Fp7 - Collaborative Project - Design Systems and Tools - Contract No. 266107

AIM 2 Newsletter No. 2

Advanced In-Flight Measurement Techniques 2

November 2012

AIM² - AN UPDATE

Welcome to the 2nd edition of the AIM² Newsletter. It provides you the latest news from the European Collaborative Project AIM² - Advanced Measurement Techniques 2, which was launched on October 2010 with a project duration of 3 ½ years. AIM² focuses on developing reliable and easy to use dedicated measurement systems and on defining design and application rules for these new in-flight measurement techniques. Within the first 24 months of the project, the AIM² consortium, consisting of industrial partners, research institutes and universities from 8 countries, made a lot of progress in the further development of the Image Pattern Correlation Technique (IPCT) applied on fixed wing and propeller deformations, Particle Image Velocimetry (PIV) to measure velocity vector fields, Light Detection and Ranging (LIDAR) which allows a precise remote measurement of the wind velocity and the Fibre Bragg Grating (FBG) to measure strain and pressure with optical fibres. After the improvement of the applicability of these measurement techniques, now the first flight tests of the project will be performed within the next months.

The first flight tests are expected on the Cranfield University Bulldog using the FBG techniques and the IPCT wing deformation measurements on the NLR Fairchild Metro II, followed by the next in-flight PIV campaign on the Dornier Do 228. Furthermore IRT and IPCT will be applied on the wing of the PW-6 motorglider of the University of Rzeszow. The planned wing deformation measurements on the Evektor VUT 100 Cobra as well as the challenging propeller deformation measurements with the new rotating camera system will also be performed in the next year. Last but not least LIDAR will be applied on the Piaggio P 180 to calibrate the airspeed measurement systems onboard.

The preparation of all these demanding measurement campaigns with these new advanced measurement techniques is done by a strong cooperation of all AIM² partners. To enable this, a project website and semi annual project meetings are organised within the project. After the Kick-off meeting at the DLR in Göttingen (Germany), the next meetings had been at Rzeszow University in Poland (the first semi annual meeting), at NLR in Amsterdam (the first annual meeting), at Cranfield University in the UK (the 18 months meeting) and the mid-term review meeting now again at DLR in Göttingen (Germany). During these meetings the AIM² partners had plenty of fruitful discussions and workshops. All partners also promoted the AIM² project during several conferences and workshops. A big highlight of the AIM² project will follow within the next year – the AIM² flight testing workshop. This workshop is intent to present the developed advanced in-flight measurement techniques to the flight testing community. At the workshop, the students will learn the basics of the measurement techniques during lessons and by means of realistic exercises. Herewith, I'd like to invite you to be part of this workshop. Stay tuned at http://aim2.dlr.de

LIDAR ANEMOMETER FOR AIR DATA CALIBRATION

LIDAR (Light Detection and Ranging) is a well established measurement method for the prediction of atmospheric motions but also for the determination of distinct flow phenomenon through velocity measurement. Recent advances in airborne LIDAR show that, the technology is mature, offers great ease of use, and is reliable and compact. In particular, LIDAR technique is quite suitable to the project AIM² whose aim is to develop powerful techniques to reduce duration and costs of flight tests.

The objective of ONERA work within the Flow Field Measurements workpackage (WP5) is to design, manufacture and test a 1.5 µm anemometer LIDAR sensor for in-flight airspeed measurement and system calibration on a Piaggio P180 aircraft. In particular, the identification of the static error, the angle of sideslip (AOS) as well as the angle of attack (AOA) with a LIDAR type device would enhance the quality of the data acquisition process during flight test certification.

ONERA work in the first year of AIM² project concerned the definition of the LIDAR system. Tasks consisted in:

- Defining the technical LIDAR specifications using Piaggio inputs concerning aircraft requirements for certification process.
- Modelling LIDAR measurement performance to define LIDAR instrumental parameters (laser axis configuration, laser power, pupils diameter, etc.).
- Studying LIDAR signal processing and data acquisition, storage and also real time visualisation to monitor in-flight LIDAR measurement.

State of the art and LIDAR measurement modelling led to a LIDAR sensor composed of a sensor head positioned to measure through the first cabin window of the P180 and a rack mount including several racks (laser, fibered architecture, and electronic rack) placed closed to the Sensor Head as illustrated on Figure 1 below. Choice of LIDAR components was established taking into account availability and performance of commercial components for optical system and signal processing.

