MathWorks

전력전자학술대회 - MathWorks 산업기술세션

MathWorks Korea 온라인 설문조사

온라인 설문조사에 참여해주신 분들중

추첨을 통해 **커피 기프티콘**을 보내드립니다!

▶ QR 코드 스캔하여 설문 참여

https://forms.office.com/r/e8mXh8zaF8

▶ 설문 URL을 통해 설문 참여

Hardware-in-the-Loop Testing of Battery Management System with Speedgoat Real-time Target Machine

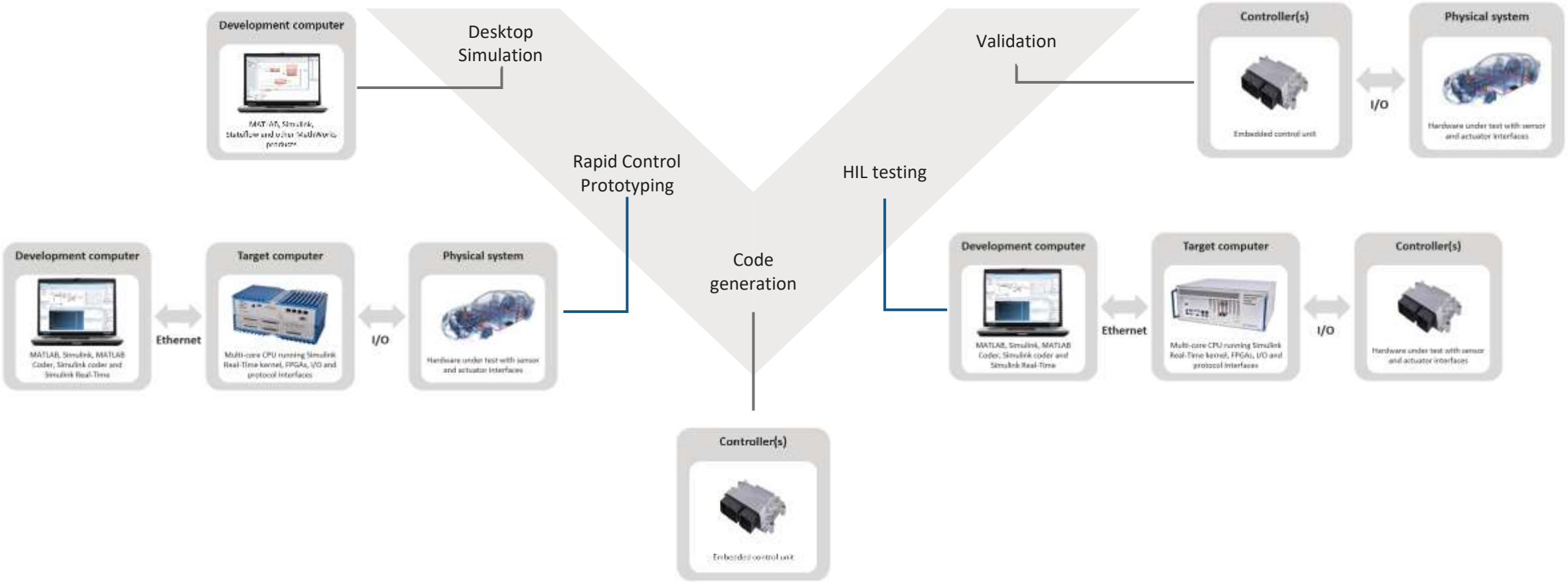
speedgoat
real-time simulation and testing

Innox
(주) 이노엑스

About Speedgoat

- MathWorks associate company, incorporated in 2006 by MathWorks employees in Switzerland, with subsidiaries in the USA, Germany and worldwide Distributors
- At MathWorks and Speedgoat people involved in developing real-time simulation and testing solutions continuously grew (currently 120)
- MathWorks and Speedgoat are collaborating at all levels
- Provider of real-time target computers, expressly designed for use with Simulink

Real-Time Testing Configurations

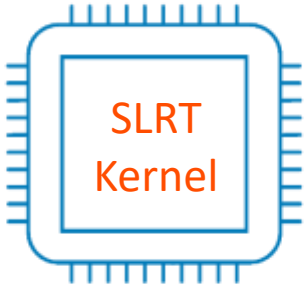


MathWorks: Simulink Real-Time (SLRT)

Two companies form a complete Solution

Speedgoat Real-time Target Machines

- RT - instrumentation
- Code Gen (C/VHDL)
- Toolboxes / Blocksets
- Simscape
- Simulink Test



- I/O-/protocol support
- FPGA-based solutions
- Speedgoat driver library
- Complete HIL-Rigs

