Flight Test: A Key Milestone for Climate-Neutral Aircraft Concepts Validation and Certification

FLIGHT TEST: A KEY MILESTONE FOR CLIMATE-NEUTRAL AIRCRAFT CONCEPTS VALIDATION AND CERTIFICATION

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ABSTRACT

The global aviation industry has been massively impacted by the COVID crisis which lead to a collapse of the traffic and urged the need for a climate-neutral aviation. The sector is undergoing great mutations with the emergence of an urban air mobility based on eVTOL modules, electric and hydrogen airplanes for the short –haul transport and fuel efficient engines combined with sustainable aviation fuels for the long-haul flights. For years, Safran Data Systems's turn-key solutions for data collection, recording, transmission and processing have given aircraft manufacturers an edge on their flight test campaigns. Based on its expertise Safran Data Systems aims at assisting aircraft manufacturers in the validation and certification of tomorrow's concepts by expanding its portfolio on flight test instrumentation solutions for electric, hydrogen and emission efficient aircrafts. Proof-of-concepts are conducted to explore new innovative solutions such as HVDC electrical systems monitoring.

Keywords: Carbon-neutral aviation, FTI, FBG, Wireless, HVDC

INTRODUCTION

A couple years ago, Zodiac Data Systems joined Safran Group and became Safran Data Systems (SDS). As of today, Safran Data Systems is a world leader in instrumentation for aerospace testing and telemetry and provides Flight Test Instrumentation (FTI) solutions to aircraft, rotorcraft, missiles and launchers. Among other equipment, Safran Data Systems portfolio includes Data Acquisition Units (DAU, XMA series), recorders (MDR series), transmitters (DTRDM), antennas (COMTRACK, SPARTE series), receivers (RTR, RX-1), and a configuration & visualization software (eZ / eZ Processing). This unique set of equipment allows Safran Data Systems to ensure both data collection in flight and real time data transmission to the ground. For the years, Safran Data Systems flight test equipment has enabled the maturation and certification of many civil and military aircraft.

Safran Data Systems continually explores new technological fields and investigates market needs to provide the most relevant, high-performance, easy to install and low intrusive FTI solutions. Furthermore, Safran Data Systems benefits from other Safran companies' expertise – i.e. Electrical & Power, Electronics & Defense, Safran Tech, Aircraft Engines … - through partnerships and projects collaboration. Lately, Safran Data Systems has put a strong focus on developing FTI solutions to address specific needs of low carbon aircraft. Series of projects are launched to expand the company's portfolio and to support the global effort of reducing aviation climate impact.

This paper presents three projects conducted by Safran Data Systems that address major pain points in the validation and certification of low-carbon aircraft concepts, may they be VTOL, civil helicopter, electric airplanes, hydrogen airplanes or fuel efficient airliners.

TOWARD A CLIMATE NEUTRAL AVIATION

In the last past months, many breakthrough projects were unveiled by aircraft and engines manufacturers. New technological bricks are studied to shift toward a more sustainable air traffic that enables territories connections, supports economic growth while relying on carbon-neutral vehicles. Different concepts are suggested for each range to meet the needs and expectations of civil society.

A new kind of air mobility is emerging at the scale of cities. Start-ups and legacy actors from the aeronautical and automobile industry are working on urban air mobility vehicles that are referred as Air Taxis, e-S/VTOL, Personal Aerial Vehicles, Flying cars or Air Cargo. These new aerial vehicles are designed to transport passengers (incl. emergency services) and goods across urban areas. The propulsion is mainly performed by low noise electric motors to address pollution and noise issues within cities. Although many uncertainties remain regarding technical choices and business models, the industry attracts many investors and first commercial flights could occur during Paris Olympic Games.

***FIG. 1**: First flight of Volocity (Volocopter VTOL) at Bourget airfield on the 21st of June 2021*

By adopting a VTOL configuration and enabling emergency services to intervene in urban areas, UAM vehicles display many similarities with civil helicopters. Both segments can leverage key learnings from one program to another. For instance, the research on future civil helicopters includes increased autonomy but also electric hybridization and the use of alternative fuels.

