33RD CONGRESS
OF THE INTERNATIONAL COUNCIL
OF THE AERONAUTICAL SCIENCES
STOCKHOLM, SWEDEN, 4-9 SEPTEMBER, 2022

ICAS 2022 SWEDEN

CERTIFICATION ASPECTS OF AN EARTH OBSERVATION PAYLOAD INSTALLED ON COMMERCIAL TRANSPORT AIRCRAFT

Ramón López Pereira[1], Lyssandre Rammos[2]

[1]Safran Engineering Services GmbH, Donauworth, Germany
[2]Skyflox Sarl, Esch-sur-Alzette, Luxembourg

Abstract

Optical and Radiofrequency Constellations on Aircraft is a concept using commercial transport aircraft as a platform to carry small equipment supporting Earth Observation applications. This paper discusses the certification aspects of such an Earth observation payload for mounting it on a commercial transport aircraft.

Keywords: Aviation climate action; Sustainable aviation; Environmentally friendly technology; Earth observation

1. General Introduction

The aviation industry operates a most reliable infrastructure for commercial air transport purposes. Optical and Radiofrequency Constellations on Aircraft (ORCA) is a concept proposing an additional use of commercial aircraft: as a platform to carry small equipment supporting Earth Observation applications.

Geospatial data is crucial to understanding more about climate and environmental issues and with ORCA, commercial flights can contribute to the climate action, which is placed at the top of the aviation industry priorities [1].

ORCA is being developed by SkyfloX, a European Space Agency (ESA) 'Spin-Off' company, licensed by ESA for the development and commercialisation of ORCA.

Safran Engineering Services, a European Aviation Safety Agency (EASA) approved Design Organisation (Part 21J.611), was tasked to tackle the technical and certification challenges of adding the ORCA modification to a commercial transport aircraft and perform the respective aircraft integration design.

This paper discusses design and certification challenges of the first ORCA payload for modification on a Boeing 737-800.

2. ORCA Concept Outline

The ORCA concept [2] proposes to use airliners as a platform to carry small equipment. Multiple equipped aircraft can form a constellation, which may support several Earth Observation and Telecommunication services. By means of a certified modification, a fully operational payload is installed, which does not interfere with regular aircraft operations, and is operated by SkyfloX.

ORCA can provide meter class resolution, multi-daily extended European coverage.

As the equipment is accessible (e.g. during aircraft maintenance) it can be easily maintained and upgraded (through approved minor changes) to keep up with technological advancements.

Taking into account that ORCA uses existing platforms (the aircraft), operated by airlines, its deployment and operational costs are much lower than the cost of an equivalent satellite constellation.

ORCA creates value and jobs for aviation and across the industry value chain with services contributing to key European Objectives (such as a multi-daily monitoring for essential variables, such as temperature or Carbon dioxide in support of the European Green Deal, or forest fires monitoring (an application for which SkyfloX was awarded with a European Commission Seal of Excellence).

In particular, airlines will be able to extract unexploited value from their existing infrastructure: SkyfloX will pay fees to airlines for the carrying of the ORCA payloads.

ORCA is aimed, for both commercial and government applications, such as Disaster Relief, Forestry and Farming, Maritime applications, and Asset management.

A notable benefit of an ORCA constellation, as compared to satellite constellations, is that ORCA avoids any launches to space and therefore creates no space debris, leaving the precious space orbits for the necessary reference satellites.

In summary, ORCA is an ‘out-of-the box’ platform for the development of new services & applications boosting innovation and creating new markets and jobs.

3. Design considerations

The ORCA payload (i.e. the on board part of the ORCA system) is designed to be installed in the tail cone area of an aircraft (initially on a Boeing B737-800, but with potential for installation in any other similar platform).

