ETW NEWS

EUROPEAN TRANSONIC WINDTUNNEL

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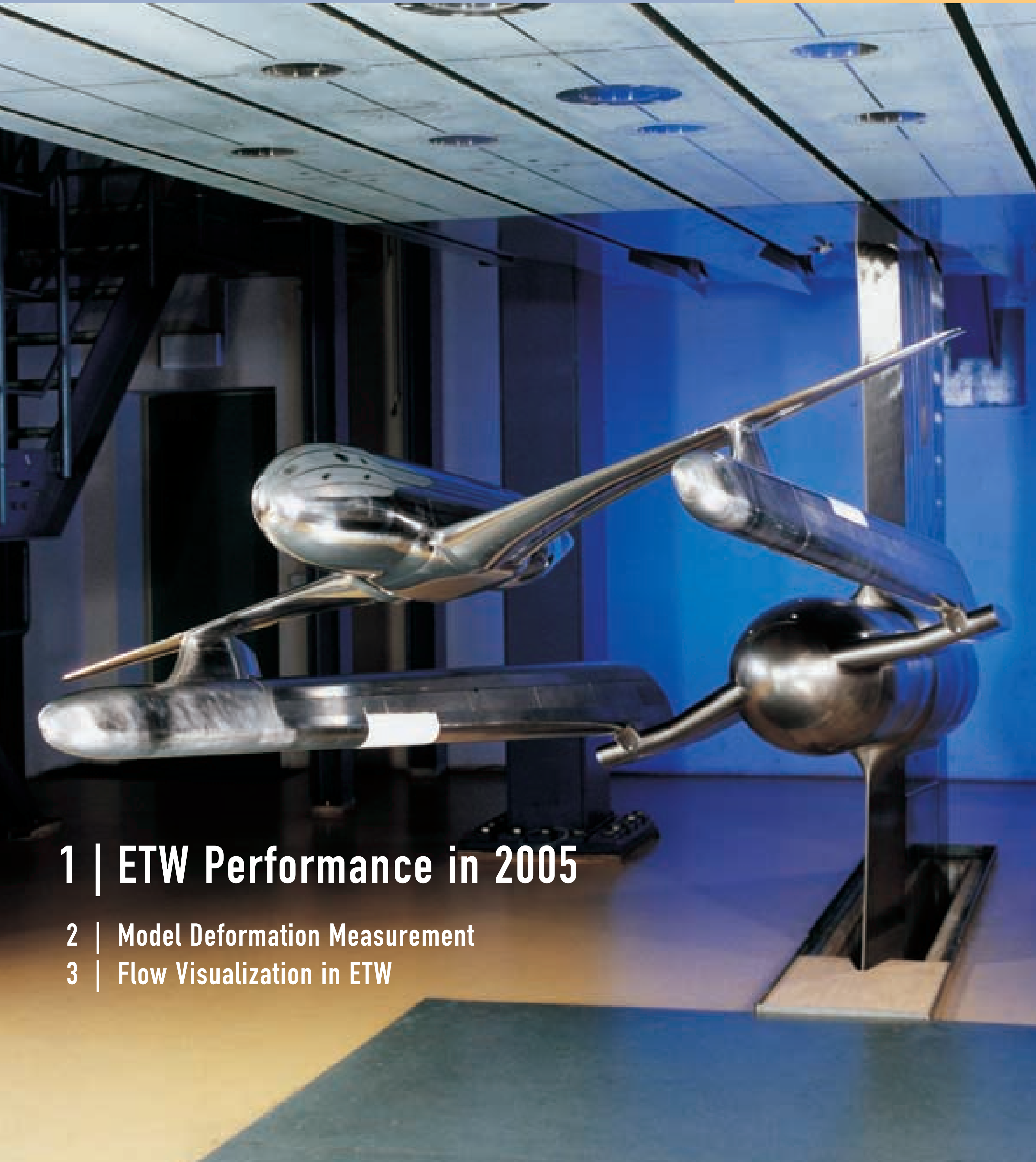

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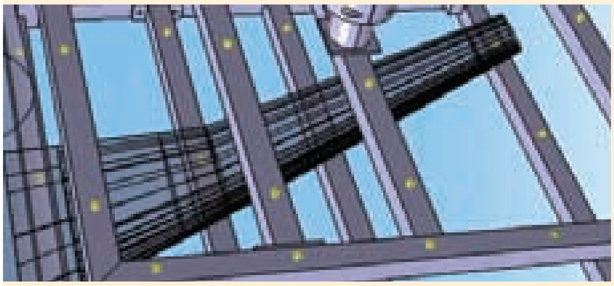

