CPU, FPGA, and I/O Solutions for Real-Time Simulation and Testing

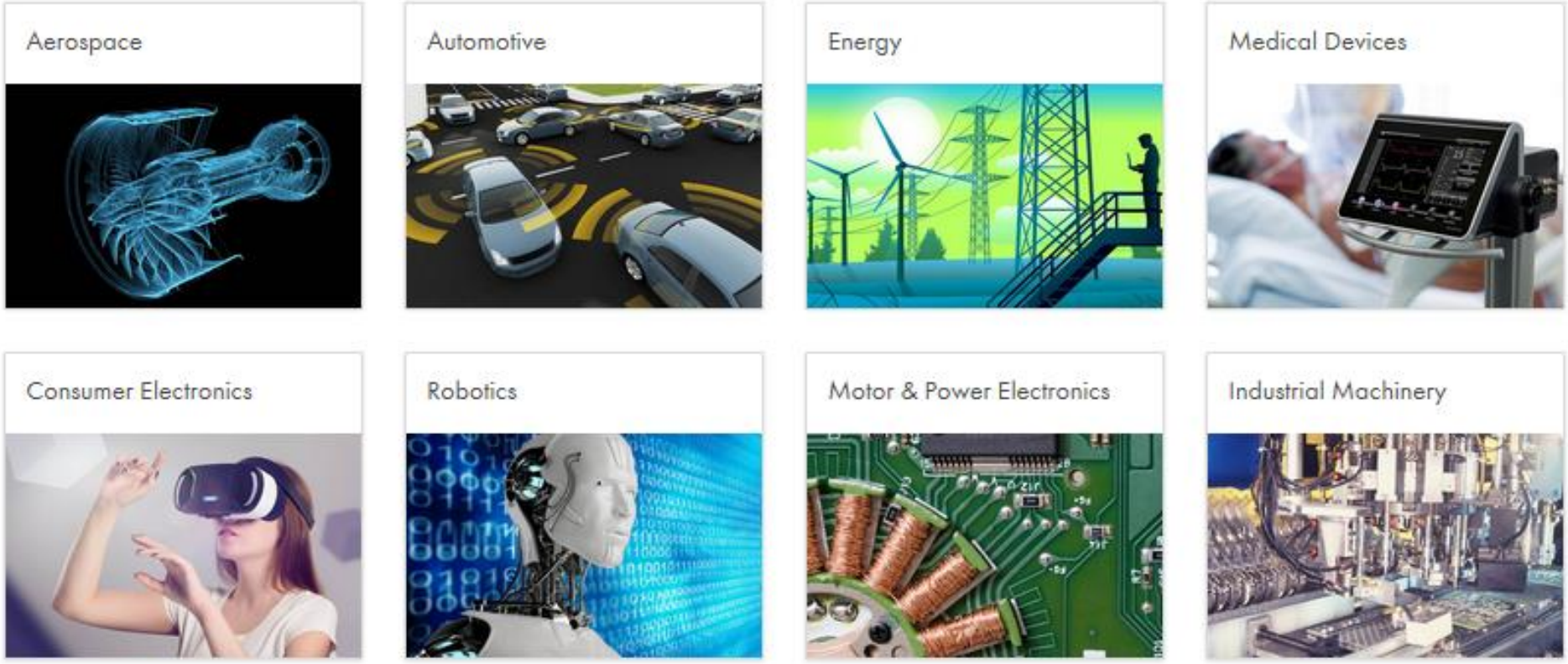
Sam Mirsky , Application Engineering, MathWorks
Martin Stoller, CEO, Speedgoat

CPU, FPGA, and I/O Solutions for Real-Time Simulation and Testing

Agenda

- **Introduction to Real-Time Simulation and Testing (RTST) including Rapid Control Prototyping (RCP) and Hardware-in-the-loop(HIL) simulation**
- MathWorks Model-Based Design workflow - from Desktop simulation to Real-Time execution
- Integration with other MathWorks products
- Speedgoat Hardware
- How MathWorks helps you to achieve your next RTST project

Why perform Real-Time Simulation and Testing?



To

- Test and investigate complex control design that is expensive to test on the field
- Reduce time to market for your engineering products
- Save costs by detecting errors early in your design process by validating your simulation model in real time with actual hardware and I/O

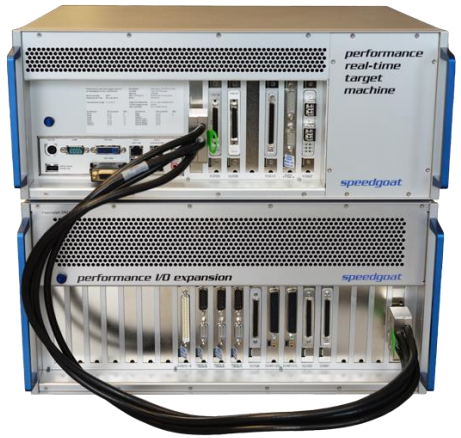
User Story: Gulfstream Aerospace, USA

Hardware-in-the-Loop Simulation of Aircraft Engines

Gulfstream G650 business jet

Gulfstream Aerospace Corporation (GAC), located in Savannah GA, USA, produces high-end civilian business jets.

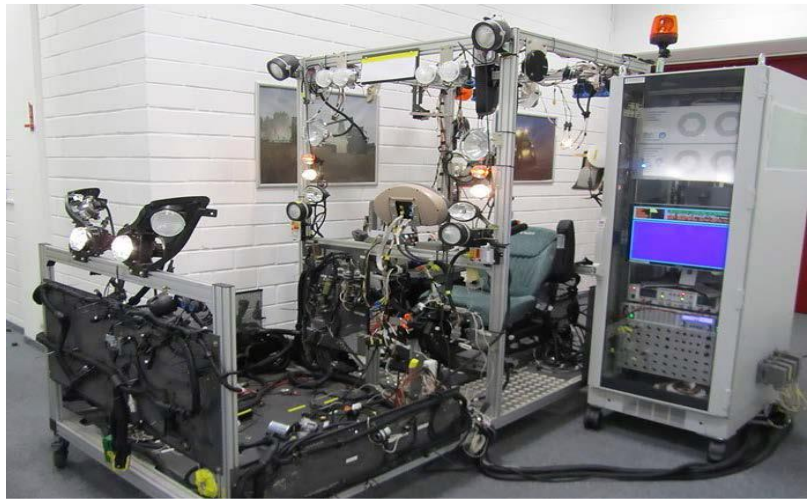
MathWorks and Speedgoat are providing a complete Hardware-in-the-Loop solution to simulate two interconnected engines, tested against the full authority digital engine controller (FADEC).



User Story: AGCO, Germany/France/Finland

Hardware-in-the-Loop Simulation of Tractors and Agricultural Machinery

- Automated testing of controllers for tractors and other agricultural machinery using Hardware-in-the-Loop test benches
- Drivetrain and engine models
- Implement a complete testing solution
- Improving the quality of the final product



“Speedgoat systems offer state of the art performance with application level support included, enabling detailed modeling of the tractor environment for ECU testing and development”

Jürgen Weinbuch, AGCO Fendt

AGCO Your Agriculture Company | FENDT

User Story: SuperGrid Institute, France

Rapid Control Prototyping for Distributed DC-DC Converters

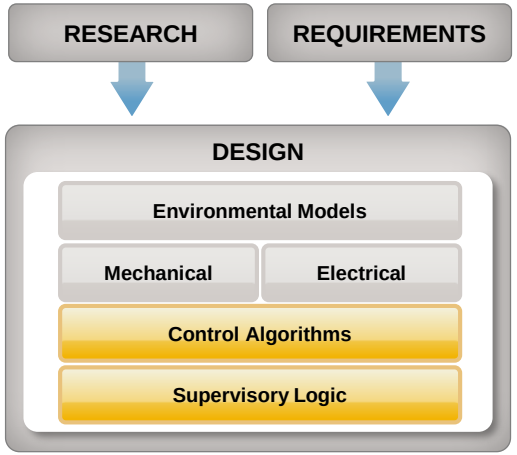
- Speedgoat hardware as central and distributed controllers for highly efficient and compact DC-DC power converters
- Power converter to operate at 20kHz closed-loop
- Controls algorithms implemented on CPU and FPGAs, connected to DC-DC converters with analog, fiber optic, and digital pulse train I/O
- Fast and agile development of next generation power distribution technology over extended ranges

“The transition from design model to real-time software was very fast thanks to the complete compatibility between MATLAB & Simulink and Speedgoat.”