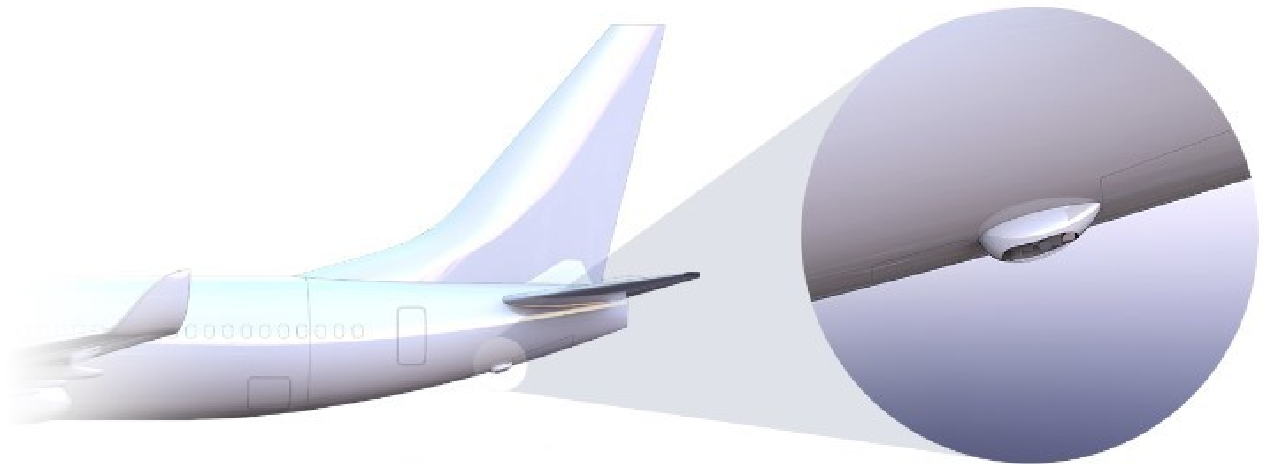

Figure 1 – Schematics of ORCA Installation on an airliner [3]

The main driver in the design of ORCA payload is to minimise the effects on standard operation on the aircraft where the system is installed. This is achieved through consideration of three aspects:

- Size and mass are to be kept to the minimum possible, minimising drag/mass penalty on fuel consumption, while also reducing certification efforts (see section 4).
- To minimise aerodynamic effects, in addition to the reduced general size, the location of the ORCA payload installation is chosen far aft on the fuselage, allowing it to be covered by the boundary layer of the fuselage.
- The payload is designed to be stand-alone, not interfacing nor dependent on any aircraft instrument. It includes all necessary subsystems for its operation: optical and thermal cameras, computers, communication transponders and antennas, and GNSS/IMU for position/orientation/time tagging of the images. Only a power connection is made to the aircraft.

This system is unique, as the added functionality is decoupled from the flight itself, the passengers, or any aircraft related topic; ORCA is independent from the rest of the aircraft.

The full image data is transferred using existing LTE networks once the aircraft is on ground.

The first version (Block I) of the payload has been designed under limited schedule and budget, using mainly Commercial Off-the-Shelf equipment with a view of serving a maximum number of applications, while keeping a robust, minimum complexity architecture.

It is foreseen to further optimise and upgrade the payload in terms of performance, size and mass, as well as developing payloads adapted to additional applications and using various cameras. Accessibility of the payload is a key advantage in this respect.

Through proprietary software, the raw data is processed and stored in the SkyfloX ground segment. Customer access to the data is via subscription and dedicated user interface.

4. General Certification aspects

Following the required analysis of ORCA payload for the classification of the change, it was opted to design the system following the guidance provided by EASA [4], regarding small or large antennas. This guidance, in combination with the design considerations defined in section 3, were the basis of the ORCA Block I design.

The discrimination between small and large antennas is based on three criteria [5]: Aerodynamic, Structural, and Location related.

4.1 Aerodynamics

An aerodynamically small antenna is defined to be fully within the boundary layer at the installation location. The boundary layer thickness may be assessed with a CFD analysis, or conservatively calculated using a Blasius Boundary layer model for the fuselage considering the nose as the stagnation point and the fuselage itself as a flat plate of finite length (that of the fuselage).

In terms of certification effort, an antenna protruding outside the boundary requires a significantly more extensive substantiation regarding vibrations, buffeting, as well as controllability/stability effects on the aircraft. Remaining within the boundary layer is therefore both a design goal as well as an important certification driver.

4.2 Structure

A structurally small antenna is defined such that the installation occurs inside one skin bay [4], i.e. between two stringers and two frames. When defining the installation, all additional structural elements shall be considered, not the payload as a standalone. Thus, if the reinforcements are carried over to more than one skin bay, the installation is considered structurally large.

