

Rapid Prototyping

Autocoding

HIL Testing

Aerospace Solutions

Systems and Applications

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The Challenge of Control System Development

Developing electronic control systems is a very expensive proposition in the aerospace industry, which has some of the world's most rigorous standards and regulations.

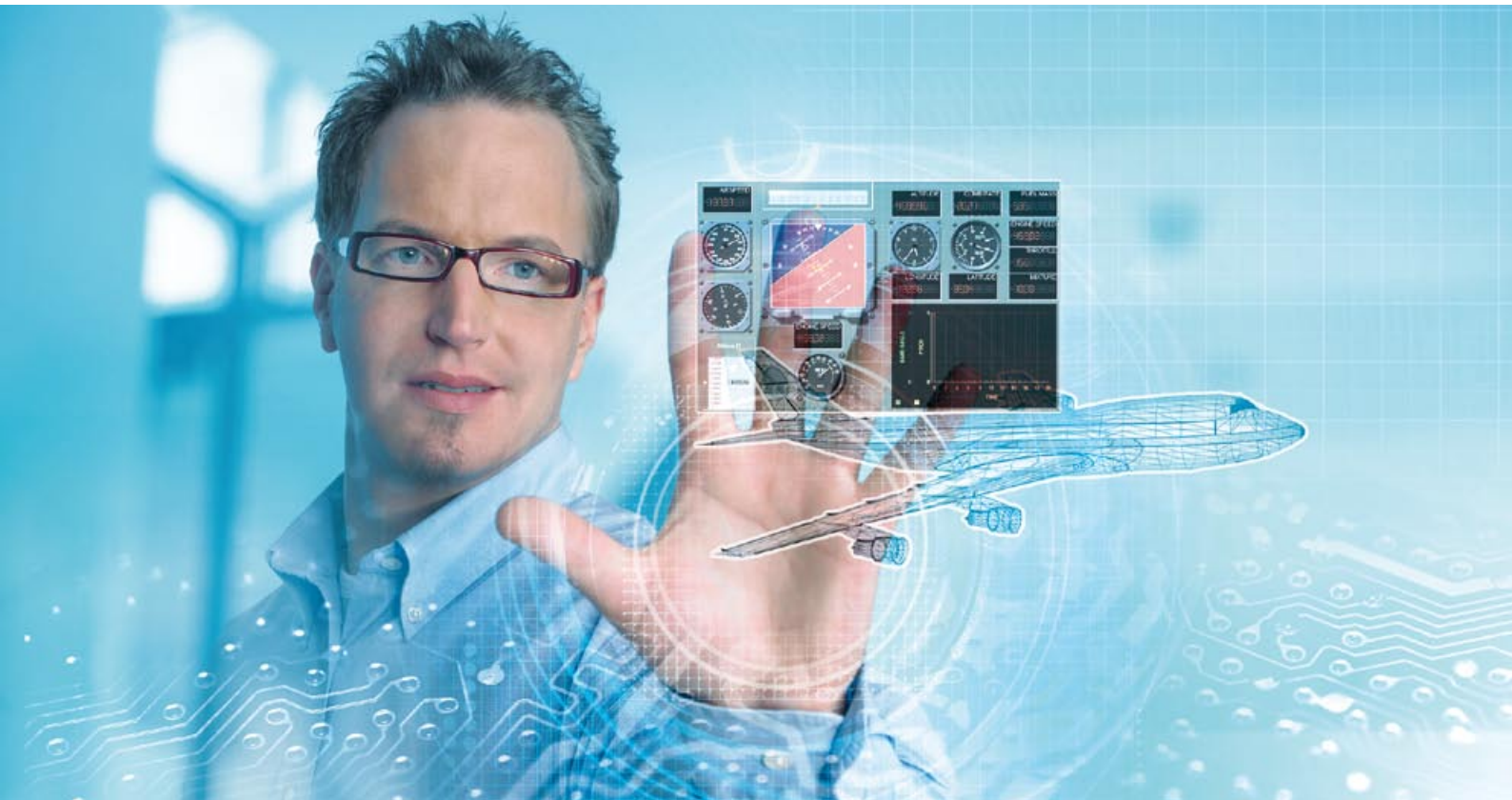
Standardized Development Systems

As standards of safety and comfort rise, so does the complexity of electronic systems in aircraft. At the same time, competitive pressure is forcing companies to drastically reduce development times. Many manufacturers and suppliers have realized that standardized development systems speed up and improve hand-off between the individual development phases. Enormous manual workloads can be reduced and expensive mistakes avoided by clear specifications and modern development processes – using a single tool chain throughout.

Single-Source Solutions

As an independent system partner, dSPACE pioneered optimized mechatronic control system development. dSPACE supports all stages of development, from block diagram-based rapid prototyping to automatic code generation, to controller testing. The advantages are threefold: a considerable saving in time and cost, greatly enhanced software quality, and more efficient interaction between manufacturer and supplier.

This brochure is designed to answer your questions concerning the dSPACE development environment. Whether you use our tools throughout the entire process or at individual stages, you can rely on dSPACE to make a real impact on the efficiency of your development cycle.





Controller Development with dSPACE Tools

As a user of dSPACE systems, you will find the same familiar working environment for developing, programming, and testing control systems. The result is an accelerated and simplified development process that helps you put your ideas into practice faster and eliminate errors sooner.

Specification in a Block Diagram

You can model your control system graphically in a block diagram using standard tools such as MATLAB®/Simulink®/Stateflow® from The MathWorks. This means that you are always working with the same model basis, whether you are validating your functions during rapid prototyping, generating the code for the production controller, or performing tests in a hardware-in-the-loop environment.

Model Implementation and Code Generation

Block diagram models can be implemented on dSPACE real-time hardware by a simple mouse-click. Design iterations can be performed simply and quickly, and almost all errors are eliminated. The same applies later to autocoding. Unlike handcode, autocode can be optimized as often as

required, because it only takes a short time to implement the model in C code.

Virtual Instrumentation

Throughout your experiments you can work with a consistent experiment interface, the virtual instrument panel ControlDesk. ControlDesk can handle a wide range of instrumentation tasks – in activities such as capturing real-time data, modifying parameters, and loading look-up tables.

3-D Interaction

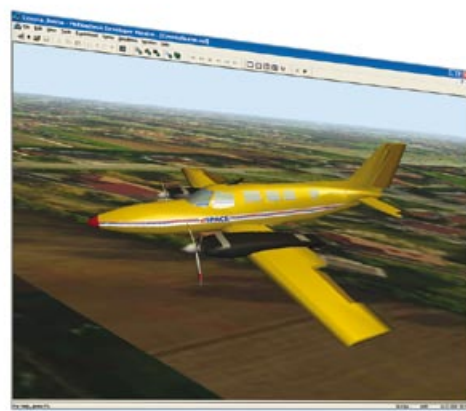
MotionDesk visualizes aircraft behavior. You can build a virtual world from 3-D objects created in the VRML2 standard, and use data from your real time simulation to move them.

Automated Testing

Automated, model-based testing in every development phase has become a key issue in the development process. AutomationDesk provides an intuitive user interface that facilitates the task of developing and managing tests.



With ControlDesk, you are working with the same layouts throughout.



3-D online animation with MotionDesk.

A Fully Integrated Process

dSPACE offers you a seamless, completely integrated development environment. In conjunction with MATLAB®/Simulink®, the dSPACE tools provide all you need for autocoding, intelligent instrumentation, and real-time simulation.