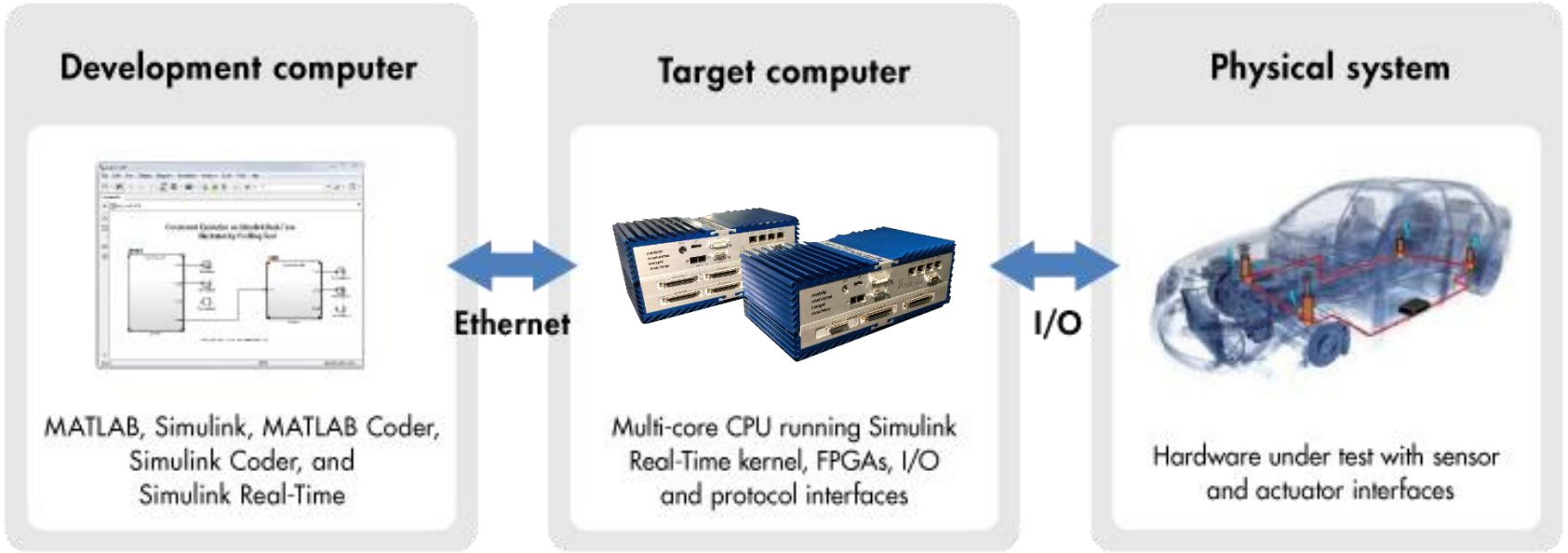
Piotr Dworakowski, Supergrid

SuperGrid Institute
Powering the electrical grid of the future

Rapid Control Prototyping

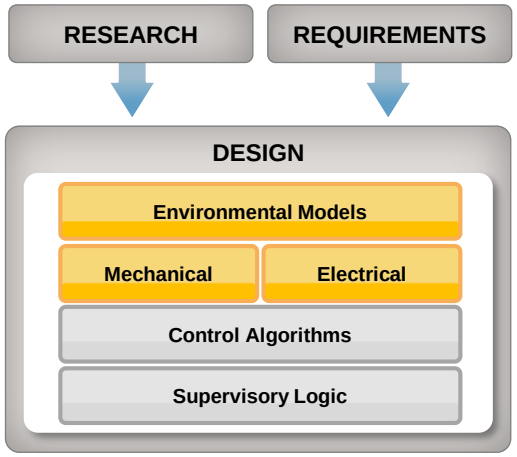


Automatically generate code from the simulation model for **real-time testing of the control algorithms**

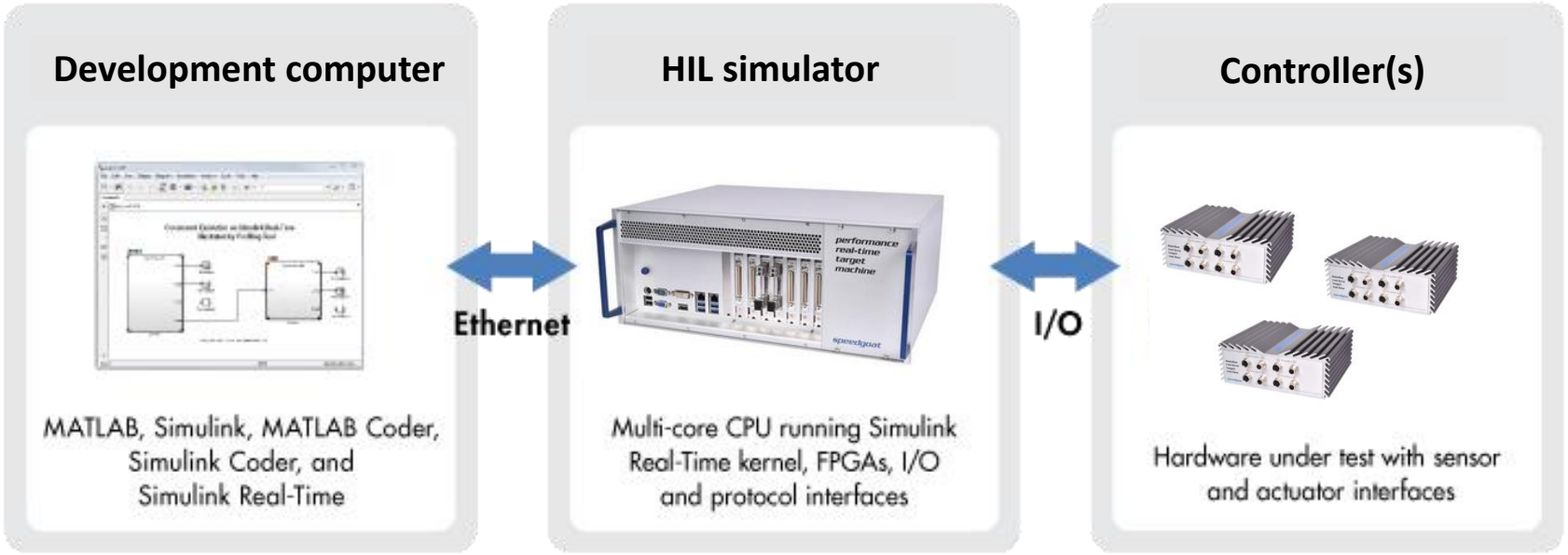


Real-time controls application autogenerated from Simulink

Hardware-in-the-Loop(HIL) simulation



Automatically generate code from the simulation model for **real-time system simulation of hardware for testing the real controller, FPGA, or PLC**