Structural certification aspects may be further simplified from the consideration of a large antenna e.g. if the installation is performed following approved SRM design philosophy. An example of this constraint is location-specific minimum edge distance to the first line of rivets, maximum pitch distance between rivet lines, or the size of the reinforcement itself (i.e. doubler size constraint).

4.3 Location

The third criterion defining whether an antenna is considered small or large, is the location of installation. The payload is considered large if it is installed piercing pressure vessels (e.g. the pressurised cargo areas or cabin), or if the feedthrough hole is performed in composite areas. An installation in composite will generally require removal and installation of a fully redesigned composite skin bay, so that the strength is correctly adapted.

Thus, the installation on short-range aircraft with mostly metallic structure allows a simplification of the certification efforts.

Another driver on the appropriate selection of the location for the installation is that, should the system be located in the so-called bird or lightning strike areas, additional testing shall be performed to certify the payload.

Finally, the selected location should consider that ice accretion and detachment in-flight, as well as debris from the payload itself, shall not damage any flight-critical parts (e.g. the tailplanes).

5. ORCA Certification Aspects

As mentioned in Section 3, even though the first payload (Block I) was designed for a Boeing B737-800, its function is decoupled from the flight itself, the passengers, or any aircraft related topic. As such, the qualification of the ORCA payload (as a mission equipment) was not as demanding as for other (flight related or even flight critical) systems. Nevertheless, the system qualification was done following the appropriate equipment qualification levels (according to DO-160), Hardware design (DO-254) and software development requirements (DO-178). The environmental requirements [6] include mechanical constraints (shock and vibration), lightning strike (direct and indirect effects), climatic constraints (temperatures, humidity, sand and salt) and electrical susceptibility and emissions. Both hardware and software requirements follow the guidance of the aeronautical standards [7] and [8].

An integration feature that has been added is the so-called removable payload, which means the external components of the ORCA payload can be removed and the design is such that an additional small skin doubler is available within the payload (including mounting elements) to swiftly cover the cable feedthrough when uninstalling the payload. This allows the aircraft in which the provisions for the payload are installed to also fly without the ORCA payload itself, while not affecting the turnaround time.

Having targeted the small antenna design goals, the ORCA payload has managed to largely satisfy these requirements. The ORCA installation occurs in the tail cone area of the aircraft, in a non-pressurized zone, the protrusion into the airflow does not extend beyond the boundary layer, and the installation is structurally located within one skin bay, following Standard SRM design philosophy.

Additionally, with the adequate location for installation, the ORCA fairing can be waived off a bird strike test, replacing this with a trajectory analysis.

In terms of electrical integration, the ORCA payload is connected through an AC/DC converter to the aircraft main electrical network. The power consumption is low in relation to other aircraft consumers, and the compliance to the requirements from [6] ensure the lack of interference with the carrying aircraft's systems.

The design of the ORCA payload components allows the quick adaptation of the system to any other platform without major efforts in terms of redesign.

5.1 Aerodynamics

The size of the ORCA payload fairing, combined with the location on the aft area of the aircraft, is such that the external parts are inside the boundary layer of the fuselage in typical short-to-medium range commercial aircraft like the Boeing B737-800. Thus, the aerodynamic drag is only marginally affected by the system. This is a major point to consider for the complexity of certification efforts of obtaining the STC. With the present design, the required substantiations regarding vibrations and buffeting, icing effects, ice/debris detachment and bird strike, are significantly simplified.

5.2 Structure

A Structural aspect to also be considered is that, additionally to the location in the aft fuselage, the ORCA payload components (both the operative components and the power elements) are installed in unpressurised areas, also alleviating the certification efforts. This means that the so-called “area below antenna” (in this case above ORCA) is not pressurised and the installation does not comprise new holes in pressurised compartments (as the power connection is done through an already existing feedthrough), thus meeting the design target to consider the ORCA payload a small antenna.

Depending on the aircraft of installation, the small antenna criteria may be met. In the specific case of the B737-800, the bay size is too small to fit the Block I design of the payload ORCA, including structural reinforcement, inside one single bay. That being the case, it can also be considered that this is an acceptable deviation due to the installation location and is to be analysed on a case-by-case basis.

