooled Large Droplets (SLD)** have been incriminated as main contributors in noteworthy accidents including Roselawn[4]. SLD icing involves much larger droplets than covered by the icing envelope in Appendix C such as *freezing drizzle*, in the range of 40-400 µm, or *freezing rain*, with droplet diameter beyond 400µm. Preliminary analyses of the existing tools have demonstrated the limitations of the ice modelling capabilities, especially since these methods have been focused towards representing the Appendix C icing envelope and not developed to account for SLD icing conditions which have much larger droplet sizes. The current methods do not adequately represent the droplet dynamics and icing physics associated with SLD: numerical methods do not take account of specific SLD phenomena such as droplet splashing and bouncing, droplet break-up or large droplet drag. The potential impacts on the aircraft design are an increase of the extent of protection due to the larger impingement area and an increase of the power consumption of ice protection systems due to the larger water catch rate. Research projects are on-going within the international community, such as the EXTICE European project, to cover this icing phenomenon.

Nevertheless, information gathered since the 1990's on over **100 weather related engine powerloss events** has also permitted the Scientific and Regulatory community to conclude that aircraft flying through areas of high **Ice Water Content (IWC)** at high altitude are subject to a specific type of weather induced incidents.

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4 Aircraft Accident Report, "In-Flight Icing Encounter And Loss Of Control", NTSB/AAR-96/01, 1994

High ice water content is often found in deep convective clouds present in the warm tropical regions around the globe. These clouds can contain deep updraft cores that transport low-level air high into the atmosphere, during which water vapour is continually condensed as the temperature drops. In doing so, these updraft cores may produce localised regions where very high concentration of ice particles, or **ice crystals**, can be encountered. Such conditions are called **glaciated icing conditions**. They are not visible by current on-board weather radar ice detectors. Very preliminary studies, predominately led in the United States and Canada, have shown that under certain conditions, these ice particles can led to ice accretion on heated surfaces of aircraft (heated probes and engines) although the surface temperature is positive at the beginning of the phenomenon.

These ice particles can also be found simultaneously with supercooled droplet. Such conditions are called **mixed phase icing conditions**.

In 2004, the ARAC (Aviation Rulemaking Advisory Committee) formed the Ice Protection Harmonization Working Group (IPHWG) to address possible needs for certification regarding supercooled large droplet (SLD), mixed phase and glaciated icing conditions. The IPHWG concentrated mainly on airframe icing issues and asked the Engine Harmonisation Working Group (EHWG) to address issues related to propulsion systems.

The work performed as part of these ARAC groups led to the issuing by FAA of the NPRM10-10 (Notice for Proposed Rule Making) on June 2010 and the issuing by EASA of the NPA 2011-03 CS25 and NPA 2011-04 CS-E in March 2011. The associated regulation rule should be applicable in 20124 The proposed rule defines a new icing envelope for SLD (Appendix O) and mixed phase and glaciated icing conditions (Appendix D and P).

Further research is needed **to face challenges related to the evolution of regulation** on SLD and mixed phase and glaciated icing conditions, **to improve aircraft operation** in such weather conditions and **to continuously enhance international flight safety**.

On top of the evolution of regulation, aircraft manufacturers are investing massively to propose new technologies to tackle world traffic growth, reduce environmental foot print, improve operational efficiency and face an increasing industry competition on short/medium range aircrafts.

Figure 3 : Research and Technology: The challenges

Indeed, new aircraft configurations are investigated and disruptive icing related technologies are developed to raise benefit at aircraft level, thanks for instance to the reduction of power off-take, while maintaining the highest level of safety.