Rapid Prototyping

The dSPACE prototyping systems offer you a wide range of hardware and software for optimizing the control designs of the real system. Design faults are found immediately and corrections can be carried out on the spot. Your design is automatically implemented on the dSPACE prototyping hardware from the block diagram and calculated in real time. The dSPACE prototyping systems also provide bypass solutions for integrating new functions into existing electronic controllers.

■ dSPACE prototyping systems (p. 6)

Autocoding

Automatic code generation for the production controller is a key phase in the development process. With TargetLink, you generate code for your production controller automatically and efficiently, and straight from MATLAB®/Simulink®/Stateflow®. TargetLink generates highly efficient C code in minimum time. This dramatically

reduces the time needed for implementation, and you will have systematic consistency between your specification and your production code. Improvements to your functions can easily be added, even after initial code implementation. TargetLink code meets the highest regulatory standards (p. 18), for example, TargetLink-generated code has been certified according to DO-178B level A, the highest safety level for civil aviation.

■ TargetLink (p. 9)

HIL Testing

When your production controller has been programmed, you can test its functions quickly and automatically, using dSPACE Simulator. These tests allow you to perform a systematic analysis of the controller functions, and any errors that occur can be reproduced. dSPACE Simulator replaces the real environment, and you can execute your tests in any conceivable test scenario, systematically and reproducibly, thanks to comprehensive test automation. This way, complicated test runs in the real environment are reduced to a minimum.

■ dSPACE Simulator (p. 12)



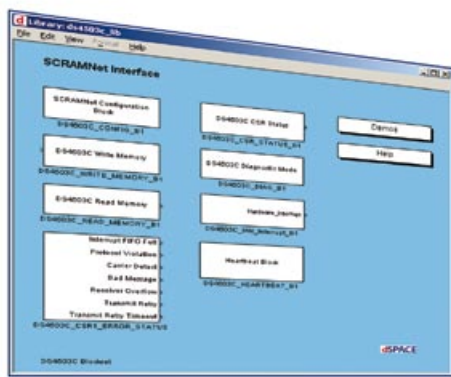
Rapid Prototyping

The dSPACE prototyping systems provide all you need for prototyping the software for your production controllers. You can combine software and hardware to create a tailor-made prototyping system for installation in the actual controlled system or on a test bench. The dSPACE prototyping systems are seamlessly integrated with the MATLAB®/Simulink® modeling tools.

Running Models on dSPACE Hardware

Real-Time Interface allows you to implement Simulink® models on the dSPACE prototyping hardware automatically and without programming knowledge.

- Graphical configuration of all input/output interfaces in the Simulink® block diagram
- Support of software interrupts
- Support of hardware interrupts
- Dialog-based configuration of real-time scheduling
- Automatic real-time code generation from the block diagram and download to the dSPACE prototyping hardware

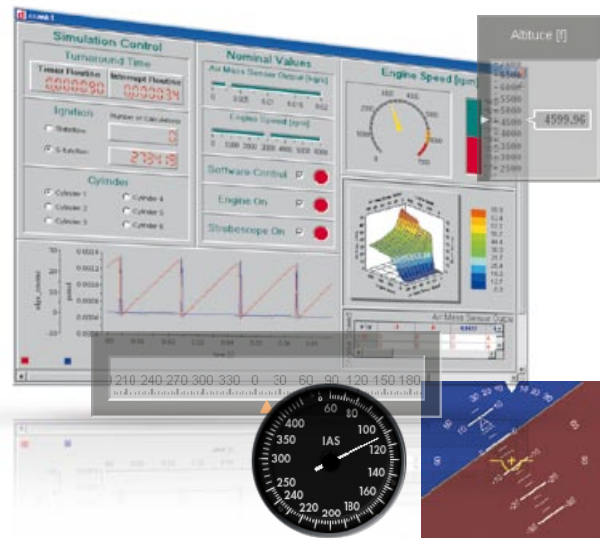


Graphical I/O configuration, in this example for the SCRAMNet+ Interface.

Instrumentation with ControlDesk

ControlDesk is a comprehensive, intuitive experiment environment for experiment management and control. The same virtual instruments support you through function design, rapid prototyping, simulation, and testing. You can modify parameters online, load look-up tables, and capture data during the test run.

- Creation of virtual instrument panels by drag & drop
- Real-time data capture and online parameter tuning
- Graphical experiment and hardware management
- Easy access to all model variables



Choose from ControlDesk's wide range of instruments to build an individual experiment environment for analyzing data and optimizing parameters.



Resolver interface for connection to aerospace resolver sensors.

Interface to the AFDX avionics data bus.



Interface for connection to the ARINC429 bus.

Ruggedized Prototyping Solutions

Prototyping Hardware for all Cases

The dSPACE prototyping hardware consists of high-performance processors which calculate your controller models in real time. Single-board and modular hardware solutions are available, with a broad selection of I/O interfaces to satisfy the needs of the most demanding projects.

dSPACE single-board systems have state-of-the-art micro-processors and offer a comprehensive selection of I/O interfaces. The boards also offer PCI and ISA bus support for installation in a host PC. The dSPACE single-board hardware will give you all the power and flexibility that you need for cost-sensitive applications with tough performance and I/O requirements.

For applications requiring multiple processors, or that have additional I/O requirements, dSPACE provides modular systems that can be configured to meet your individual requirements. Thanks to the compact and robust construction of the hardware, and the option for stand-alone operation, the dSPACE prototyping systems provide portability and high performance for field or test bench use.

- Support of widely used interfaces, including AFDX, SCRAMNet+, MIL-STD 1553, ARINC429, Ethernet, Giga Ethernet, Firewire 1394B, CAN, and serial communication
- I/O support for PWM, digital in/out, D/A, A/D, TTL, and incremental encoder communication
- High performance, with analog capture rates of over 100 kHz
- Integrating and testing existing real-time functions in Fortran
- Support of resolver interfaces, LVDT transducers, thermocouple sensors, RTD sensors, torque motor interfaces, and others

Versatile Hardware Platforms

Onboard experiments for computing new functions require a robust and compact solution for mounting the processor and I/O boards. MicroAutoBox and AutoBox provide the ideal environment for installing your dSPACE real-time-system onboard the aircraft.

MicroAutoBox – Extremely Compact

MicroAutoBox is the ideal hardware if you already know exactly what input/output interfaces the controller will have. MicroAutoBox's particular strength is its combination of high computing power and comprehensive input/output interfaces, including typical signal conditioning – all in an extremely compact design. Application programs are stored in nonvolatile memory, allowing MicroAutoBox to start up autonomously after power-up. MicroAutoBox is available in three standard variants which differ in terms of interfaces and I/O functionalities. dSPACE will develop new MicroAutoBox versions according to customer specifications, when and as required.



MicroAutoBox has all the advantages of prototyping hardware, yet it is nearly the same size as a production controller.



The modularity of AutoBox means it can be adapted to any requirements, at any time.



The RapidPro units can either be used individually or combined in a stack. They can be adapted to specific applications flexibly by means of modules.

AutoBox – Scalable and Flexible

If your main concern is scalability and you would prefer to remain flexible with regard to processor power and input/output interfaces, AutoBox is the right hardware for you. AutoBox is a modular hardware system for onboard and test bench use. Its functionality is decided exclusively by your requirements. You can choose from a wide range of interface and processor boards to meet your project needs.

RapidPro Hardware for Signal Conditioning

For the signal conditioning, power stages, and intelligent I/O subsystems that you need, you can use the RapidPro hardware and its corresponding software. With its compact, robust housing, the RapidPro hardware is ideally suited to both in-vehicle and test bench use. Its great selection of hardware- and software-configurable modules lets you reuse, reconfigure, and extend all the components in later projects, with a minimum of effort.



