Test of Strength in the Sky

- **Determining structural loads during flight**

- **Avoiding unnecessary aircraft inspections**

- **Multiprocessor environment of DS1006 Processor Boards**

Due to flight maneuvers and gusts, loads are acting on an aircraft structure during the flight. Severe gusts can result in high structural loads, so that when damages are suspected, the aircraft has to be grounded and a mandatory inspection has to be carried out. To monitor the structural loads during flight, Airbus Germany and DMecS GmbH developed an "observer" – a parallel model of the aircraft – which was tested onboard an A340 using dSPACE equipment.

Avoiding Expensive Grounding Time

To avoid unnecessary inspection and grounding time, we aim to monitor structural loads at any time during operation of an aircraft. Since the loads cannot be measured simultaneously for all locations of the aircraft structure, we have to reconstruct the loads from control surface deflections and the flight data (acceleration, air speed, body rates, Euler angles, etc.) available onboard a passenger aircraft by using a model of the aircraft. In addition, estimates of the gust velocities that impact the aircraft are needed to determine the loads caused by gusts.

The Observer – A Model of the Aircraft

To determine the structural loads caused by gusts, an observer was developed in a joint project by Airbus Germany (Airbus Deutschland GmbH); Department EGLG23, Hamburg; and DMecS Development of Mecha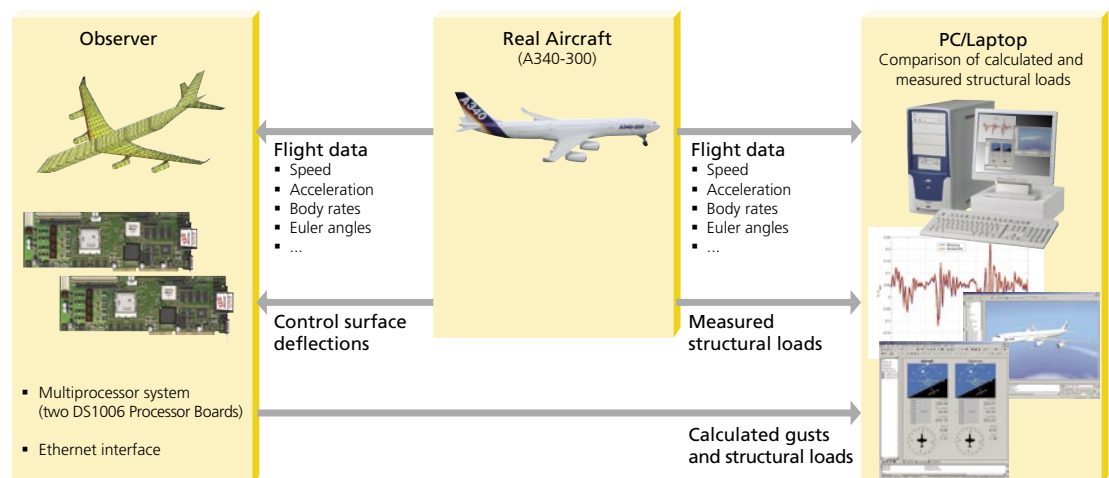tronic Systems GmbH & Co. KG, Cologne. The observer is a parallel model of the aircraft that is driven by the control surface deflections and corrected via measurements of the resulting aircraft motion. An extension to the aircraft model in the observer accounts for the unknown gust velocities in the observation process. The observer output comprises the estimates of gust velocities and the resulting structural loads due to maneuvers and gusts.

> *"The dSPACE development environment was an indispensable tool for carrying out the flight tests."*
> **Lars Bensch, Airbus Deutschland**

The basis for the observer design is a nonlinear aircraft model developed by Airbus Germany. It takes into account the flexible structure of large, modern passenger aircraft and allows the internal loads at any desired point on the structure to be calculated.

▶ *The observer installed on the dSPACE system receives the control surface deflections and various flight data from the real aircraft and computes the gusts and structural loads.*
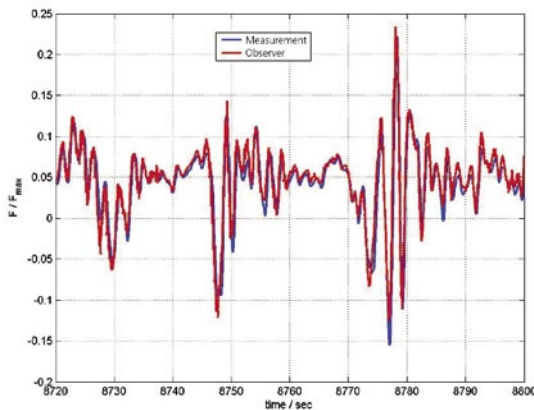

Observer

- Multiprocessor system (two DS1006 Processor Boards)
- Ethernet interface

Real Aircraft (A340-300)

Flight data
- Speed
- Acceleration
- Body rates
- Euler angles
- ...

