

# MOVING YOUR WORLD

IDEAS IN MOTION CONTROL FROM MOOG INDUSTRIAL

OCTOBER 2006

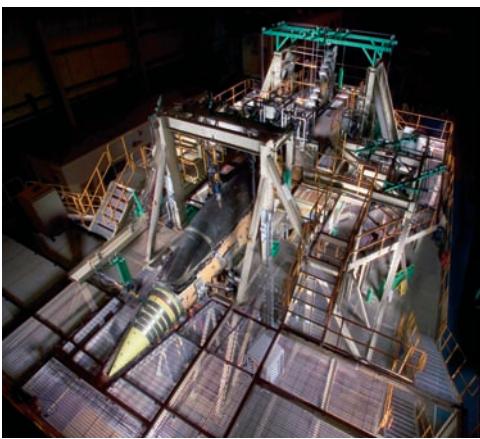
ISSUE 13

MOOG

## FEATURE

### MOOG FCS OFFERS ADVANCED FORCE CONTROL TECHNOLOGY FOR AIRCRAFT STRUCTURAL TESTING

By Bob Barrett, Aerospace Sales Manager



Courtesy of BAE SYSTEMS  
Typhoon production MAFT

Moog FCS is a recent addition to Moog, following the acquisition of FCS Control Systems by Moog in 2005. Originally formed from a division of the Fokker Aircraft Company, Moog FCS has a long history of providing hydromechanical and electromechanical control systems. The control technology was developed to provide high fidelity loading to flight control systems used in aircraft flight simulation applications. This flight control loading capability was soon developed and adapted for use in new applications such as full-scale static load and durability testing of aircraft structures, testing for product development in the automotive industry and even in haptic devices which are small robots designed to present to a human user the feeling of actually touching a virtual or remote world.

Aircraft structural testing is a demanding control application, as it requires the introduction of accurately controlled forces derived from hydraulic actuators, synchronously applied by up to two hundred actuators at a time. Hence, Moog FCS moved from “control loading” to “load control” applications.

Safety, when testing full-scale aircraft, is naturally very critical as the actuators can apply destructive loads to experimental aircraft worth many millions of dollars. The safety of Moog FCS’ testing systems is proven by the fact that no structure under test has ever been damaged by a faulty control system. This is due to extensive software safeguards and the fail-safe hardware architecture of the Moog FCS solution.



Moog FCS testing systems from last century to the 21st Century systems



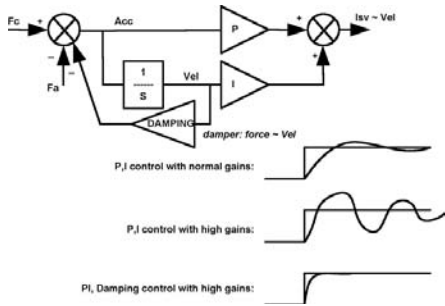
FA/18 Full scale fatigue test for  
RUAG, Switzerland

The heart of all high performance control systems supplied by Moog FCS is the control algorithm itself. This control algorithm adds to the standard PID loop controller a damping term. In physical terms, this can be thought of as a value proportional to velocity that is subtracted from the force summation point. The inclusion of this control parameter means the instability inherent on control loops with high gain can be damped and the result is faster step-response and improved system stability. The faster response results in shorter setup time and importantly allows customers to run the required fatigue flight spectra faster, thus saving time and money.

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## FEATURE

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SmartLOOP schematic structure and effect of damping on step response

This technology is attracting major customers from around the world. The SmarTEST solution has been selected along with HBM data acquisition systems purchased through Moog FCS for the F35 JSF project and will be used to test all variants of the F35. This project, running for some 5 years in the delivery stage is worth over \$14,000,000 USD. We have been awarded a contract with BAE systems in the UK for all their testing requirements and also have recently secured a 10 year contract with Airbus to supply them with their next generation testing solution for all tests in Germany, France, UK and Spain.

As part of the Moog family, we have local offices around the world that can support local requirements of our global customers. In Korea, for example we won our first project for the Korean Helicopter Project with KARI due to our collaboration between Moog FCS, our Moog site in Korea and the customer. With our new global footprint, we can share our expertise in high-performance testing solutions with new and existing customers around the world and support the local needs of some of the world's most challenging load control applications.