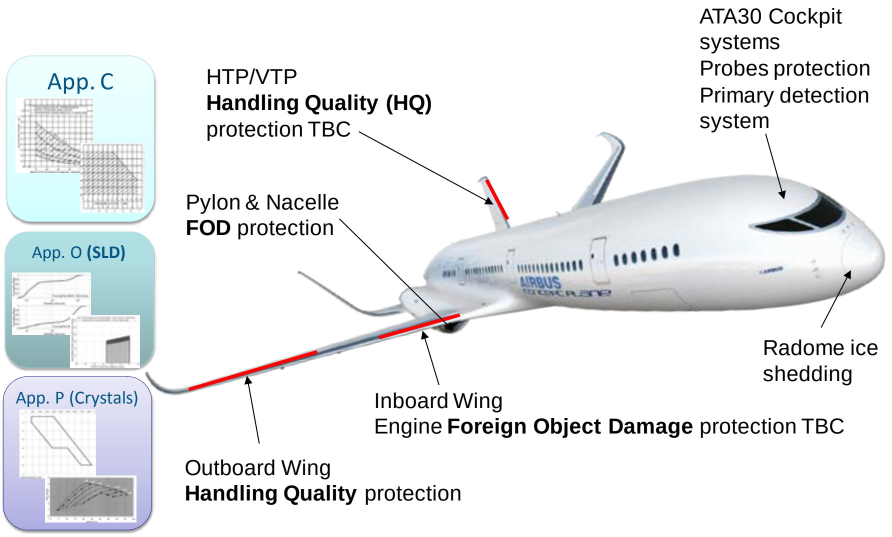

Figure 4 : Research and Technology: The icing challenges

To sum-up, the major icing related challenges that aeronautic industry has to face in the future are:

- Evolution of **icing regulation** (SLD, Glaciated & mixed phase icing conditions,…)
- Development and integration of **new and disruptive technologies** (electrical wing ice protection system, Primary in-flight ice detection systems,…) to enable new aircraft configuration, bleedless aircraft,…
- Development and validation of **capabilities** to support technologies development, integration and certification (Test facilities, simulation tools, processes,…)
- Development and securisation of **icing expertise** in Europe

The work performed by WEZARD has led to the issuing of the WEZARD R&D Roadmap for icing and the launch of two projects in the framework of the FP7 Cooperation work programme.

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 regarding mixed phase and glaciated icing conditions, the HAIC (High Altitude Ice Crystals) 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 is a 4-year integrated project comprising 34 partners representing the European stakeholders of the aeronautical industry from eleven European countries and 5 partners from Australia, Canada and the United States. The project started in August 2012.

Icing conditions are one of the most severe for aircraft and engines as experienced in the certification process and in-service events. Certification tests are never simple because icing phenomena is a very complex domain and designers have access to a very low level of prediction capability compare to other fields, mainly relying on a very fragmented knowledge based on empirical past experience. With the development of next generations of engines and aircraft, there is a crucial need to better assess and predict icing aspects early in design phases and identify breakthrough technologies for ice protection systems compatible with future architectures. The STORM (Efficient ice protection **S**ystems and simulation **T**echniques **O**f ice **R**elease on propulsive syste**M**s) project will provide advanced simulation methodologies in three specific fields: ice release, ice accretion with runback aspects and ice trajectory applied for aero propulsive systems to improve the knowledge of engine components behaviour under icing conditions. STORM will also increase the maturity (TRL4) of the most promising innovative technology for Ice protection by developing and testing against selected representative engine & nacelle components, including rotating features. In particular, a step forward in ice phobic coating is a major objective of the project. This research work will greatly contribute to improving cost efficiency for future engines and in developing a higher level of competitiveness in the field of Ice protection systems (IPS). STORM is a 3-year collaborative project comprising 14 research and industrial partners from 7 European countries. The project started in October 2013.

Finally, one additional **High Priority Need** was identified by WEZARD to fill the remaining gaps in the development of the Acceptable Means of Compliance (test facilities and numerical tools) for SLD and thus to face challenges related to the evolution of regulation. The EXTICE project (EXTreme Icing Environment, FP7) launched in 2008 and led by CIRA, aimed at enhancing existing simulation tools to accurately predict individual droplet dynamics and ice accretion involving SLD. The project addressed specific SLD physical phenomena such as droplet break-up in shear flows, modified drag of large and/or deformed droplets, the impact and splashing of droplets upon oblique impact and the solidification of sheared liquid layers. The project concluded in May 2012 and provided preliminary engineering tools (test facilities and numerical tools) to support design and certification of future aircraft products. However some limitations were highlighted: only Freezing Drizzle icing conditions were addressed, Instrumentation should be further developed in order to improve test facilities calibration wrt droplet temperature or LWC measurement, models and tools do not properly simulate yet the complex physical phenomena related to splashing. This initiative should lead to the submission of the proposal for the 'EXTreme ICing Environment II' (EXTICE II) project in the framework of HORIZON2020. EXTICE2 would also promote international cooperation in order to avoid gaps and/or overlaps and maximize benefit.