Control surface deflections

PC/Laptop Comparison of calculated and measured structural loads

Flight data
- Speed
- Acceleration
- Body rates
- Euler angles
- ...

Measured structural loads

Calculated gusts and structural loads

Airbus implemented the model in the VarLOADS (Variable Loads Simulation) environment by means of MATLAB®/Simulink®.

Flight Tests with dSPACE System

We tested the observer in flight tests conducted as part of the European technology project AWIATOR (Aircraft WIng with Advanced Technology OpeRation) coordinated by Airbus Germany. The objective was to reconstruct the gust velocities acting on the aircraft during flight and validate them by comparing the estimated and measured structural loads. The observer was implemented on a dSPACE real-time system and installed onboard an A340-300 test aircraft. The flight data and control surface deflections are read in UDP format by a DS4502 board, which is equipped with an
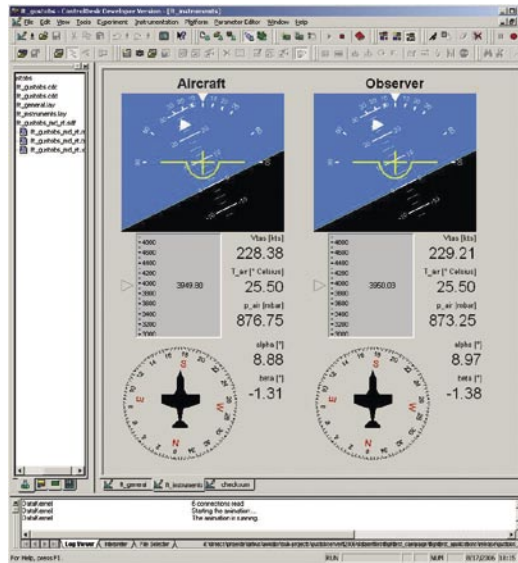
◄ ControlDesk allows comparison of measured and calculated values.

▲ There is high correspondence between the measured structural loads and the ones estimated by the observer.

Ethernet communication module. Afterwards, the data are spline interpolated on the first DS1006, sampled at a common frequency of 100 Hz, and passed on to the observer hosted on the second DS1006.

The turn-around time for processing 44 measurement signals is 260 microseconds, and for the observer it is 60 microseconds. The aircraft model used in the observer includes the 6 degrees of freedom for rigid body motion and 34 modes for the flexible structure of the aircraft. The model also provides the structural loads at 20 different locations along different aircraft components.

ControlDesk and MotionDesk are used to visualize the results from the observer and for comparison with the real aircraft motion.
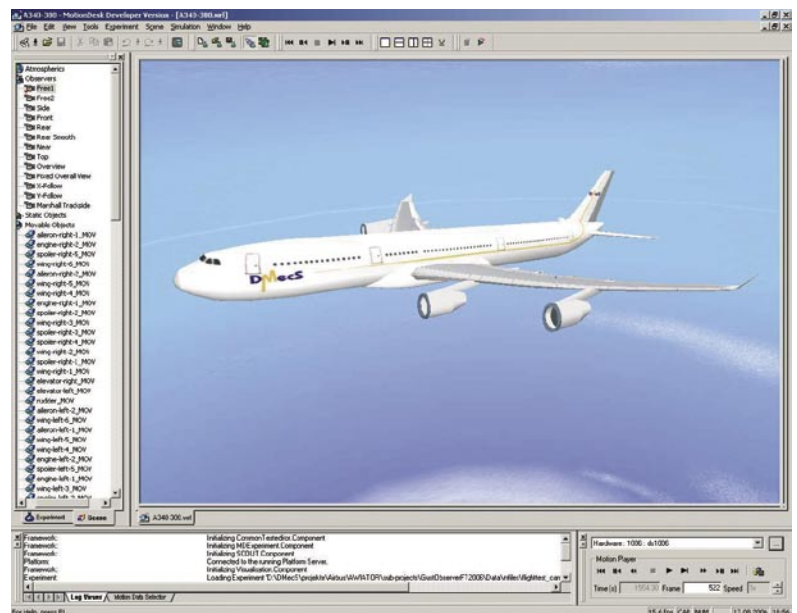
Implemented within 6 Months

Using the dSPACE development environment, we implemented the observer and all the additional functions needed for the flight test within half a year. The dSPACE tools provided the necessary high computing performance and all the resources for real-time operation and for animating the results. The system worked perfectly throughout the 50 flight hours.

Lars Bensch, Michael Enzinger,
Airbus Germany
Jürgen Jusseit, DMecS –
Development of Mechatronic Systems
Germany

▲ MotionDesk provides 3-D animation for visualizing the results.