Autocoding

By employing dSPACE's automatic code generation software, you can reap the benefits of rapid prototyping and capitalize on shortened software development cycles. A 40% reduction in development time is common for TargetLink users, and will give you a new sense of time as you develop code for your control system.

TargetLink has numerous other advantages in addition to cutting development time:

- C code always consistent with model
- Unified coding standard
- Code documentation always up to date
- No implementation errors
- Shorter debugging and commissioning phases
- Greater focus on model design
- Even very complex models take less time
- Software-in-the-loop testing

Efficiency and Reliability

TargetLink generates processor- and compiler-optimized code for implementation on your controller, and provides a range of scaling options that allow you to optimize precision, memory usage, and performance. You can easily

verify the performance of your generated code against the output from your model, and quickly identify and analyze errors that result from changes in precision.

Certified Code

TargetLink code meets strict production requirements and the highest regulatory standards. For example, TargetLink-generated code has been certified according to DO-178B level A, the highest safety level for civil aviation.

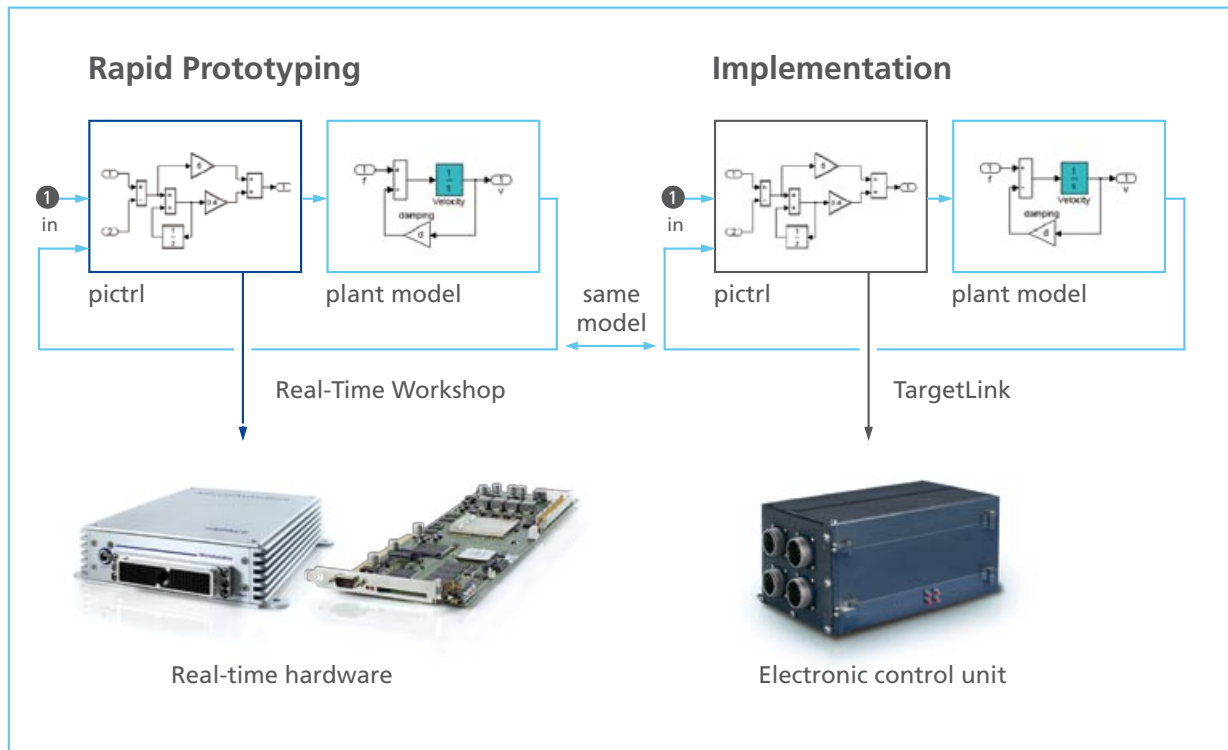
The Controller Model as the Starting-Point

Because you are using the same block diagram for production code generation and rapid prototyping, you can be sure that the control laws are valid and match your specification. TargetLink gives you the tools to prepare your model for deployment on the production controller, and allows data typing and scaling.

Simulation on the Host

You can test your controller design and its parameterization in simulation on the host. TargetLink records the signal behaviors of each block during the simulation, allowing you to quickly scale your variables – manually or automatically – by using the minimum and maximum signal values that were saved.

The image displays the dSPACE TargetLink software environment. On the left, a snippet of C code is visible, showing function calls and variable declarations. In the center, a block diagram of a control system is shown, with various blocks and signal paths. On the right, a physical dSPACE hardware unit is shown, which is a rack-mounted device with multiple ports and a cooling fan.



You can use the same block diagram for rapid prototyping and production code generation.

Testing the Production Code on the Host

After the model has been validated in the host simulation, you are ready to generate production code and test it on the host. TargetLink gives you the tools that you need to use your PC host to simulate the fixed-point limitations of the target, and to make the necessary adjustments to your model for deployment on the production controller.

- Analyzing deviations between floating-point in the simulator and fixed-point for use on the target
- Testing search algorithms for look-up tables
- Numeric comparison of time histories
- Easy inspection of the C code for each block in the model

Testing the Production Code on the Production Controller

To test the code on your production controller, simply build the code and load the executable to your evaluation board. dSPACE provides hardware and compiler optimization modules for a wide range of commonly used embedded processors, ensuring that the ANSI C code that is generated by TargetLink will run on your system.

Run TargetLink on the host while your model runs on the controller, and analyze precision, execution time, and stack and memory usage requirements. The ability to analyze the model on your target system quickly and finetune your control laws on the host will provide huge time savings in your software development cycle.



HIL Testing

Test runs can be an expensive business. They can take place in the freezing cold or the searing heat to test controllers in the most extreme conditions. And such hardships are only one obstacle among many. Delays are frequent, and simultaneous engineering, which requires development processes to run in parallel, is difficult to achieve.

Controller Testing is a Key Phase

Real test runs can also deliver incomplete test results; not to mention the fact that the tests cannot be reproduced or automated. Yet as the complexity and size of software increases at a breath-taking pace, comprehensive controller tests are more necessary than ever before. Only comprehensive testing can avoid the risks resulting from software misoperation. So controller testing is a key phase in the development process.

Virtual Test Runs

There is an established method for performing reliable and comprehensive controller tests in the lab: hardware-in-the-loop (HIL) simulation, in which the controller is connected

to a simulator to perform virtual test runs. This reduces the number of test runs in the “real” world outside and brings enormous savings in cost and time. The simulator copes easily with safety-critical borderline cases, and there is no danger involved. Moreover, the tests are reproducible and can be automated (lights-out testing).

Virtual test runs impose tough demands on the simulator. It has to run a model representing the behavior of the real environment, and real-time capability is vital. Another challenge is to generate sensor signals that are unbelievably complex in real life. dSPACE provides excellent solutions for all this and offers a wealth of know-how in the development of simulators.

dSPACE constructs several hundred simulators every year and is the world market leader as a controller-independent specialist for hardware-in-the-loop simulation. For our customers, dSPACE Simulator is the key to testing controllers fast, automatically, and at lower cost.

Hardware-in-the-loop:
Controller and simulator form
a closed control loop.





