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Instrumentation for Outer Measurements in Aeronautical Applications

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Abstract:

Measuring a lot of in flow wall parameters (more than thousands like pressure, acoustic, temperature, vibration…) needs to set up sensors on the outer airframe skin where temperature is as low as -40°c (-40°F), flow Mach number as high as 0.92 and dynamic pressure as high as 320 hPa. The installation has to avoid any disturbance of both the flow and the measured signals.

But setting up sensors and connecting them to a data acquisition system which has to be powered is very time consuming. For a flight test, a lot of data had to be extracted in order to analyze them. LMSM has developed a system for solving such challenge by sticking the whole system (power, acquisition system, control system and wireless downloading). Thanks to its CaptiFlex™ technology, tested by DGA EV in flight (www.captiflex.fr), it avoids any hole into the airframe and it allows different kinds of sensors to be housed in a same CaptiFlex™ device.

Our paper will detail a new autonomous power and wireless system for taking highly resolution pictures of a commercial Aircraft leading edge during long term experimentation (14 months)

The system operates at flight temperature (-40°C up to 70°C) and includes a power supply, a micro-camera, control system and software, and a CaptiFlex™ architecture allowing the system to be to stick down the outer skin of an aircraft.

The system is very fast to install and cuts the costs not only in workshop but also for the program by getting more flight parameter values at the same time.

Thanks to Clean Sky and Airbus collaboration and thanks to Captronic support, LMSM has achieved the requirements of this very innovative solution which is now a product adaptable to other applications.

Key words: Autonomous energetic system, Micro-Camera, flight test instrumentation, HD photo, system plug and play.

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Introduction:

The dream of the instrumentation staff is to have a "plug & play" system fast to install and easy to maintain.

The dream of test engineers is to collect the more measured parameters as possible and to exploit them just after the end of the flight.

The dream of the pilot is not to be disturbed by the flight test instrumentation and so having one which is thin and as light as possible.

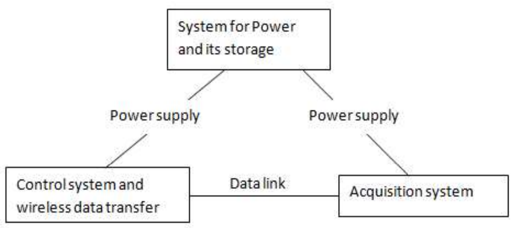
The dream of program manager is to minimize test costs and test duration.

Are these dreams compatible? Yesterday the answer was No, but by now the answer is Yes.

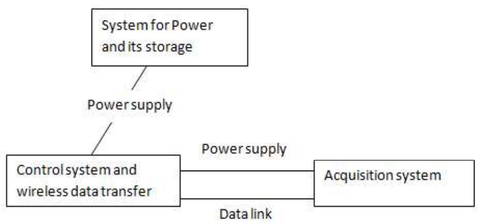
With conventional technology, if you want to set up sensors on the outer skin of a wing, you need sensors (highly cost), and inboard data acquisition system, a power source from the aircraft, and a lot of time and workload both for design (where and how wires go through the aircraft) and installation. During this last phase, aircraft is under a hangar and does not fly and so it has no productivity.

In order to cut the flight test costs and their duration, we propose a "plug & play" system which is stuck on the outer skin of the aircraft and includes an autonomous power system able to meet the power need, an acquisition system for collecting data, a control system software for saving measurements with wireless data transfer capabilities capable of downloading measurement data in few minutes.

Many configurations exist to take up such a challenge as, for instance, those illustrated by the following bloc diagrams:



Exemple of bloc diagram 1



Exemple of bloc diagram 2

The Clean Sky project implements one of these architectures and provides an autonomous micro camera system intended to be mounted on the outer skin of a commercial aircraft. The project was supported by the European Clean Sky program and the French Captronic organization.

Clean Sky topic: "Camera development for in-service monitoring of leading-edge contamination":

The Clean Sky Smart Fixed Wing Aircraft Integrated Technology Demonstrator (SFWA-ITD) consortium is interested in understanding the typical level of contamination and minor damage to a wing leading-edge in operational service.

Ideally this would include improved information about the rate of insect or other contamination and its currently unknown dependence on altitude, climatic zones, seasons and environment as well as the cleaning impact of flight through rain, or clouds and any impact of WIPS (Wing Ice Protection System) operation.

In this call of proposals topic, one has to develop a compact and autonomously working camera system suitable to record the contamination on the wing leading-edge. The camera system will be installed on a short-range or long range aircraft at a position to view a section of the wing leading-edge. The system will be used to perform camera recordings during regular operational flights.

One has to develop an autonomous high resolution micro camera system for the installation on an in-service aircraft that can

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view a section of the wing leading-edge (either a fixed leading-edge or the leading-edge of retracted slats). To ensure an adequate field of view it is proposed to install the camera in a fairing at the fuselage or pylon.