IV. Potential impact, exploitation of results and main dissemination activities

A. Potential Impacts

1. WEZARD structure to provide R&D roadmap

The WEZARD project through the technical topics to be reviewed and choice of participating organizations (either in the project itself as partners or those organizations that are part of the Advisory Board) will complement and enhance the actions already initiated by the European Commission in this area.

A pragmatic, coherent and realistic R&D roadmap, based on the comparison, analyse and validation promising and sufficiently mature technologies and approaches, will be produced in a structured peer review process which will take maximum benefit from past work, currently dispersed knowledge, and already identified future activities.

Indeed, the participating partners of the WEZARD project are linked to existing projects, initiatives, networks, committees, regulatory boards and experts. This will ensure that the project is able to access the necessary inputs and opinions to allow the project elaborating its R&D roadmap in a coherent and complete manner as well as ensuring that the necessary communications channels exist outwards to the necessary actors, who will be reliant or impacted by the future R&D roadmap.

2. Strengthening the information sharing network

The Advisory Board involves the major players of the aeronautic community. Its members are connected to the main national, European and international working and advisory groups and projects in the field of weather hazards for aeronautics. This will contribute to enhance the project's visibility, as well as to guarantee an early awareness of the project's findings by different stakeholders. This will also contribute to strengthening an international network of expert and specialists coming from different sectors and comprising various disciplines and ensuring technical, operational & functional consistency across stakeholder airborne segments (Commercial Aircraft, Business Aviation, Helicopter, UAS).

3. Future impacts related to the existence of the R&D roadmap

The WEZARD R&D roadmap will provide a harmonized and coherent set of recommendations which will meet the requirements of different actors concerned by these topics:

- The **European Commission** will have a clear view of in which areas future research should be performed,
- The **Authorities** such as ICAO, EASA and FAA will be aware of existing solutions and future research orientations to assist them in the establishment of contingency plan and then safety standard and regulations,

- The **Meteorological organizations** will have clear orientations on the improvement of forecasting, new technologies to be deployed for observations and a rational to data standardization,
- **Enabler organization** such as the VAAC and ATM's will be made aware of existing future orientations. They will also have a clear view of the feasibility of promising technologies and existing and future means for decision making. This will be done in accordance with SESAR and NextGen requirements and will be fed directly into these projects,
- **Manufacturers and research organizations** will have clear definitions of the requirements for new technological needs,
- **Airline operators** will be aware of future technological orientations, training needs, new operational procedures and functions which are envisaged.

Lastly, the **general public and scientific community** will be made aware through the defined dissemination actions of the measures planned to reduce the impact of major disruptive on the air transport system.

B. Steps to bring about impact in future EU research

The WEZARD project is the first necessary step to enable the European community to face challenges related to icing and volcanic ash.

The WEZARD R&D roadmap could be used by the European Commission to set-up a consistent multi-year plan addressing the priorities and gaps which will have been highlighted as part of the project.

- WEZARD will identify and propose activities and topics to be investigated by relevant projects in the FP7 and H2020 work programmes. Such a multi-year plan will ensure the sustainability of the WEZARD network at mid and long term and then will contribute to secure and re-enforce the European expertise on atmospheric hazards.
- European Commission to have available on-time the necessary information for the definition of future research priorities to be included into the FP7 and H2020 work programmes.

C. Exploitation of the results

The WEZARD R&D Roadmap which is the main result of the project will serve a large number of organizations as previously described in the previous section of the report.

1. Performed exploitation by the WEZARD partners

The work performed as part of the project already has concrete impacts:

- WEZARD set-up an interdisciplinary and cross-sectoral network, represented by the WEZARD consortium and associated WEZARD Advisory Board, and comprising expertise from observation and measurement, the aeronautics industry, aircraft operators, network managers, risk management specialists, scientists, etc.
- The WEZARD roadmap spawned three proposals for Seventh Framework Programme (FP7) funding with active participation by the WEZARD consortium
  - o Identification of the need to anticipate regulatory changes and develop effective means of compliance for mixed phase and glaciating conditions led to submission of the proposal for the 'High Altitude Ice Crystals' (HAIC) project. This was successfully

funded and is investigating mixed phase and glaciating conditions, in particular as related to heated probes and engines.
    - Identification of the need to enhance knowledge and tools for accretion, runback and shedding led to submission of the proposal for the ‘’efficient ice protection Systems and simulation Techniques Of ice Release on propulsive systems’ (STORM) project. This was successfully funded and is investigating the development and validation of advanced simulation methodologies and ice protection concepts for aero propulsive systems
    - Identification of the need to develop an onboard volcanic ash detection and avoidance system led to submission of the proposal for the ‘Volcanic Ash Detection & Awareness System’ (VADAS) project.
- The WEZARD roadmap is preparing two proposals for HORIZON2020 funding with active participation by the WEZARD consortium
    - Identification of the need to anticipate regulatory changes and further develop effective means of compliance for supercooled large droplet (SLD) should lead to the submission of the proposal for the ‘EXTreme ICing Environment II’ (EXTICE II) project.
    - Identification of the need to develop an integrated observation system to monitor distal volcanic ash clouds should lead to the submission of the proposal for the ‘EUropean Volcanic ash Observing NETwork’ (EUVONET) project.
- Last but not least, the work performed as part of the project allowed strengthening the cooperation and exchange on icing with North America. During the WEZARD SLD workshop held on 10/06/2013 at European Commission, the FAA stated : “*The complexity, costs, and skills required to address current SLD research requires international partnerships and coordination of resources. We have a unique opportunity with EU and North American funding and skills/expertise/facilities to address major gaps in SLD engineering tools and methods development over the next few years by working together*”

2. Planned exploitation by the WEZARD partners

A summary table of the planned exploitation that the WEZARD partners intends to perform based on the anticipated emerging technologies is presented below:

Partner	WEZARD results and planned used	Timetable for exploitation
A-F	Internal – Review of the atmospheric threat and impact on Airframe, Engine & System.	Immediately when the information is available
	Internal – Roadmap to answer natural hazard issues	T0+5 to 8 years
	External – Build and participate to future European projects based on development and mitigation plans produced by the WEZARD project.	T0+1 to 3 years L1 or L2 projects as part of the FP7, 5th call and 6th call
	Global – Re-enforcement of the European expertise thanks	T0+1 to 2 years

Partner	WEZARD results and planned used	Timetable for exploitation
	to the set-up of the relevant network of expert from airframers, engine manufacturers, system suppliers, Met Office and research institutes.	
	Global – Development of acceptable means of compliance with regards to future evolution of icing regulation rules (SLD, mixed phase and glaciated ice conditions).	T0+3 to 5 years
	Global – Implementation of operational and ATM-related procedures and process to improve the response in the case of major air traffic disruption linked to “hazardous weather conditions”.	T0+1 to 3 years
BR&T-E	Review of the atmospheric threat, volcanic ash: Results will be used to enhance risk based assessments for flight operation during a volcanic eruption. The enhanced knowledge of the volcanic ash atmospheric threat will also allow more efficient airspace control.	Immediately when the information is available.
	Airframe, Engine & System impact: Results of the review of the airframe and engine manufacturer’s operating limits, instructions and recommendations for monitoring and maintenance guidance & procedures will ensure safe efficient flight operations during a volcanic ash event	Immediately when the information is available.
	Technology: Results of the review of the current technologies needed to detect unusual atmospheric conditions and to improve the robustness of the current designs will provide enhancements to current operations and airspace controls.	After validation of technology maturity and compatibility with existing airplane systems.
	Meteo: Results of improved data collection, data access, quality of observations data and monitoring/observing volcanic eruptions will provide immediate enhancements to flight operations and airspace controls. Coordination with International Civil Aviation Organization (ICAO), as the global presiding aviation regulatory authority, and with World Meteorological Organization (WMO), as coordinator of the global system of VAACs. (Short-term focus on Volcanic Ash) will ensure the European industry is on a level competitiveness with the global aviation industry.	Improvements in the quality of meteorological forecasting will provide immediate improvements in flight operations and airspace control.
	Scientific Support: Results of an integrated and consolidated roadmap regarding scientific aspects will support the Manufacturer, Meteo and Procedures WPs.	The roadmap will be used immediately to progress the Manufacturer, Meteo and Procedures WPs and to initiate the Science group work.
SNECMA	Internal Use: establish roadmaps to answer weather hazards issues and inform and modify design practices.	T0 + 1 to 3 years