Broad Range of Applications and Industries

Wherever Real-Time Electronic Controls is Applied

Industries	Applications
Aerospace/Space and Defense	Civil and military aircrafts, military vehicles, unmanned crafts, missiles, satellites, ships, submarines, space crafts and components, …
Automotive	Driverless and non driverless passenger and racing cars, trucks, off-highway vehicles, motorbikes, construction and agricultural machinery. Electric and combustion engines, inductive charging, …
Energy	Supergrids and microgrids, fusion reactors, linear colliders, solar inverters, wind turbines, alternative-fuel engines, …
Automation and controls	Motion control, power and energy systems, robotics, industrial control, sensors and actuator technology, building control, and process machinery
Medical devices	Medical devices such as eye laser surgery equipment, prosthesis and exoskeletons, hearing devices and implants, bio-medical process machinery, ...
Consumer Electronics	Smartphones and laptops including camera, audio, thermal, and battery technologies, augmented and virtual reality technologies, storage devices, printers, …
Academia	Verification and test of theoretical concepts, teaching of students, development of new technologies for commercial applications

User Stories and and Customers

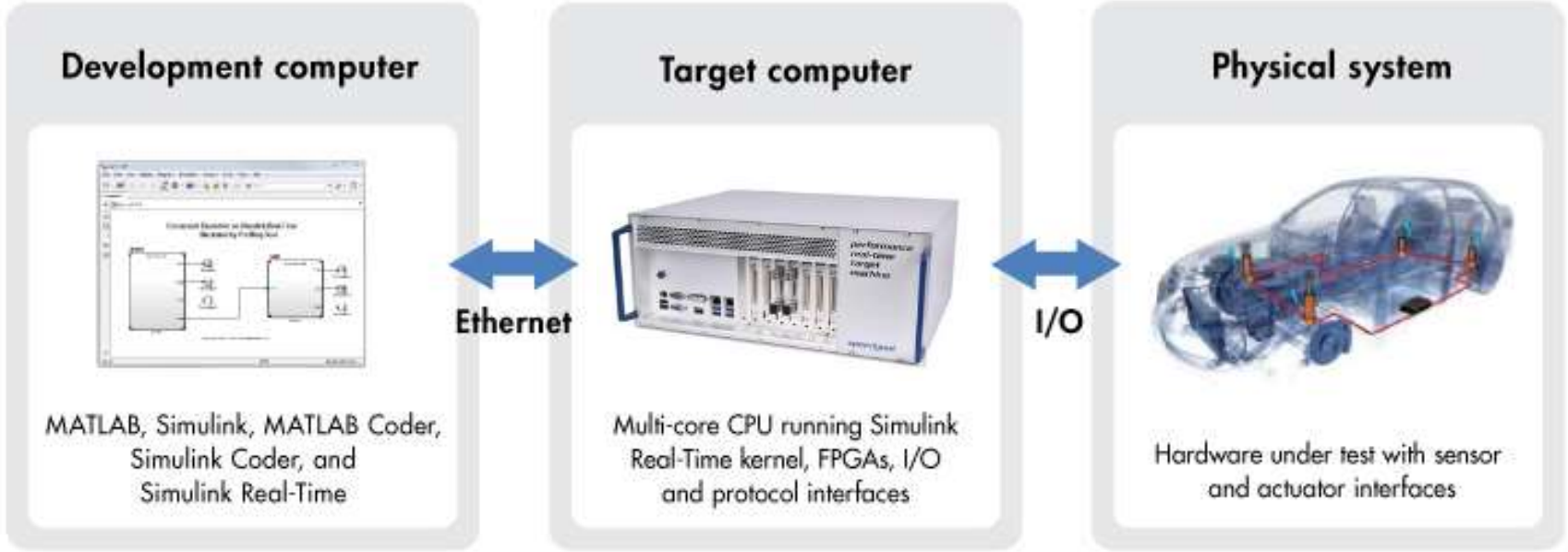
Find all the user stories here ->

Speedgoat User Stories

Simulink Real-Time User Stories

A Complete Solution for Desktop and Real-Time Simulation and Testing using Simulink

Real-time simulation and testing from within Simulink, with real-time hardware tailored to your needs