The research regarding domestic and short range flights then focuses on (hybrid-) electric and hydrogen propulsion. For electric propulsion, the idea would be to generate thrust with electric motors combined with e-propellers. In such configuration, electricity could be generated by electrochemical systems such as batteries (Li-ion, Li-sulfur …) or fuel cells (PEM FC). As electrochemical systems are limited by low levels of energy density, some manufacturers rather bet on hybrid-electric propulsion and add a turbogenerator or turboprop to support electricity generation and/or thrust. Last by not least, Airbus announced working on an aircraft whose propulsion would be performed via by hydrogen combustion in a compatible turbomachine [1]. A few months after Airbus' announcement, GE Aviation and Safran unveiled the CFM RISE (Revolutionary Innovation for Sustainable Engines) program to conceive the next generation of single-aisle aircraft engine which should be compatible with alternative fuels such as hydrogen [2].

FIG. 2*: EcoPulse hydrid-electric demonstrator developed by Daher, Safran and Airbus with the support of France's CORAC*

FIG. 3*: Airbus ZEROe turboprop hydrogen aircraft concept*

FIG. 4: *CFM RISE (Revolutionary Innovation for Sustainable Engines) program launched by GE Aviation & Safran*

The final focus concerns long-range flights. The reduction of aviation carbon footprint on this segment should be achieved by optimizing airliners architectures, engines and flights trajectories, by using sustainable aviation fuels (SAF) and by electrifying aircraft systems. Aircraft manufacturers are working on new designs (such as BWB, BLI, biomimicry …) and new materials (such as composites) to reduce induced drag, lighten the structures and reduce fuel consumption. At the same time, engines manufacturers are studying advanced engines configurations to reduce aircraft fuel consumption and CO2 emissions. For instance, the RISE program should include open fan architecture, hybrid electric capability and be a 100% compatible with SAF [2].

INNOVATIVE ROTOR FTI USING WIRELESS TECHNOLOGIES

FIG. 5: *Airbus RACER demonstrator*

In the frame of European "Cleansky 2" call for partner (JTI-CS2-2017-CFP06-FRC-02-27), Safran Data Systems is developing a wireless solution to instrument, in a low intrusive way, Airbus Racer's rotors. The Racer (Rapid And Cost Efficient Rotorcraft) is a helicopter demonstrator. The program is conducted by Airbus Helicopters and was first unveiled in 2017. The Racer includes Safran innovative eco-mode hybrid-electrical system which allows fuel saving and adopts a particular configuration that contributes to lowering its operational acoustic footprint [3].

To support the maturation of the demonstrator, Safran Data Systems launched the HIRIS project (Helicopter Innovative Rotating Instrumentation System) dedicated to flight test operations on the Racer's rotors. This project aims to solve one major issue for helicopters testing which is the transfer of a large amount of data between the rotating parts and the fuselage. This pain point is associated with three major technical challenges: first, ensuring a reliable data transfer between the two parts of the helicopter (lossless data link, highly isochronous and accurate data measurement), second, delivering the necessary power supply to the equipment mounted on the rotating parts and third, reducing as much as possible the intrusiveness of the instrumentation system and easing its installation on the test vehicle.

To ensure data transmission and synchronization, a new module, referred as the XMA-WLS, was developed. This module is meant to be inserted in an XMA Data Acquisition Unit (DAU). The XMA-WLS leverages two well-known technologies which are WIFI and IR-UWB (Impulse Radio Ultra WideBand). WiFi technology is used for large data transfer while IR-UWB is used to implement a "PTP IEEE1588 like" protocol and ensure a robust synchronization (from 50ns in the lab to 150ns typ. in the field). The two radio signals are combined by an innovative diplexer minimizing signal losses while allowing the use of a single antenna. The power supply of the DAU is then performed using a smart inductive power system which displays a yield of more than 50%, very limited side radiations and a permanent digital monitoring of the energy transfer [4].