Plant simulation application autogenerated from Simulink

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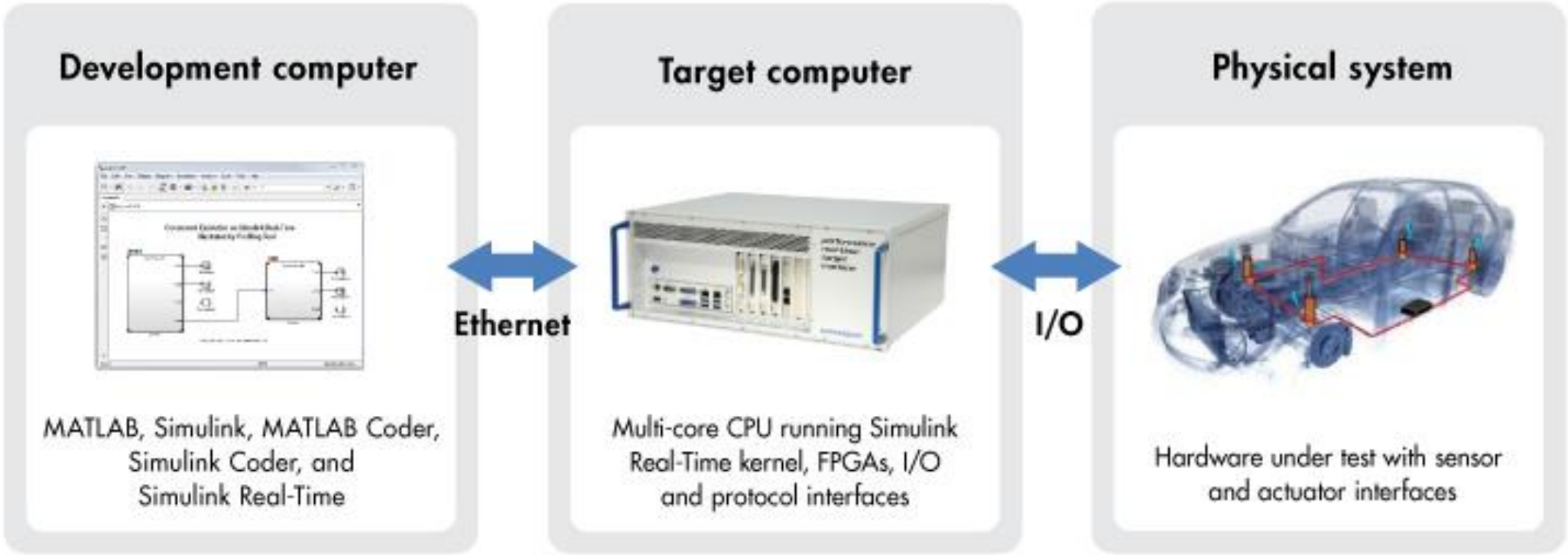
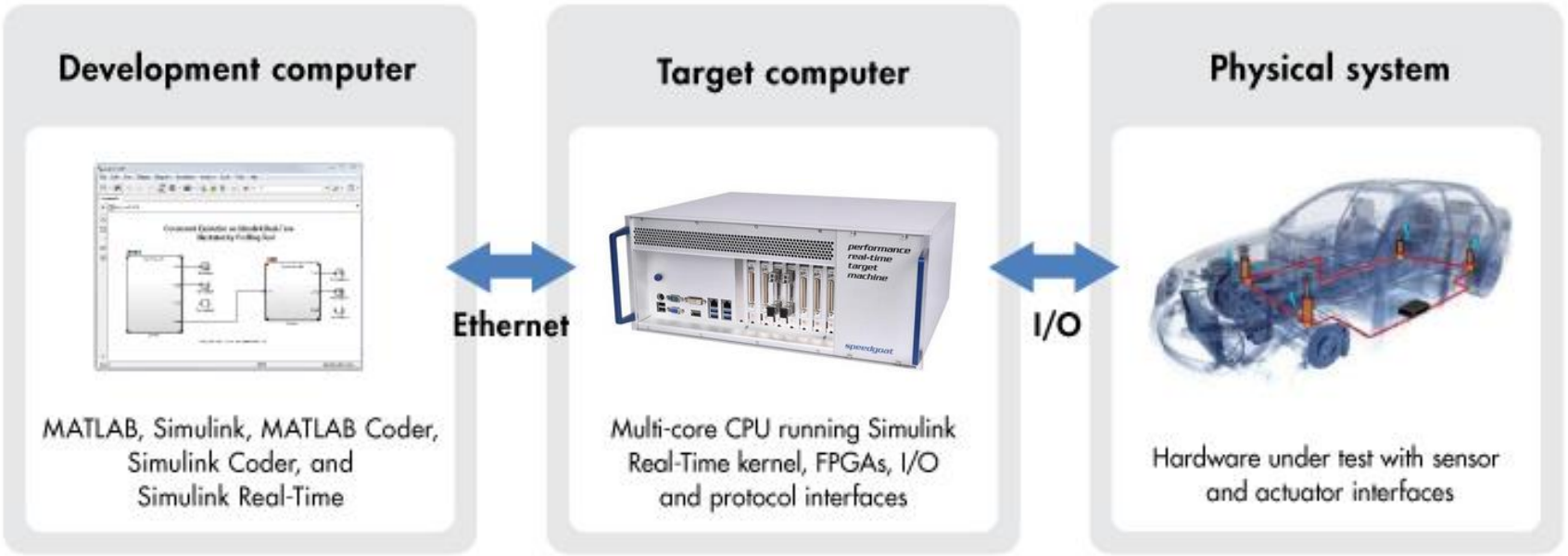
Create model and build and test



How to get started and run your model in real time



MathWorks Speedgoat Your Product

Made for Simulink

Vast Range of I/O & Protocols

Built for Speed

Scales with Your Projects

Configured to Your Needs

With Quality Services

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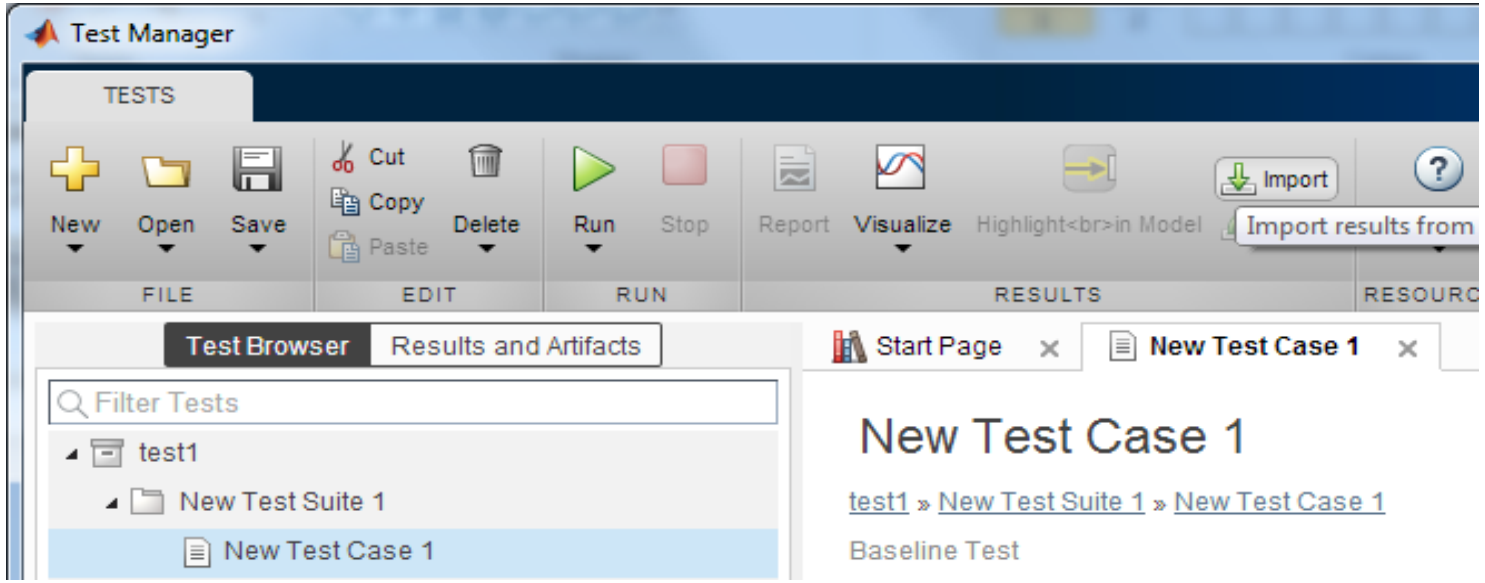
Integrated solution