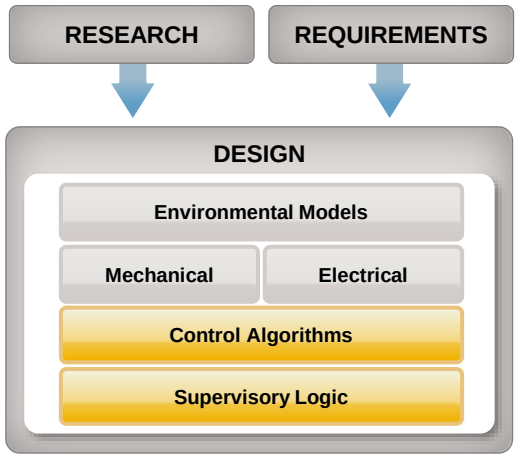


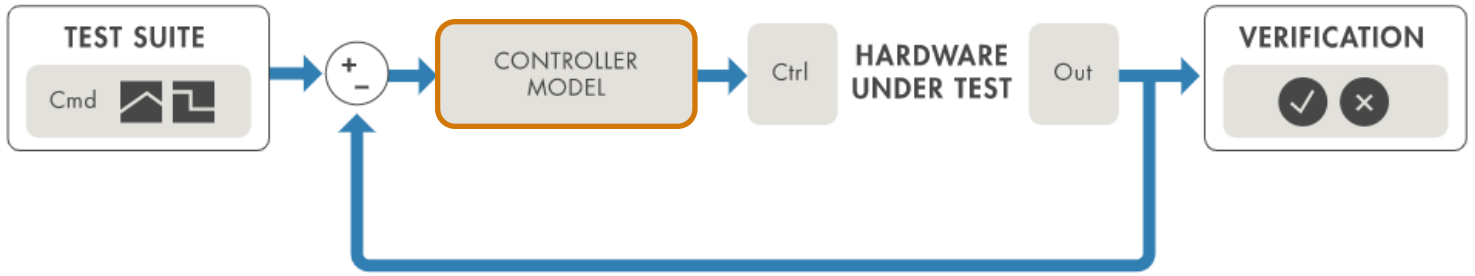
MathWorks | Speedgoat | Your Product

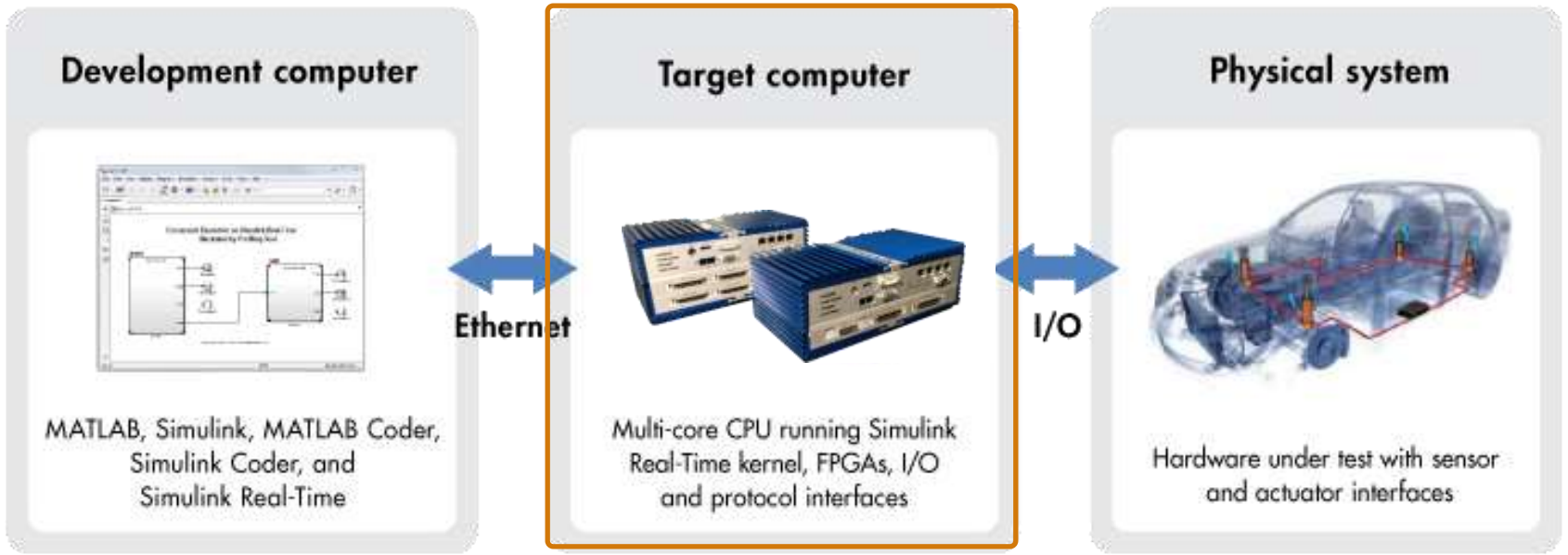
”…plug-and-play real-time platform for Simulink.”

