The European Collaborative Project AIM² - Advanced Measurement Techniques 2 was launched on October 2010 with a project duration of 3 ½ years. The precedent EU project AIM was intended to make advanced, non-intrusive measurement techniques applicable for flight testing. It presented possibilities to measure wing and rotor deformation, surface pressure distribution, heat distribution and flow velocity fields in a non-intrusive way and with a minimal sensor setup. AIM also identified major challenges to be coped with before the demonstrated measurement techniques can leave the research and development level and become state-of-the-art measurement techniques for industrial use. The follow-up project AIM² intends to further develop these measurement techniques to be easily and routinely applied to in-flight testing with industrial demands. Whereas AIM proved the principal feasibility of using modern optical wind tunnel measurement techniques for in-flight measurements, 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.

The AIM² consortium consists of industrial partners, research institutes and universities from 8 countries. Most of the partners have already worked together within the AIM project. With AVIA propeller in the Czech Republic and RUT in Poland new east – European partners complete the consortium now. The AIM² project is coordinated by the DLR in Göttingen. Measurement techniques investigated within AIM² are deformation measurement techniques like Image Pattern Correlation Technique (IPCT) applied on fixed wing and propeller deformations, infrared thermography (IRT) used to investigate laminar-turbulent transition on aerodynamic surfaces, 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 Background Oriented Schlieren method (BOS) to visualise density gradients in the flow. With the Fibre Bragg Grating (FBG) method a new measurement technique sensitive to strain, pressure and temperature completes the set of techniques investigated within the project. Flight tests will be performed on different small aircrafts like the Evektor VUT100Cobra and the motor glider RUT AOS-71 as well as on the Piaggio P180, NLR Fairchild Metro II and the DLR Dornier 228.

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In contrast to the stationary IPCT system which was used in the Piaggio campaign in 2009 - 2010 a rotary IPCT system was proposed for the AIM² project. This new system has been designed to measure the deformation of a selected blade during the flight test. Due to the phase shifter function a 360 degree scan can be performed.

Consisting of a stereo camera, a miniature computer, a phase shifter, a GPS receiver, and a LiPo Battery, the complete system will be placed in front of the examined propeller in or instead of its spinner and will therefore be part of the rotating system (Figure 1).

The field of camera view is limited to a selected blade of the propeller providing the IPCT pattern. The sequence of image pairs will be acquired and stored on the computer’s flash drive in real time. Afterwards the sequences will be retrieved and evaluated.

Each pair of images is tagged with the phase shifter data. If required the GPS data can be stored as well.

The bi-directional data transfer (of both, system parameters and acquired images) can be executed via LAN to the laptop operated within the fuselage.

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**Specifications of a Rotating Camera System for Propeller Blade Deformations**

- Complete optical and electronic system integrated and rotating with the propeller
- Miniature double camera with 2 lenses
- CMOS camera sensor with 1280 x 1024 pixels
- Asynchronous global camera shutter
- Camera real time image transfer speed will be at least 50 pairs of images per second
- Optical path over two mirrors (stereo image)
- Double Scheimpflug configuration for high focal depth at full lens aperture
- Programmable high resolution digital phase shifter for precise blade position scan
- Simultaneous triggering of both cameras
- Image acquisition / camera controller PCB
- Miniature digital phase shifter
- External trigger sensor (e.g. optical)
- Optional pulsed Hi-power LED propeller blade illumination (over projection lenses)
- Flash / SSD hard discs
- Additional WLAN interface
- Optional GPS receiver with antenna
- Power supply board based on miniature high-efficiency DC/DC converters delivering various stabilized voltages for all electronic system components

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**Figure 1: The IPCT image acquisition system in front of a propeller**

**Block diagram of the rotary 3D-imaging system**
Introducing a New Technology for Flight Testing:

Fibre Bragg Grating (FBG)

A fibre Bragg grating (FBG) is the refractive index modulation in the core of an optical fibre. Presence of an FBG causes partial selective reflection of the light propagating in the fibre. This allows the fabrication of arrays of sensors at multiple locations along a single optical fibre that are wavelength encoded and identifiable. The sensing capabilities of FBGs rely on the fact that any fibre refractive index change or FBG period change will induce a measurable wavelength shift of the reflection Bragg peak. This makes FBGs inherently sensitive to axial strain and temperature. The use of FBGs as transduction elements allows the development of other sensors capable of measuring other physical parameters such as humidity and pressure.