### About the Author:

Bob Barrett has 11 years experience of selling instrumentation normally constituting capital good on a business-to-business basis. He has worked for the last 7 years primarily in the Aerospace industry initially with HBM, selling data acquisition systems before moving to FCS to offer complete control, data acquisition and hydraulic turnkey solutions. He has a degree in Cybernetics and Control Engineering gained at Reading University and lives in the UK.

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## PRODUCT SPOTLIGHT

### MOOG FCS' FLEXIBLE SMARTTEST ONE SERVOCONTROLLER

By Jan Peter Veldhuizen, Sales Manager, Aerospace Test Systems

One of the secrets to the success of Moog FCS in the testing and simulation markets is the SmarTEST ONE stand-alone digital servocontroller. This product is the core of the SmarTEST family of servocontrollers which can handle general-purpose tests, with or without a PC, of up to four servo channels. This servocontroller is ideal for a variety of testing applications due to Moog FCS' unique force loop technology, its flexibility for operators and its ability to handle even complex testing formulas. While this servocontroller can be run stand-alone without off-line, external software, many customers use our aerospace SmarTEST or automotive FasTEST software as well as multiple software suites that provide profiles for common tests and easy set-up for custom tests.



Operator-friendly and flexible SmarTEST ONE Servocontroller

### Flexibility

Moog FCS has an operator-friendly and flexible product to meet the needs of test labs that perform various tests in different configurations. During our design process, we included the input of many customers from automotive and aerospace test laboratories reflecting their specifications for a controller that would match their needs.

Some of the benefits of the SmarTEST ONE that are most valued by customers include:

- Advanced control that is expandable up to 4 channels
- Advanced control loops (e.g. force, displacement and acceleration) allowing for faster and more efficient testing as well as reduced set up time
- Simple operation that allows the customer to add just the functionality needed for cost-effective integration
- Built-in data-acquisition (up to 2500Hz/channel), integrated oscilloscope display and data storage capability on a local hard-disk, make testing easier and save both lab space and running costs
- Flexibility to drive with any hydraulic or electric actuator is important in the modern testing lab environment
- Plug and play with all connectors for cost-effective, immediate integration

## **Reliability**

The heart of the SmarTEST ONE is the SmarTEST Control Unit that is proven technology with thousands of units in use all over the world. Whether testing an aircraft or an automotive prototype, safety features are critical to protect the test article and the test data. Our independent safety system checks all inputs against user-defined limits or test calibration for force sensors, i.e. advanced safety is built-in. The “dying seconds recorder” for example, allows tests to run unattended at off hours and in the event of a failure will record test details to help operators with fault diagnosis and correction options.

## **High Performance**

The SmarTEST ONE has many powerful features that enable it to work well in complex applications such as durability, vibration, shock and performance testing of components, seats, elastomers, modules as well as 4-Posters or even 3 or 4 Degrees of Freedom (DOF) suspension test rigs.

Some unique features include:

- Pseudo channels capability allowing the user to create online calculated channels using formulas and other inputs, offering greater flexibility and cost savings for the lab
- Matrix control provides measurement and control flexibility for more efficient testing
- Dual mode, bumpless switching (e.g. stroke to load or load to stroke) allows the user to take advantage of the full range of application
- Scripting for digital & analog I/O as well as limits and peak detectors makes set up and running of tests easier
- Online adaptive controls for amplitude and phase saves set-up time

## **Appendix: Specifications**

The Graphic Display

- 640 x 480 full VGA 65,536 color display

Controller

- Up to 10 kHz digital control loop (software selectable)
- Classical PIDF controller
- Unique force loop
- Control based on feedback of any input
- Three feedback control possibility (e.g. Force, Displacement and Acceleration)
- Bump less instant mode switching between two feedbacks (e.g. Force and Displacement)

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## PRODUCT SPOTLIGHT *continued from page 3*

### Function generation

- Frequency range 0.01 to 500 Hz
- Multi-channel function generation with user defined “mixer” functions (e.g. mix a low frequency offset with a higher frequency load)
- Waveforms: sine, saw tooth, block/square, rounded ramp, exponential, trapezoid, random (psd frequency definition)
- Analog input can be used as command
- Complex simulation spectrum support
- Constant amplitude and phase matching