Joaquin Reyes, Controls Engineer, Proterra Electric Buses, USA

Rapid Control Prototyping

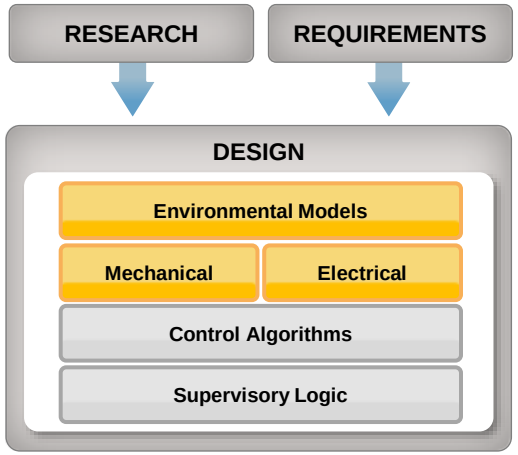


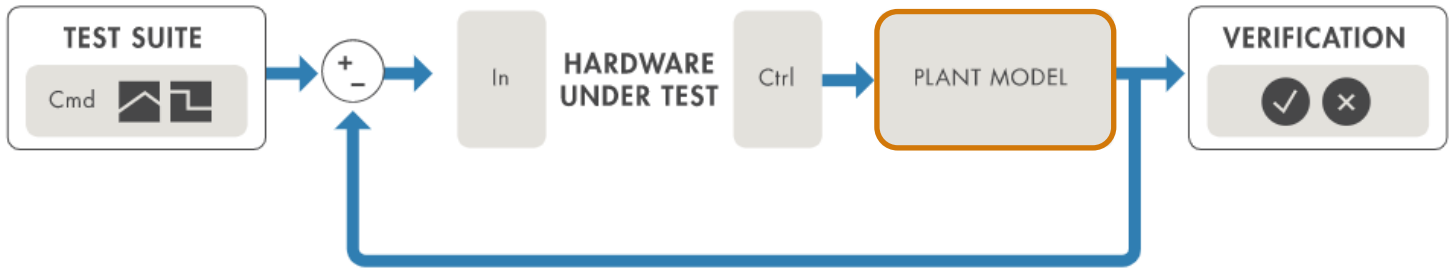


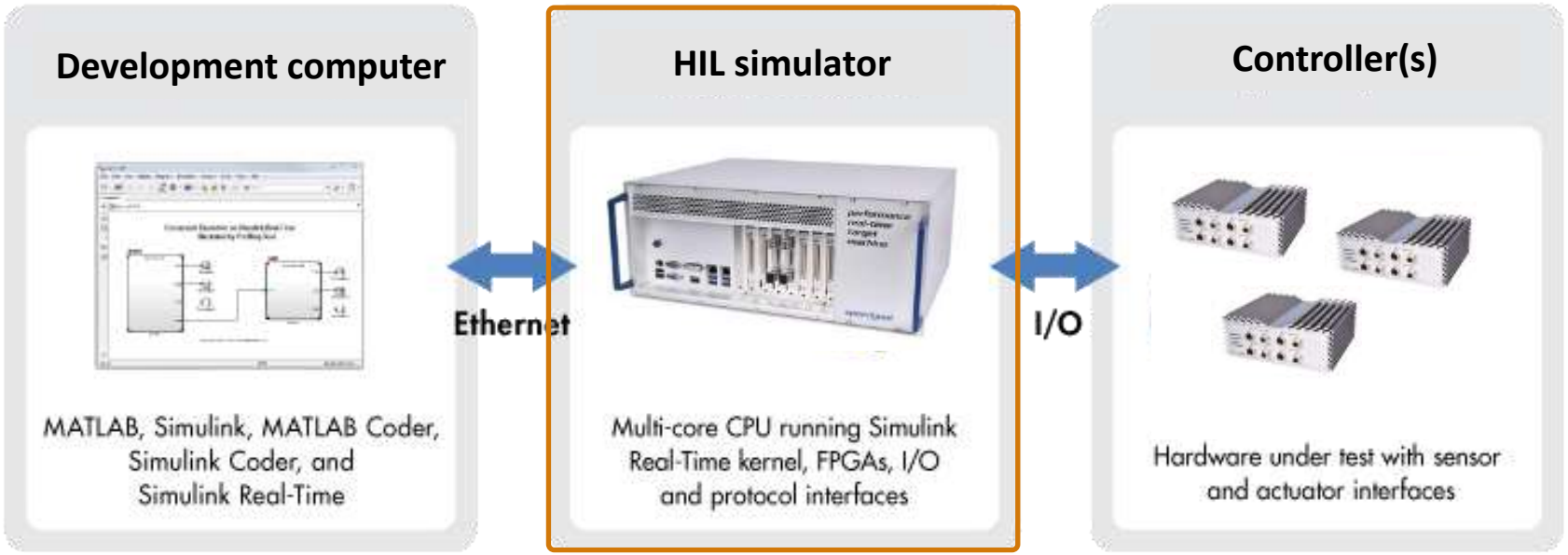


Real-time controls application auto-generated from Simulink

Hardware-in-the-Loop Simulation



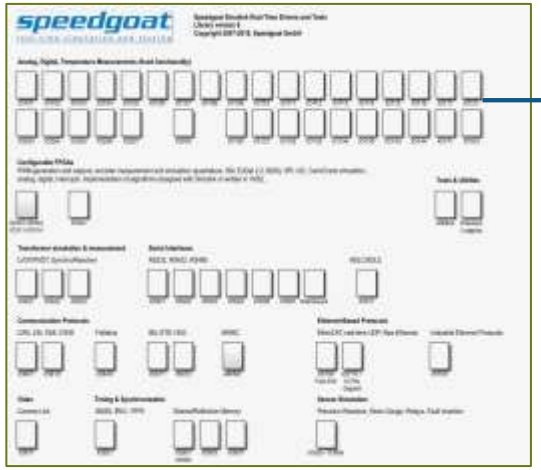


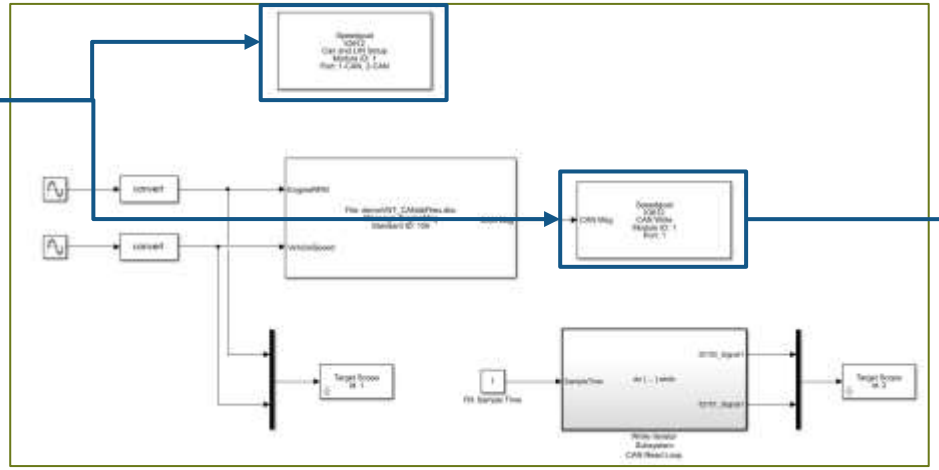


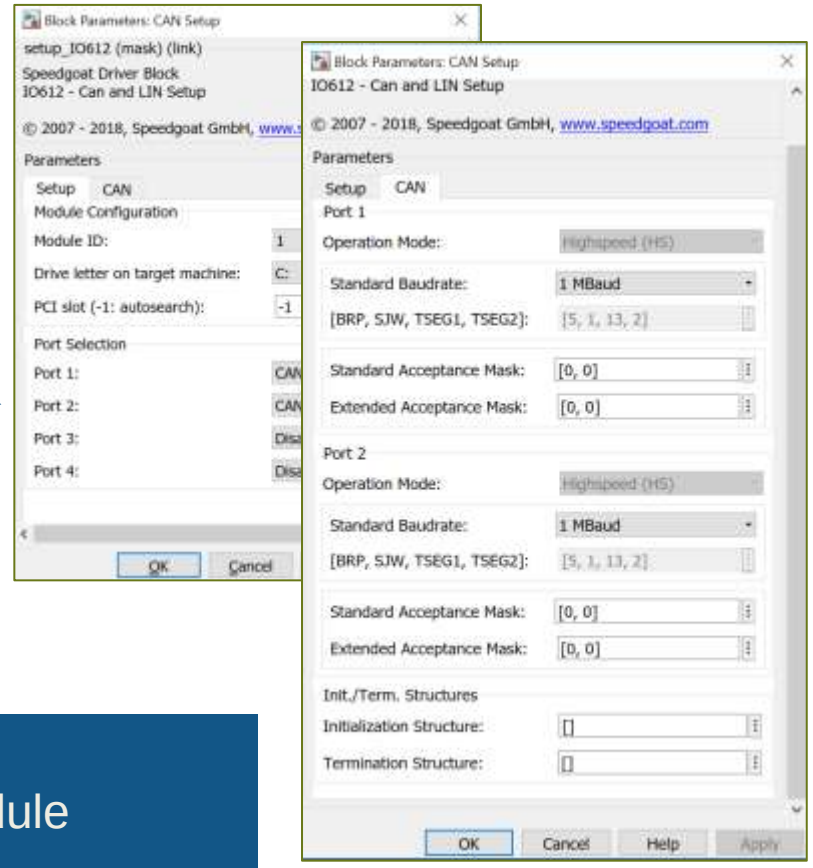