The camera system should include the following components: camera, power system, memory and control system, mount for all components, aerodynamic fairing to cover the complete camera system.

One has to ensure installation of the camera system and fairing during an overnight check without the necessity of permanent changes to the aircraft structure.

The selection of the camera equipment will be under the consideration of typical operating conditions during the flight.

The viewing area should be about 500 mm span by 250 mm chord and the span wise location should be defined to suit the camera choice and installation.

One has to provide the camera and ensure camera view to be of suitable quality to be able to capture insect contaminations within the recordings. A minimum spatial resolution of about 4 px/mm will be needed as typical insect residues have the size of about 1 mm in lateral direction.

One has to provide recording equipment that operates fully autonomously without external power source for the expected number of days away from the home base or until down loading of data is practically possible. System ensures that recording equipment take pictures every 10-60 seconds during climb-out and descent and every 15 minutes during cruise.

System has to record altitude for each image (e.g. GPS sensor) and ensure allocation of altitude data to the recorded images. Time (GMT) and date to be inserted on the images.

System has to ensure easy access to data storage (e.g. wireless data reading to avoid necessity of camera access).

The certification of this micro camera system is due by the “Airbus Deutschland” Topic Manager.

Further requirements during the development

During the development the system was further improved so as to meet the following requirements:

- The viewing area was increased to 800 mm/1000 mm span which is about twice the initial requirement.
- Pictures have also to be taken during the takeoff and landing phases, every ten seconds.
- The aircraft can be an A320 and its slats are extended during takeoff and landing phases.
- There are about 5 flights a day and about 100 pictures are to be taken during each flight. Data downloading must be performed only every two days.
- The camera must be arranged on the fuselage at 4 m from the middle of the leading edge.
- Monitoring will be performed during 14 months except December and January months.

The A320 flight domain temperature is between -38°C and +45°C, the cruise Mach number is M0.78, the cruise speed goes up to 220 m/s, the cruise altitude is 33 000’ and pressure varies from 250 hPa to 1500 hPa.

These updates led to:

- A three times greater viewing area and the same increase in picture volume, and their consequences on the allocated data storage and power required for the wireless data transfer.
- Improvement of the camera in order to achieve the high spatial resolution required.

and to take up the following challenges:

- Designing a power system working at low temperature (about -40°C) and at low pressure (250 hPa) for supplying enough power for two days.
- Identifying automatically flight and ground phases that are not known by the system. For instance the landing phase begins respectively at 3010’ before landing in Marseille-Marignane arrival and 4400’ before landing in Zurich.
- Providing high picture resolution at 4 m.

- Adapting the CaptiFlex™ technology to the micro camera system. CaptiFlex™ is a technology allowing sensors to be installed on the outer skin of airframe.

Project management:

The technical project was organized in 4 Work Packages:

- Camera and control system
- Power system
- Integration into CaptiFlex™
- Aircraft installation

The development time was 18 months.

Results

The architecture of developed system is shown in bloc diagram 2 and has a separate power supply coupled to the control system which includes the micro camera as well as the acquisition system.

Camera

To meet the different requirements, the chosen camera has the following specifications:

- Retina sensor with 1.1 µm pixel dimension
- High quality 6-lens, f/2.2 and a 26 mm focal length
- Total thickness of about 10 mm and low weight
- Low-power camera
- Shooting time less than 5 seconds.

So, due to the 25° leading edge swept angle and greater area view, the spatial resolution is comprised between 3 Px/mm and more than 4 px/mm. Each picture has at least a 3MB volume.

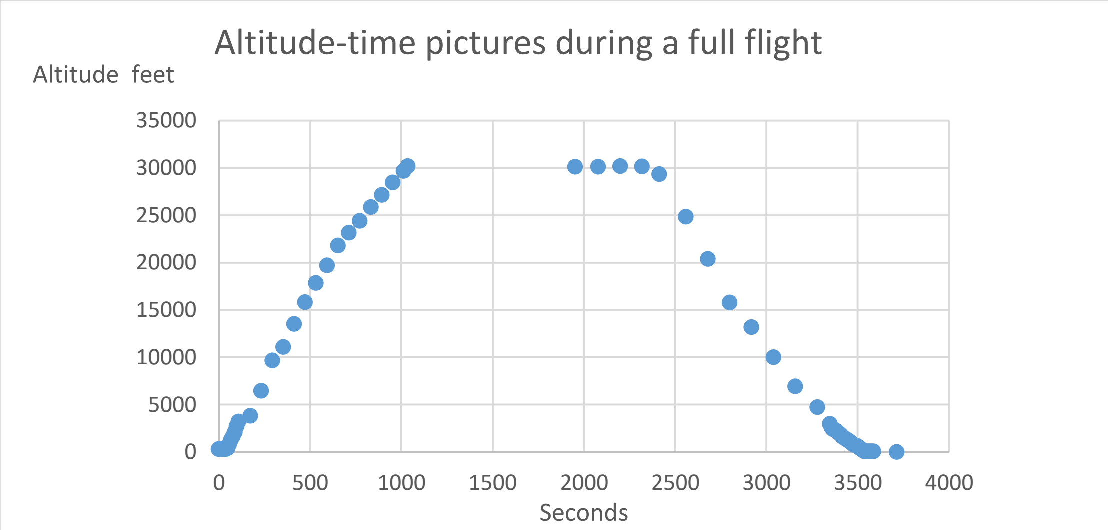
Control system

Work at an external temperature of -40°C.