The LIDAR Sensor Head includes an optical switch and 4 measurement axes. Airspeed vector, AOA and AOS are deduced from measurements of these 4 axes. The advantage of this 4 axes configuration is to provide measurements reliability due to redundancy of the fourth axis. Hence, if the LIDAR measurement is ambiguous or not available on one of the 4 axes, a reconstruction of airspeed vector is possible using the remaining 3 axes, but with a loss of accuracy. In fact, the 4 LIDAR axes are obtained by fibre optical switch based on a micro - mechanical commutation. This sequential scanning solution has been selected in order to have the whole laser power instead of parallel scanning where 4 axes are available in parallel by laser power splitting. Maximum power is necessary to reach LIDAR measurement performance especially at high altitude. The mechanical mount of LIDAR sensor head including the 4 measurements axes was defined as described on Figure 2.

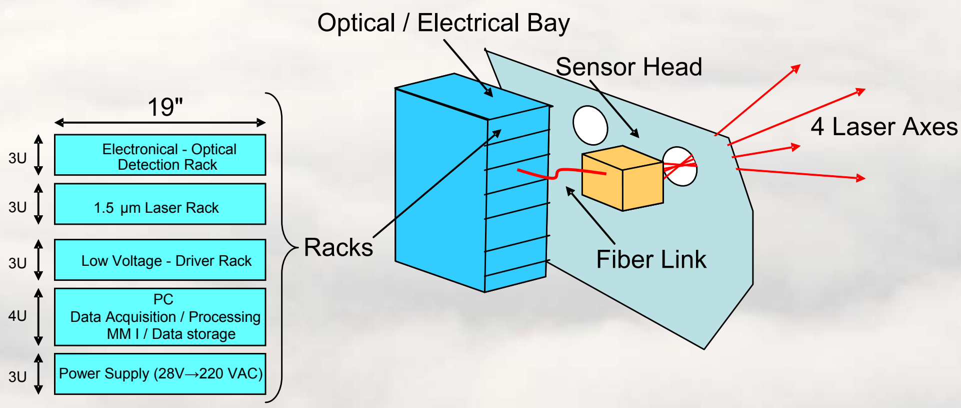

Figure 1: LIDAR Sensor Description

The LIDAR implementation in an aircraft was studied using CATIA models of P180 cabin provided by Piaggio as described on Figure 2: LIDAR positioning in P180 aircraft has been precisely defined for optimal performance of the LIDAR

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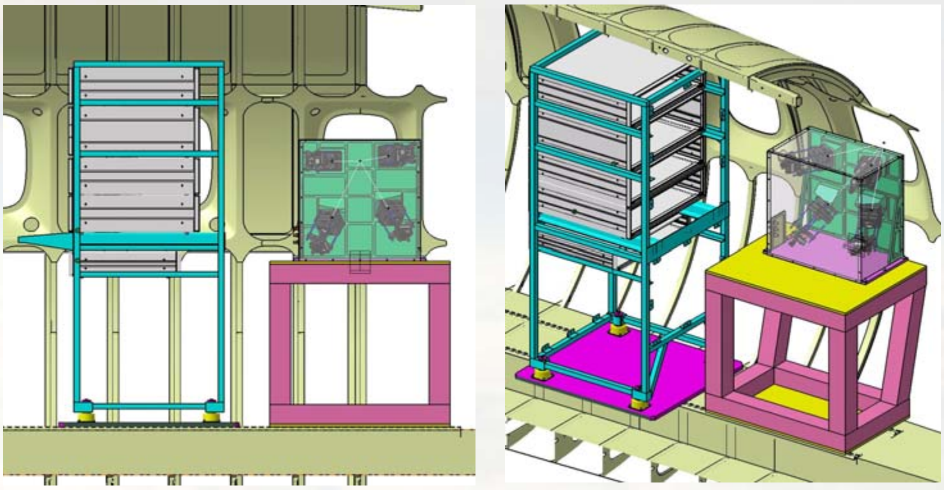

Figure 2: LIDAR Implementation onboard P180

measurement. A specific laser emitting window, already used during flight tests onboard a Mystere XX, was proposed to Piaggio. This laser emitting window whose optical qualities (planarity), size and thickness are suited in terms of aeronautic and LIDAR constrains should be integrated inside the first left cabin window: demonstration of robustness to pressure and temperature constrains are described in a document provided to Piaggio which may be helpful for mechanical window installation and window certification onboard aircraft (compatibility with pressure and temperature constrains).