Plant simulation application autogenerated from Simulink

From Desktop to Real-Time Simulation and Testing

Add and Configure I/O and Protocols Blocks to a Simulink® Model





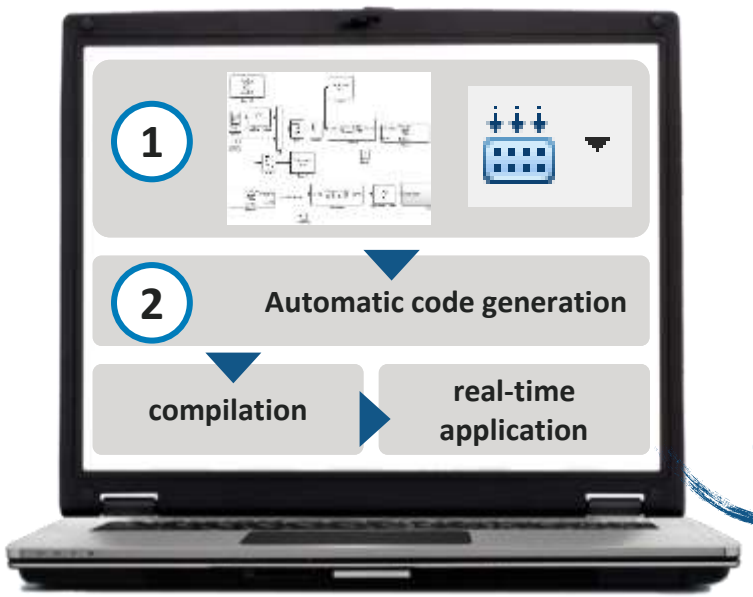


1. Drag and drop the Simulink® Speedgoat driver blocks for the I/O module installed in the target machine and into the Simulink® model
2. Connect driver blocks I/O ports to the Simulink® blocks
3. Configure the I/O and protocol settings in the dialog fields of the driver blocks