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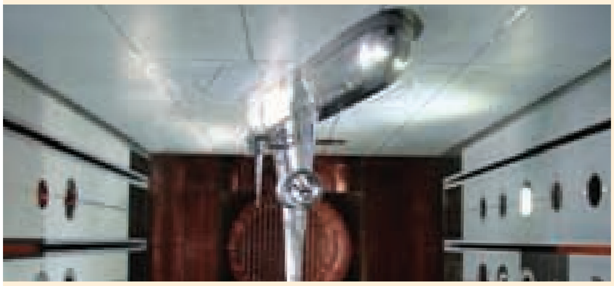

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EDITORIAL

The European Transonic Windtunnel, ETW, being in operation for about ten years now, has demonstrated the value of high Reynolds number testing for the development of new aircraft and has, in many demanding test campaigns, met the high expectations of the clients.

I consider it a great honour and a motivating challenge to have been appointed Managing Director of this most advanced wind tunnel of the world, succeeding Wolfgang Burgsmueller after his retirement.

The competence of the ETW technicians and engineers, the productivity of the facility and the quality of the test results have been praised by our clients in many appreciative statements after the test campaigns. I thank the ETW team for their professional dedication and I encourage them to continue with delivering excellent service to our clients. I am convinced that the ETW, with its unique capabilities, will further strengthen its position as a decisive tool in the aerodynamic optimization of new aircraft projects, and I shall endeavour to contribute personally towards a successful future.

Lionel Baranes has been appointed Managing Director of European Transonic Windtunnel GmbH (ETW), Cologne, Germany, as from 15 August 2005.

Lionel Baranes (56) holds an engineering degree from Ecole Polytechnique, Paris, and specialized in Aerospace engineering at Ecole Nationale Superieure de l'Aeronautique et de l'Espace in Toulouse, France, his native country.

After different aircraft and aerospace related jobs with the French Ministry of Defence he was employed by Thales, in which amongst others he was Director of Aeronautical Systems, followed by the management of INRETS, a French research institute for Transportation and Safety.

Mr. Baranes' last appointment was Vice-President of the European Patent Office in The Hague and Berlin.

Cryogenic Pressure Sensitive Paint

The conventional way of acquiring pressure measurements on a model is with a pressure-plotted model. Pressure taps can be machined on the model surface, then linked for the test to pressure sensors installed in the model by means of small tubes routed through the model. This method is well-known and widely used, however, it contains drawbacks: the pressure measurement is performed at discrete locations, the installation of pressure ports in a wing is a long and costly action, it limits the maximum wing load capacity and can therefore reduce the test envelope. For these reasons a Pressure Sensitive Paint, which changes its colour with the local pressure on the surface, is of great interest.

ETW started with testing Temperature Sensitive Paint (TSP) in order to validate the setup (cameras and lights) for the major development of a Pressure Sensitive Paint (PSP) able to work under cryogenic conditions. In addition to the testing at low temperatures, the challenge of a cryogenic PSP lies in mastering the necessary oxygen concentration in a wind tunnel usually operating with pure nitrogen.

First PSP trials have been made in the small PETW in August 2004, followed by a test in ETW in October 2004.

Both tests were carried out in cooperation with DLR, the German Aerospace Research Centre, and it was possible to handle the oxygen injection and measurement of oxygen concentration with the desired accuracy. In both facilities an oxygen concentration between 500 and 2000 ppm could be achieved and held constant to ±5 ppm during PSP image acquisition. This is sufficient for doing PSP measurement under cryogenic conditions. These first trials were successful, and future developments performed by DLR will concentrate on increasing the sensitivity of the paint.

