

AIM NEWSLETTER NO. 1

December 2007

Advanced In-Flight Measurement Techniques

AIM – a European Cooperation Project

The European Specific Targeted Research Project (STReP) AIM – Advanced In-Flight Measurement Techniques was launched on November 1, 2006. This project intends to make advanced, non-intrusive measurement techniques applicable for time and cost effective industrial flight testing as well as in-flight testing for research. In the AIM consortium, ten Partners from aircraft industries, airport services and research organisations coming from 7 countries are working closely together. These partners are: Piaggio Aero Industries (I), Eurocopter France (F), Eurocopter Deutschland (D), Airbus France (F), DLR (D), ONERA (F), NLR (NL), EVEKTOR (CZ); Flughafen Braunschweig Wolfsburg GmbH (D), Cranfield University (GB), MPEI-Technical University (RUS). AIM is coordinated by DLR in Göttingen, where Mr. Fritz Boden¹ functions as the coordinator of this 3.6 million € STReP.

The purpose of the 3-year AIM program is to further develop measurement techniques in such a way that they can be routinely applied to flight tests, hence providing comprehensive planar information on various important parameters such as wing and propeller deformation, thermal loads on the structures of helicopters, the surface pressure distribution on a wing, density gradients of strong vortices generated by airplanes and helicopters and velocity flow fields near airplanes and helicopters.

All measurements will be carried out in full-scale outdoor flight



tests on 5 aircrafts (VfW614 ATTAS, BAe Jetstream, Piaggio P180, Fairchild Metro II, Airbus A380) and 3 helicopters (Eurocopter EC-135 ACT/FHS, Eurocopter Superpuma, MBB Bo 105).

measurement setups had been designed for this purpose and some of them have actually been tested on the aircrafts e.g. wing and propeller deformation measurements with the Image Pattern Correlation Technique (IPCT) on

During the last year, several



¹ He is the successor of Dr. Falk Klinge who left the DLR in December 2007 and whom we want to thank for his great job at AIM.

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the Piaggio P180 and the Fairchild Metro II. These tests and the measurement technique will be described briefly on the following pages.

Information on other advanced in-flight measurement

techniques, for instance to measure surface pressure distribution in a non-intrusive way or to investigate of the flow field around the aircraft in free flight, will be given within the next AIM-Newsletter in December 2008.

The AIM project clearly demonstrates innovative possibilities of a joint multi-national cooperation between aircraft industries and research organisations.

The Metro II flight test campaign

In AIM Workpackage 1, wing deflection measurements on the NLR Fairchild Metro II will be performed using IPCT. Directly after a workshop held in Amster-

dam on January 9 2007, involving partners in AIM which are dealing with deformation measurement techniques (DLR, NLR, EC-D, Piaggio and Evektor), NLR started

their preparations for the flight test with the Metro II. NLR equipped the A/C with four cameras - two state-of-the-art cameras installed in the cabin and two miniature cameras on top of the fuselage. The cameras recorded an area of the wing tip where a foil with irregularly distributed rectangles (to measure the local deformation) and four large crosses (to register the coarse deformation) had been glued. The NLR used these four single cameras to check different viewing conditions. Each of these single camera measurement systems was calibrated by controlled bending of the wing on ground using a micrometer screw as a reference for the deflection of the wing tip. By using a wing deflection model, the deformation of the wing can then be ascertained from the single camera pictures.

Using this setup, NLR carried out a ground test in the hangar to assess and improve the accuracy of the installation. After this pre-test, NLR performed a successful flight test campaign. During three flights in the period August 22 - 24 2007, large amounts of good quality measurement data were recorded. The analysis of measured data is still in progress. Preliminary calculations show that the wing heaves and twists as a function of wing loading. These results are well within the accuracy limits requested.

The two cameras inside the cabin



The pattern on the outer wing



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The Image Pattern Correlation Technique (IPCT)

The Image Pattern Correlation Technique (IPCT) is a non-intrusive measurement technique to determine the location and the shape of any three-dimensional object (e.g. wind tunnel model, wing, rotor blade). Therefore, two or more cameras observing the object surface are used as sensors.

By comparing the measured shape under different load conditions deformations and strain can be deduced.

IPCT is based on the application of photogrammetry in combination with the correlation algorithms of the Particle Image Velocimetry (PIV). The basic principle is very similar to the spatial vision in humans.

Objects in the field of view are simultaneously observed under different viewing angles, like humans do with the right and the left eye. Similar patterns in both pictures are recognized. If the viewing positions and the mapping function of the two optical systems are known, the 3D coordinates of the observed object can be determined from the coordinates of this similar pattern in both pictures.