ONERA work in the second year of AIM2 project concerns the LIDAR construction. LIDAR aircraft interfaces defined in collaboration with Piaggio were purchased (inverter 28V/220V, racks for the rack mount provided by Piaggio). The mechanical interface between the LIDAR sensor head and the aircraft Sensor head mount has been approved by Piaggio. Man-Machine interface for activation/deactivation of LIDAR system during flight tests is under definition.

LIDAR components such as lens, quarter wave and fibered couplers have been purchased and characterized in laboratory. The laser unit dedicated to AIM² LIDAR flight tests has been tested in laboratory

The mechanical structure of the Sensor Head has been validated by Piaggio and the realisation by sub-contracting is in progress. Integration of LIDAR components inside the structure is in progress: adjustments of each laser measurement axis have been done in laboratory (Figure 2)

Concerning signal processing, implementation of Data acquisition and implementation of tools for stored data extraction are studied. Real time display of each LIDAR axis measurement for checking LIDAR behaviour during flight is studied.

Planning of the work for next 6 months will concern the integration of the whole system (Sensor Head, LIDAR racks and signal processing). The integrated LIDAR will be tested in laboratory, then on motorised vehicle for performance validation in representative conditions.

Presenting our new project partners

- Part II -
Avia Propeller (AP)

Avia was founded in 1919 and produced aircrafts until 1960, aircraft engines until 1988 and propellers ever since the company's foundation.

The new company history is started in 1992. In this year the company Avia-Hamilton Standard Aviation Ltd. was founded, as a joint venture with UTC Hamilton Standard Division. The possibility to use the Hamilton Standard trade mark known in a great majority of the aviation population world-wide played an important role, especially for the "heritage" propeller blades manufactured by Avia Propeller under license agreement. An example is the blade for P 51 Mustang.
Further ownership structure change was performed in the end of 1998. Mr. Gerd Muehlbauer, the owner of aircraft propeller manufacturing company MT PROPELLER Germany, replaced the Hamilton Standard company and became the majority shareholder. During the year 1999 the company name was changed to AVIA PROPELLER.
Our company has 42 employees now. Only five people are working in Engineering. All design and testing work is done in-house. On the base of in flight tests and calculation, the propeller fatigue test for each new propeller design is performed.
We are producing propeller from Sport airplane category (airplanes with piston engines up to 600HP), to Commuter airplane category (turboprop engines up to 1800 HP). Avia Propeller produces two, three, four and five blades hydraulic constant speed propellers. Since 1999 Avia Propeller started design and production of propeller governors for piston constant speed propellers and governors for turboprops. Most pilots from Red Bull race used our governors.
The goal for AIM² program WP3 is to measure a real deformation of the propeller blade during one revolution. Avia Propeller is supporting this project by providing the three bladed propeller AV723 which will be installed on Cobra airplane. In addition, Avia Propeller will make a standard in-flight vibratory stress survey for optical method comparison.

Predecessor overtakes the AOS71 motorglider

Rzeszów University of Technology has planned to use a novel AOS71 motorglider as a basic testbed for IPCT and IRT in-flight measurements. Although the vessel passed the series of static tests in May and flight tests in June, what is more a wide community could see her on the ILA static display in September, no one may predict entering into service.

The time running inevitably, and in the beginning of the present year the aircraft was substituted for PW-6 twoseat glider, a direct predecessor of AOS71.

PW-6 has been designed by the team of Warsaw University of Technology as a further development of the successful one-seater PW-5 – World Class and finalises the series of several designs led by Roman Świtkiewicz, Ph.D, Eng.

This selection has not been only by chance. Experiments planned in AIM² project in this area are focused on wing deformation and flow measurements. The geometry and the structure of the wing of both gliders are practically identical. The main differences are in the slant angle of leading edge and composite reinforcement. Second issue that testified in PW-6 selection was its research purpose, rather known for some individuals because the glider is famous as an excellent basic and advanced trainer. From the very beginning of design the fuselage obtained reinforced main frames with additional joints for possible test installations. During its career one item became a flying wind tunnel with sophisticated upper turret over the wings.

Rzeszów University of Technology selected one of its few, possessed by University's "Akaflieg". It will be a platform for a universal test-pod mounted over the turret and used in IPCT and IRT in-flight measurements.

The first two quarters of the present year were dedicated for object identification. The aircraft began its life in the era, when CAD methods were not as popular and accessible as nowadays. Technical documentation exists within the form of classical blueprints. The structure was calculated without support of numerical methods. Several actions of reverse engineering were performed, e.g.: transfer of geometry into digital form, creation of wing numerical model for Finite Element Method calculations. It demanded also some supporting experiments, as verification of structure stiffness, identification of material properties like strength, elastic constants and thermal diffusivity, as well.