Partner	WEZARD results and planned used	Timetable for exploitation
	External use: Build and participate to future project based on development and mitigation plans produced by the project.	T0 + 1 to 5 years
	Global use : mitigate short term volcanic threats through specific procedures and guidelines	T0 + 1 to 3 years
RR PLC	Optimisation of the engine icing protection systems for the Trent XWB (the A350 engine) and future RR engine projects; the intention is to reduce the weight and performance burden to these engines, thus saving on fuel burn and CO_2 emissions.	The application to the Trent XWB will happen contemporaneously with WEZARD project. Future engine projects will have the output from WEZARD embedded within them as they are launched.
	Improved management of RR's installed aircraft engine fleet during volcanic eruption and ash events.	Volcanic activity is essentially continuous, i.e. all the time somewhere on the planet there is a volcano erupting. The information on likely volcanic ash distribution will be of immediate use.
THAV	To adapt our R&T strategy i.a.w. the resulting targets and roadmap from WEZARD.	Mid-2011 and mid-2012, following the WEZARD reports deliveries.
ONERA	Internal: use the roadmap as a guideline to prioritize applied research activities on aircraft and engine icing detection and modelling.	Immediate application
	External: set up European cooperation between industries and research organization ONERA via the establishment of partnership with SMEs.	T0+1 to 3 years
	Global: contribute to the effective integration of the European partners' skill and expertise in the domain of volcanic ashes effects, icing of aircraft.	Immediate application
DLR	Internal use: Input of review of ash and dust particles to publications in peer-reviewed journals.	Immediate application
	Internal use: Input of review on icing modelling and simulation into future research strategy. Editing of the review for publication at a conference and in a peer-	Immediate application

Partner	WEZARD results and planned used	Timetable for exploitation
	reviewed journal.	
	External use: Input of Task 5.1 (Atmospheric conditions causing air transport system disruptions) results to further improvement of dust and ash forecast models for aviation (in close collaboration with partner EUMETNET).	T0+1 to 3 years
	External use: Input of review of ash and dust particles and of roadmap for instrumentation development to EU project IAGOS for further improvement of IAGOS measurement capabilities.	T0+1 to 5 years
EADS G	Enhancement of test facilities by adapting to unusual test conditions	T0+1 to 3 years
	Exploit the use of Lidar-based on-board methods for the active remote sensing of volcanic ash particles	T0+1 to 5 years
EUMETNET	Future operation of current research-based European volcanic ash observing capabilities to include the development of an operational data hub for collection, dissemination and archiving of observations.	T0+1 to 3 years.
	Improvements in volcanic ash plume dispersion products and advisories, through discussion with ICAO, aviation authorities, and aviation regulators	T0+2 to 5 years
	Improvements to dispersion modelling science both through the assimilation of standardized, real-time volcanic ash observations and verification of model output.	T0+3 to 5 years.
	Basis for development of similar capabilities in other parts of the world.	T0+3 to 8 years.
DGA	WEZARD results will be used to coordinate undergoing efforts at DGA EP for the improvement/development of its test facilities dedicated to simulated altitude conditions (icing or ashes), with the aerospace community.	Immediate application
	WEZARD results will be used to better serve the aerospace engine/aircraft manufacturers' community in qualifying their products in icing/ashes flight conditions through the development of innovative test facilities.	T0+2-3 years for crystals T0+5-6 years for ashes
CNR-IMAA	Road map for the optimization of an operational lidar network in support to volcanic emergency	T0+5 years
CAA	Internally, CAA will gain a greater understanding of potential mitigating actions to minimize disruption of the aviation system. Our focus will be very much on safety aspects. It will also support CAA actions in new areas such as uninhabited aircraft systems.	Ongoing for future use
	Externally it will support the extensive CAA activities with	Of particular

Partner	WEZARD results and planned used	Timetable for exploitation
	external bodies such as ICAO. It will ensure that CAA is fully up-to-speed on European activities and thereby provide a mechanism for European concerns to be properly considered.	significance with extensive international collaboration for the next few years
	Global competitiveness of European industry will be impacted by CAA ensuring the maintenance of a safe air transport system in the event of external disruptive events.	A long-term benefit