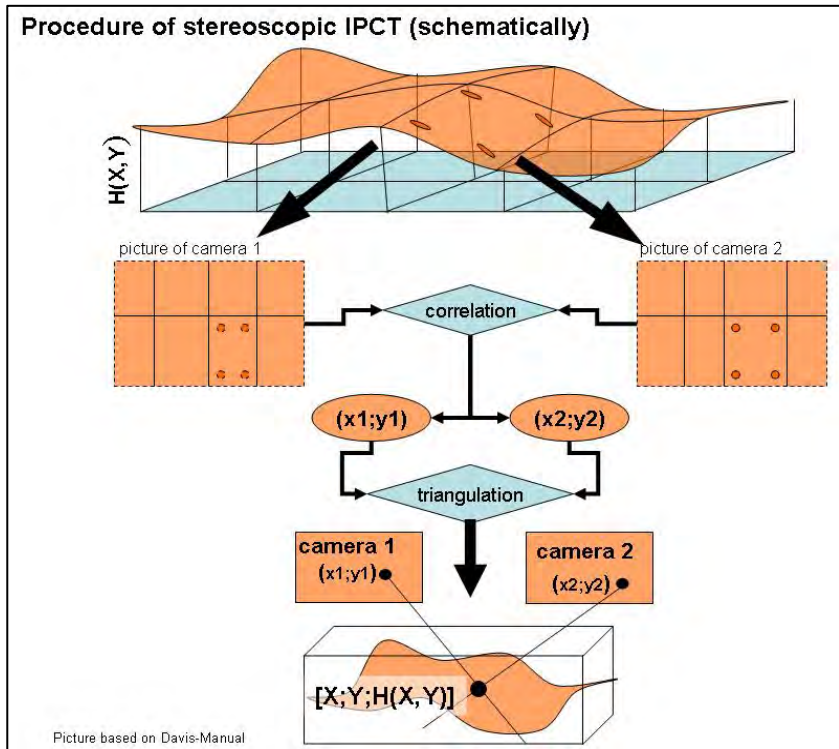
The human brain performs the pattern recognition and the calculation of the 3D - position of the observed object within milliseconds.

IPCT is the transformation of this natural principle of spatial vision to an advanced measurement technique to obtain 3D coordinates with a high accuracy.

The picture schematically shows the functionality of IPCT in the case of a measuring system with two cameras (stereoscopic setup).

During the first step, the observed surface $H(X;Y)$ is recorded by two cameras (camera 1 and camera 2).

The cameras are looking at the same field of view, but under different viewing angles.

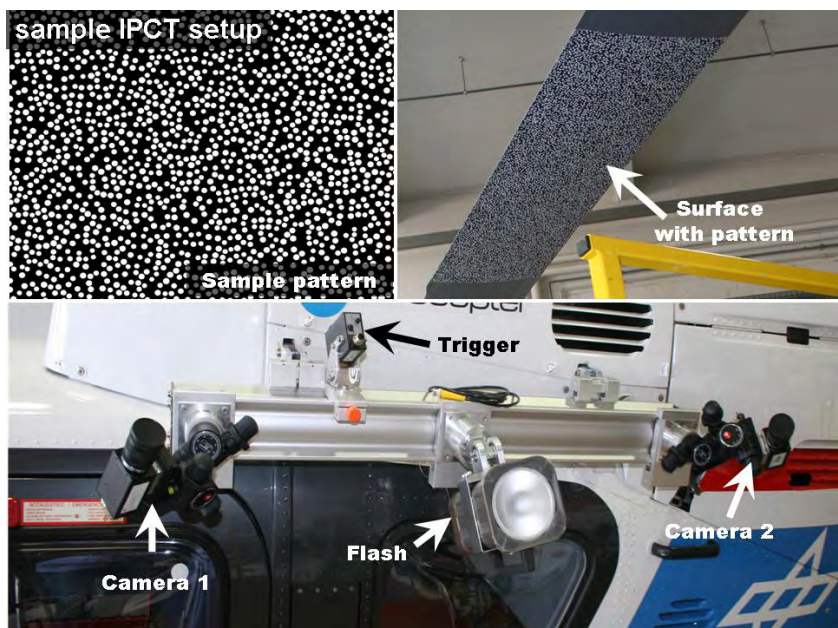


A cross correlation algorithm identifies similar regions in the pictures of both cameras. To make this recognition process easier and faster, a random dot pattern is applied onto the surface.

The correlation calculation gives the coordinates of areas with similar dot pattern in picture 1 (coordinates x_1, y_1) and in picture 2

(coordinates x_2, y_2).