5.3 Location

The installation is performed at the tail cone area of the aircraft, in an unpressurised area.

A size-related design advantage is that, due to the size and position in the aircraft, the bird strike aspects of certification can be met just with a trajectory analysis showing that the ORCA payload is not affected by this requirement thus reducing certification efforts.

Analyses for Ice and debris detachment have been performed as well. These are required in order to assess if any detached part of the system could collide with the aircraft. Due to its size and location, the ORCA payload does not have any effect on aircraft, even if detachment of ice or debris occurs.

6. Development Status

SkyfloX as a prime contractor, with Airlines and expert industries in certification, telecommunications and earth observation, developed ORCA and the team, under the privileges of the Safran Engineering Services (SES) DOA is completing certification activities in view of obtaining an EASA STC and performing pilot tests on a Boeing 737-800 airliner.

6.1 Bird Strike Analysis

An article published by Boeing [9] provides guidance and statistics regarding bird strikes on their aircraft. In this document, it is shown that only 4% of all bird strike cases was recorded on the fuselage. Over 40% of the cases were engine-related, as the surrounding air is ingested by the intake. The effective engine diameter for this ingestion is estimated to be approximately double of the actual engine diameter, although this was conservatively not used in the analysis for the ORCA payload. The installation was assessed for an envelope of angles of attack (AoA) and sideslip (AoS).

Due to the size and installation location of the ORCA payload, the system is shaded by the fuselage for AoA exceeding the maximum values encountered in flight, with the Airplane Flight Manual (AFM) [10] listing the maximum level flight angle of AoA of 6.5°, and lift-off attitude approximately 8.5° [11]. This means that within the normal envelope of AoA, the ORCA Radome (the payload protective cover) will not be exposed to Bird Strike.

Similarly, compliance with regards to AoS is assessed, using the approach conditions defined and a conservative max cross wind as from the AFM [10], the maximum AoS is calculated to be 15°. Several AoS in combination with AoA have been assessed and it was found that the ORCA radome was protected by the engine, even with the conservative approach of not considering an effective diameter for air ingestion.

It was thus concluded that the ORCA installation is not in a location with bird strike risk and a test or further analysis is not required.

6.2 CFD Analysis

A Computational Fluid Dynamics (CFD) Simulation was performed by the Institute of Aerodynamics and Flow Technology of the Deutsches Zentrum für Luft- und Raumfahrt (DLR) by using the TAU software, which uses a Reynolds-Averaged Navier-Stokes (RANS) basis. The flow field for this simulation was composed of over 50 million points.

Two flight conditions have been simulated:

- Sea Level and low speed with a variety of AoA and AoS
- High-speed case at maximum design dive speed (VD) for the B737-800 at a flight altitude of approximately 7000m.

The turbulence model applied was the Spalart-Allmaras turbulence model in its negative formulation (SA-neg) [12] and in combination with a rotational correction (RC) approach in order to provide an enhanced resolution of vortical flow structures. The conclusions of several investigations ([13], [14] and [15]) are that TAU together with one- and two equations or Reynolds-Stress turbulence models (Spalart-Allmaras, Wilcox-kω, Menter kω-SST, ω-SSG-LRR) can be used successfully. The predictions of shocks are possible, boundary layers and interactions can be accurately computed. Particularly, the TAU Software in combination with the SA-neg turbulence model has been shown to be accurate for the calculation of transonic flows and accurate prediction of forces for transport aircraft (refer to [15] and [16]), thus the results are deemed applicable for the ORCA installation.

The results show that for none of the investigated cases significant unsteady flow fluctuations have been predicted by the numerical calculations. The propagating wake flows from the tailskid and mounted camera radome are not varying over time. The wake flow of the mounted camera radome in some cases interferes with the rear base of the tailskid, otherwise an interaction of the wake flow of both devices occurs downstream of the devices with no further impact regarding unsteady fluctuations.

6.3 Noise Effects

The effects of ORCA on overall external noise and the presence or absence of perceivable noise inside the passenger cabin is required. An assessment has been made based on the CFD analyses performed.