Table 1: Individual exploitation plans

D. Main Dissemination Activities

Within the WEZARD project, dissemination involves the means (i.e. press releases, conferences, scientific publications, exhibitions, workshops, newsletters, websites, etc.) through which research results are presented to the public. The target of dissemination may be the general public or a specific group of professionals in the WEZARD related research fields. This normally depends on the nature of the dissemination activities, which may address a larger or more limited group of professionals, consumers and end-users. WEZARD related dissemination activities may fall into one of the following categories: Scientific publications in journals or conference proceedings, Conference/Workshop presentations, Web-based project information, Press releases, Flyer distribution, Poster display, Articles published in the popular press, Project related video, Media briefings, Presentations, Exhibitions, Thesis, Interviews, Films, and TV clips.

Dissemination activities in WEZARD took place with the following objectives:

- Ensure that the results are appropriately disseminated at consortium level and within each partner organisation
- Ensure exchange of information, coordination of activities and complementarities with other large programmes running in parallel and after WEZARD
- Ensure a public dissemination by contributions to national and international scientific conferences.
- Ensure appropriate dissemination of information to international, European and national working groups and bodies through the organisation of WEZARD forums.

The following groups of interest for the WEZARD Consortium were identified:

- Aircraft safety regulation authorities (EASA, FAA, etc.),
- International Volcanic Ash community (IVATF, VAAC,...)
- International Icing community (SAE-AC9C, EHWG, EIWG, ICC),
- Academic Research and Development Community,
- Industry,
- Policy Makers,
- Designers,
- Test engineers,

- Certification bodies,
- Research agencies,
- Project participants,
- General public (for certain issues),
- Fluid mechanics communities,
- Atmospheric research & meteorology research communities,

The abovementioned dissemination objectives have been achieved through the following dissemination actions:

- A public website has been set-up
- Communication material (flyer) has been developed.
- Scientific publications and presentations: targeting key conferences, such as SAE Icing Conference, AIAA Aerospace Sciences Meeting, etc.
- Participation to workshops: WEZARD organised 3 international workshops to disseminate the project results and invited worldwide stakeholders to exchange feedback on future collaborations towards safe aircraft operation into icing conditions or volcanic ash contaminated area.
- WEZARD also participated and provided dissemination material to workshops and forums organised by other projects or the European Commission, such as the AERODAYS, Aviation Safety Forum, CANNAPE Workshops, etc.

The list of PERFORMED dissemination activities is presented in Annex A : List of PERFORMED dissemination activities

V. Annex A : List of PERFORMED dissemination activities

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
1.	Website	A.Petzold, H.Schlager / DLR	WEZARD website: www.wezard.eu	N/A	N/A	Scientific Community, Industry, Policy makers, General public	N/A	Europe, USA
2.	Flyer	F.Dezitter / AIRBUS	WEZARD Flyer	N/A	N/A	Scientific Community, Industry, Policy makers	N/A	Europe, USA
3.	Workshop	F.Dezitter / AIRBUS	WEZARD overview, WEZARD R&D roadmap	WEZARD 1st Workshops, WMO, Geneva	30th May– 1st June 2012	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
4.	Workshop	A.Verbeke / Thales	On-board icing Detection and awareness technologies	WEZARD 1st Workshops, WMO, Geneva	30th May– 1st June 2012	Scientific Community, Industry, Policy makers	~ 50	Europe, USA

5 Conference presentation, workshop presentation, web based project information, press release, flyer , articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

6 Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, General public (multiple choices are possible).

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
5.	Workshop	N.Schmitt / EADS IW	On-board VA Detection and awareness technologies	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
6.	Workshop	C.Marizy / AIRBUS	Using the aircraft as a sensor in global process for safety improvement	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
7.	Workshop	J.L.Brenguier / EUMETNET	SESAR SWP 11.2 MET Services to ATM, Icing in-situ and remote sensors	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
8.	Workshop	B.Weinzierl / DLR	Volcanic Ash in-situ and remote sensors	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
9.	Workshop	F.Hervy / DGA	Overview of icing test capabilities with respect to appendix O and D/P requirements	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
10.	Workshop	M.Balland / SNECMA	Preliminary reflexions for future volcanic ash test capabilities development	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 50	Europe, USA