Most acquisitions on the rotors are strain gage acquisitions which are made, for the Racer testing campaign, with an XMA-ABC module. This module can support full-bridge, half bridge and quarter bridge acquisition on the same module providing 8 independent channels. To ease even more strain gauge acquisition, Safran Data Systems is currently working on a new XMA module based on Fiber Bragg Grating technology. This low intrusive and innovative technology is detailed in the next section.

In addition, an XMA variant, called the XMA Rotor, was developed to optimize the form factor of the DAU for rotary parts. The XMA Rotor is a XMA stack in a cylindrical shape that is balanced to enable the instrumentation of rotary parts.

Beginning 2021, the very first prototype of HIRIS was delivered to Airbus Helicopter. An intensive successfully laboratory test campaign was performed Q1 2021 and “on board” ground test and 1st ground run were successfully performed beginning of June 2021. In addition, on the 7th of June 2021, a complete flight envelope of the H175 was conducted and demonstrated stability and operability of HIRIS in flight. More flight tests are to be conducted until the end of July 2021 [4].

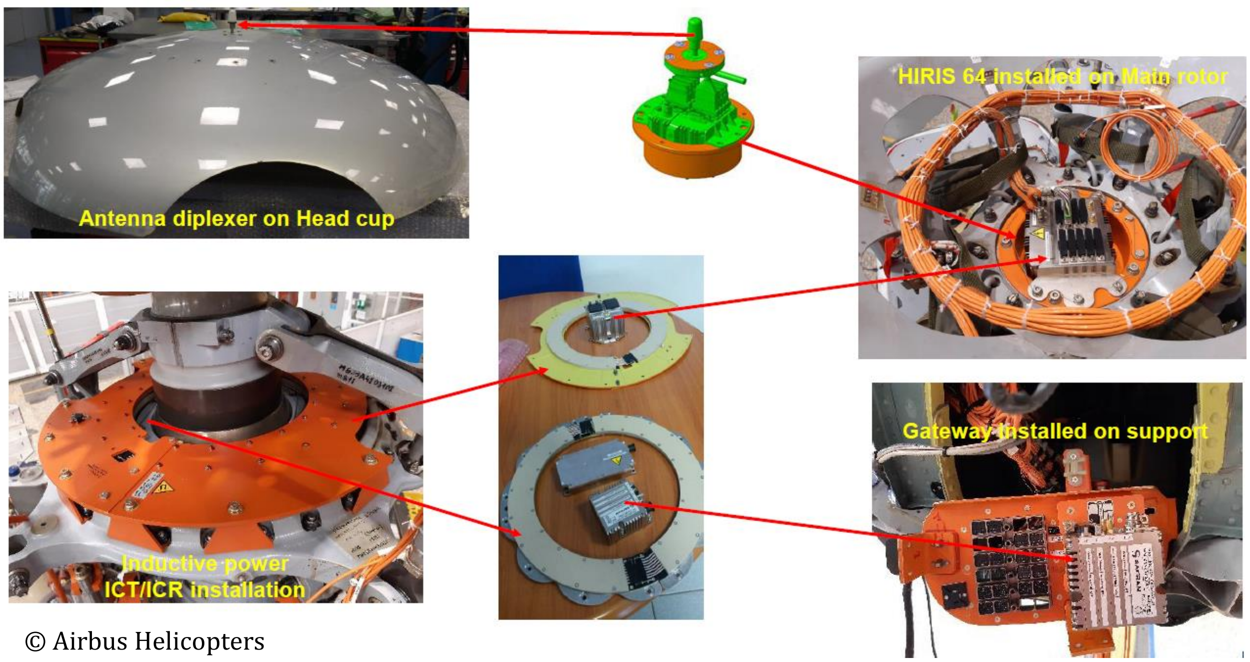

FIG. 6*: Some illustrations on HIRIS installation on main rotor H175 [5]*

FIBER BRAGG GRATING FOR STRUCTURAL HEALTH MONITORING (SHM) IN FLIGHT

Safran Data Systems keeps mapping different sensing methods for aviation available on the market to stay up to date and offer a cutting-edge FTI to aircraft manufacturers. In this context, Fiber Bragg Grating (FBG) sensing systems were identified be of great interest to conduct flight test campaigns on aeronautical structures.