Turn-Key Systems for Controller Tests

With expandable hardware and a wide variety of I/O and signal conditioning options, dSPACE Simulators can be scaled to match the complexity of your models. They either run in stand-alone mode or can be easily integrated into your existing hardware-in-the-loop system. Graphical programming, photo-realistic displays, 3-D online animation of virtual aircraft behavior, and intelligent automation options make our simulators easy to use and allow you to focus on the results of your simulation, and not the hardware that is running it.

Real-Time Models

Whether you are simulating an electrostatic bearing, a control surface actuator, or a gas turbine, you need real-time data to test your controller design. dSPACE Simulator provides you with the tools to get your MATLAB®/ Simulink® or model simulation up and running in real time on dSPACE hardware quickly and seamlessly.

- Create models graphically in Simulink and drag & drop input/output interfaces
- Implement models automatically on dSPACE Simulator
- Integrate third-party and handcoded models
- Parameterize your simulation completely

Instrumentation

The ControlDesk software environment provides you with everything you need to instrument your experiments on a PC. A comprehensive library of virtual instruments and a hierarchical experiment navigator give you an intuitive environment from which you can manage and run your tests.

- Graphical user interface for experiment and platform management
- Generate virtual instrument panels
- Preconfigured layouts for HIL applications
- Design your own layouts

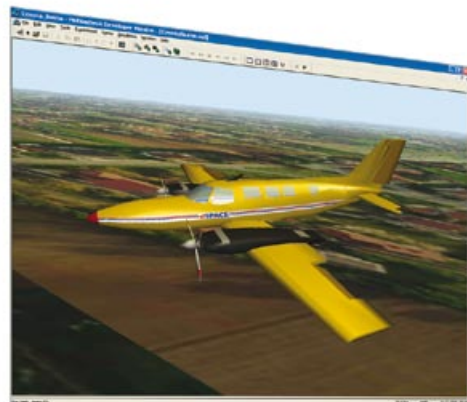
3-D Online Animation

MotionDesk performs 3-D online animation of all the objects on a dSPACE Simulator to give you a visual impression of what is happening.

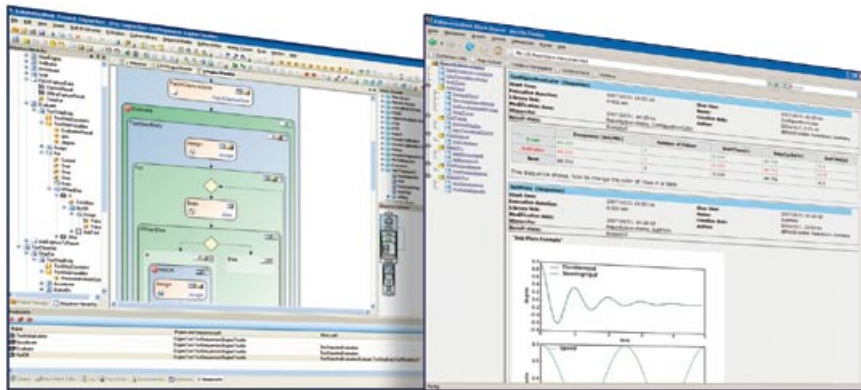
- 3-D online animation of HIL simulations in real time
- Graphical user interface similar to other dSPACE tools
- Graphical interactive scene design



ControlDesk layout for experiment control.



3-D online animation with MotionDesk brings your simulation results to life.



AutomationDesk's user interface – a convenient way of organizing test projects.

Intelligent Hardware and Software Architecture

Test Automation

With the AutomationDesk test automation software, you can manage and automate hardware-in-the-loop (HIL) simulations. AutomationDesk is a convenient test automation environment which supports the development and handling of large test projects. AutomationDesk's Debugger makes it easy to find the source of an error that occurs during test execution. With AutomationDesk's Evaluation Library you can analyze recorded data and compare it with reference data.

- Automated testing in HIL simulations
- Management of large test projects
- Graphical editor for describing automation sequences

Powerful, Scalable Processor Hardware

dSPACE hardware is designed with scalability in mind. Add power and speed to your system with additional processors, or expand the I/O capabilities of the system by incorporating any of the wide variety of modular I/O boards that we offer. dSPACE Simulators support a

variety of standard interface protocols, so you can easily integrate your dSPACE Simulator in a network of HIL simulators. You can add additional dSPACE processors via Gigalink 1.25 Gbit/s high speed optical fiber interfaces.

Flexible I/O Hardware

dSPACE Simulators have a variety of I/O options and can easily be interfaced with real system components and loads, such as actuators, sensors, hydraulics, and mechanics. Moreover, the system's modular components can easily integrate your own hardware or third party hardware such as:

- Relay and fault boxes, break-out boxes
- Application-specific power supplies
- Custom signal conditioning





Success Stories

dSPACE systems are used in numerous applications throughout the aerospace industry and by a wide range of customers – with great success, as the following examples show.

Many manufacturers and suppliers have realized that standardized development systems can streamline and shorten development phases. dSPACE products support modern processes and a seamless development tool chain, which reduces the manual workload and avoids expensive errors.

Some typical application areas for the use of dSPACE systems in the aerospace industry are:

- FADEC (Full Authority Digital Engine Control) development for military and commercial aircraft engines
- Developing novel control surfaces
- Actuator modeling and testing
- Hardware-in-the-loop simulation of gas-turbine engines
- Active noise and vibration control

The following success stories will give you an idea of the wide range of applications in which dSPACE systems are used.

Airload Simulation on the A380

Complex System of Slats and Flaps

Movable slats and flaps enable commercial aircraft to increase the lift acting on their wings as required. The largest passenger aircraft in the world, the Airbus A380, has a particularly complex system of slats and flaps. The Airbus test bench for this “high-lift” system uses a multiprocessor system consisting of DS1005 PPC Boards.

The High-Lift Test Bench

The entire system of the A380’s slats and flaps, with all their drives, has been constructed in actual size. The core task of the control system for the facility is precise control of the hydraulic and pneumatic cylinders that represent the varying aerodynamic airloads. The entire control system is based on two DS1005 PPC Boards, six DS2003 Multi-Channel A/D Boards, and two DS2001 High-Speed A/D Boards, which have been in continuous operation for two years.



Reference: Hacker R., Dr. Ing. Finke T., “Airload Simulation on the A380”, dSPACE NEWS 1/2006.

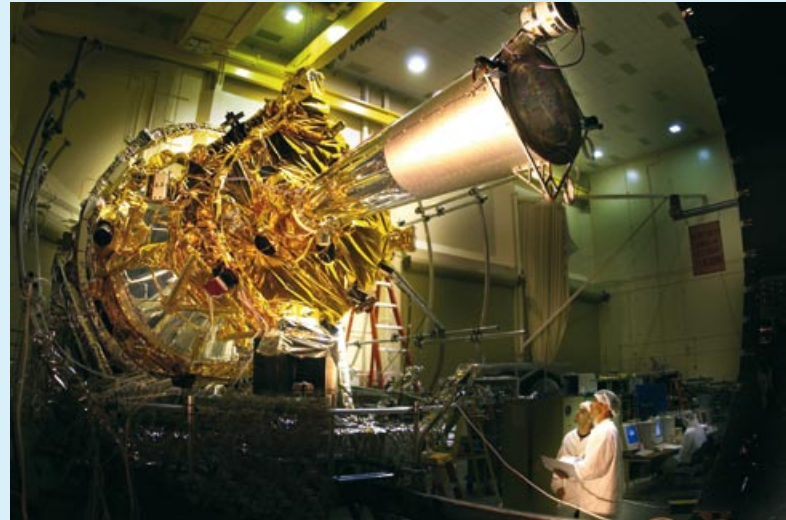
Testing General Relativity

Measuring a Tiny Angle

On April 21, 2004, the Gravity Probe B spacecraft was launched from Vandenberg Air Force Base to orbit the Earth. With four high-precision gyroscopes onboard, its mission is to measure the expected relativistic effect of the Earth slowly dragging space and time around with it, known as the frame-dragging effect. The General Theory of Relativity predicts that this effect will cause the gyroscope's axis to drift out of alignment to a guide star by an angle of 42 milliarc-seconds. The challenge is to measure this microscopic angle to a precision of 1% or better. The final results of this unprecedented test of General Relativity are expected in 2009.