### Standard inputs (per channel)

- 2 x high resolution (0.003 %) with selectable gain and bridge excitation
- Pot meter input (0.003 %) (+/- 5V, 5mA) OR (hardware selectable) LVDT input, (0.003%) with LVDT excitation (5V peak to peak @ 3kHz)
- 16 bit input (+/- 10V)

### Standard outputs (per channel)

- 16 bits  $\pm$  100 mA valve driver output, with a limit in software from 0 to 100% OR (hardware selectable) +/- 10V output
- 2 x 16 bit D/A converters, +/- 10 V differential

### Optional inputs

- 8 opto-coupled digital inputs

### Optional outputs

- 4-20 mA
- 3 stage valve driver
- 8 digital outputs

### Hydraulic manifold switch output

- 2 A @ 24 V

### Dimensions (WxHxD)

- 450x177x280 mm
- Unit can be mounted in 19 inch cabinet with use of optional rack mount kit

### Input voltage

- 100-240 VAC; 47-63 Hz

### **About the Author:**

*Jan Peter Veldhuizen has 9 years experience in industrial sales for technical products used in the machine-building, semi-conductor, automotive and aerospace industry. After being responsible for the SmarTEST ONE sales and product management, he recently moved to complete sales for aerospace test systems. He studied mechanical engineering in The Hague, Netherlands.*

## ASK THE EXPERT

### REDUCING AUTOMOTIVE PRODUCT DEVELOPMENT TIME WITH H<sup>2</sup>IL SIMULATION

By Jan van Bekkum, Manager of Product Development Test Systems

One of the most challenging applications for advanced motion control is in the area of testing vehicles. Today, in automotive testing, virtually all-subjective driver feedback necessary for vehicle, module, or even component development is gathered on the test track. Test track work is both expensive and inefficient. To overcome these deficits, Moog FCS is pioneering a combination of “hardware-in-the-loop” and “human-in-the-loop” simulation (H<sup>2</sup>IL), and thereby significantly reducing the amount of test track work during development. This will lead OEMs and automotive tier suppliers to shorten product development times and reduce the costs of testing.

Hardware-in-the-loop (HIL) testing describes a process where actual vehicle hardware components are tested in an otherwise simulated environment. Using this technique, the simulation interfaces with the “hardware under test” to create a normal operating environment for the hardware. The interface can be hydraulic, electric, mechanical, or in fact, any interface necessary to accomplish the objective of simulating the operating environments of the component. This may also include use of environmental chambers to simulate temperature, humidity or air even under pressure.

Moog FCS has extensive experience in the complex simulation of precise movement in areas such as flight simulation and testing. From servocontrollers and software with advanced algorithms to superior control loading actuators. This competency is key in many of the systems built today and positions Moog FCS as a key supplier of testing systems.

#### Background on H<sup>2</sup>

Hardware and human-in-the-loop testing has been employed for many years in the aerospace world to reduce research and development time. In doing so, new prototype components can be developed and validated on a test system under real working conditions together with a human being in the test to get actual pilot response and perception.

Most people are aware of human-in-the-loop simulation used for training purposes in aircraft flight simulators. In this case, the human is the only non-simulated “part” of the chain; no real aircraft parts are used.

A more real scenario is when engineering simulators are used to combine human-in-the-loop with hardware-in-the-loop testing. One of the obvious reasons to take this approach is that no pilot would want to fly an experimental piece of new hardware before getting some confidence in its performance. Equally important are cost considerations associated with aerospace developments where prototypes can cost tens of millions of dollars.

The hardware-in-the-loop/human-in-the-loop or H<sup>2</sup>IL simulators range from simple mockup cockpits to testing out a new on board computer, to full “iron bird” rigs where a complete aircraft representative structure is outfitted with all moving parts normally found on the aircraft.