A FBG system is composed of a sensor and an optical interrogator. A FBG sensor consists of an optical fiber that contains microstructures - called FBG - engraved periodically in its core. The microstructures modulate periodically the refractive index of the core and allow the transmission of some wavelengths and reflect others. The periodicity of the FBG defines which specific wavelength gets reflected. Any elongation or contraction of the fiber changes the periodicity of the FBG and leads to a specific wavelength shift of the light reflected at the FBG. In this way, the Bragg sensor can function as strain or temperature sensors. A fiber contains several FBG engraved which each acts as specific sensing points. For instance, the small compressor blade in figure 7 is instrumented with a FBG sensor that includes 14 sensing points.

FIG. 7: Small compressor blade instrumented with a FBG sensor in the frame of SDS POC

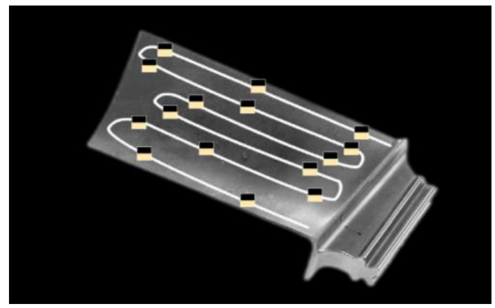

FIG. 8: Visualization under eZ Processing of different constraints applied on the small compressor blade (cf. FIG. 7) using a FBG sensor - color gauge representation

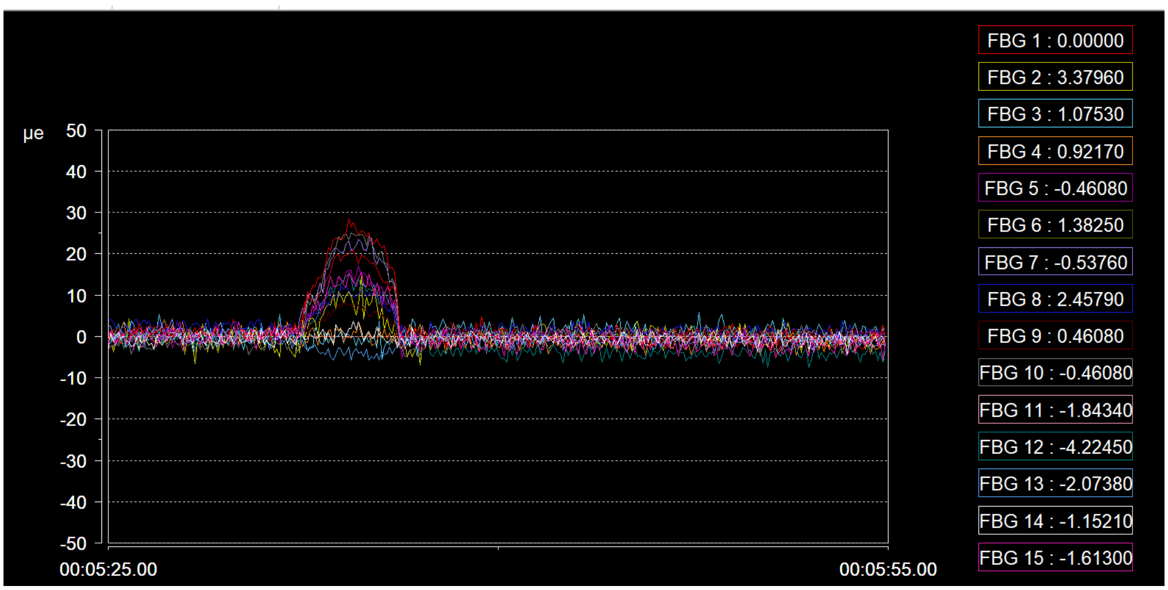

FIG. 9: Visualization under eZ Processing of different constraints applied on the small compressor blade (cf. FIG. 7) using a FBG sensor - µe as a function of time

FBG systems are very interesting to monitor structures in flight and obtain a mesh of the different constraints applied in terms of strain and temperature. FGB sensors are low intrusive and could be integrated directly in between composite layers as composite materials get more and more used in aviation. Moreover, aircraft manufacturers are increasingly working on disruptive architectures to reduce aircraft fuel burnt. Thus, there are major stakes regarding structural, aerodynamic and thermal analysis on vehicles in flight.