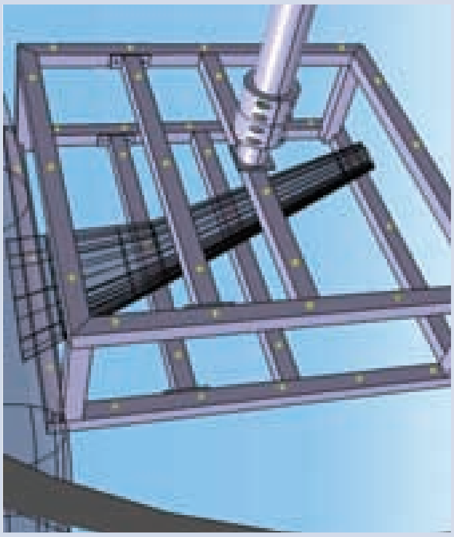
MODEL DEFORMATION MEASUREMENT

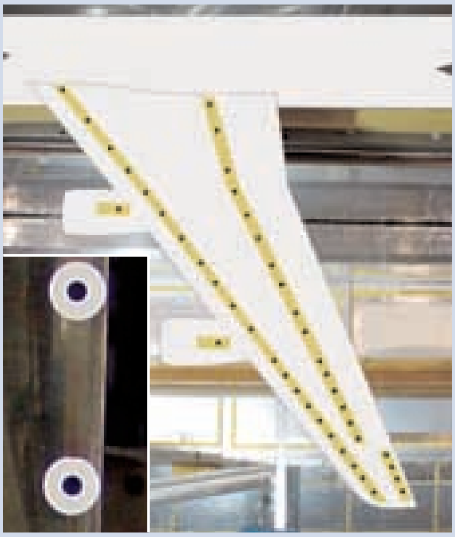
Stereo Pattern Tracking (SPT) System

Since metallic wind tunnel models are not perfectly rigid, the accurate determination of wing twist and bending under aerodynamic load is important in wind tunnel testing. Aerodynamicists require the exact wing geometry to perform correct analyses of the test data.

After investigating various possibilities, ETW has adopted the Stereo Pattern Tracking (SPT) method (see ETW News Nr. 12) for operational half model deformation measurements with the Wing Pressure Evaluation (see ETW News Nr. 10) being used for verification and backup. SPT has recently been extended for full span models and for inclusion of smaller model parts like ailerons and flaps.

The basic principle of the SPT is rather simple, as is the setup itself. The processing of the images is performed automatically and on-line, which is an inherent advantage.





The optical system focuses on markers distributed on two lines along the leading edge and the trailing edge as shown in Figure 1. The system requires a good contrast to the background, which must not change with the model position. Therefore, the markers are circular black dots of 10 mm diameter (corresponding to approximately 15 pixels) with a thickness of 5 µm surrounded by a white circle.

Two cameras suitably installed in the test section walls look at the wing surface with two different viewing angles. By processing these images, the SPT system can compute the 3D coordinates of up to 40 markers. The distance between the markers decreases towards the wing tip to compensate for the shortening of the wing chord, and thus still guarantee a good accuracy at this region of the wing.

The positions of the cameras need to be calibrated. This is performed with a special frame carrying about 30 small electric bulbs (Figure 2). The relative coordinates of each bulb are known exactly by measurement in the workshop (with an accuracy of better than 0.1 mm). The frame is installed together with the model in the test section. The bulbs are sequentially switched on, automatically identified by the SPT and linked to their 3D coordinates. The position of the frame relative to the tunnel or to the model is not relevant, it just identifies the volume of observation and recording.

The position of one reference marker on the wing is manually measured in model coordinates to define the offset between SPT and model system. The SPT system then determines the model marker coordinates in the model system. Reference images are taken wind off while pitching the model through an adequate alpha-range. Marker positions in the model system are determined prior to each run with new reference images to compensate for effects caused by changes of temperature and gas density. During the test, the markers are moving on circles around the axis of rotation (e.g. the pitch axis), which is determined by a non-linear least square fit. For each marker the center, radius and angular offset of its movement are determined. A software package has been developed to transform these coordinates into twist and bending.

FLOW VISUALIZATION IN ETW

At ETW, different methods of far field flow observation with optical installations and Laser techniques are in development. For example, a wake vortex visualization or even measurement can be achieved with these techniques. Due to the cleanliness of the nitrogen flow in ETW, seeding of the flow is necessary to get sufficient laser backscatter, and this is achieved with ice particles at such a low level that the model is not affected in any case.

Doppler Global Velocimetry

Doppler Global Velocimetry (DGV) is a non-intrusive technique, which provides planar velocity data through the imaging of light-sheet illuminated particles suspended in the flow. DGV relies on the indirect measurement of the frequency shift of light scattered by the particles. A single camera imaging a single light sheet can only provide a single velocity component. Measurement of all three velocity components requires a combination of multiple viewing positions or multiple (coplanar) light sheet directions. In ETW, three cameras placed behind windows of the sidewalls of the test section obliquely view two coplanar light sheets spanning the test section (Figure 1).

A series of tests was conducted at low speed with active seeding in the framework of the M-DAW EU-project. Figure 2 shows velocity vector fields behind the wing tip obtained with the DGV technique during this project.