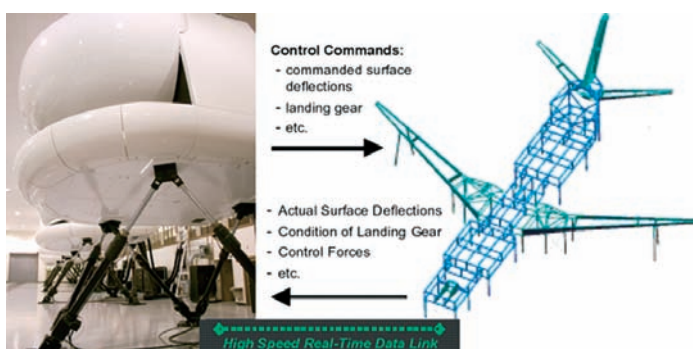


Figure 1: Hardware-in-the-loop/  
human-in-the-loop aerospace example

For the safety of the testing personnel a flight simulator is used. All the parts in the simulation actually represented in hardware are coupled into the simulation at a sufficiently high frequency so that their response mimics the bandwidth of the simulated events. Actuators are coupled to the “iron bird” surfaces to simulate the aerodynamic loading. If one of the surfaces is blocked on the rig, the pilot will feel a blocked control as a consequence. Moog FCS has delivered such systems to the aerospace industry for many years.

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## H<sup>2</sup>IL Testing for Automotive Applications

Consider the application presented above: traditional hardware-in-the-loop testing e.g. powertrain. The powertrain is still driven (or tested) on a dynamometer. By replacing the simulated driver input with a full 6 degrees of freedom (DOF) motion simulator and an actual driver (human) in the loop, we create the hardware-in-the-loop/human-in-the-loop (H<sup>2</sup>IL) simulation. In the H<sup>2</sup>IL testing scenario, the driver of the motion simulator drives a vehicle model on “mapped” proving ground roads while the powertrain operates on the dynamometer, now coupled to the motion platform. As illustrated below in Figure 2.

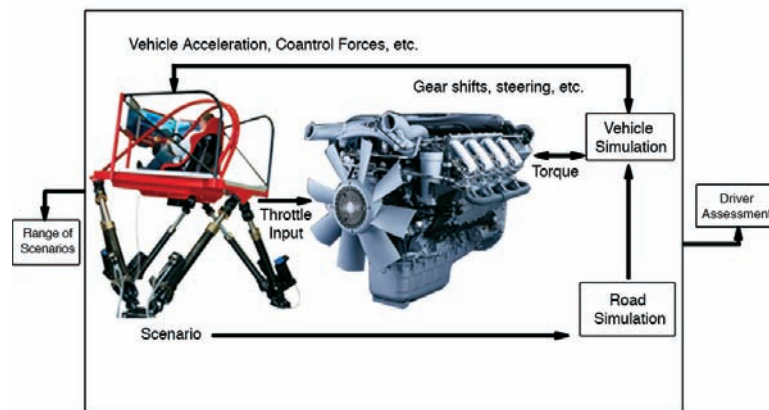


Fig. 2: Hardware-in-the-loop/human-in-the-loop – Proposed automotive example

In an H<sup>2</sup>IL configuration, the initial automotive system development can be brought into the laboratory. Here are a number of advantages that may be achieved compared hardware-in-the-loop testing:

- **Immediate Driver Response:** Immediate driver feedback can be obtained. Drivers respond instantly and give qualitative feedback on the direction of a solution. Evaluating the differences between multiple drivers can provide instant feedback. By recording driving habits for given conditions on this new design, objective driver metrics can be developed.
- **Track Time Reduction:** New scenarios can be created and recorded for playback without ever leaving the lab. With the ability to simulate track surfaces, ambient conditions and vehicle models, virtually any road or climatic conditions can be simulated. Development time and test time are dramatically reduced and controlled because we no longer require access to the track or proving grounds and we no longer have to wait until climatic conditions are correct. For example, rainy days can be avoided or repeated over and over again.
- **Allowing Component Modification:** Often it is desirable to study vehicle response to one specific road condition. Using these technologies the same road section can be replayed over and over while making subtle system changes, allowing fast, repeatable A-B-A testing.
- **Increased Test Driver’s Safety:** Dangerous road conditions can be tested in safer, more controlled environments. Drivers will not be subjected to dangerous road or ambient conditions since they will be operating the simulator. Track scenarios may be taken to the limit of performance on the new design but safety limits in the simulator will protect the driver and even the test parts from uncontrolled or out of control responses.
- **Exact Replicability:** Driver aids can be deployed to improve driver performance or train drivers to perform specific maneuvers. The performance of each lap can be recorded. Deviations to this lap performance can be observed as vehicle hardware is modified or swapped. Laps can be superimposed on screen so a driver has reference to previous performances. This can aid a driver in operating the “vehicle” on a certain part of the track consistently and repeatedly. If a component does not respond well on a certain part of the track, just that part of the track can be evaluated repeatedly while recording the results. This can offer strong driver evaluation especially in racing scenarios.