In order to take advantage of FBG systems on future flight test campaigns, Safran Data Systems is working on the integration of an optical interrogator in its DAU with the development of a specific module. The first use-case anticipated for this solution would be to associate it with the latest wireless technologies (efficient power, resilient data, and high synchronization) in the HIRIS project in order to offer accurate rotor blade monitoring during flights. FBG sensing also offers interesting opportunities to instrument hydrogen pipelines and distribution networks.

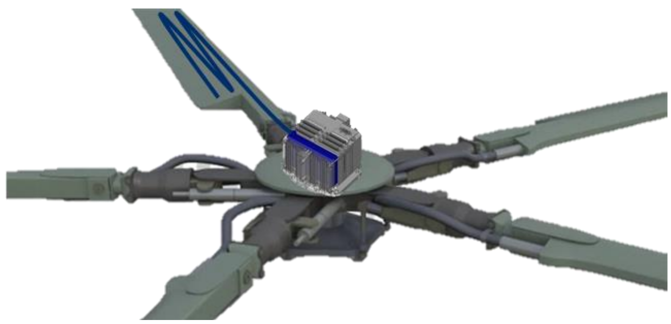

FIG. 10: *Illustration on a XMA including a FBG module and fiber to monitor rotor blades constraints*

FTI FOR ELECTRICAL SYSTEMS MONITORING

As mentioned in the first section, aircraft propulsive and non-propulsive systems are increasingly relying on electricity. As a consequence, the total amount of electric power needed rises. As of today, the main electric source of an aircraft comes from the turbojet engines coupled with generators which produce a 3-phases 115V to 230V alternative current (AC). Batteries are also encountered, mainly for short term action, and deliver 28V direct current (DC). Should electricity be used for propulsive systems of light aircraft, the voltage on board could reach 800V. As the main trend consists in by-passing fossil fuels to limit aviation contribution to climate forcing, electricity generation should mainly come from electrochemical systems, generating DC and HVDC.

In order to enable a smart monitoring of electrical systems in flight, Safran Data Systems is working on an end-to-end FTI solution dedicated to electrical systems. The solution developed aims to monitor 3-phases AC, DC and HVDC and to assess the quality, stability and safety of electrical systems in flight. A Proof-Of-Concept (POC) is currently conducted by Safran Data Systems Innovation Cell to investigate the technical feasibility of the project. The POC is composed of a XMA acquisition module, a XMA processing module and a XMA Ethernet module. The acquisition module gathers current and voltage data while the processing module processes the electrical signals to extract relevant information. The Ethernet module is then used to send in real time the tests results to a computer on eZ Processing - SDS configuration & visualization software – to oversee the running of the tests. At the end of the tests, eZ Processing displays of small report pointing unusual and hazardous events on the electrical system monitored.

In order to monitor HVDC systems, Safran Data Systems partners with Safran Electrical & Power (SEP). The idea is to combine SDS FTI equipment with SEP innovative current and voltage sensors. SEP current sensors are based on both the Neel effect and Rogowski coil. They are low intrusive and allow measuring both high and low current with high levels of precision. This new generation of sensors overcomes many limitation encountered with shunt and Hall Effect sensors. In the frame of SDS POC, the XMA acquisition module is connected to one of SEP current sensor.

Regarding the processing of the electrical signals, many functions were implemented in the dedicated XMA module. For instance, the period, amplitude, RMS (Root Mean Square), crest factor or powers (active, apparent, power factor) are computed in real time. In addition, a frequency analysis is available that includes a FFT and the calculation of the THD (Total Harmonic Distortion). Finally, the processing module includes an events detection system that raises a red flag in case of abnormal behavior of the electrical systems. This includes voltage saturation, frequency imbalance between the voltage and current channel, abnormal value of the fundamental frequency and so on.