With known intrinsic parameters (e.g. focal length, distortion, principal point) and orientation (e.g. position, optical alignment) of both cameras, the 3D coordinates of the recognized areas with similar dot pattern can be determined by means of central projection and triangulation.



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The application of the described algorithm to all areas with similar dot pattern finally yields to a high accurate reconstruction of the complete 3D surface.

The accuracy of the non-intrusive measurement technique IPCT is in the dimension of 0,01 %

of the observed area (e.g.: 0,1 mm in 1 m ROI).

By comparing the measured 3D surface under an unstressed reference state (e.g. wing of the aircraft standing on ground) to the surface under load conditions (e.g. bended wing in curve flight), the

displacement vectors and thus deformations can be deduced.

If the material characteristics of the observed object are known the local tensions can be calculated too.

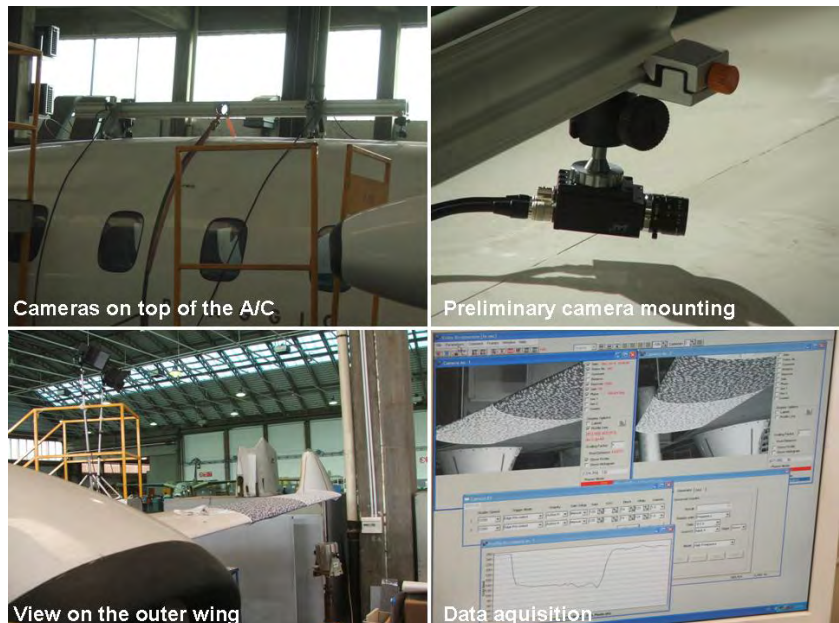
Advanced Aircraft testing on Piaggio P180

Another AIM task is using stereoscopic IPCT to optically measure the wing and propeller deformation on a Piaggio P180 during flight.

- Wing Deformation and Flutter Testing -

In Workpackage 1, DLR carried out some preliminary ground tests on their Dornier Do 728 to check the applicability of the technique to an aircraft. They used a stereoscopic camera system mounted inside the cabin of the Do 728 so as to be able to observe an area of the wing which had been equipped with an irregular dot pattern. To produce a deformation, the wing was excited by an electromagnetic shaker. This setup, which is similar to that used for a ground vibration test², was shown to be most suitable and was then adapted to the Piaggio P180. To have a good view on the outer wing, the two cameras were mounted on top of the fuselage of the P180. The control of the cameras and the shaker was performed by a DLR Videostroboscope which can work as a phase shifter to record the wing in different phase angles of the excitation and thus to get the structural response. This Videostroboscope

² Normally, accelerometers are used to get the structural response on the excitation. These have to be fixed onto several points on the structure and need to be wired which means a lot of preparation for the test. The accelerometers only give the acceleration in the turning points whereas the IPCT can give the position/deflection too by spending less effort.



can be used in real-time evaluation mode which enables the user to obtain deformation vectors of the surface immediately. This real time evaluation was presented to the Consortium at the first annual meeting in November 2007 at Genoa (Italy). Until now, this real time evaluation only works with one camera but will be improved to enable real time evaluation for a stereoscopic camera setup and thus enable the flight test engineer to obtain 3D deformation data during the flight test.