Specifications PW-6

General Characteristics

Crew:	2
Capacity:	2
Length:	7.85 m
Wingspan:	16.0 m
Aerofoil section:	NN 18-17
Wing Area:	15.25 m²
Aspect Ratio:	16.8
Empty Weight:	340 kg
Gross Weigth:	550 kg

Performance

Max. Speed:	260 km/h
Max. Glide Ratio:	34 at 105 km/h
Rate of Sink:	0.8 m/s at 90 km/h

Figure 3: PW-6 glider during the verification wing stiffness tests

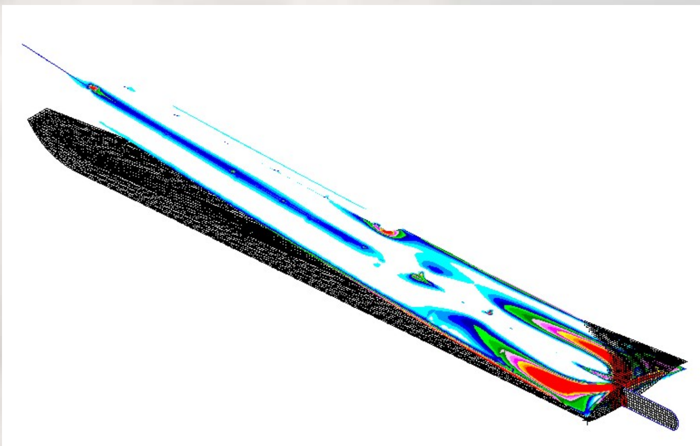

Figure 4: Example of stress distribution in FEM numerical model of PW-6 wing

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Software tools for flight Tests by means of Image Pattern Correlation Technique

- Part I -

Graphical User Interface for the industrial user of the Image Pattern Correlation Technique

Within the AIM² project the goal is to make the application of advanced measurement techniques available for the industrial users. NLR developed in the AIM project a methodology and software to process images of a wing to retrieve wing deflection using the IPCT method. The method was successfully applied for measuring the wing deflection of the NLR Fairchild Metro II wing and the Airbus A380 wing. The processing process and software was developed such that the developers could gain the results and could optimise the process and the software. The process needed many steps where inputs and outputs had to be managed carefully. The process was flexible, but time consuming and needed much training for the adequate application of the process. It was decided to make the process much faster and easier to apply.

The user is to be guided to input all the required data and to manage the processing steps. The IPCT method and software developed in AIM was therefore adopted in AIM² in a tool named Optical Wing Deflection Modelling (OWDM). The original AIM processing software was developed in MATLAB® and has been implemented in a Java environment. The OWDM tool is initially intended for processing images taken on NLR's research aircraft or other aircraft with approximately conically shaped wings. The tool will be extended for aileron and flap rotation measurements during AIM². An extension for other wing shapes is also foreseen. The aim for the development is to generate a tool for continued usage of the processing functionality of OWDM during AIM² and in the future by a variety of users from research institutes and industry. A Graphical User Interface (GUI) has been developed as part of the OWDM tool that guides the user through the process of entering all required data and runs the MATLAB® scripts. A MATLAB® license will no longer be required when using OWDM.

Examples of the GUI screens are given in Figure 5 and Figure 6.