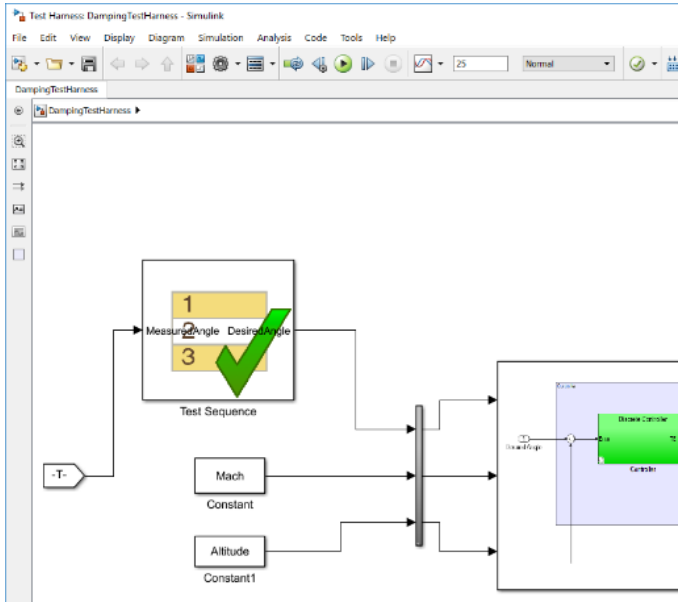
- Test automation
- Running models on FPGAs
- Automate analysis/optimizations
- Physical modeling, Powertrain blockset

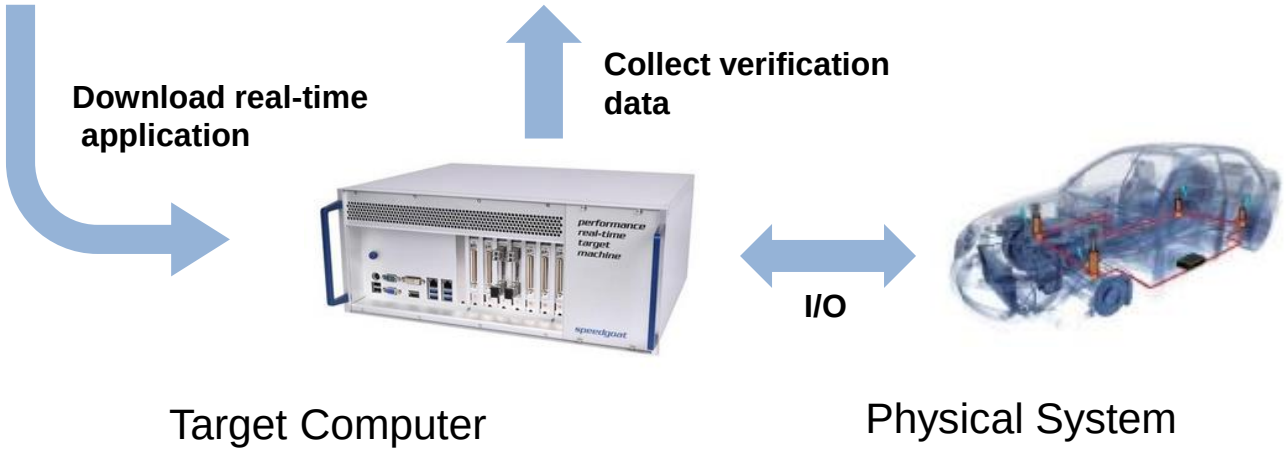
One workflow with software and hardware used for Real-Time Simulation and Testing