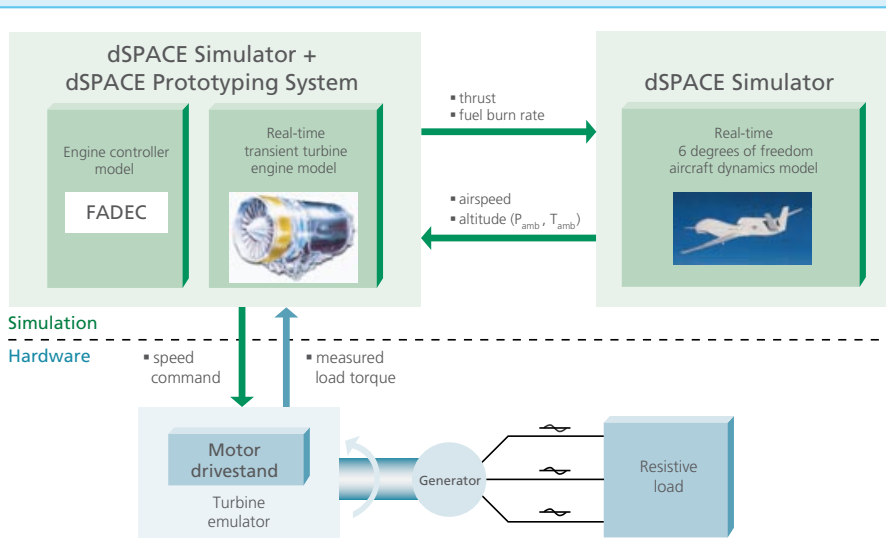
Electronic System Test with dSPACE Hardware

Developed by NASA and Stanford University, the Gravity Probe B experiment is the most stringent and precise test of general relativity ever performed. A hardware-in-the-loop



setup with dSPACE hardware and software was used to test the gyroscope suspension system.

Turbine Tweaking on Virtual Aircraft



Simulation of a Complex Aircraft Model

The Air Force Research Laboratory (AFRL) uses hardware-in-the-loop (HIL) simulation with dSPACE Simulator to develop and optimize the propulsion systems for the next generation of aircraft. Real-time simulation of turbines and aircraft models performed together with real turbine hardware components opens new possibilities for turbine engine controls. The optimized algorithms allow aircraft to achieve higher altitudes, faster speeds, lower fuel consumption and lower heat rejection into recirculated fuel.

Reference: Transient Analysis of an Aircraft/Propulsion System with Hardware-in-the-Loop Power Extraction, Kyle L. Miller, J. Mitch Wolff, Eric A. Walters, 43rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference, 2007, OH, USA.

Advanced Actuator Testing

Modern commercial aircraft are as safe as they are because of the comprehensive tests that flight systems have to pass while still on the ground. The German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, DLR) is using dSPACE equipment for a test facility that provides enormous flexibility for developing future flight systems.

The “More Electrical Aircraft”

In what is known as the trend towards a “more electrical aircraft”, hydraulic actuators are increasingly being replaced by electrical ones. Electrical actuators are lighter, less complex, and easier to maintain. The DLR test facility is suitable for testing diverse types of actuators in different configurations. The test facility’s main tasks are:

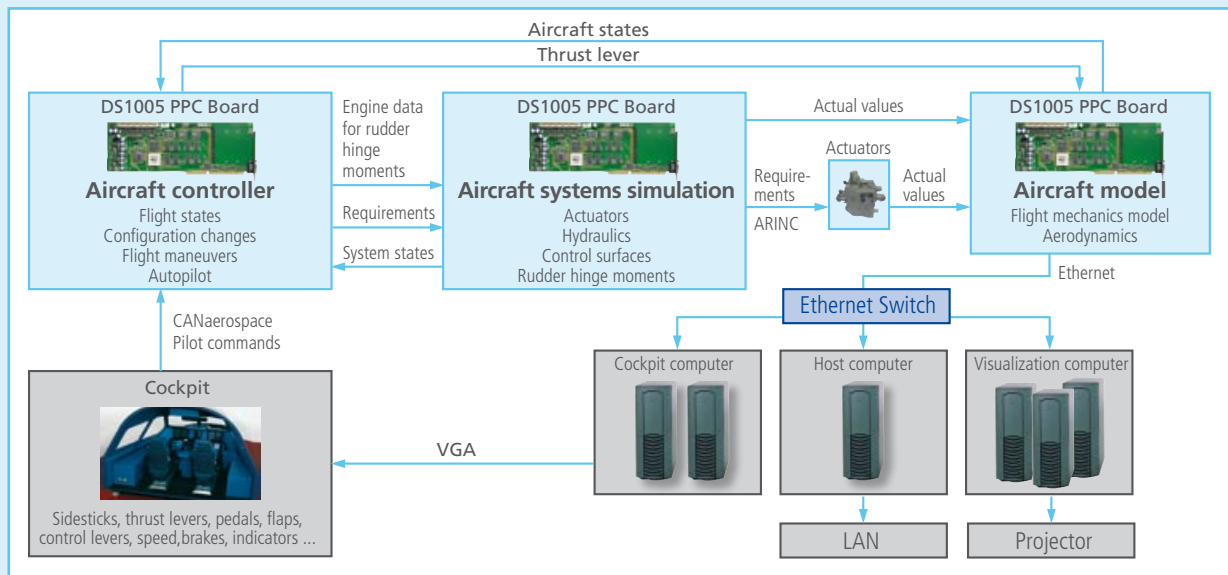
- Implementing hydraulic systems for pressures up to 5000 psi
- Testing different actuator systems in different configurations
- Simulating realistic flight conditions
- Developing novel control surfaces
- Integrating a variety of cockpit systems

Simulation Environment

The simulation environment consists of three DS1005 PPC Boards and diverse I/O boards from dSPACE. Each of the DS1005 boards has its own task to perform, such as calculations for the real-time simulation of flight maneuvers, the hydraulic system or control surfaces, or autopilot functionalities like automatic landings. The boards are easy to configure for their tasks using MATLAB®/Simulink®. The control algorithms are also easy to reconfigure by modifying the Simulink model. Because the simulation environment is modular in design, additional DS1005 or I/O boards can be added and existing ones replaced to produce a multiprocessor environment that is tailor-made for a wide range of tasks.

The dSPACE components provide the flexibility needed for easy adaptation of new actuator and aircraft concepts.

Schematic of the test facility. Three DS1005 boards form a multiprocessor system for real-time calculation of items such as flight maneuvers, the hydraulic system, control surfaces, and autopilot functionalities like automatic landings.



Cabin Pressure Control

Since 2000, Nord-Micro has been using dSPACE TargetLink, the production code generator, to develop cabin pressure controls for a wide range of aircraft types. In Nord-Micro's development processes, the autocode software effortlessly fulfills the strict requirements of aircraft manufacturers such as Boeing and Airbus, and also those of the FAA and EASA aviation authorities.