From Desktop to Real-Time Simulation and Testing

Automatically Create Your Real-Time Application from Simulink®

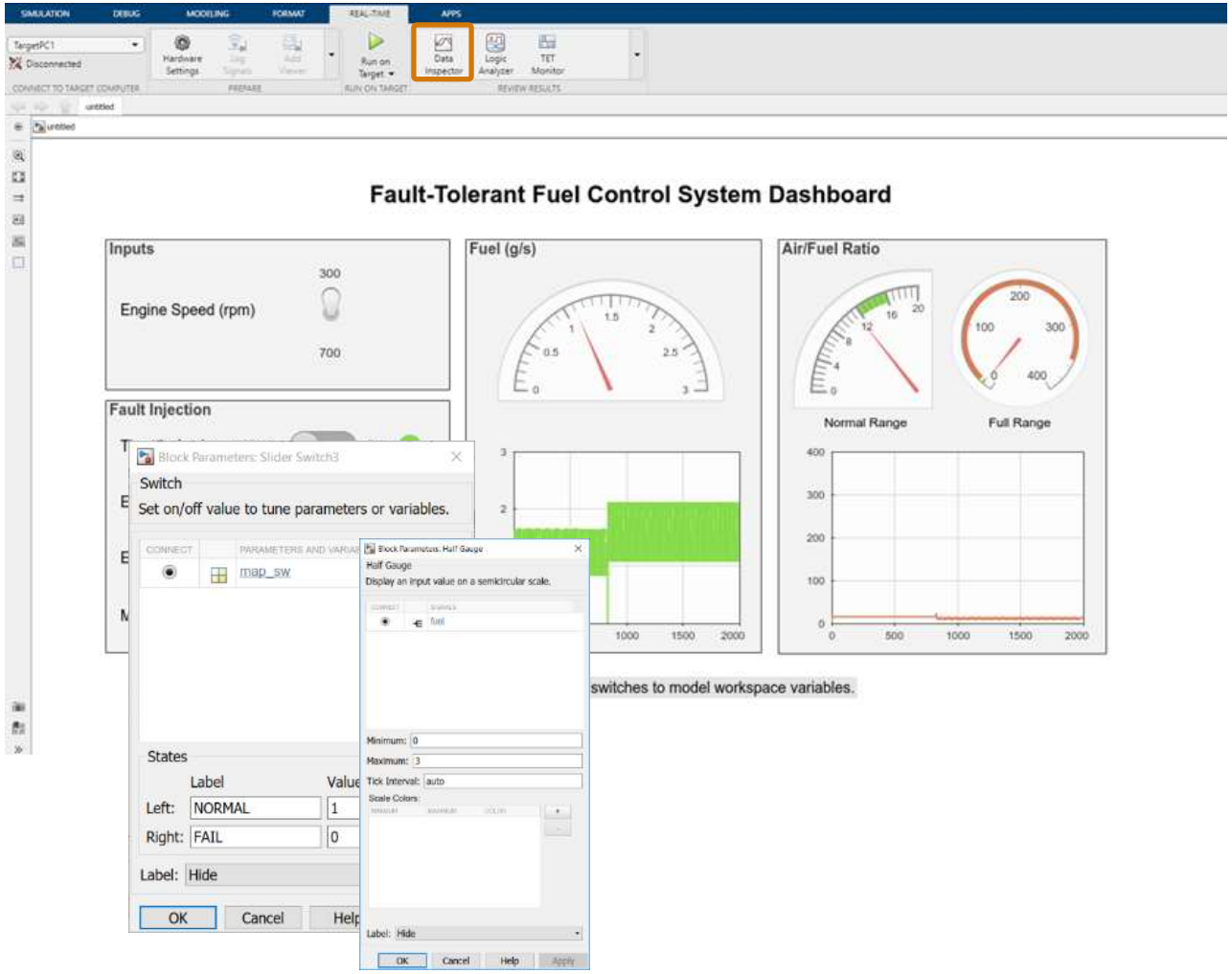
1. Add Simulink® Speedgoat I/O driver blocks
2. Automatic C and VHDL code generation and compilation
3. Automated target transfer, ready to run