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
11.	Workshop	Ian Lisk & Deborah Lee / EUMETNET	Volcanic Ash integrated observing/prediction network; International Volcanic Ash Activities Update	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 70	Europe
12.	Workshop	Sigrún Karlsdóttir / EUMETNET	Geophysical and volcanic eruptive plume monitoring	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 70	Europe
13.	Workshop	Delia Arnold / ZAMG/DMM	The ESA Project VAST – Monitoring and modelling of volcanic ash in the atmosphere, operational demonstration services	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 70	Europe
14.	Workshop	P.Villeudieu / ONERA, O.Brodersen / DLR	Icing numerical simulation capability – state of the art, gaps and way forward	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 70	Europe

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
15.	Workshop	R.Clarkson / RR	Volcanic Ash numerical simulation capability – state of the art, gaps and way forward, Volcanic Ash Engine Damage Mechanisms, Assessment of Global Volcanic Ash Risk to Aviation	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 70	Europe
16.	Workshop	C.Lebot / EUMETNET	Icing Observations network	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 70	Europe
17.	Workshop	C.Lebot / EUMETNET	Why icing observation are useful observation? and why they need to be developped?	WEZARD 1st Workshops, WMO, Geneva	30th May–1st June 2012	Scientific Community, Industry, Policy makers	~ 70	Europe
18.	Workshop	F.Dezitter / AIRBUS	WEZARD overview, WEZARD R&D roadmap	WEZARD 2nd Workshops, EC, Brussels	11th–13th Jun, 2013	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
19.	Workshop	W. Thomas / DWD	Ceilometer and Lidar networks for aerosol detection	WEZARD 2nd Workshops & General Assembly, EC, Brussels	11th–13th Jun, 2013	Scientific Community, Industry, Policy makers	~ 70	Europe

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
20.	SLD Workshop	F.Dezitter / AIRBUS	WEZARD overview, EXTICE2 proposal	WEZARD SLD Workshops, EC, Brussels	10th Jun 2013	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
21.	SLD Workshop	F.Hervy / DGA, B.Esposito / CIRA	Water content and drop size instrumentation & use for test facility calibration, Overview of SLD test facilities in Europe	WEZARD SLD Workshops, EC, Brussels	10th Jun 2013	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
22.	SLD Workshop	F.Hervy / DGA	Drop temperature measurement	WEZARD SLD Workshops, EC, Brussels	10th Jun 2013	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
23.	SLD Workshop	P.Villedieu / ONERA, I.Roisman / TUD, Per Ohme, DLR	Overview of basic research in Europe	WEZARD SLD Workshops, EC, Brussels	10th Jun 2013	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
24.	SLD Workshop	P.Villedieu / ONERA	European SLD Numerical Tools State of the art, gaps and way forward	WEZARD SLD Workshops, EC, Brussels	10th Jun 2013	Scientific Community, Industry, Policy makers	~ 50	Europe, USA
25.	Conference	F.Dezitter / AIRBUS	2F1 – Weather Hazards : How to best respond to this challenge? (presentation and proceedings)	AERODAYS 2011 Madrid (Spain)	30th March - 1st April 2011	Scientific Community, Industry, Policy makers	>500	Europe

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
26.	Conference	A.Grandin, F.Dezitter / AIRBUS	HAIC - High Altitude Ice Crystals	SAE Icing Conference, Chicago, USA	June 2011	Industry, Higher Education, Scientific Community, Policy makers	~100	International
27.	Workshop	F.Dezitter / AIRBUS	HAIC – High Altitude Ice Crystals	1st CANNAPE workshop, Residence of the British Ambassador to France, Paris, France	June 2011	Industry, Scientific Community	~100	International
28.	Presentation	F.Dezitter / AIRBUS	HAIC - High Altitude Ice Crystals	FP7 Information Days for Transport, Brussels, Belgium	July 2011	Industry, Scientific Community	~500	European
29.	Conference	F.Dezitter / AIRBUS	HAIC - High Altitude Ice Crystals	Aviation Safety Forum - AIR-TN, EASA, Koln, Germany	November 2011	Industry, Policy Maker	N/A	European