It includes Wi-Fi, a GPS and other sensors such as accelerometers.

A 32 GB memory allows to record about 10 500 pictures, with a 21 days autonomy.

During a Paris Orly-Marseille commercial flight, the system took pictures according to the following scheme: one picture every 10 s during take-off and landing, one picture every minute during climb out, no picture during cruise and one picture every two minutes during descent. During its cruise, the aircraft's altitude decreased a little down to the 30 000' limits (which is the beginning of the descent phase) and afterwards increased a lit bit over 30 000'; that is why on the following graph, pictures were taken during the end of cruise phase.



During this flight, mean power consumptions are:

Phase	Power consumption (W)
Taxi out	0.8
Take off	1.6
Climb out	0.9
Cruise	0.9
Descent	0.9
Landing	1.6
Taxi in	0.8
Parking	0.7

But some functions of the micro camera system demands power peaks from about 6W up to 20 W.

Wireless transfer:

For downloading pictures Wi-Fi is used. Test for downloading 85 pictures of about 1MB each with an ADSL link shows a transfer rate of about 700 kb/s. But for downloading 1000 pictures of 3MB each, it is insufficient.

So, the choice is to get fibre optics as internet link with a real speed of 50 Mbps at least as internet flow. Afterwards, the bottle neck is the real Wi-Fi flow. Such a solution allows transferring the two day picture records in less than about 10 minutes.

Power system:

- operates at -40°C and under low pressure such as 250 hPa
- Supplies high power peak when needed.

Integration into CaptiFlex™:

In order to match with easy installation on Aircraft and A320 flight domain constrains (temperature [-38°C ; +45°C], M0.78, FL350, [250 hPa ; 1500 hPa]), the CaptiFlex™ technology was used. It provides support sheet with adhesive tape and tapered edge on its boundaries, cavities to set up sensors and/or electronics and covers to close cavities.

Mechanical and thermal and pressure stresses were testing during flight test up to M0.92 and FL400 and dynamic pressure 320 hPa. In addition, long term lab-tests were successfully performed with a cycle of 3 h simulated flight during more than 300 cycles.

Vibration lab-tests were successfully performed under the French military GAM EG 13 standard which is equivalent to the DO 160 standard.

CaptiFlex™ EMI lab-tests and light protection were also performed under NF 17025 standard.

Installation on aircraft:

Topic Manager has the responsibilities of Certification process and installation of the micro camera system on aircraft; LMSM gives only installation procedures and will deliver technical assistance for its installation.

For the first installation of the system on a DGA EV Alpha-Jet aircraft, the duration for setting up 10 sensors was about 2 hours. Such a time matches with the installation time requirement during an overnight check.

In a few words, the installation procedure begins by mounting the system on the aircraft outer airframe.

Then, energy storage is charged and afterwards control system software is powered on.

Finally, every cover is set up on its own cavity and a waterproofing around it is performed.

Intellectual properties:

Following to Clean Sky rules (grant agreement), Foreground shall be the property of the beneficiary carrying out the work generating that foreground. So LMSM is the only owner of these technologies. As soon as the authorisation to disclose their content is granted, detail specifications of the system will be available on our website www.le-captiflex.fr.

The research leading to these results has received funding from the European Union's Seven Framework Programme (FP7/2007-20013) for the Clean Sky Joint Technology initiative under grant agreement project number 641577.

NDA were signed with Captronic and our subcontractors.

Summary:

LMSM has developed the required innovative Clean Sky micro camera system to be installed on the outer skin of an A320 fuselage. The system includes a compact and autonomous micro camera for taking high quality pictures for long periods up to 14 months with enough power; a memory and a control system; and an aerodynamic housing. An automatic control system software identifies the flight and ground phases and their corresponding picture rates. An automatic wireless transfer process with high data transfer rate is also provided, which needs only few minutes to download 3 GB of data. The system also offers a reduced installation time without permanent changes to the aircraft structure. The system also meets the Topic Manager requirements in order to achieve the SFWA-ITD aims.

Thanks to the new technologies and solutions implemented during the development of the system, the "stick and measure" concept is now a reality. LMSM products are available and thanks to its know-how and design methodology they can be adapted to various other configurations or applications.