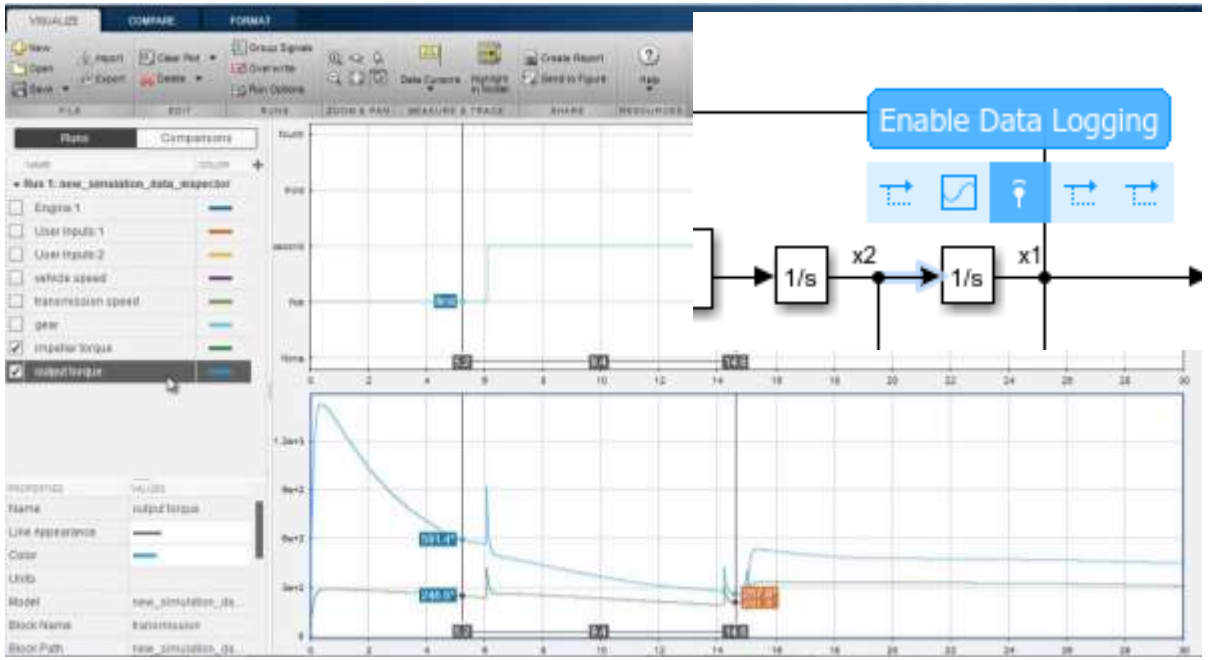


Target machine with multicore CPU, FPGAs and I/O

Fast-Track from Desktop to Real-Time Simulation and Testing

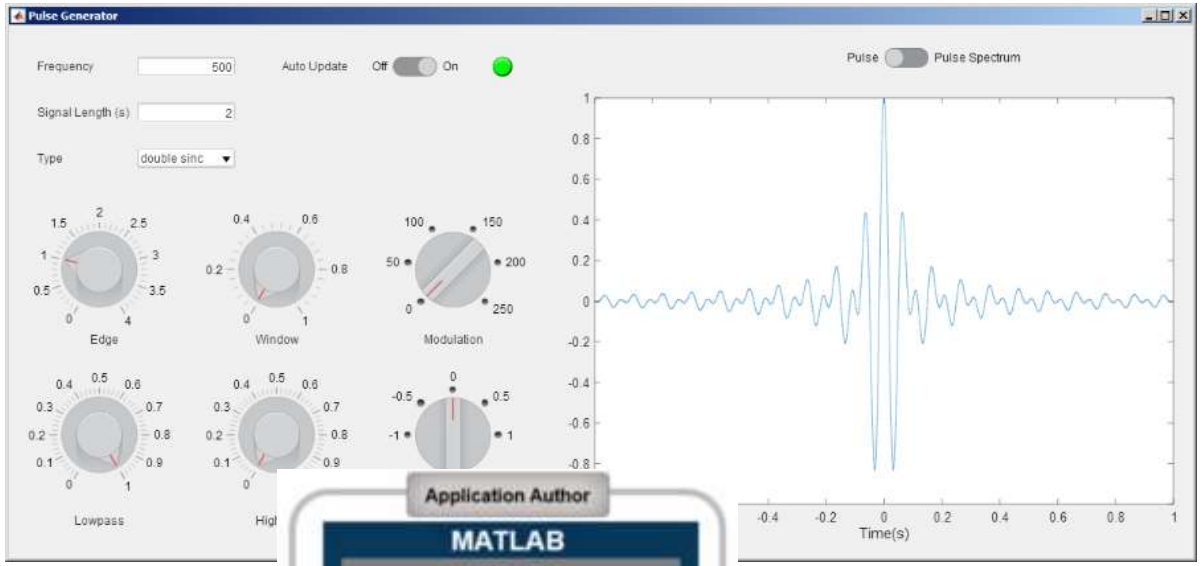
Real-time tune parameters, monitor signals and data logging