Cabin Pressure: Safety First

Automatic cabin pressure control in aircraft is not only important for comfort, but also a safety-critical functionality. An error in the cabin pressure control system could cause the crew and passengers to lose consciousness.

Successful Use of TargetLink since 2000

Nord-Micro has been using TargetLink to develop and autocode controller software since 2000. Thus, numerous aircraft, from regional jets to the Airbus A380, have cabin pressure control systems on board that contain controller software developed and autcoded with TargetLink. The controller software meets the rigorous requirements defined by aircraft manufacturers and aviation authorities, including certification up to DO-178B level A.

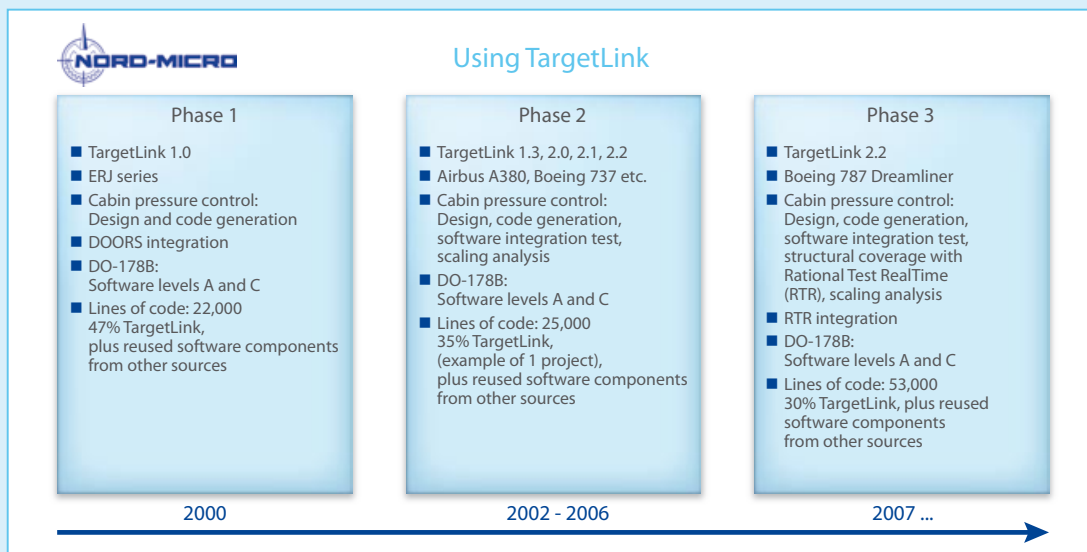
Reduced Test Workload

In the development process at Nord-Micro, TargetLink is not only used for autocoding, but also in other process steps such as automatically generating documentation, defining software requirements, model design, automatic scaling, code review, and software integration test. Amongst the TargetLink features that considerably reduce the test workload at Nord-Micro are the good readability of the TargetLink code, traceability between the code and the model, and deterministic code generation. Moreover, the flexible configurability of the source code enables Nord-Micro to integrate several TargetLink models into the real-time software without much difficulty. The efficiency of the source code always fulfills the real-time requirements. Integration with other development tools such as Telelogic® DOORS® and Rational® Test RealTime ran smoothly.

TargetLink for Future Projects

Following positive experience with TargetLink, Nord-Micro will continue to use the tool for developing cabin pressure control systems in new aircraft in the future.

Production code generator TargetLink has been used successfully for many years to develop safety-critical software at Nord-Micro.





Braking at Full Speed

ETRAS[®], the thrust reversal system on the Airbus A380, is a fully electrical system with no hydraulic or pneumatic components – the first ever in passenger planes. It was developed by Hispano-Suiza, a SAFRAN Group company, using a dSPACE prototyping system.

Why Reverse Thrust to Brake?

Thrust reversal in aircraft is an additional braking system that takes some of the load off the mechanical wheel brakes to shorten the braking distance. It is also helpful in rain, ice, and snow, when the wheel brakes lose some of their effectiveness. In the Airbus A380, thrust reversal is achieved by a system of flaps that open on the side of the engine when the plane lands, to deflect some of the air flow forward.

The ETRAS[®] System – Fully Electric

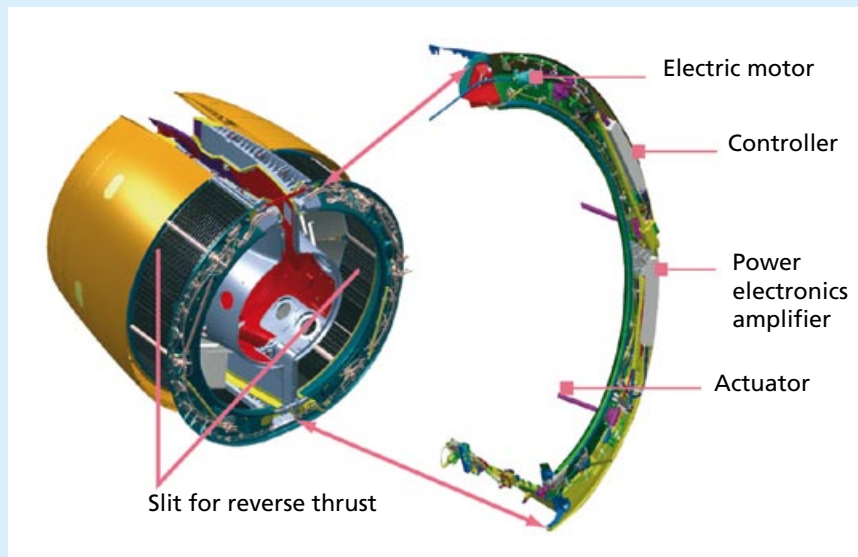
The dSPACE prototyping system helped Hispano-Suiza to reduce the risks involved in the complete plane nacelle system for ETRAS[®] (Electrical Thrust Reverser Actuation System) by validating and optimizing the control algorithms (functional and safety levels). This way, they saved a lot of time and were able to begin the final embedded software development at an early phase, and validate it

The thrust reverser is one of the engine nacelle modules (outer diameter around 4 m). The control algorithms for the thrust reverser were developed via a dSPACE prototyping system.

according to the aviation standard DO-178B level A. The ETRAS[®] system, developed in partnership with Honeywell, is fitted on the nacelles, which were designed and produced by fellow SAFRAN Group company Aircelle for both the engines offered on Airbus A380: the Rolls Royce Trent 902 and the Engine Alliance GP7200.

Flexible Development Environment

The dSPACE prototyping system, consisting essentially of the DS1005, I/O, and interface boards, and the ControlDesk experiment software, gave the engineers an-easy-to-use environment for developing the algorithms for thrust reversal control in the Airbus A380. The control algorithms were designed using MATLAB[®]/Simulink[®] and executed on the prototyping hardware using dSPACE's experiment interface, ControlDesk. One of the tasks of the dSPACE prototyping system was to capture sensor signals (incl. the speed and positions of various positioning motors and threaded spindles, and air flow) via I/O interfaces and a resolver interface dedicated to electric motors. This data was then used to calculate the actuating variables for the strength of thrust reversal.



Integration Testing on HondaJet



Testing Aircraft Subsystems

The Honda Aircraft Company will utilize dSPACE simulators for automated integration testing of aircraft electrical

and avionics subsystems. Production aircraft subsystems and line-replaceable units (LRUs) will be tested against high-fidelity flight dynamics models, engine models and engineering prototypes running on networked dSPACE HIL platforms.