For the test in AIM, which is scheduled for the first half of 2008, the measuring system will run in recording mode, which means that pictures from both cameras will be recorded during the test and the data processing and calculation of the 3D - deformation will be

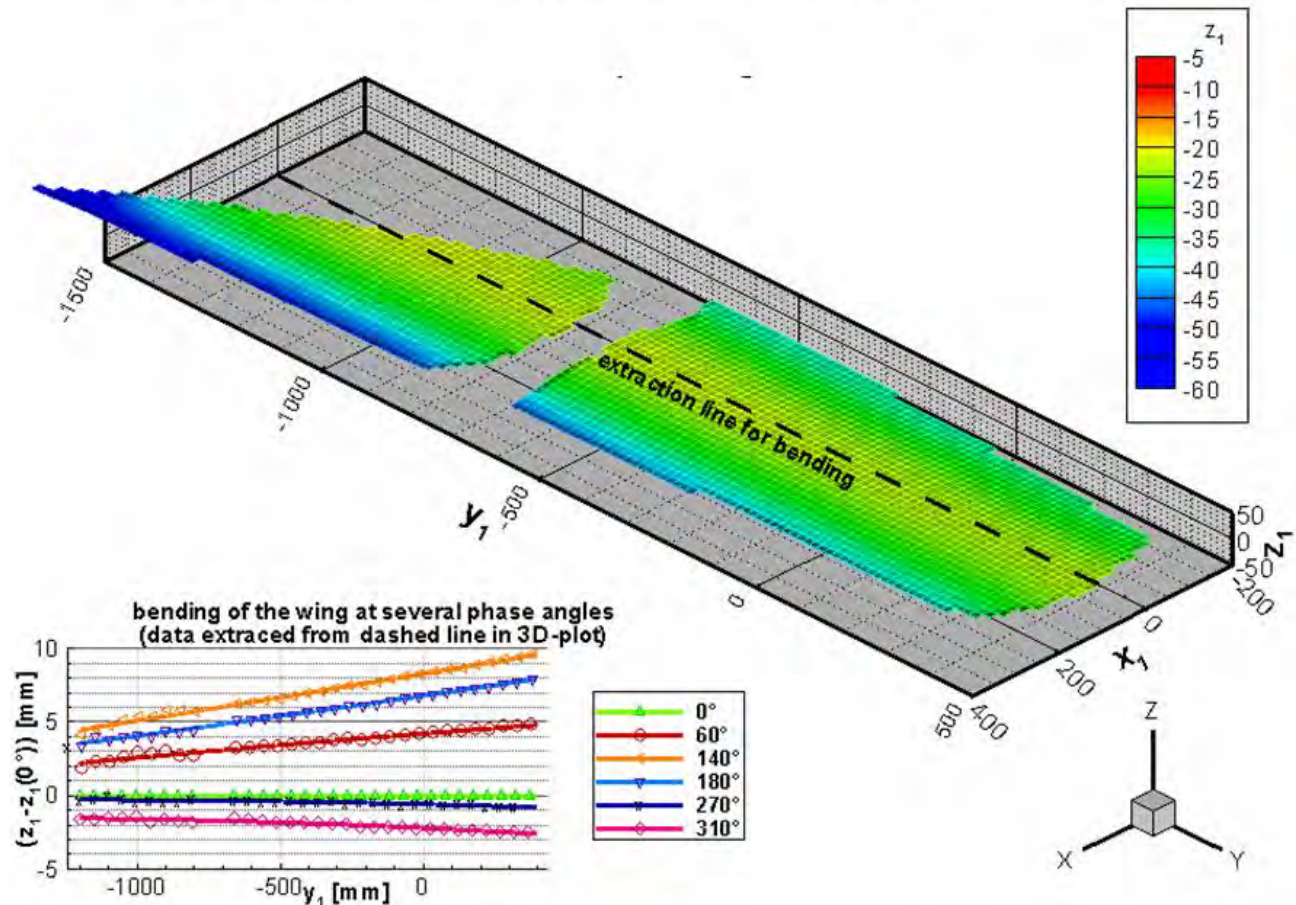
carried out afterwards. The test will be split into a ground vibration test with the shaker excitation and a flight test with static deformation and flutter excitation. During the ground test, the cameras will be triggered by using the shaker phase. The resulting harmonic oscillation will be sampled stroboscopically by using the phase shifter. First results of a preliminary test in Genoa showed the robustness and accuracy of the measurement technique – the 3D surface and thus the bend and twist of the wing were measured correctly.

During the flight test the movement and deformation of the wing is most likely not harmonic; therefore, the recording will be started by the flight test engineer and the cameras will run freely



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calculated 3D-Surface (upper surface of outer wing Piaggio P180)



with their highest frame rate in order to get the real time history of the deformation in flight.