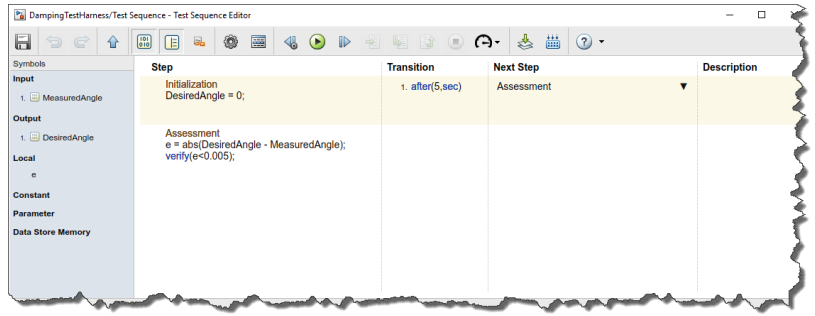
Automated Testing with Simulink Test

Real-Time Test Automation, ideal for Hardware-in-the-Loop

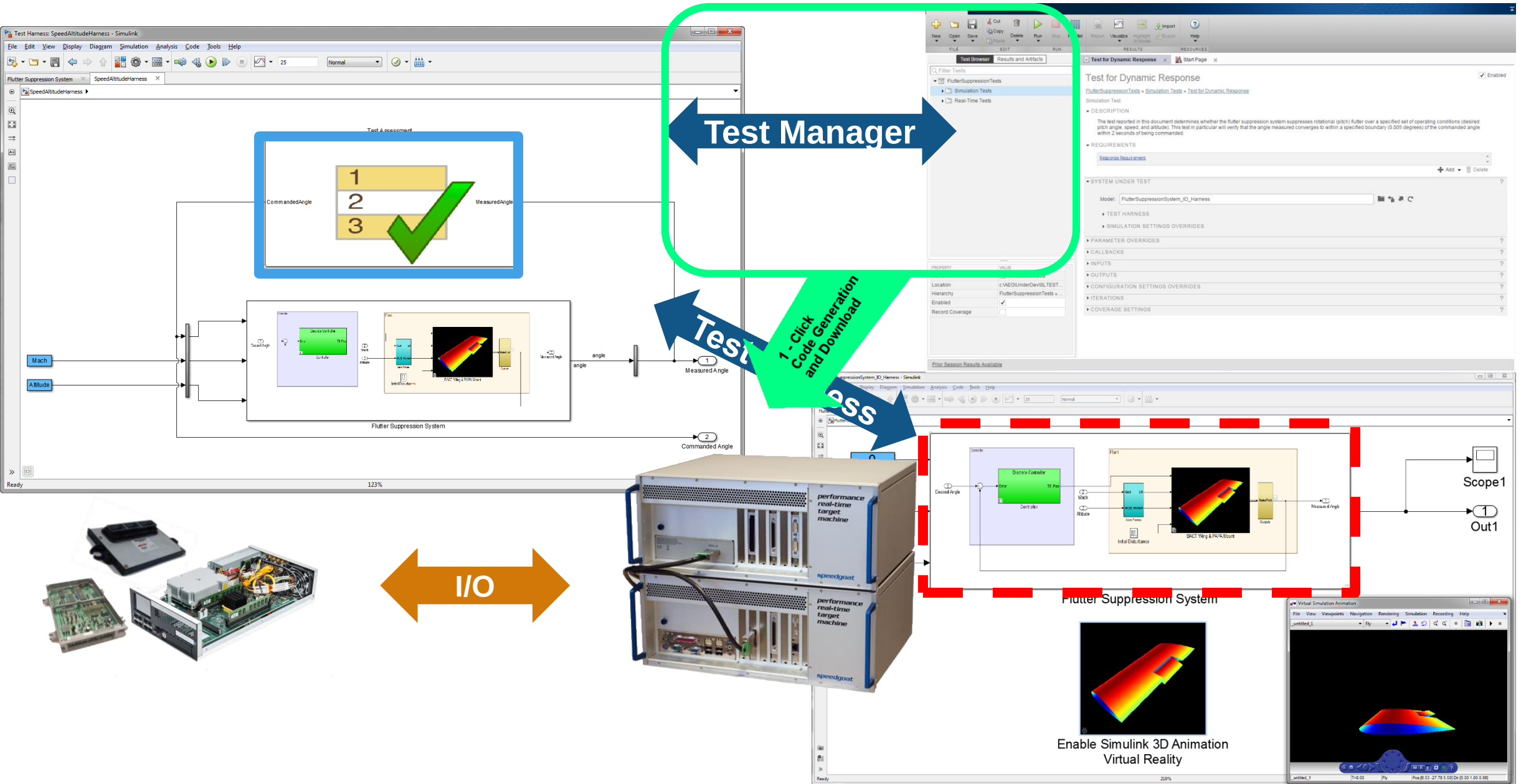




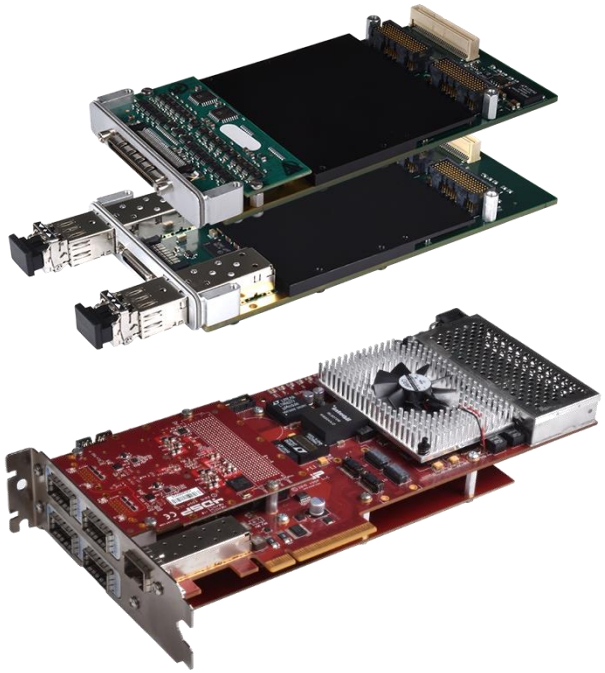


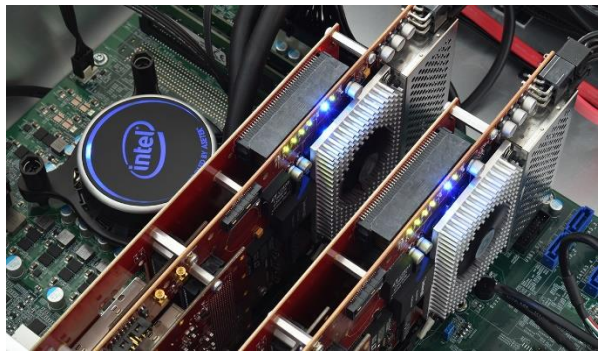


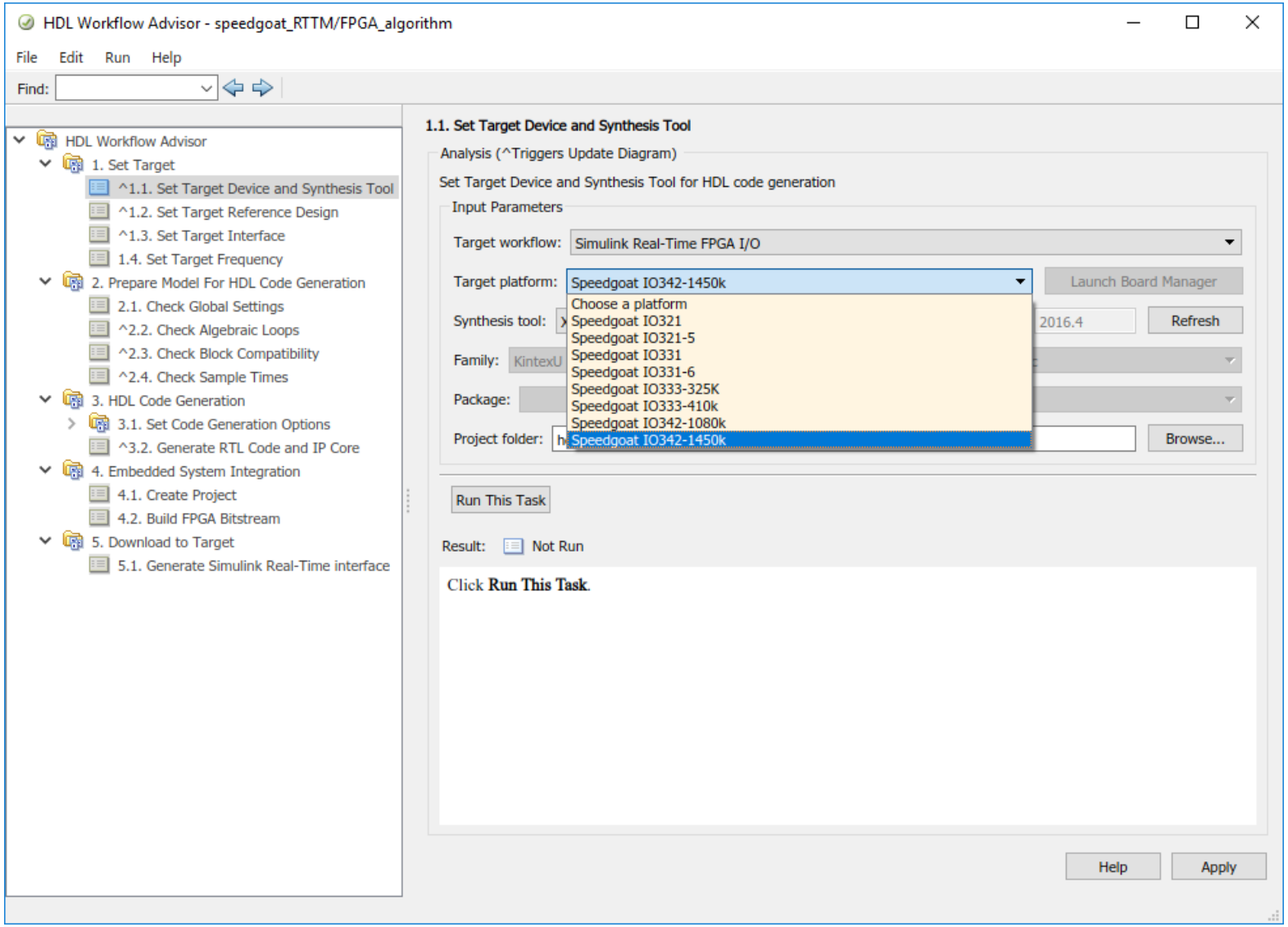
Fully Tested Algorithm in Simulink Test



Running models on Simulink programmable FPGA I/O modules







Physical modeling for HIL simulation

- Simscape
- Simscape Driveline
- Simscape Electronics
- Simscape Multibody
- Simscape Power Systems
- Simscape Fluids
- Powertrain blockset in Auto

Libraries to utilize for HIL simulation

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Speedgoat Products and Services

Made for Simulink, Tailored to Your Needs

Made for Simulink | Vast Range of I/O & Protocols | Built for Speed | Scales with Your Projects | Configured to Your Needs | With Quality Services

- Seamless workflow experience: Speedgoat and Simulink Real-Time are expressly designed to work together
- Turnkey configured to your needs:
  - sample rate
  - I/O and protocols
  - environmental
- Highest performance, vast range of I/O, scalable at any time
- Continuously prove and improve your next generation controls, DSP, vision, and plan designs with hardware

Speedgoat Products and Services

Mainstay Real-Time Target Machines and HIL simulators

Full size hardware-in-the-loop simulators, and desktop prototyping and HIL units

- Performance real-time target machine with Core i7 and Xeon CPUs and rack solutions
- Baseline real-time target machine