Complete Testing Framework

dSPACE HIL Simulators provide systems engineers with a complete testing framework for the integration of networked electronics, with support for a wide range of aircraft configurations. A comprehensive suite of tools facilitate model-based design, automated testing and automated failure insertion. The environment offers a fully customizable human interface, automated traceability to requirements, and automated reporting and documentation.

Telescope with Wings

Stratospheric Observatory at 40,000 ft.

MPC¹⁾ Products Corp., based in Skokie, Illinois, USA, has developed an actuator control system used by NASA to control a drive system for the Cavity Door System that covers a large cavity in the rear fuselage of a modified Boeing 747 housing a large infrared telescope. The telescope is the largest to ever be placed in an aircraft and will aid in the study of infrared light emitted from astronomical objects.

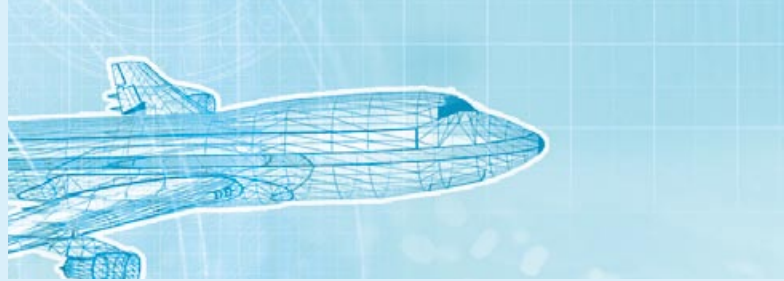
Modular System with dSPACE Tools

A modular system was established with a dSPACE DS1005 processor board to achieve real-time and high sampling rates, a dSPACE resolver card, a dSPACE encoder card, and a dSPACE DS2201 analog-to-digital multi-I/O board designed for applications requiring a lot of varying I/O

types. The dSPACE tools were used to fine-tune the control design and generate a control methodology for simulating the aerodynamic and gravitational loads.



¹⁾ today: Woodward



Anti-Noise Flaps

The noise produced by helicopters, particularly as they come into land, is far from pleasant, and their vibrations also affect the pilot. Both are caused by the air currents in the plane of the rotors.

Eurocopter Germany is working on producing piezoelectrically controlled flaps for the rotor blades that will considerably reduce noise and vibrations. The control system for the flaps is being implemented with the aid of a dSPACE prototyping system.

Air Vortices Cause Noise

The noise arises when one rotor blade collides with the vortex trail of the rotor blade in front. But noise is not the only problem: helicopters also vibrate continuously. The vibrations are largely due to the air flow striking the blades asymmetrically, as typically happens in helicopters. This means that an advancing rotor blade has greater lift than the rotor blade opposite it, which is moving towards the tail. As a result, the dynamic forces are not in overall balance – and the helicopter vibrates.

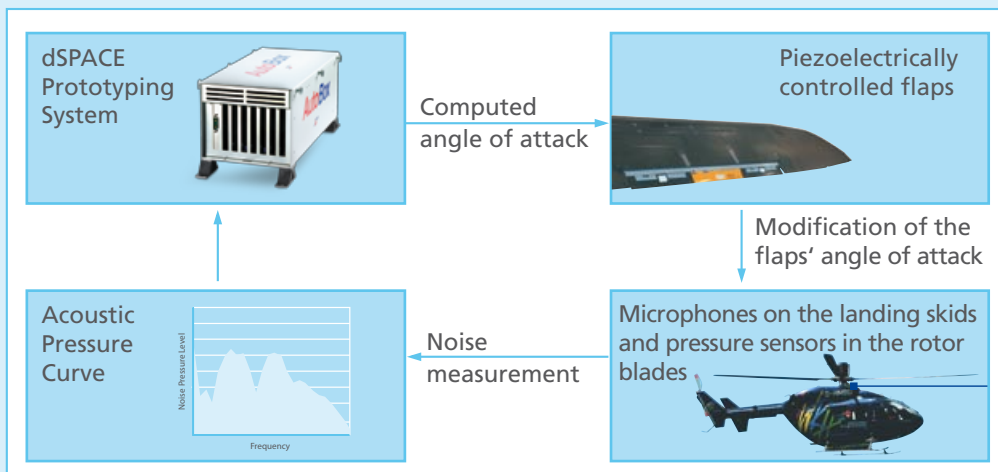
The Solution: Additional Flaps in the Rotor Blades

By using controlled deflections of additional, piezoelectrically controlled flaps in the rotor blades, Eurocopter can considerably reduce both the noise and the vibrations.

The flaps perform two tasks: First, they divert the air vortex leaving one rotor blade away from the next rotor blade. Second, their deflections generate additional forces that decrease the imbalance of forces in the helicopter, thereby reducing the vibrations. Controlling the approx. 35 flap deflections per second is the task of the dSPACE prototyping system, which is based on a DS1005 board. The control system “hears” the collision between blade and air vortex via a microphone on the landing skids and a pressure sensor in the rotor blade, and uses the acoustic behavior to calculate the optimum control for the piezoflaps. To calculate useful control signals for the piezoflaps, Eurocopter has to sample the acoustic behavior at frequencies of up to 5 kHz.

Noise and Vibrations Reduced

The piezoflaps considerably reduce the noise and the vibrations. The piezo-controlled flaps are far faster and more compact than the first version, which was hydraulic. Eurocopter regards this system as an important step towards production level. It is even conceivable that the piezoflaps might later be used not only for noise reduction, but also for the primary steering of the helicopter – which would make control rods and swash plates unnecessary.



The noise level is measured by microphones on the landing skids and pressure sensors in the rotor blades. The noise behavior is then used to compute the angle of attack for the piezoflaps that will minimize blade-vortex interaction and noise.

Turbine Development

Propulsion Systems Research

The Intelligent Controls Facility (ICF) at the Wright Patterson Airforce Base operates a facility for propulsion systems research. The ICF provides capability for component-based modeling – for example for simulation of gas turbine propulsion systems – and for testing turbine engine-related components such as servo-actuators, advanced fuel valves, and engine control units. The test facility supports multiprocessor operation and diverse interface buses (ARINC 429, MIL-STD-1553 etc.).

Engine Model on dSPACE System

The ICF uses a dSPACE system to run engine models for the simulation of gas turbine propulsion systems in real time. The engine models are run against a simulated FADEC (Full Authority Digital Engine Control). A typical example is the engine model of a two-spool turbofan, non-augmented, with mixed flow through a single nozzle – loosely based on the AE3007 engine.



Reference: <http://www.pr.wpafb.af.mil/>; Monthly Accomplishment Report, October 2002.

Prototyping at Moog

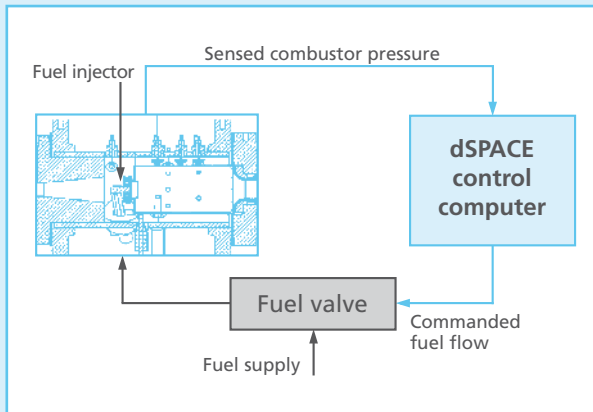


70% Reduction of Development Time

Engineers at Moog Inc. have developed the control algorithms for positioning actuators for flight control surfaces on various aircraft, including the Joint Strike Fighter. A dSPACE prototyping system is used for automatic testing of the actuators for certification. The actuators are run at different operating temperatures, vibration levels, and loads. The prototyping system automatically switches between different operating conditions, captures test data, and generates test reports. Rapid control prototyping has helped Moog reduce its overall development time by about 70%.

