ALGeSMo

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Responsible:	Name(s): Jerry Symons, Raphael Goutagny
Organization(s):	MSSUK / MSA

Abstract

This report describes the technical results of the ALGeSMo project and shows in which areas the project have been beyond the previous state of the art. This document being public, it is free of sensitive content (Airbus' or partners' intellectual property or trade secrets).

ALGeSMo

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Signature Page

Compiled by:..
Name: Raphael Goutagny
Position: System engineer
Organisation: MSA

Agreed by:..
Name: Bertrand Pichon
Position: Head of Systems and Technology
Organisation: MSA

Agreed by:..
Name: Jerry Symons
Position: Head of Systems and Technology
Organisation: MSSUK

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00	N/A	R. Goutagny	27/10/20

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1 INTRODUCTION

1.1 Scope

This document aims at presenting the ALGeSMo project and its outcomes to the general public. It presents the work that has been performed and explains how this project went beyond the previous state of the art.

1.2 Applicable Documents

None.

1.3 Abbreviations

A/C	Aircraft
ALGeSMo	Advanced Landing Gear Sensing and Monitoring System
DAL	Design Assurance Level
FBG	Fibre Bragg Grating
FOPU	Fibre Optic Processing Unit
LRU	Line Replaceable Unit
MCU	Modular Concept Unit
MLG	Main Landing Gear
MSA	Meggitt Switzerland (part of Meggitt Airframe Systems)
MSSUK	Meggitt Airframe Systems UK (part of Meggitt Airframe Systems)
MPC	Meggitt Polymers & Composites (part of Meggitt Airframe Systems)
NLG	Nose Landing Gear
NLR	Netherlands aerospace centre
TRL	Technology Readiness Level
UK	United Kingdom
WDM	Wavelength Division Multiplexing

ALGeSMo

2 PROJECT PRESENTATION

The primary objective of the Advanced Landing Gear Sensing and Monitoring (ALGeSMo) project is to bring together a world-class team from across Europe to deliver a state-of-the-art optically-based load monitoring system for aircraft landing gear. This will yield a step change in the way landing gear is utilized and managed in operational and flight situations, leading to a new paradigm in aircraft availability and operability. This will assist the development of European capability within this domain such that Europe will be well-positioned to provide state-of-the-art equipment to future aircraft development.

The ALGeSMo consortium is composed of:

- Meggitt Polymers & Composites (UK, part of the Meggitt Airframe Systems Division - www.meggitt.com)
- Meggitt SA (Switzerland, part of the Meggitt Airframe Systems Division - www.meggitt.com)
- Meggitt Sensing Systems (UK, part of the of Meggitt Airframe Systems Division - www.meggitt.com)
- Netherlands Aerospace Centre (Netherlands - www.nlr.org)
- Technobis (Netherlands - www.technobis.com)

The goal of the project is to develop and deliver the following:

- A Fibre Bragg Grating (FBG) optical sensor system using Wavelength Division Multiplexing (WDM) techniques to accurately detect and translate landing gear strain and torque to the aircraft control systems.
- A state-of-the-art and highly accurate integrated photonics fibre-optic interrogator that will result in the smallest system currently available anywhere in the world. This will make integration and certification of the system highly achievable compared to existing optical interrogator systems.
- Detailed design of system architecture and integration to ensure that the appropriate Design Assurance Level (DAL) requirement can be achieved.
- Definition and build of loading and calibration rigs in order to characterise sub-system and system components using a full landing gear slider tube assembly.
- Completion of system testing and partial qualification testing to de-risk the technology and demonstrate TRL5.

The starting point of the project was a general concept, demonstrated at component level on fairly basic table-top test fixtures. The project included all system development steps starting with the specification phase and finishing with the full system test phase on a full-size test rig.

More details can be found on the project public website https://algesmo.eu.

3 SYSTEM DESCRIPTION

ALGeSMo is a system that measures loads on the landing gears and provides load data to various aircraft systems. This data is expected to be used for structural health monitoring, hard landing detection, weight and balance and flight controls, among others.

This project took place between September 2016 and October 2020. This system is developed under the Clean Sky 2 European research program. This program covers the design, manufacturing and testing of a prototype in order to achieve TRL5.

The main goals are:

- Manufacturing of robust, reliable and accurate optical load sensors using FBG
- Integration of the sensors into large passenger A/C landing gear axles
- Integration of the optical signal processing units in robust and reliable avionic units
- Reaching the appropriate level of system reliability and availability
- Proving the system performances during lab tests

Reaching the technical goals of this research project will pave the way to a production system to be fitted on a future Airbus aircraft.