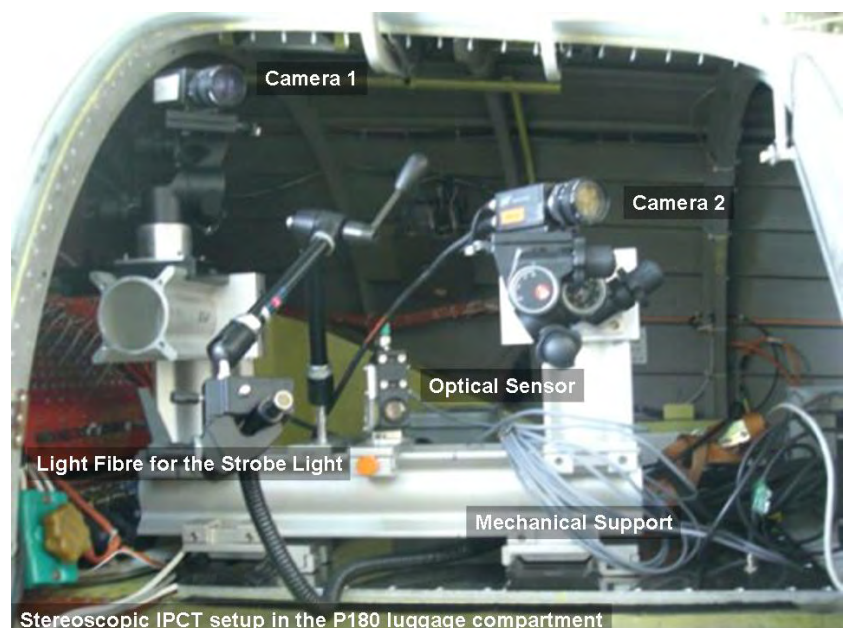
- Deformation of the Propeller -

On the P180, it is also planned to use stereoscopic IPCT to measure the deformation of the propeller blades under different flight conditions. The setup, used for this investigation in AIM Workpackage 2, is similar to the setup for the wing deformation in Workpackage 1. There will also be two cameras and the DLR Videostroboscope to control them. To avoid smear when recording the irregular dot pattern on the fast rotating propeller blade, the shutter time of the cameras has to be very short (about 50 to 10 μ s). When using such short shutter times the background light from the sun is not sufficiently strong, thus DLR

will be required to use a strobe light to provide the necessary light intensity.

To be able to record the same propeller blade every time, the

Videostroboscope runs phase-locked and triggered by a laser-based optical sensor aimed at a reflector on the spinner of the propeller. All components of the



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equipment are located in the luggage compartment. The cameras, the strobe light, and the optical sensor look at the propeller through windows in the compartment door. The measuring system has previously been checked successfully on a ground run at Piaggio in Genoa.



The large flight test at the end

The objective of AIM is to develop advanced measurement techniques for in-flight applications. Consequently, the methods developed have to be tested in actual flight tests of industrial relevance and assessed for their potential for future use in industrial flight testing and certification. Minimization of the effort for the flight test preparation while maximizing the output of the test itself can be realised by fast exchange of knowledge and by preparing, wherever possible, standards for image based measurement techniques for the different applications. Thus, all industrial flight tests will be combined in workpackage 6 under the leadership of a manager from the flight test department of AIRBUS-France. For industrial purposes, the robustness and capability of an individual measurement technique will determine its applicability for flight testing. For each of the individual measurement techniques, a decision has to be reached on its suitability for and

applicability to flight testing. Such a decision will be reached during an assessment meeting of DLR, AIRBUS France, EC-F, EC-D, Piaggio and EVEKTOR at the end of 2008. There will be an assessment of all the measurement techniques used and developed by AIM with respect to their usability in total and with respect to the common measurement techniques.

The most promising measurement techniques will then be used under real industrial flight test conditions. To perform the tests Airbus will provide an A380 test aircraft, Piaggio a P180 experimental aircraft and EC-F an Superpuma Helicopter.

aim.dlr.de: the consortium's exchange platform

Since January 2007 the AIM website is online. The homepage of the project is intended to enable an easy data exchange among the partners. On the AIM website,

which can be found under <http://aim.dlr.de>, all members of the consortium and some guest accounts can be found, together with their contact data. The main point-of-contact from each partner can modify or register new members from his group and therewith the contact data can easily be kept up to date.

In the File Exchange part of the website every partner can upload and download deliverables, presentations, minutes of the meetings, reports and literature of common interest. Until now the AIM website is in a state of basic functionality, but it is in the process of being continuously improved. The release of the new version of the AIM website is planned for the end of January 2008. New or improved functions will be, for example, a better sorting of the different documents, the grouping of files for download, the automatic creation of mailing lists and grouping in functional groups, management of deadlines and meeting dates. More features and a public AIM website may follow soon.