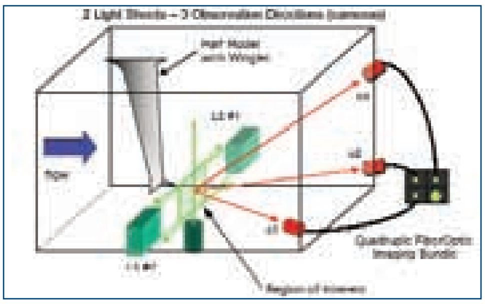


Figure 1. Doppler Global Velocimetry Installation

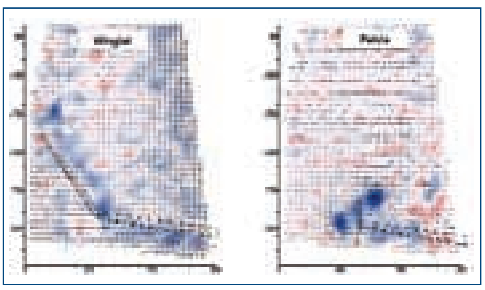


Figure 2. Velocity vectors in the wing tip area measured by DGV at cryogenic conditions

Laser Light Sheet

The Laser Light Sheet (LLS) technique was tried for the first time in November 2004 in cooperation with DLR. This non-intrusive technique was applied to a half model test in order to determine the position of the wake vortex at low speed in high lift configuration. The black spot visible on Figure 3 corresponds to the centre of the wake vortex in a plane defined by laser illumination. As for DGV, the Laser Light Sheet technique uses seeding in the form of small ice particles. Two cameras fixed in the sidewalls of the test section observe a light sheet generated by a single laser. The ice crystal particles visible in the flow give information on local flow density only, the technique does not give values of the local velocity.

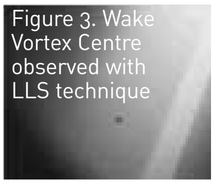


Figure 3. Wake Vortex Centre observed with LLS technique

Background Oriented Schlieren

The Background Oriented Schlieren (BOS) technique was first tried at ETW in November 2004 in cooperation with DLR (in parallel to the LLS technique). This technique was proven to be operational in laboratory tests for accurate qualitative visualization of the density gradients in a flow. The technique aims at observing the position of the wake vortex for various test conditions and model attitudes at low speed. The set-up involved three cameras fixed in both sidewalls and in the top wall. Each camera is focused on a special speckle background fixed to the opposite tunnel wall (see Figure 4), and observes the displacements of the image. These displacements occur through light ray deviation due to variations in the local fluid density. Displacements of the markers from the speckle background with respect to a reference wind-off image are correlated to flow density variations in the volume covered by the camera field of view.

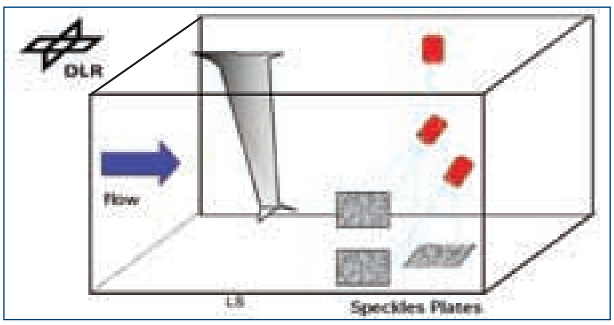


Figure 4. Background Oriented Schlieren Set-up

ETW'S PERFORMANCE IN 2005

In the course of the year 2005, ETW performed ten test campaigns for clients from the aerospace industry and for EU sponsored research projects. These tests comprised twenty weeks of wind tunnel operation with full-span models or half models and some forty weeks of preparatory work outside of the test section of the tunnel.

Bombardier Aerospace at ETW for Flight Reynolds Number testing on the C-Series

Bombardier Aerospace performed an extensive test campaign at ETW in summer 2005 in order to develop the C-Series aircraft. A large amount of test conditions, including the first cruise flight Reynolds number tests on this next generation aircraft was successfully performed. ETW's most advanced testing techniques (TSP and Infra-Red imaging, SPT deformation measurements, second-generation Anti-Vibration System) were used in all test conditions.

Following completion of this test campaign, the client stated "the excellent quality of the test data and professionalism of the ETW team", essential things that the ETW staff "can be proud of". This high-quality experimental data correlated and augmented predictions made with Bombardier's Advanced CFD methods.

787 High Lift Development Testing at ETW

During the summer of 2005 the Boeing Company performed an extensive series of low speed high lift tests over the complete pressure and temperature range of ETW.