The figures below provide a high-level vision of the system:

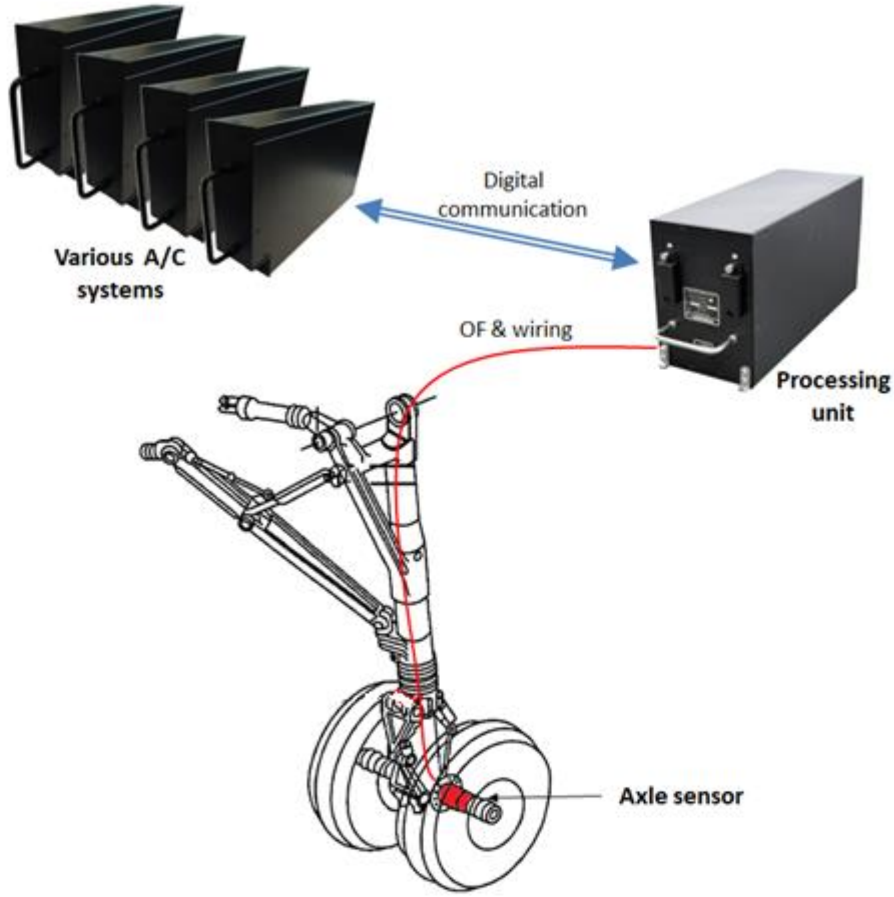

Figure 1 High-level system overview

4 PROTOTYPES

4.1 Fibre Optics Processing Unit

The Fibre Optics Processing Unit (FOPU) is the “brain” of the system. It is an avionic unit installed in the aircraft avionic bay. It is as per the standardized ARINC 600 2MCU format (dimensions and interfaces). Three units have been assembled.

The FOPU generates light in a specific bandwidth, sends it to each the axle sensors, reads the light signal coming back from the axel sensors and processes it to convert a wavelength into a load value. It also performs some self-diagnosis functions.