Considering the magnitude of the aerodynamic effects at aircraft level for ORCA, the influence in both the external and cabin noise (starting point being that the main source of noise is the engines, in both low and high frequency bands) is deemed negligible.

6.4 Icing Effects

Two potential Icing effects are assessed.

The first point is the possibility of ice build-up in the ORCA radome, including its separation posing a risk to the aircraft (e.g. by damaging the horizontal stabiliser). According to [17], in order to be compliant to the regulation, “Ice shedding from components, including antennas, of the airplane should cause no more than cosmetic damage to other parts of the airplane, including aft-mounted engines and propellers”. In particular, the analysis is oriented in the case of ORCA in demonstrating that the ice shedding from the radome will not adversely affect the downstream components of the aircraft. ORCA is deemed a minor risk component, as even if and when it accumulates ice, the amount of it is negligible and no critical downstream components are found. Considering the location of the ORCA installation, the ice formation will be reduced due to the shadowing by the forward areas of the fuselage and engines.

The second part of the icing effects analysis is oriented towards a change in the aerodynamic and vibration effects in the form of unsteady fluctuations of aerodynamic characteristics. The results from the CFD analysis overwhelmingly confirm that the addition of the ORCA payload does not produce such fluctuations in a clean configuration, even for the high level of conservatism considered.

6.5 Radome Separation

Within the scope of the analytical assessment of ORCA's influence on the aircraft, an analysis of the trajectories after a full radome separation was performed. This was assessed through a study based on the wake trajectory established in the CFD analysis. The streamlines are shown in Figures 2 and 3. With this information, multiple scenarios involving (partial) detachment of the radome with various shapes and masses confirmed that, in the unlikely case of detachment of (any part of) the radome from the fuselage it would not approach any control surfaces of the tail area.