A new high lift half model compatible with ETW's test envelope was developed to enable parametric investigations of takeoff and landing configurations over an extensive range of Reynolds numbers. The new model incorporated design features to enable rapid model changes to be performed resulting in high levels of productivity. In addition to the measurement of forces and pressures the tests also included deformation measurements with Stereo Pattern Tracking and flow visualisation using Mini-Tufts.

MEETINGS AND WORKSHOPS

The European Windtunnel Association (EWA) held a Presentation and Workshop at ETW on Model Deformation Measurement Techniques on 20 October 2005

ETW has the unique capability of varying Reynolds number and dynamic pressure independently. Thus, aeroelastic deformation effects can be studied by varying the dynamic pressure, whilst holding the Mach number and Reynolds number constant. This ability is of advantage for the understanding of aerodynamic effects on a model, but the study can only be complete if the wing deformation is known accurately for the different testing conditions, particularly for crosschecks with CFD computations. Therefore the development of accurate deformation measurement methods is an important issue for all wind tunnel testing.

On 20th October 2005, about 40 experts from industry and research institutes attended a Workshop on Model Deformation Measurement Techniques organized by ETW on behalf of the European Windtunnel Association.

Different wind tunnel model deformation measurement techniques, in use with European wind tunnels, were presented in the morning. In the afternoon, a demonstration test was performed in ETW to illustrate this topic. It was followed by an additional presentation of an optical method for flap gap measurement and a tour of the ETW facility.

For the demonstration in the wind tunnel, the N44 Full Model was used (ATTACH 2000 from the HiReTT programme). It is the best example for a demonstration test on deformation measurement since an extensive database is available for this model, including deformation evaluations derived from different techniques.

Three optical methods were demonstrated in the wind tunnel test: The ETW Stereo Pattern Tracking System (SPT), the ONERA method and the DLR Image Pattern Correlation Technique (IPTC). While the latter two methods require storage of the acquired data and post processing, the ETW method provides the results for twist and bending of the wing in real time during the test. Therefore, a direct comparison of the results was not possible and will be included in the final report once post processing is completed.

104th Meeting of the Supersonic Tunnel Association International (STAI)

ETW was selected to host the 104th meeting of the Supersonic Tunnel Association International, STAI, which was held in Cologne from 16 to 18 October 2005. The meeting was attended by 34 engineers and 18 papers were presented. The meetings of STAI take place twice yearly at different venues around the world and act as a forum where users of these facilities can exchange ideas and experiences.

The meeting in Cologne ended with a visit to ETW and a tour of the facility.

European Transonic Windtunnel

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Conferences/Expositions

20th International Congress in Aerospace Simulation Facilities (ICIASF)
August 2003, **Göttingen, Germany**
- Transition Detection by Temperature Sensitive Paint at Cryogenic Temperatures in the ETW
  U. Fey (DLR), Y. Egami (NAL), J. Quest (ETW), U. Jansen (ETW)
- On the Development of Doppler Global Velocimetry for Cryogenic Wind Tunnels
  C. Willert (DLR), J. Quest (ETW), U. Jansen (ETW)

5th International Symposium on Particle Image Velocimetry
September 2003, **Busan, Korea**
- On the Development of Planar Velocimetry Techniques for Cryogenic Wind Tunnels
  C. Willert (DLR), J. Quest (ETW)

42nd AIAA Aerospace Sciences Meeting January 2004, **Reno, Nev., USA**
- The ETW Wall Interference Assessment for Full and Half Models
  N. Gross (ETW), J. Quest (ETW)

Aerospace Testing Expo (ETW was represented with a stand in the Exposition)
March 2004, **Hamburg, Germany**, Technology Forum
- European Transonic Windtunnel – High Productivity for Cryogenic Testing
  D. Schimanski (ETW)

43rd AIAA Aerospace Sciences Meeting
January 2005, **Reno, Nev. USA**
- The Development and Application of Optical Measurement Techniques for High Reynolds Number Testing in Cryogenic Environment
  E. Germain (ETW), J. Quest (ETW)

Aerospace Testing Expo Europe (ETW was represented with a stand in the Exposition)
April 2005, **Hamburg, Germany,** Technology Forum
- Advanced Measurement Techniques at High Reynolds Number Testing in ETW
  D. Schimanski (ETW), E. Germain (ETW), W. Strudthoff (ETW)

Aerospace Testing Expo America
November 2005, **Long Beach, Cal., USA**, Technology Forum
- Advanced Measurement Techniques at High Reynolds Number Testing in ETW
  D. Schimanski (ETW)