## Conclusion

H<sup>2</sup>IL testing is a truly viable form of validating design of vehicles and vehicle components. This approach has been employed for many years in the aerospace industry will prove to be the way of the future for the automotive industry. As proving ground and track time becomes more costly and as shortened program timescales drive parallel development to become the norm, the use of H<sup>2</sup>IL will become more interesting and important to the OEMs and automotive tier suppliers, not to mention race teams. Moog FCS has effectively served this industry by both the simulator and testing solutions and the range of advanced motion control solutions we offer to the marketplace.

### About the Author:

*Jan van Bekkum is was one of the founders of the former FCS (now Moog FCS) and worked for more than 15 years in the test system industry both in Holland and the US. Originally being responsible for aerospace test product development, he moved to automotive testing product development. He studied technical computer science in Amsterdam.*

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## DID YOU KNOW?

### FLIGHT SIMULATION TECHNOLOGY IS REVOLUTIONISING AUTOMOTIVE TESTING

By Roy Park Managing Director and Site Manager, Moog Australia

Multi-axis simulation of road surfaces for static and dynamic testing has traditionally relied on complex mechanical assemblies comprised of X-Y tables and bell crank linkages.



All-Electric Flight Simulator  
with "Stewart" 6 DOF  
motion platform

Moog FCS, our business that focuses on simulation and testing systems, has a heritage of designing and building motion bases. These electric and hydraulic actuation systems are used for the highest qualified flight simulators in the most demanding man-rated environments. The 6 degrees-of-freedom [6-axis] motion base required for aircraft simulators uses the so-called "Stewart" platform as the most mechanically efficient solution for actuator connection. Also known as "Hexapods" they are now providing optimum motion control for a wide range of automotive testing applications.

Moog FCS Hexapods when used in automotive testing offer a number of key advantages. The compact mechanical design uses less floor space, which is an important cost savings in busy testing labs. The design also offers the maximum mechanical stiffness, which adds to controllability. The patented force-acceleration control loop used in the HexaTEST Servocontroller allows the operator to feel the real-time response of the test, increasing accuracy and speed of the testing process.

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## **DID YOU KNOW?** *continued from page 7*

Moog FCS is developing, for a customer, a test rig for static testing of high performance vehicle suspensions. The solution uses a compact, independent Hexapod under each wheel to manipulate the suspension for measuring the kinematics and compliance [K&C] behaviour of the car. This is the first time an electric Hexapod has been applied to a K&C machine and will provide benefits to the customer in terms of reduced set up time, reduced facility requirements, greater operator safety and lower maintenance.

### **About the Author:**

*Roy Park has over 30 years experience in engineering, marketing and management in the hydraulics industry including the past 23 years as Managing Director and Site Manager for Moog Australia. He has a B.E. honors degree in mechanical engineering from Monash University.*



HexaTEST 3D

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## **HOT WEBSITES**

### **The International Test and Evaluation Association (ITEA)**

<http://www.itea.org>

A not-for-profit educational organization founded in 1980 to further the exchange of technical information in the field of test and evaluation. Its members include professionals from industry, government, and academia, who are involved in the development and application of policy and techniques used to assess the effectiveness, reliability, and safety of new and existing systems and products.

### **Re:Test Consulting Training and Resources**

<http://www.re-test.com>

A web-based company that provides resources to structural and fatigue test engineers, primarily in the automotive industry. It is a source of information, networking, training, jobs and used equipment.

### **The Society of Automotive Engineers**

<http://www.sae.org>

This Society has more than 90,000 members from over 97 countries that share information and exchange ideas for advancing the engineering of mobility systems. SAE is a resource for standards development, events, and technical information. They also offer expertise in designing, building, maintaining, and operating self-propelled vehicles for use on land or sea, in air or space.

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## **MOOG**

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