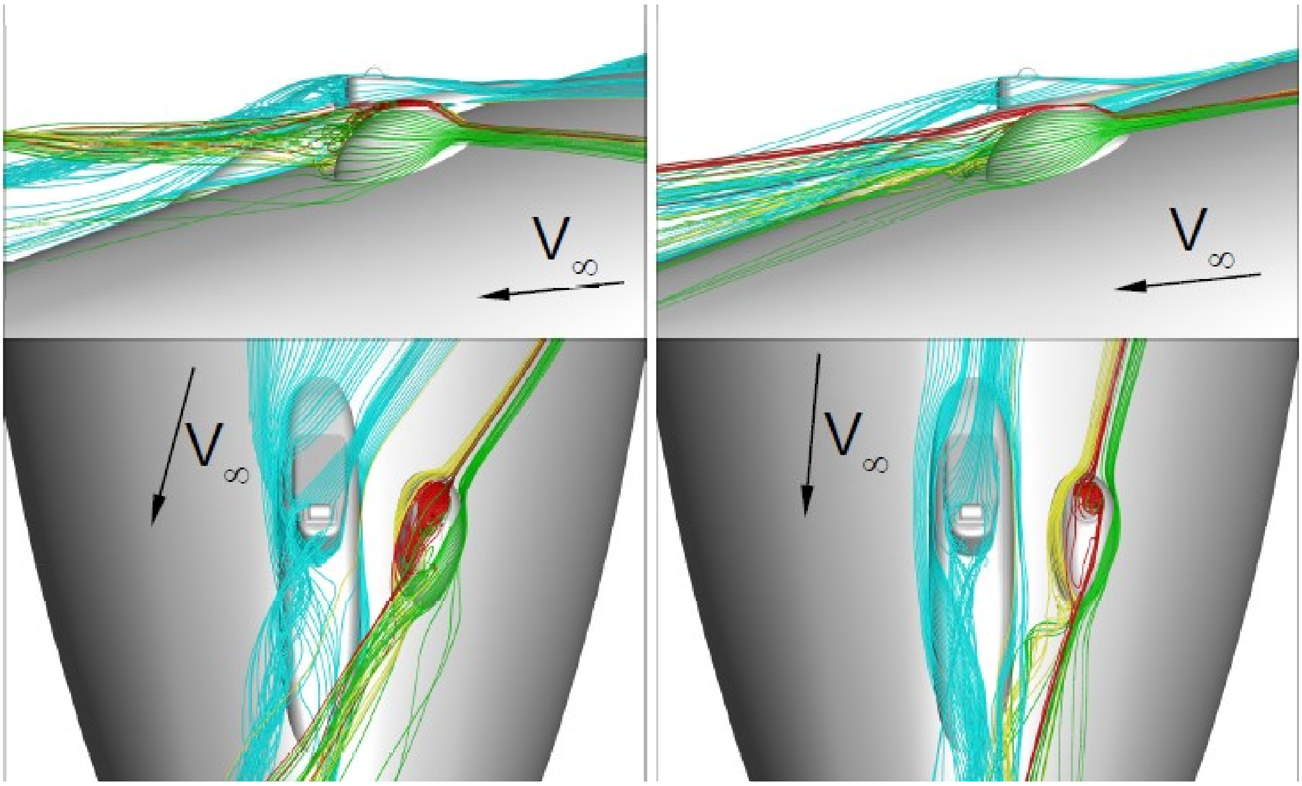

Figure 2 – Indicative flow topologies showing the radome wake characteristics with negative AoS

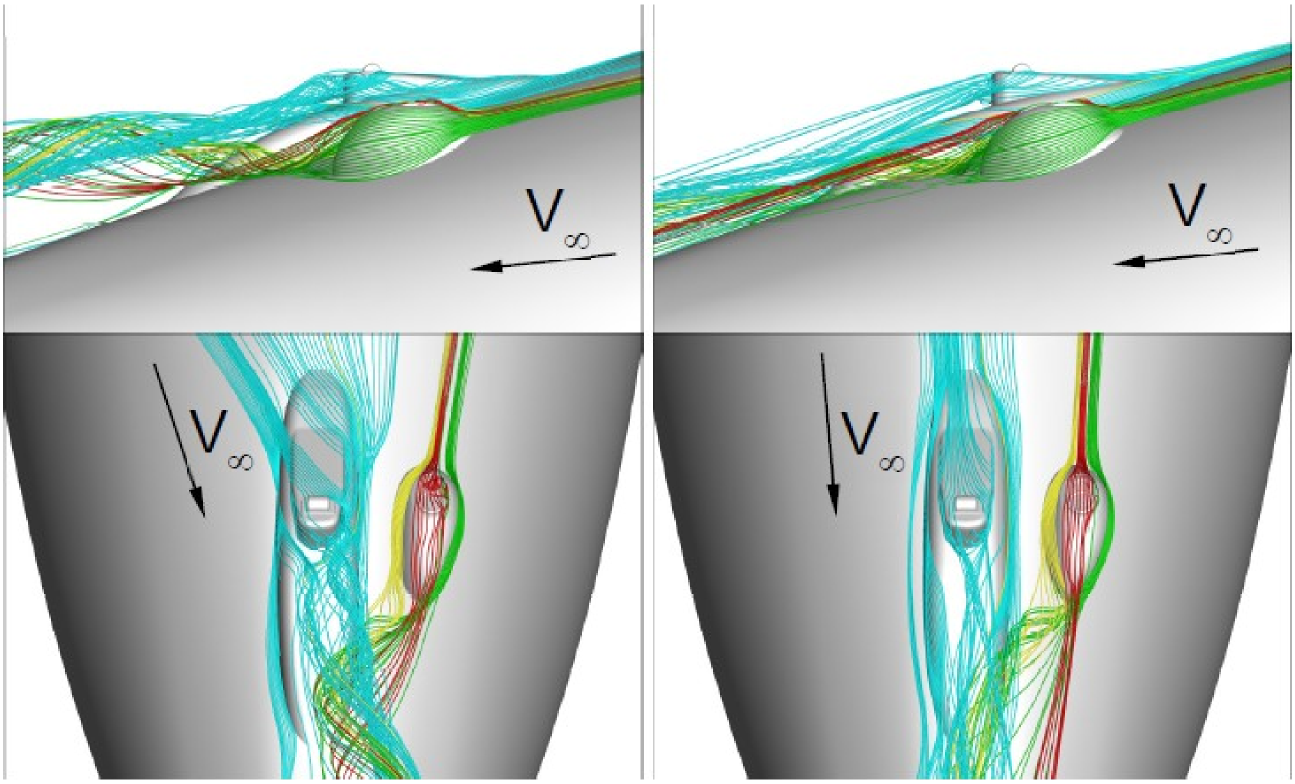

Figure 3 – Indicative flow topologies showing the radome wake characteristics with positive AoS

7. Conclusions

The use of commercial transport aircraft as platform for carrying Earth Observation equipment is an innovative use of the existing aviation infrastructure. Certification of the equipment is a sine-qua-non condition for mounting third party equipment on the commercial aircraft.