Figure 2: FOPU prototype- External view – ARINC 600 2MCU rackable avionic unit

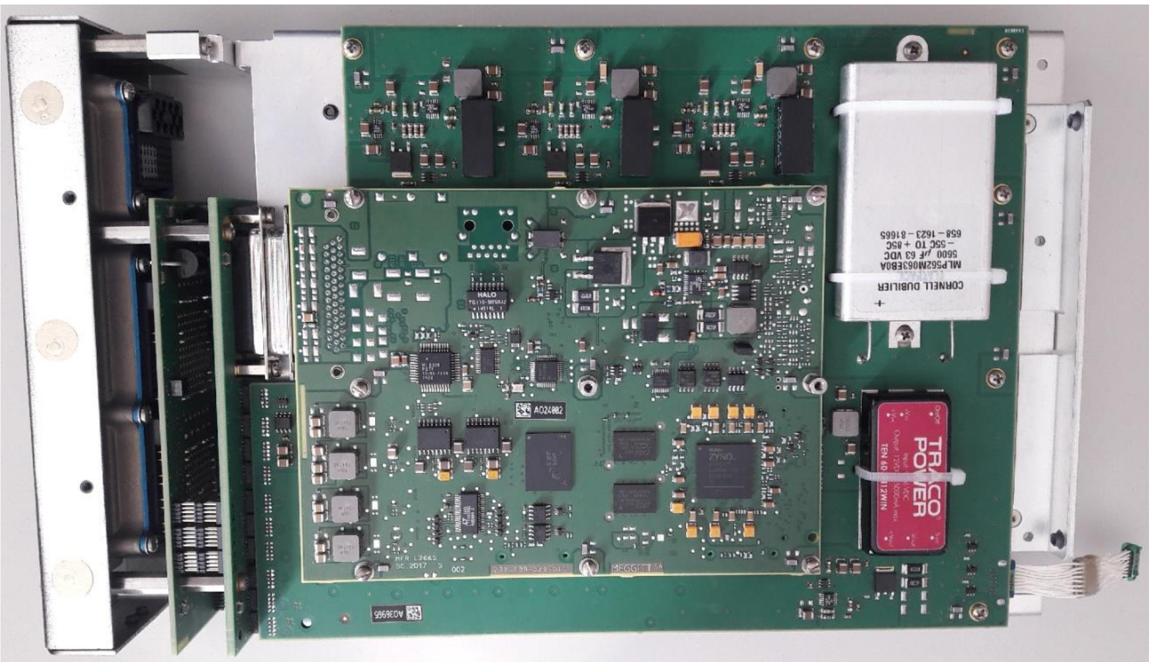

Figure 3: FOPU prototype - Digital processing part

Figure 4: FOPU prototype - Optical part – 6-channel FBG interrogator fitted with heat sinks

4.2 Axle sensor

The axle sensor is the sensing element of the system. There are two sensors per axle, with one sensor each for the port and starboard wheels. The sensor is located inside the axle bore and is held in place by a bespoke clamping mechanism which is designed to allow fitment of the sensor into an unmodified Airbus A320 axle. The sensor itself consists of optical fibres embedded into a thin cylinder-shaped composite carrier. The clamping mechanism secures the carrier in such a way that any loading in the axle is transmitted though the composite and detected by the optical fibres.
Since the sensor is located in an area of high temperature, being mounted close to the braking systems, and subjected to large temperature variations, local temperature is also measured by the optical fibres allowing for compensation for the measured strain. The sensor is connected to the FOPU by means of a bespoke optical harness, designed to deal with the harsh environmental conditions of the landing gear area.

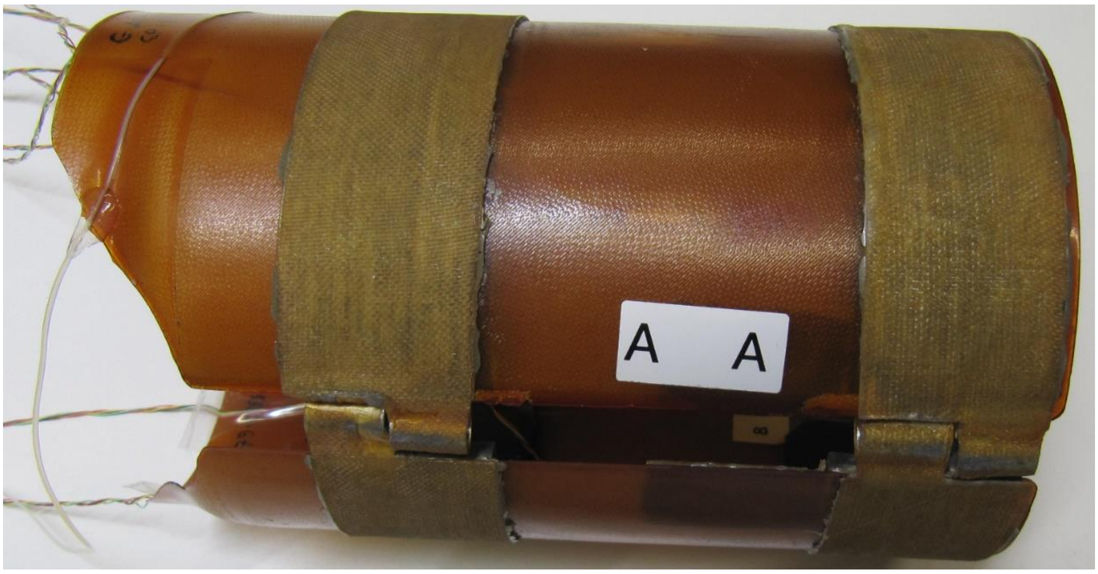

Figure 5: Axle sensor prototype - Carrier only, with specific test instrumentation fitted