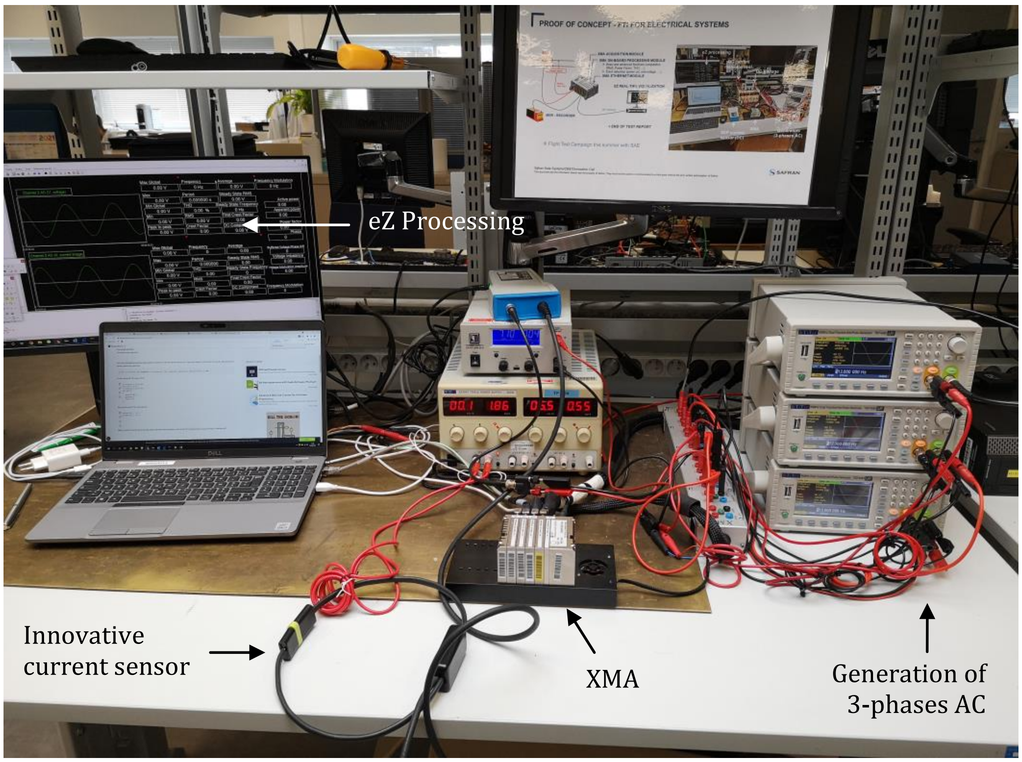

FIG. 11*: SDS POC regarding FTI for electrical systems*

CONCLUSION

This paper illustrates some innovative projects conducted by SDS to support aircraft manufacturers in the maturation of ambitious carbon-neutral concepts. The innovations presented address a great variety of FTI pain points: data transmission in a rotorcraft, composite SHM using FBG sensors and electrical systems safety.

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GLOSSARY

BLI: Boundary Layer Ingestion
BWB: Blended-Wing-Body
DAU: Data Acquisition Unit
FBG: Fiber Bragg Grating
FTI: Flight Test Instrumentation
HIRIS: Helicopter Innovative Rotating Instrumentation System
HVDC: High Voltage Direct Current
PEM FC: Proton Exchange Membrane Fuel Cells
POC: Proof-Of-Concept
RACER: Rapid And Cost Efficient Rotorcraft / Airbus Helicopter demonstrator
SAF: Sustainable Aviation Fuels
SDS: Safran Data Systems
SEP: Safran Electrical & Power
SHM: Structural health monitoring
UWB: Ultra WideBand
VTOL: Vertical Take-Off & Landing
XMA: Safran Data Systems Data Acquisition Unit