Rugged controls, DSP, and vision prototyping units for mobile and in-vehicle use

- Mobile real-time target machine
- Baseline real-time target machine

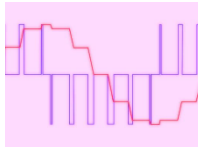
Speedgoat Products and Services

Vast range of over 200 I/O Modules

Analog
A/D D/A 16-24 bit

Digital
TTL, RS422, LVDS

Communications
CAN, UDP, PROFINET…



Digital
TTL, RS422, LVDS

Encoders
Resolvers

Relays
SPST, SPDT, DPST

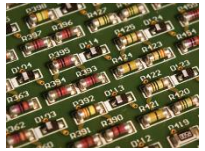
Included in delivery

- I/O module installed into Real-time target machine
- Simulink driver blocks and test models included
- Cable and terminal board
- Optional panels and boxes

Shared Memory
2.5 Gbps

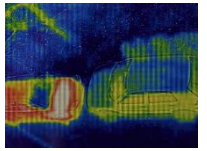
Fault Injection
MOSFET switch

Timing
GPS, IRIG, PTP



Resistors
High Precision

Temperature
Strain



Video
Camera Link, USB

Speedgoat Products and Services

I/O Connectivity Examples



Analog	A/D, D/A, simultaneous, low latency, high resolution, frame support, up to 5GHz
Digital	TTL, LVCMOS, LVDS, RS422, RS485, 24V, 48V, ..
Pulse Train	PWM generation and capture, interrupt, negation
Encoders	Absolute and incremental encoder measurement and simulation (quadrature and SSI), EnDAT 2.2, SSI2, SPI, and BiSS encoder measurement
Shared Memory	Shared and reflective memory
Fault Insertion	Electromechanical or solid state switches for fault insertion
Temperature	Thermocouple, RTD, and NTC measurement and simulation
Strain, Pressure	Strain gauges and pressure sensor measurement and simulation
Accelerometers	IEPE/ICP measurement
Resistors	Resistor, potentiometer, and reed-relay (SPDT, DPST, SPST) simulation

…

Speedgoat Products and Services

Protocols Examples

Multi-Industry

- Serial RS232, RS422, RS485
- Real-time UDP
  CAN / SAE J1939
- SPI Master and Slave
- I2C Master and Slave
- Shared/reflective memory
- IRIG with GPS
- Precision Time Protocol (PTP) 1588

Vision

- USB 3 UVC Vision
- GigE Vision
- CameraLink
- HDMI and SDI
- MIPI CSI-2

Industrial Automation

- Profinet
- Modbus/TCP
- Modbus RTU
- Profibus
- EtherCAT
- EtherNet/IP
- POWERLINK

IIOT and Robotics

- DDS
- OPC UA
- MQTT

- TSN
- …

Automotive

- XCP Master/Slave (CANape/INCA)
- CAN / SAE J1939
- LIN 2.1
- SENT
- FlexRay
- Cam and Crank
- Resolver measurement and emulation
- …

Aerospace

- ARINC 429
- ARINC 629
- ARINC 664P7/AFDX
- MIL-STD-1553
- Synchro, Resolver
- RVDT, LVDT
- SDLC, HDLC
- …

Speedgoat Products and Services

Examples for Hardware-in-the-Loop

Analog and digital
- Large portfolio of I/O modules available
- High-density connectors and high channel count
- Terminal boards and breakout panels

Encoder emulation
- Absolute / Incremental, hall sensors
- EnDat, BiSS
- Synchro/Resolver, LVDT/RVDT
- Cam / Crank

Emulation of passive components
- High precision resistors (thermocouples / RTD)
- Potentiometer
- Reed relays
- Strain gauges, pressure sensors

Fault insertion
- Wide range of channel counts and fault bus configurations
- Designed for safety critical applications

Battery simulation

Many Node with Protocols Simulators

Examples of rack scale HIL simulators

Example of a 128 protocol node simulator

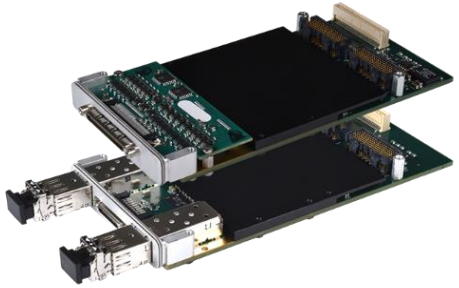
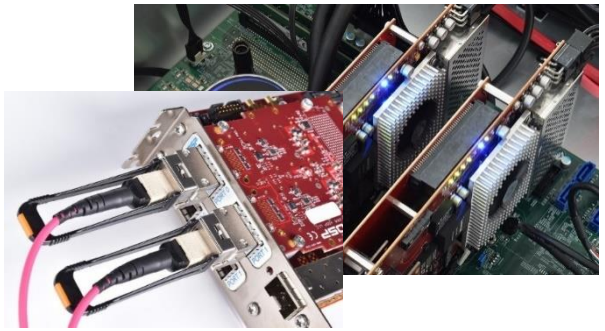
Profinet, EtherNet/IP, EtherCAT, Modbus, Powerlink, and more, plus a wide range of analog and digital I/O, to simulate complete ships, smart grids, wind farms, or train networks. 100+ interconnected units with thousands of nodes are feasible