Figure 6: Axle sensor prototype, including clamping mechanism

5 TECHNICAL RESULTS

5.1 Robustness tests

Optical interrogators are traditionally very delicate systems. One of the objectives of ALGeSMo was to bring this technology to aerospace standards. The first set of tests performed on the FOPU demonstrated that it can withstand the kind of environment found on aircraft in an avionic bay. The FOPU has been subjected to the following tests, among others:

- High temperature
- Low temperature
- Vibration
- Shock
- Humidity

The FOPU showed satisfactory results in all of these tests, and in many others. It is considered safe for flight.

5.2 Functional tests

The entire optical load measurement system (a pair of axle sensors, an optical harness and a FOPU) was fitted on an actual landing gear axle and installed into a bespoke test rig.

Figure 7: ALGeSMo bespoke test rig

A several month long test campaign has been performed. The axle sensor was instrumented with strain gauges and temperature sensors for comparison. It started with calibration tests (intended to provide data for the calibration of the axle sensors) and then moved on to high-load tests, dynamic tests, tests at high and low temperatures, shock and vibration tests, etc. The outputs of the ALGeSMo systems were continuously recorded and compared to the loads actually applied and the measurements of the strain gauges and temperature sensors.

Three successive iterations of axle sensors have been tested, each of them improving on the issues identified on the previous one.

The loads applied during testing are representative of aircraft operation.

The load measurement accuracy varies upon many parameters (e.g. temperature, load amplitude, etc). The plots below show a representative example of the accuracy obtained during the tests. The axis are purposefully left blank in order not to disclose sensitive data. These plots show the accuracy (vertical axis, expressed as a percentage of the maximum load) depending on the load amplitude (horizontal axis). These are for vertical loads and for each side of the axle (there are two wheels per axle, hence two axle sensors).

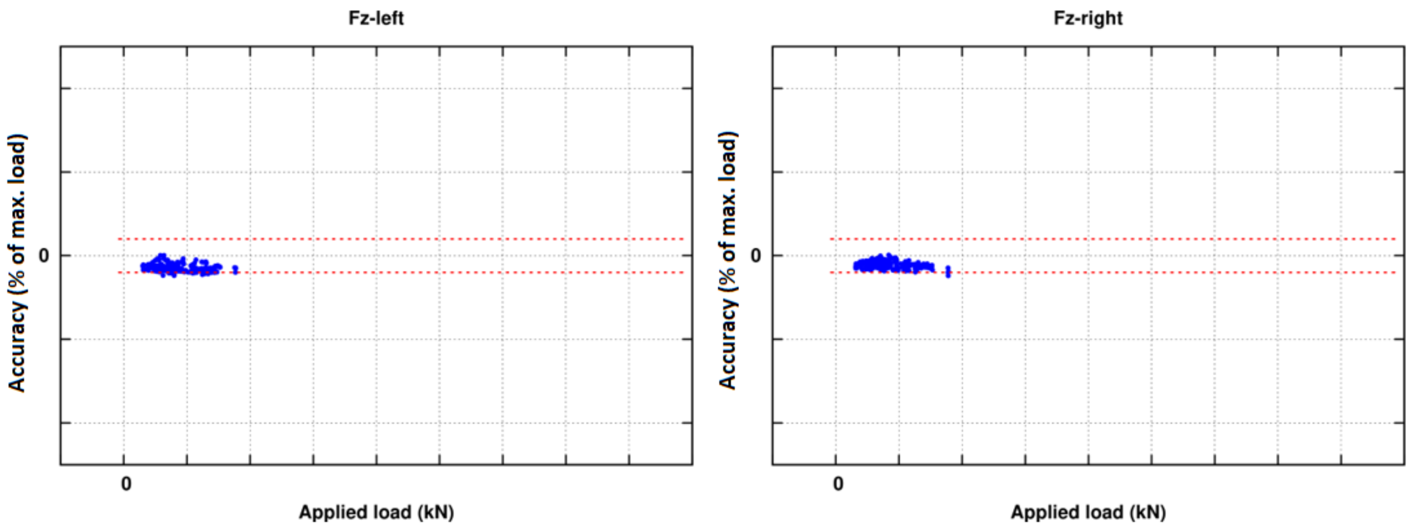

Figure 8: Example of load measurement accuracy

It can be seen that the accuracy is generally within the specified range, with the exception of a few data points. This is representative of the overall results. Load measurement in some specific situations must be improved.