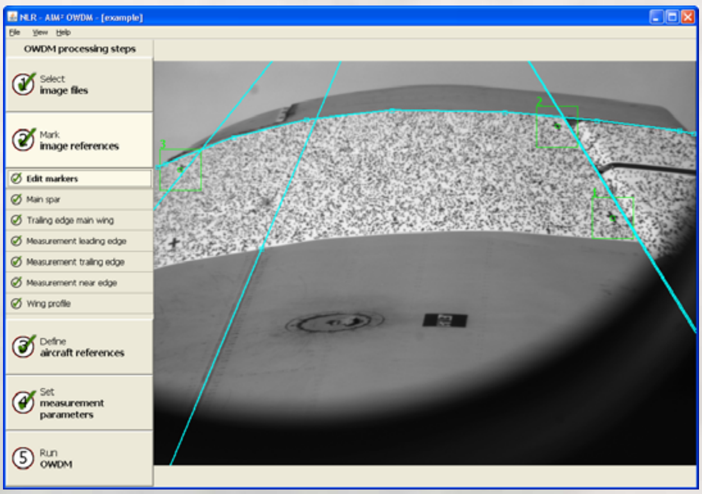

Figure 5: Input of wing geometry

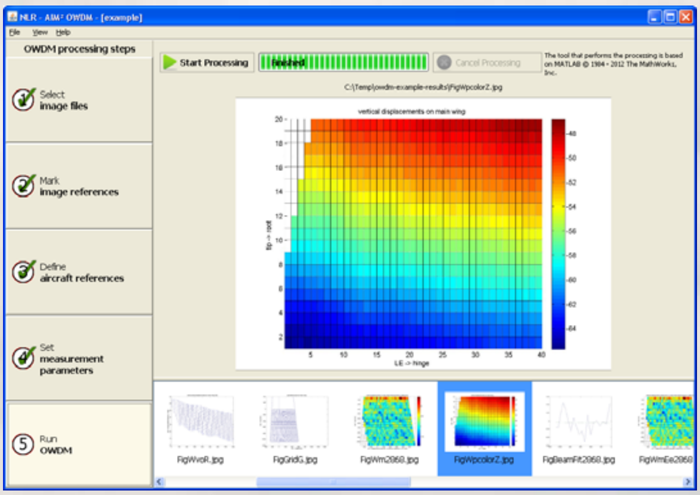

Figure 6: Screen with results after running the processing of images

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- Part II -
Virtual IPCT

Virtual reality has proven to be a particularly useful tool in engineering and design. A related area of aviation in which VR simulation has proven particularly significant is flight training, since it requires many hours of practice and to use real planes for all training is both expensive and more dangerous.

Research conducted at the Rzeszów University of Technology showed that VR can be successfully used for planning IPCT flight tests. Works within AIM project has proved applicability of IPCT method for different categories of aircraft flight testing and and have shown, that one of the most time consuming stages of the testing is a selection of a pattern to the specific aerodynamic surface, the best camera location, the inspection of the viewing angle and different weather (light) conditions.

To shorten the time and reduce the cost of testing, a computer tool, VirlIPCT was created at RUT to preliminary preparation of real flight tests by use virtual reality. VirlIPCT is a synthetic IPCT image generator. This is a computer tool that permits to perform virtual IPCT setup on an airplane. Using it, we can shoot markers on the wing, using a virtual camera. The camera is placed on a computer model of an aircraft, that is created by the program (Catia, Unigraphics, Solidworks, etc.), based on the real aircraft. The markers are placed on the virtual wing of the aircraft. The resulting collection of the shoots can be analyzed by standardised IPCT program.

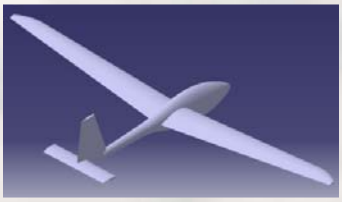
The Virtual IPCT enables:

- reading IGES, etc. files from CAD programs,
- generation of pattern bitmaps or markers,
- mapping bitmap on a testing surface,
- locating and orientating of cameras,
- simulation of camera's optics,
- simulation of structure's deformations (based on real or virtual data),
- photographing of area of interest.

However, since virtual reality interfaces are difficult and expensive to build, Virtual IPCT utilises some of existing 3D computer graphical tools and home- made software such as Solid Works (CAD/CAM/CAE), CPG - Synthetic IPCT Image Generator, Blender 3D, Octane Render and PIV View 3,3.

In conclusion we can state that preliminary tests results show, that Virtual IPCT can be used at the very early stage of IPCT flight test preparation to avoid efforts with the real aircraft. It allows you to test the impact of: patterns, lighting conditions, arrangement of cameras on IPCT results in virtual reality and significantly shorten the time and reduce the cost of testing real aircraft in fly.

CAD PW-6 glider model (left) with pattern and camera setting on the wing (right):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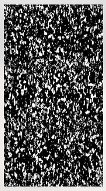
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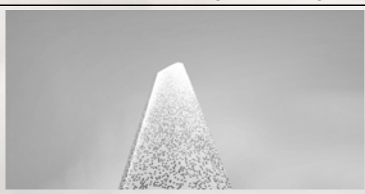
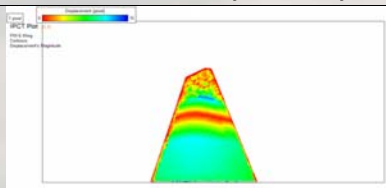
PW-6 glider wing before (left) and after (right) deformation:




PW-6 glider wing vector field displacement (left) and displacements magnitude (right):

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