Fibre optic sensors (FOS’s) have been extensively studied for nearly 3 decades and offer a number of significant benefits when compared with conventional pressure and strain gauge sensing systems. For example they offer small dimensions (typically, 80 - 125 μm in diameter), low weight, a large operating temperature range and have highly flexibility structures – a 0.2 mm diameter fibre can have a bend radius as low as 2 mm. FOS’s also can be used in harsh environments, being chemically inert, resistant to high radiation environments, and are immune to electromagnetic interference. In addition, FOS’s may be readily incorporated into composite parts or in pressure vessels with minimal effect upon the mechanical integrity of the structure. Furthermore, with the multipoint and multiplexing methods available when using FBG’s, long fibre lengths can be routed through large aircraft structures for example with the acquisition of many thousands of data points at kHz data rates.

In AIM², FBG based techniques are being developed to measure wing strain and local unsteady static pressure from a given or multiple points on an aircraft surface. The first in-flight test using an FBG strain measurement system is planned for the first half of 2012 using a Scottish Aviation Bulldog light aircraft.

Presenting our new project partners

- Part 1 -
Rzeszów University of Technology (RUT)

Rzeszów University of Technology (RUT) is the new partner in AIM² consortium, being a member since the beginning of the AIM² project. The main task dedicated to RUT is the final Workshop for industrial and academic researchers interested in implementation of experimental methods, developed over the AIM and AIM² projects. The workshop is preceded by participation of RUT scientists in tasks about IPCT and IRT measurement methods with strong input of flight tests with general aviation aircrafts and new motoglider.

The University celebrates its 60th anniversary in this year. The extensive development of Polish aviation industry in 1970s had a strong influence on the main profile of the University. Aviation courses for engineers and masters started in the beginning of the decade and in 1977 the course for airline pilots was opened. The scientific base was strictly connected with industrial demands. Several laboratories and research groups, like strength of aircraft, avionics, turbojet engines, aerodynamics were created and continue their works to the present times. Since its beginning, the University has promoted over forty five thousands of alumni, including almost five hundred airline pilots.

Nowadays, Rzeszów University of Technology is the largest university of technical profile in the Subcarpathian region. The number of students at all Faculties exceeds fifteen thousands each year. Academic and scientific staff consists of seven hundred employees, including a hundred and forty professors. The University has six Faculties and several independent units engaged in students teaching and scientific researches. Two of them are involved in AIM² project activities - Faculty of Mechanical Engineering and Aeronautics and Aviation Training Centre.

Regarding the Seventh Framework Programme, RUT is involved in several other projects, besides AIM², most of them belong to Aeronautics and Air Transport, like SCARLETT, HIRF, FUSETRA and the newest ESPOSA.
Particle Sizing Instruments and Techniques for Application to In-Flight PIV Testing

Current technologies suitable for airborne measurement of cloud droplet size for in-flight particle image velocimetry (PIV) experiments were reviewed at Cranfield University, UK. The particles of interest are primarily liquid, but also solid, in the range of 10 to 500 µm in diameter. A survey of commercially available instruments and techniques that may be suitable was compiled along with some explanatory background information. This survey focussed primarily on optical techniques with an additional review which included information on physical particle sizing methods. Optical techniques surveyed included 1D and 2D fast optical imaging systems, interferometric based methods and phase Doppler methods.

Physical particle sizing methods were commonly used before the advent of computers and CCD imaging technology. Improvements in data and signal processing, however, enabled further developments in optical techniques. A few companies produce instruments specifically for the purpose of measuring cloud droplets. Some of these probes, such as Cloud Droplet Probe (CDP), Cloud Imaging Probe (CIP), Cloud Combination Probe (CCP), can be installed externally as probe pods, while those like Back-scatter Cloud Probe are mounted along the skin of the aircraft.

One technique of interest is the Interferometric Laser Imaging for Droplet Sizing (ILIDS). Based on this technique, TSI Inc, LaVision GmbH, and Dantec Dynamics GmbH have developed Global Sizing Velocimetry (GSV), Interferometric Mie Imaging (IMI), and Interferometric Particle Imaging (IPI), respectively. These techniques, although not specifically designed for measuring cloud droplets, share much of their equipment with PIV systems and are capable of measuring particles in the correct size range. Given the previous PIV flight test in AIM, this cross-compatibility offers significant advances for the next AIM² flight test.