6 PROGRESS BEYOND THE PREVIOUS STATE OF THE ART

6.1 Load measurement on landing gears

Since the 1950's many companies have tried to design and put on the market load-monitoring for aircraft landing gears. Few systems reached the production state and none of them were successful. Some system have been used in service for short periods of times but have always been discarded due to a lack of reliability and convenience.

Unlike the previous systems, ALGeSMo relies on optical sensing rather than strain gauges. The optical sensing principle of ALGeSMo does not present the usual drawbacks of the typical strain gauges used so far (mainly the issue of drift over time).

ALGeSMo does not only measure the vertical loads on the landing gears like the previously fielded system. It measures the loads along all three axis and the torque about the wheel axles. It therefore allows more benefits that previous systems, beyond the weight and balance measurement:

- Overload detection (typically hard landings, but also ground loads)
- Landing gear weight optimization (due to accurate load monitoring)
- Health monitoring and on-condition maintenance
- Real-time brake control (based on brake torque)

6.2 Integration of optical fibres in a composite material

It is a common practice to embed optical fibres in a stiff composite panel designed for a narrow temperature range (e.g. structural part, typical using carbon fibres). However embedding optical fibres in a thin, flexible composite panel designed to withstand high temperature is a novelty. This brings some constraints not seen on typical low-temperature structural panels, like:

- Carbon fibres composite are too stiff for the ALGeSMo axle sensor, so glass fibres are used. Glass fibres have different mechanical properties to carbon which make integration of the optical fibre more difficult.
- Resins able to withstand the high temperatures seen by the ALGeSMo axle sensors create problems not seen with low-temperatures resins. They are cured at higher temperature and can generate non-uniform mechanical strain on the optical fibre.

The ALGeSMo team successfully tackled these challenges, and in that respect went beyond the previous state of the art.

6.3 Integrated optical interrogator in avionics

The FOPU is a small, fully integrated avionic unit containing an optical interrogator (i.e. a device that reads an analogue optical signal in order to extract a specific property). Optical interrogators are typically bulky, fragile devices with high power consumption. This is not compatible with use on an aircraft. The FOPU was made possible by the technology developed by the ALGeSMo consortium. The Application-Specific Photonic Integrated Chip (ASPIC) technology developed by Technobis allowed the system to have a small and robust interrogator.
The optical interrogator is integrated into an avionic unit together with processing and communication electronics. The combination of the optical interrogator and the processing and communication electronics makes the FOPU a novel product.

6.4 Optical connections for analogue signals through single-mode fibres

The few optical avionic equipment currently in-service are communication equipment (data transfer). They transfer digital signals into multi-mode optical fibres. The ALGeSMo system is a sensing system as opposed to a data-transfer system and uses FBG as sensing elements. Therefore it transfers analogue signals into single-mode optical fibres. Analogue signals are much more sensitive to perturbations and power loss, and single-mode fibres have significantly smaller cores than multi-mode ones. This makes the connections a lot more challenging than on existing systems, especially under varying temperatures and vibrations.

The connectors have been carefully selected for their performance, whilst still complying with the weight and dimension constraints. The connection between the FOPU and its rack was especially complex because of the constraints of the ARINC 600 standard to which the FOPU had to comply. A fruitful collaboration with a connector supplier led to the development of a new reliable and robust connection for this type of environment. This is a clear example of how the ALGeSMo project went beyond the previous state of the art.

7 CONCLUSION

The ALGeSMo project comes to an end with several noticeable successes. The system-level tests performed on the bespoke full-size test rig showed very promising results. Loads along all three axis of the landing gear and the torque about the wheel axles were measured and showed a very good correlation with the applied loads.

The research activities have advanced the state of the art in several key areas for the deployment of optical sensing systems for safety-critical applications (e.g. integration of optical fibres into composite material, robust optical connections, avionic-compliant optical interrogator and landing gear load measurement).

The technology building blocks developed during this project can also be used in other aerospace applications, not only for landing gear load measurement. There is a general consensus in the aerospace industry that optical sensing can bring significant benefits. Thanks to ALGeSMo, the project partners and more generally the European industry are better prepared for the “more optical aircraft”.