

# CARCO Electronics Reduces Development Costs by 30% Using MathWorks Simulation Tools

Intercept missiles are susceptible to very high frequency dynamic motion, such as vibration. This susceptibility can result in sensor line-of-sight errors on missile closed-loop guidance. To address this problem, engineers use flight motion simulators to replicate the disturbances. However, the most advanced test systems have bandwidths of only 60 to 100 Hz, contributing to unreliable test results.

CARCO Electronics used MathWorks products to design and manufacture a six-degrees-of-freedom motion test system that could operate at frequencies of 1,000 Hz. MathWorks products saved CARCO time and money by enabling them to simulate the behavior of the controller and the mechanical system together and then optimize the control system before building a costly prototype.

“Without MathWorks tools, we wouldn’t have touched this problem,” says Robert Peterson, vice president of engineering at CARCO. “We would have had to use C or Fortran to construct a simulation model. We wouldn’t have been able to analyze the behavior of the controller and the mechanical system together before prototyping. It would have been a nightmare!”

**THE CHALLENGE**  
CARCO needed to develop a motion test system that could accurately represent low-amplitude, high-frequency dynamics up to 1,000 Hz. Whether they could create a mechanical instrument that exhibited the required properties was questionable. Designing a traditional Stewart Platform (hexapod) that could operate at frequencies of 1,000 Hz presented challenges. For instance, the mechanical structure had to



CARCO's six-degrees-of-freedom motion test system.

be stiff yet remain light in weight, while the actuators and the control system had to respond to motion instantly.

They therefore needed to overcome two major hurdles: design a mechanical system flexible enough to meet their structural requirements and create a controller capable of achieving a 1,000 Hz response rate. To meet the high-frequency requirements, CARCO needed to optimize the components of the mechanical system and the controller together.

By themselves, these basic criteria could be met. However, in an integrated system, they presented a formidable engineering problem.

**THE SOLUTION**  
CARCO used MathWorks tools to develop a high-frequency motion simulator that consists of three anchor blocks, a plate on which the payload is mounted, six lower and three upper joints, and six electromagnetic linear actuators.

The development process involved five phases: modeling the mechanical system using MATLAB® and Simulink®, developing a control system in Simulink and optimiz-

**THE CHALLENGE**  
To design and manufacture a motion test system capable of replicating the disturbances experienced by a typical missile guidance system in flight

**THE SOLUTION**  
Use MathWorks tools to develop a prototype of the motion test system controller, generate code, and simulate the controller with the real mechanical system

- THE RESULTS**
- Development costs reduced by 30%
  - Design time shortened by more than two months
  - Controller optimized to specifications



Without MathWorks tools, we would have had to use C or Fortran to construct a suitable simulation model. We would not have been able to analyze the behavior of the controller and the mechanical system together before prototyping.



Robert Peterson, CARCO Electronics

ing the behavior of the mechanical system with the controller, automatically generating code using Real-Time Workshop<sup>®</sup>, running a simulation of the model with the real motion test system using xPC Target, and verifying the mechanical system model with SimMechanics.

For the mechanical system, CARCO designed a new set of specialized mechanical actuators and modeled these actuators in Simulink.

For the controller, they developed a multiaxis, dynamically decoupled control system to minimize the impact of the multiple eigenvalues in the coupled kinematics of the Stewart Platform. They implemented the control algorithms using Simulink and MATLAB and defined the control system architecture with Simulink blocks. Each system subblock defined a C-callable function and its corresponding input and output variables.

Next, they used Real-Time Workshop to generate ANSI C code from their Simulink block diagram representation of the control law.

For the next step, they used xPC Target to run the control algorithm in a production environment and execute it in real time on PC-compatible hardware. They then built the physical hardware and tested the combined system by connecting the hardware to the controller using xPC Target.

They verified their design with SimMechanics. CARCO found that building a complex model with SimMechanics was straight-forward, reducing development time by more than two months.

The controller is undergoing integration and final test.

## THE RESULTS

### ■ Development costs reduced by 30%.

After a two-year study of the impact of MathWorks products on costs and productivity at CARCO, the Software Engineering Institute at Carnegie Mellon University determined that CARCO reduced development costs by 30% using Real-Time Workshop for automatic code generation.

### ■ Design time shortened by more than

**two months.** “The original model took approximately three months to construct and verify,” explains Peterson. “With SimMechanics, the model was completed within two weeks.”

### ■ Controller optimized to specifica-

**tions.** “By using Simulink, we found the maximum dynamic performance of the motion simulator and then, based on this information, determined the performance criteria of the real actuators,” Peterson says. “This enabled us to optimize our designs before generating any code.”

To find out more about CARCO Electronics, visit [www.carcoelect.com](http://www.carcoelect.com)

## APPLICATION AREAS

- Aerospace and defense
- Algorithm development
- Control systems
- Flight control
- Simulation
- Test

## PRODUCTS USED

- MATLAB
- Simulink
- Real-Time Workshop
- xPC Target
- SimMechanics

[www.mathworks.com](http://www.mathworks.com)