Reference: www.machinedesign.com

Controlling Combustion Instability



Reference: Delaat, J.C., and Chang, C.T., "Active Control of High Frequency Combustion Instability in Aircraft Gas-Turbine Engines", ISABE 2003-1054, proceedings of the International Symposium on Air-Breathing Engines, Cleveland, OH, Sept. 2003.

Suppressing Pressure Oscillations

Combustion instabilities are common in aircraft engines. Caused by interaction between fluctuating heat release and naturally occurring acoustic resonances, they can shorten the life of the engine and result in premature mechanical failure. At the NASA Glenn Research Center, a dSPACE prototyping system was integrated in a combustor rig for the control of combustion pressure oscillations. Two instability control methods, one model-based and one based on adaptive phase-shifting of the valve-regulated fuel flow, were developed and evaluated with the combustor rig. Both methods reduced pressure oscillations by 30%.

Flywheel System for Energy Storage

Energy Storage for Space Applications

Energy storage on the Space Station and satellites currently takes the form of chemical batteries, most commonly nickel hydrogen or nickel cadmium. A flywheel energy storage system is an alternative technology that is being considered for future space missions. Flywheels offer the advantage of a longer lifetime, higher efficiency, and a greater depth of discharge than batteries.

Control with a dSPACE Prototyping System

A flywheel energy storage system testbed was constructed at the NASA Glenn Research Center. The control algorithm for the charging and discharging modes of the flywheel energy storage system was executed with a dSPACE prototyping system and written in Simulink

Reference: Barbara H.K., Kascak P.E., Jansen R., Dever T., Santiago W., "Control of a High Speed Flywheel System for Energy Storage in Space Applications", NASA TM-2004-213356, NASA Glenn Research Center, Nov. 2004.



Scanning the Earth's Atmosphere

Collecting Atmospheric Data

Onboard of the European weather satellite MetOp (Meteorological Operational Satellite) is the Infrared Atmospheric Sounding Interferometer (IASI), an instrument for measuring the distribution of temperature and humidity, and the chemical composition of the atmosphere. The high quality of the measurements is largely determined by an optical delay line control developed using a dSPACE prototyping system.

Regular as Clockwork for 7 Years

At the heart of the optical delay line is a moveable mirror, which must move 13 mm backward and forward at a constant speed of 132 mm/s, and continue to do so for up to 7 years – the useful life planned for the satellite. In the development setup, the control system (based on the



dSPACE DS1005 PPC Board) captures the position of the moveable mirror at a sampling rate of 2 kHz via an optical encoder and calculates the optimum control input from this.

Control Effectors for Future Aircraft



Reference: Raney D., Cabell R., Sloan A., Hautamaki B., Barnwell W., Lion S., "Wind Tunnel Test of an RPV with Shape-Change Control Effector and Sensor Arrays", AIAA-2004-5114.

Less Fuel, Enhanced Maneuverability

Future aerospace vehicles might replace the conventional, highly specialized control devices – rudder, aileron, elevator, flaps – by a larger number of smaller, less specialized, distributed effector and sensor device arrays. The benefits include enhanced maneuverability and reduced fuel consumption.

Closed-Loop Control

At NASA's Langley Research Center, a hardware-in-the-loop setup consisting of dSPACE hardware and software was implemented for the 12-ft low-speed wind tunnel. The aircraft's 24 effectors were controlled by both open-loop commands and closed-loop signals from the pressure distribution controller. Remote control via the dSPACE setup made it possible to automate test sequences and rapidly cover a large test matrix.

dSPACE – Your Systems Partner

Since its foundation in 1988, dSPACE has become one of the leading suppliers of tools for rapidly developing and testing mechatronic control systems. Over 900 employees and more than 15,000 installed systems are proof of this success. dSPACE customers are supported by its headquarters in Paderborn, Germany, subsidiaries in the USA, France, the UK, Japan and China, and by distributors worldwide.

Training and Support

To help you get off to a good start, we regularly offer training in Germany, France, Japan, the UK, and the USA. However, our work does not end there. Our engineers in sales, applications, and support are available worldwide, and if necessary on-site, to answer all your questions about your dSPACE system.

System Engineering

To support you in developing your control systems, we offer you additional services in all aspects of the development process. Experience has shown that integrating dSPACE systems is easy. Even so, in the early stages of any project, questions crop up that need answering promptly. So we can offer you:

- Feasibility studies
- Pilot projects
- Benchmarking



Training at dSPACE in Germany.



Turn-Key Solutions

Even though dSPACE systems are easy to install and handle, customers often ask us for turn-key systems. The reason is the pressure they are under to develop controllers quickly. With turn-key delivery and commissioning, customers can



The open architecture of dSPACE systems lets you easily modify and extend your dSPACE hardware.

concentrate on their core activities without losing time. This service has been especially welcomed in the field of HIL simulators. The services provided with turn-key systems are typically:

- Configuration
- Customer-specific hardware development
- Integration of third-party software and hardware components

dSPACE Systems Stay Up-to-Date

To ensure that your system works optimally, even if requirements change in the future, dSPACE supports you far beyond system delivery. The open architecture of dSPACE systems guarantees that your system is always up-to-date and remains a long-term investment. Our update services include:

- Software updates
- Extension of interfaces
- Hardware modification and expansion

Conferences

dSPACE User Conferences take place at regular intervals and provide a forum where users can meet and discuss their own experiences with dSPACE systems. Our User Conferences, held since 1998, have been a great success, giving customers an opportunity to present their applications, share information, and discuss their development strategies with dSPACE systems. User Conferences are held in Germany, USA, Japan and other countries. For information on the topics, please take a look at our Web sites.



Our customers are very satisfied with the reaction time and the quality of our support services.



Active Worldwide

The international nature of our operations means a commitment to partnership with our customers, partners and distributors throughout the world. Our rapidly increasing sales figures and workforce speak for themselves. This success is also the result of the contributions of our subsidiaries and distributors. With their commitment and expert know-how, they make dSPACE products accessible to customers all over the world.

Headquarters

Germany: dSPACE GmbH, Paderborn
Branches: Stuttgart, Munich

Subsidiaries

USA: dSPACE Inc., Detroit
France: dSPACE SARL, Paris
United Kingdom: dSPACE Ltd., Cambridge
Japan: dSPACE Japan K.K., Tokyo, Nagoya
China: dSPACE GmbH Shanghai Representative Office, Shanghai

Representatives

Australia: Sydney
Brazil: São Paulo
China: Beijing
Czech Republic and Slovakia: Prague
India: Bangalore
Korea: Seoul
Netherlands: Rotterdam
Poland: Krakow
Sweden: Stockholm
Taiwan: Taipei

Our Customers

dSPACE systems are used by a wide range of customers all over the world. Here are some of our current customers from the aerospace industry:

Adersa
Airbus
Alcatel Alenia
Astrium
BAE
Boeing
Diehl Avionik Systeme
DLR
EADS
Eurocopter
General Electric
Giat
Goodrich Corporation
Honeywell
LIEBHERR-AEROSPACE
Lockheed Martin
Matra Marconi
MBDA
Messier Bugatti
Moog
MTU
NASA
Nord-Micro
Northrop Grumman
Onera
Qinetiq
Raytheon
Sagem Defense
SciSys
SNECMA
THALES
The Aerospace Corporation
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Vospert Thornycroft
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