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
30.	Conference	A.Grandin / AIRBUS	AIRBUS R&D initiative vs Ice crystals	ENVIROTREC, Aerospace Ice Crystal Testing Conference, Winnipeg, Manitoba	November 2011	Industry, Policy Maker	N/A	International
31.	Paper, Conference Presentation	F.Dezitter / AIRBUS	HAIC - High Altitude Ice Crystals	5th AIAA Atmospheric & Space environment conference	June 2013, San Diego, USA	Industry, Higher Education, Scientific Community	N/A	International
32.	Conference Presentation	F.Dezitter / AIRBUS	Overview of In-flight icing research	EASA Safety conference,	Oct 2013, Koln, Germany	Industry, Scientific Community, Policy makers	~300	International
33.	Workshop	F.Dezitter / AIRBUS	WEZARD R&D Roadmap	Cleansky icing workshop	April 2013, EC, Brussels	Industry, Scientific Community	~50	Europe

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
34.	Report to ICAO – June 2012	Barði Þorkeslsson (ed) / Icelandic Meteorological Office	The 2010 Eyjafjallajökull eruption, Iceland	ICAO/IVATF4 meeting – Montreal Canada	13.–15. of June 2012	Aviation community (Aviation Service providers, Aviations Authority, Aircraft manufacturers, Pilot associations, Meteorologists	100-200	The report was distributed at the ICAO IVATF/4 meeting in June 2012. It can be downloaded from the IMO's web-site: http://www.vedur.is/media/ICAOreport_web.pdf
35.	Presentation	W. Thomas / WMO/DWD	Use of Lidars and Ceilometers for volcanic ash monitoring and detection	WEZARD General Assembly, WMO, Geneva	13-15th Dec 2011	Scientific Community, Industry	~ 50	Europe
36.	Poster	Ian Lisk & Deborah Lee / EUMETNET	Volcanic Eruptions and the threat to air transport systems: a coordinated European Roadmap	AGU Chapman Meeting on "Volcanism and the Atmosphere", Selfoss, Iceland	10-15th Jun 2012	Scientific Community, Industry, Media	~ 100	Worldwide
37.	Conference Presentation	Ian Lisk & Deborah Lee / EUMETNET	Improving Volcanic Ash Observation Capabilities Across Europe	Aerosol Society Meeting, Oxford University, UK	25th Sep 2012	Scientific Community, General public	~ 100	UK

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
38.	Presentation	Ian Lisk & Deborah Lee / EUMETNET	WP3 Summary & Progress	MoU collaboration meeting, IMO Reykjavík, Iceland	15-16th Oct 2012	Scientific	~10	Europe, USA
39.	Presentation	Ian Lisk & Deborah Lee / EUMETNET	WP3 Summary & Progress; High Priority Needs; WMO VAAC 'Ins and Outs' Dispersion Modelling Workshop Outcomes	WEZARD General Assembly, WMO, Geneva	22nd–23rd Jan 2013	Scientific Community, Industry	~ 50	Europe
40.	Workshop presentation	Ian Lisk & Deborah Lee / EUMETNET	Volcanic Ash integrated observing/prediction network (focus EUVONET); WP3 Summary & Progress; International Volcanic Ash Activities Update	WEZARD 2nd Workshops & General Assembly, EC, Brussels	11th–13th Jun, 2013	Scientific Community, Industry, Policy makers	~ 70	Europe
41.	Workshop presentation	Ian Lisk & Deborah Lee / EUMETNET	The WEZARD Project	European Supersites Workshop, EC, Brussels	10th – 11th Jun, 2013	Scientific Community	~ 70	Europe

NO.	Type of activities[5]	Main leader (Name / Organization)	Title of the disseminated material	Title and Place of the Dissemination Activity	Date	Type of audience[6]	Size of audience	Geographic coverage
42.	Keynote Presentation (proposed, to be confirmed)	Ian Lisk & Deborah Lee / EUMETNET	The Status of Volcanic Ash Observations in Europe	ECATS Conference, Berlin	18th-21st Nov 2013	Scientific Community, Industry, Policy makers	Not yet held	Europe
43.	Conference	A.Petzold / DLR	2F2 - Scientific Aspects of Weather Hazards for Aviation (Presentation)	AERODAYS 2011 Madrid (Spain)	30th March - 1st April 2011	Scientific Community, Industry, Policy makers	>500	Europe