ILIDS is a technique for measuring sizes of droplets and bubbles using a coherent light sheet to illuminate the droplet. The reflected and the refracted rays yield glare points visible on the droplet surface when the image is recorded in the focused plane (see Figure 2). If the image is recorded in an out-of-focus position, the light from each point will give an interferometric fringe pattern. The spatial frequency of these fringes (or the spacing between the glare points) is related to the particle diameter. By combining this with standard PIV and PTV techniques the size and velocity of the particles can be measured simultaneously.

Each particle in the image field of view will produce a set of fringes which can lead to difficulties in distinguishing the fringe patterns from different particles (see Figure 3). To overcome this, a cylindrical lens or a slit shaped aperture may be used to compress the fringe pattern in one dimension to a line. This allows a higher droplet concentration to be measured. There is also the related technique Glare Point Velocimetry and Sizing (GPVS) which uses the in-focus image of the glare points to size the particles based upon the separation of the two glare points.

AIM² is now actively seeking to apply an ILIDS technique to the PIV flight test, to allow in-situ sizing during the flight test to ensure optimisation of any subsequent PIV data.

![Figure 2: Principle of GPVS and ILIDS](Dehaeck, S. and van Beeck, J. P. A. J., "Multifrequency interferometric particle imaging for gas bubble sizing", Experiments in Fluids, Vol. 45, No. 5, pp. 823–831, 2008)
The project of two seats motor glider AOS-71’s designing and building is the first joint venture undertaking by Rzeszow and Warsaw Universities of Technologies. This is a continuation of both Universities shared activities which were leading for many years. The aim of these works is taking advantage of worldwide unique properties which we obtained in a time where the Academic Glider Center in Bezmiechowa was built. The Center was established in 2006. It inherits traditions of the glider pilot school founded in this place before World War II. The village in the southeastern part of Poland near the Bieszczady Mountain was the place of many gliders virgin flights during the Golden Age of Aviation. It was known as a place of the take off for the first 500 km - cross country glider flight. The Tadeusz Góra’s achievement was awarded by FAI with the first Medal of Lilienthal.

The AOS-71 program, initiated by the intercollegiate team, is a direct continuation of the ULS (Ultra Light Glider) program which is coordinated in The Faculty of Power and Aeronautical Engineering of Warsaw University of Technology for more than 30 years. The aim of program among other things was the design of the PW-5 and PW-6 gliders. The AOS-71 is a descendant of the PW-6 glider. It inherits...
its main aerodynamic and structural features. New developments are affecting the fuselage, wing structure and construction materials. The fuselage has a new cockpit arrangement with side by side seats compared to the tandem configuration of the PW-6 glider. The wing geometry has not changed but the new design is based on a carbon / epoxy composite structure (the PW 6 was built with glass fiber). The AOS design is based on two 2 engine configurations: conventional piston and electric engine.

The idea behind the AOS-71 project is the allocation of a test bed for many experiments in the area of aeronautical engineering. The main fields of operation of the AOS-71 motorglider are studies and applications of innovative, light composite airframes; testing of damage detection methods and their propagation observations in composite structures as well as the design and construction of ecological electric drives; onboard data acquisition and telemetric tests, research and development of new measurement methods and equipments and a flying wind tunnel for airfoils and small flying objects. Other objectives of this project are the preparation, testing and validation of numerical models as well as testing the effectiveness of signals reception for navigation systems. A modular structure of the cockpit allows the installation of new equipment and eases the preparation of the motorglider for other in-flight tests.

During the realization of AIM² project the AOS-71 will be used for IPCT tests (for measurements of structure deformations and the validation of MES calculations by comparison of their results) and investigation of the laminar – turbulent transition and separation on airfoils with the help of an Infrared observations system.

The project started in 2008 and it was financed by The Polish National Centre for Research and Development. At this moment the project is close to completion. All structural components are built and tested. In the end, the AOS-71 motoglider has to be equipped and prepared for its first flights.

### Specifications AOS-71

**General Characteristics**

- Crew: 1
- Capacity: 1
- Length: 7.7 m
- Wingspan: 16.4 m
- Height: 2.45 m
- Wing Area: 15.8 m²
- Aspect Ratio: 17
- Empty Weight: 350 kg
- Gross Weight: 550 kg
- Powerplant: Electric Engine Sineton A37K015, 30 kW

**Performance (calculated)**

- Max. Speed: 250 km/h
- Max. Glide Ratio: 31
- Rate of Sink: 0.8 m/s