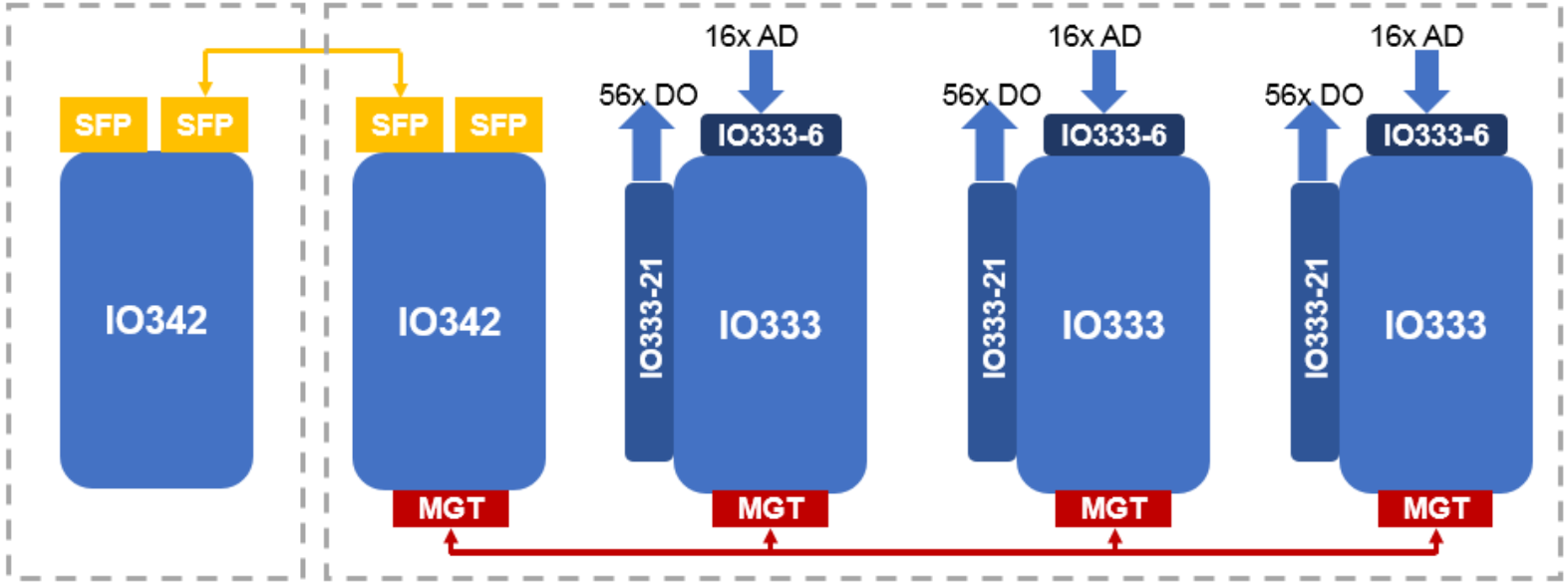
Speedgoat Products and Services

Simulink Programmable FPGA I/O modules



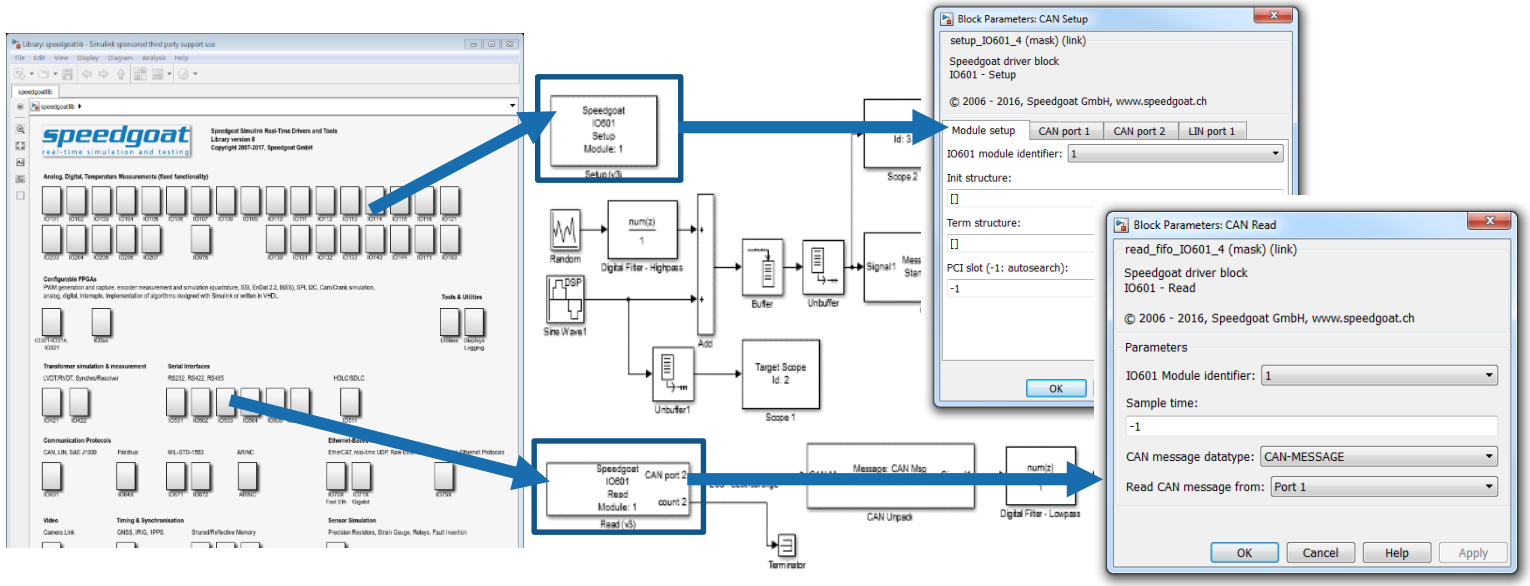
- Xilinx Artix, Kintex and Ultrascale, and Intel FPGAs
- With support for analog, digital (DIO, PWM, encoders, SPI, I2C, cam/crank, UART, ….) and vision I/O
- Very scalable: Many FPGA I/O modules can be interconnected with lowest latency links. Over 50 interconnected FPGAs with hundreds of I/O links are not a problem.
- Allows to achieve fastest closed-loop rates e.g. for motor and inverter controls, and fastest processing and data logging e.g. for high speed analog and digital vision processing applications



Speedgoat Products and Services

Fast-Track to Real-Time: Add Driver Blocks and Connect with Your Hardware

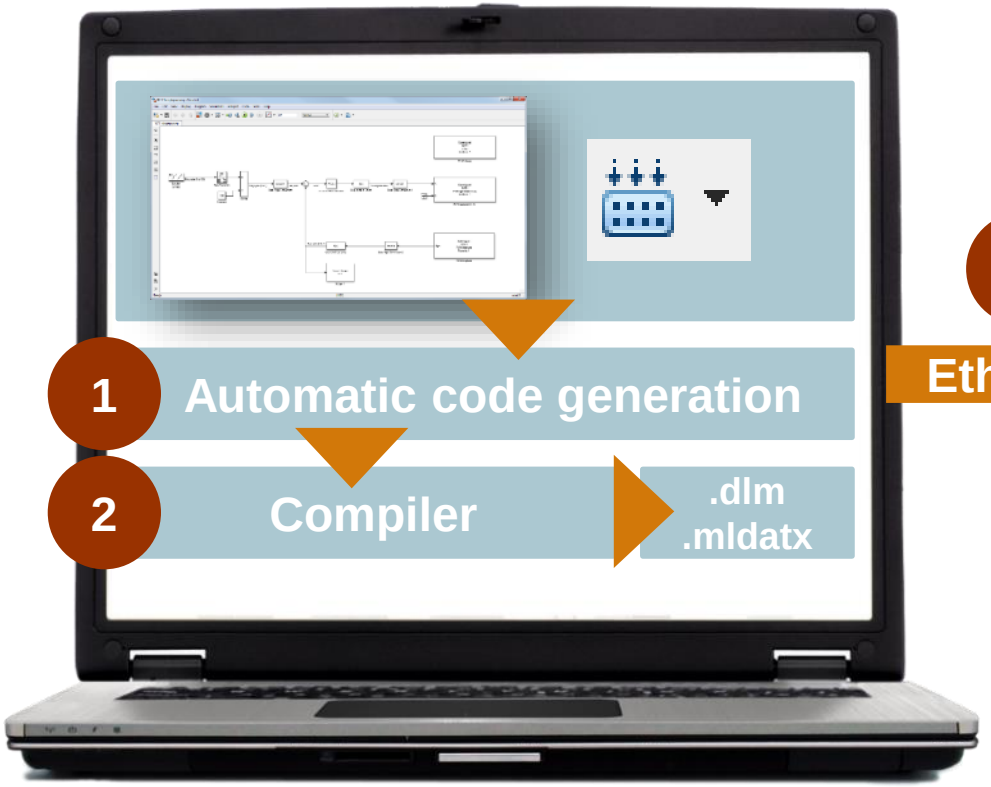


1. Drag, drop, and connect Speedgoat Simulink driver blocks to your model
2. Configure I/O settings in dialog fields
3. Connect your target computer with your hardware under test