SkyfloX and SES in close cooperation developed a design/certification process, taking into account multiple technical and operational aspects. This derived in a time- and cost-efficient certification process.

The challenges of developing a system with as little operational interference as possible to regular operation – which is key to the acceptance within the airline community – have made the development and certification process of the ORCA payload one of a kind.

8. Contact Author Email Address

Contact Author:

Mr. Ramón López Pereira

mailto: ramon.lopez-pereira@safrangroup.com

9. Copyright Statement

Disclaimer: The work described in this paper was co-funded under an ESA contract. Responsibility for the contents resides in the author or organisation that prepared it.

References

[1] Airbus, "COP26 and the aerospace industry, explained - How aerospace is contributing to the Paris Agreement," 29 October 2021. [Online]. Available: https://www.airbus.com/en/newsroom/stories/2021-10-cop26-and-the-aerospace-industry-explained. [Accessed 24 May 2022].

[2] E. Rammos, "Method for creating a constellation of electronic devices for providing optical or radio-frequency operations on a predetermined geographical area, and a system of such a constellation of electronic devices". Patent EP3257168A1, 17 December 2020.

[3] SkyfloX, "https://skyflox.eu/," [Online]. [Accessed 24 May 2022].

[4] EASA, "General Structural Aspects of Antenna Installations," in *STC Structural Substantiation Workshop - Antenna Installation Damage Tolerance & Cabin Interior Issues*, Cologne, 2014.

[5] EASA, "Large Antennas," in *STC Structural Substantiation Workshop - Antenna Installation Damage Tolerance & Cabin Interior Issues*, Cologne, 2014.

[6] RTCA Inc., DO-160G Environmental Conditions and Test Procedures for Airborne Equipment, 2010.

[7] RTCA Inc., DO-178B Software Considerations in Airborne Systems and Equipment Certification, 1992.

[8] RTCA Inc., DO-254 Design Assurance Guidance for Airborne Electronic Hardware, 2000.

[9] R. P. Nicholson and W. S. Reed, "Strategies for Prevention of bird Strike Events," *AERO (Boeing),* pp. 17-24, Q3 2011.

[10] Boeing, "D631A001.8K2 - 737-600/-700/-800/-900 Airplane Flight Manual," Seattle, WA (USA), 2019.

[11] Boeing, "737 NG Flight Crew Training Manual," 2016.

[12] S. R. Allamaras, F. T. Johnson and P. R. Spalart, "Modifications and clarifications for the implementation of the Spalart-Allmaras turbulence model," 2012.

[13] T. Gerhold, "Overview of the Hybrid RANS Code TAU," in *MEGAFLOW – Numerical Flow Simulation for Aircraft Design, Notes on Numerical Fluid Mechanics and Multidisciplinary Design, Vol. 89*, Springer, 2005, pp. 81-92.

[14] D. Schwamborn, T. Gerhold and R. Heinrich, "The DLR Tau-Code: Recent Applications in Research and Industry," in *European Conference on Computational Fluid Dynamics, ECCOMAS, CFD 2006*, The Netherlands, 2006.

[15] B. Eisfeld and O. Brodersen, "Advanced Turbulence Modelling and Stress Analysis for the DLR-F6," in *AIAA Paper 2005-4727*, 2005.

[16] C.-C. Rossow and L. Cambier, "European Numerical Aerodynamics Simulation Systems," in *Notes on Numerical Fluid Mechanics and Multidisciplinary Design, Vol. 100,*, Springer, 2009, p. 189 – 208.

[17] Federal Aviation Administration (FAA), "Advisory Circular 25.1419-1A Certification of Transport Category Airplanes for Flight in Icing Conditions," 2004.