Seamless Simulink Workflow

Automatically build, connect, and run real-time applications with your hardware

1. Automatic C or VHDL Code Generation
2. Compile and Synthesize
3. Download and Ready to Run

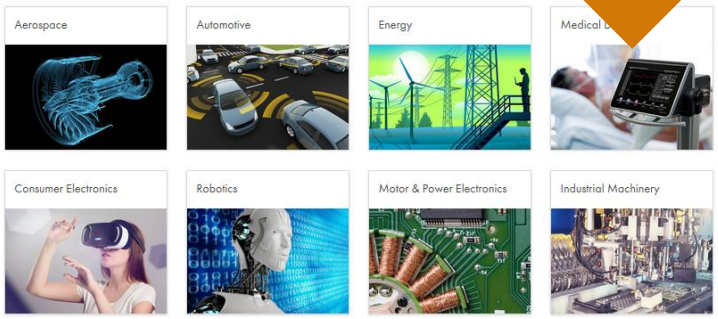


3

Ethernet

Target machine with multicore CPU, FPGAs, and I/O

I/O

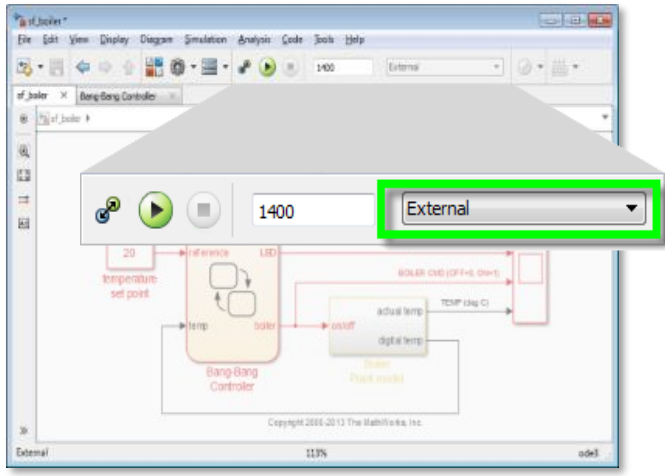


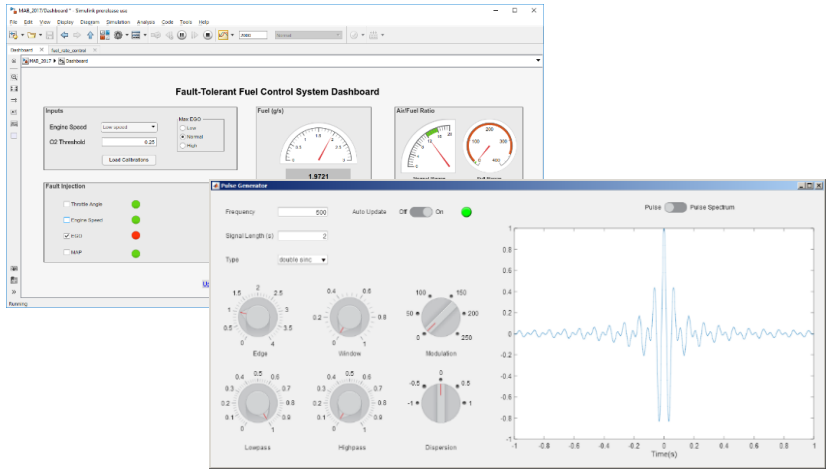
"The transition from model design to real-time was very fast thanks to the complete compatibility between MATLAB, Simulink, and Speedgoat solutions"
Piotr Dworakowski, DC/DC Power Converters team lead, Supergrid, France

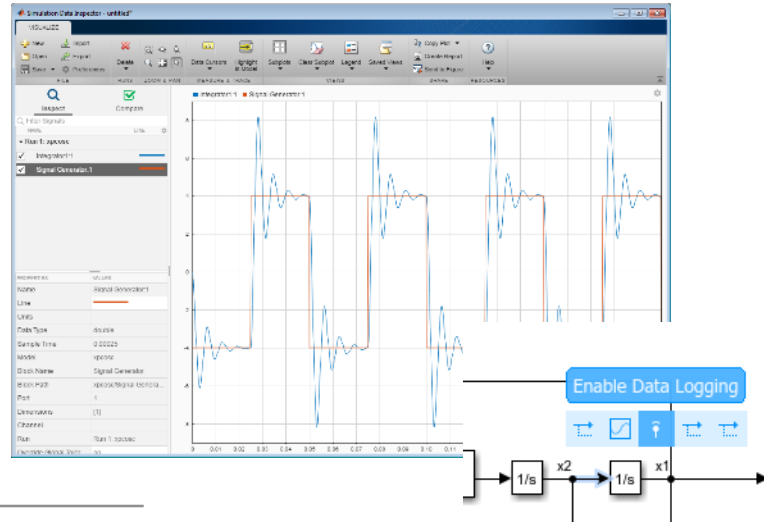
Seamless Simulink Workflow

Rapidly Prove your Designs and Try new Ideas, all from within Simulink

- Monitor and tune signal parameters with Simulink HMI blocks on the fly in real-time
- Live stream, monitor, and log signal data to Simulink Simulation Data Inspector, compare with desktop simulation results, and feedback results to your design





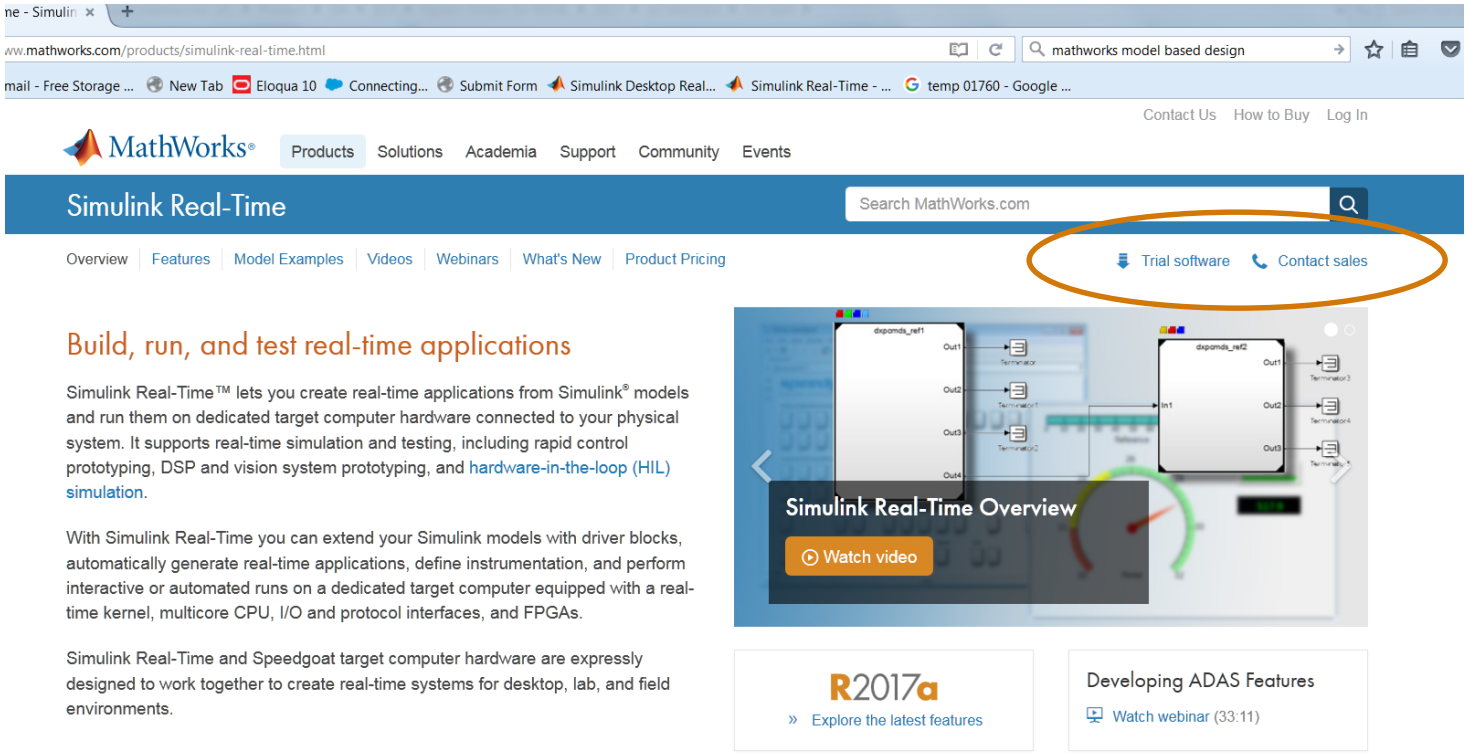


“The target machine works flawlessly with Simulink, providing me with powerful tools for prototyping and debugging.”

Jonathan Abir, School of Aerospace, Cranfield University, UK

How MathWorks and Speedgoat can help you build your Real-Time Simulation and Testing project ?

- Technical support
- Training
- Consulting services



Contact us by going to our website

https://www.mathworks.com/products/simulink-real-time.html

https://www.speedgoat.com/