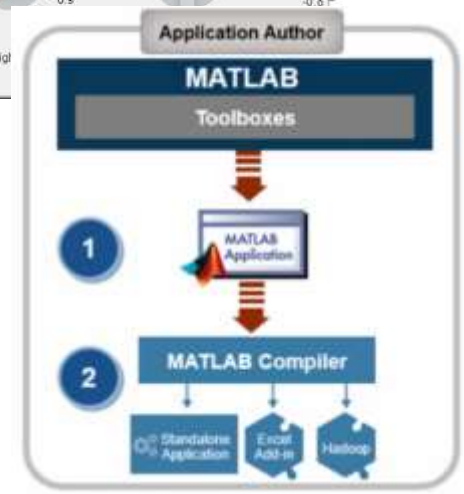


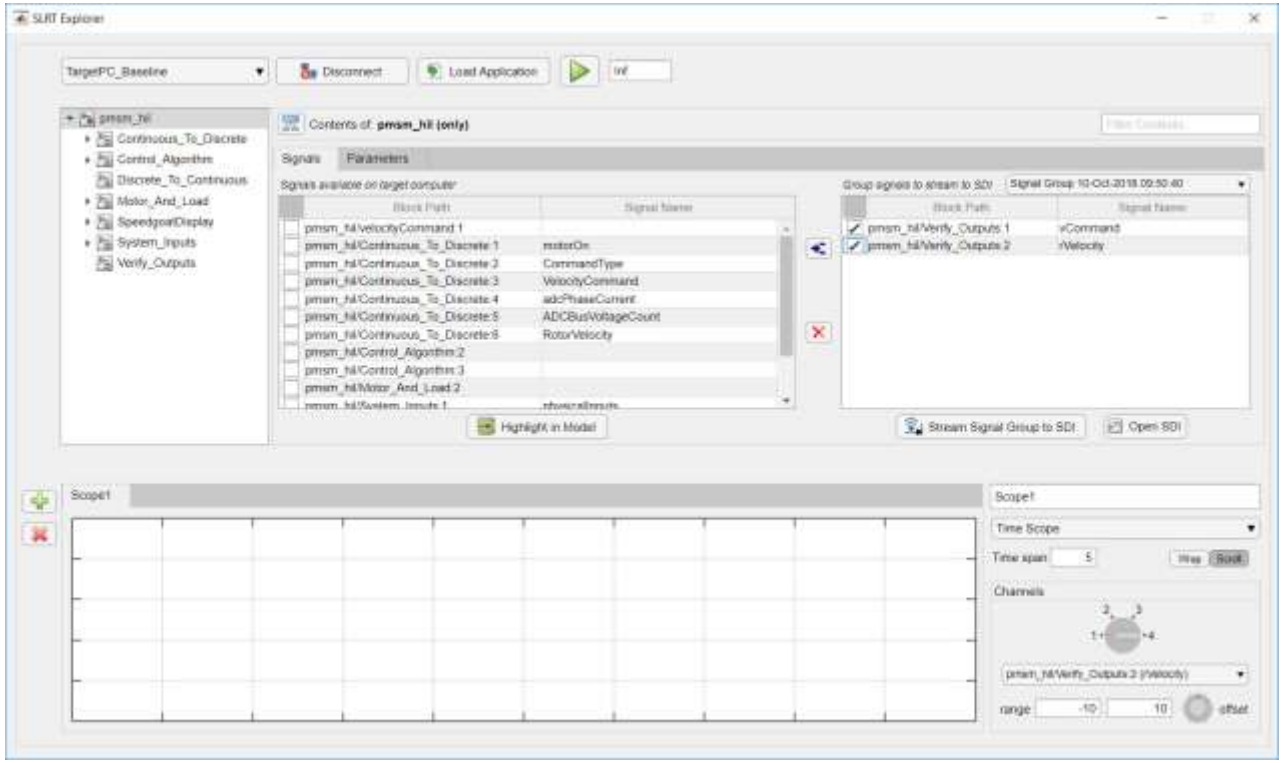


Real-Time Simulation and Testing
Instrument and Monitor Your Real-Time Application

Using standalone Windows GUIs with royalty free application distribution



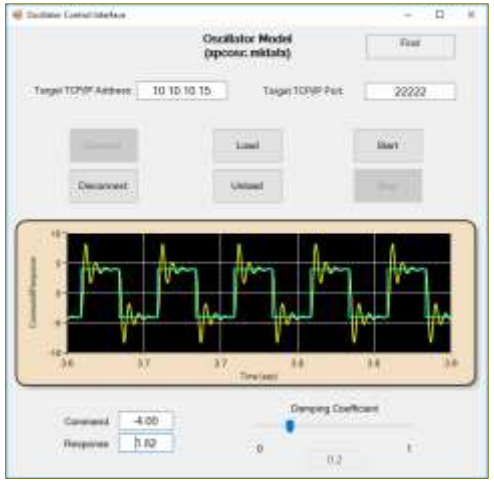


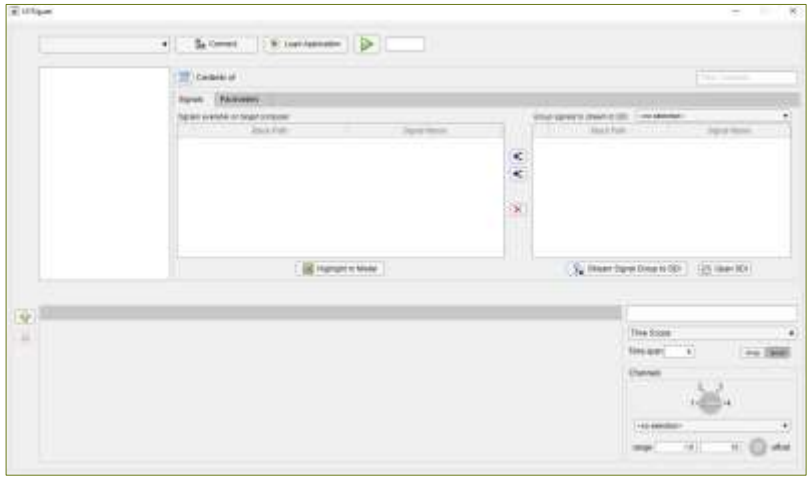


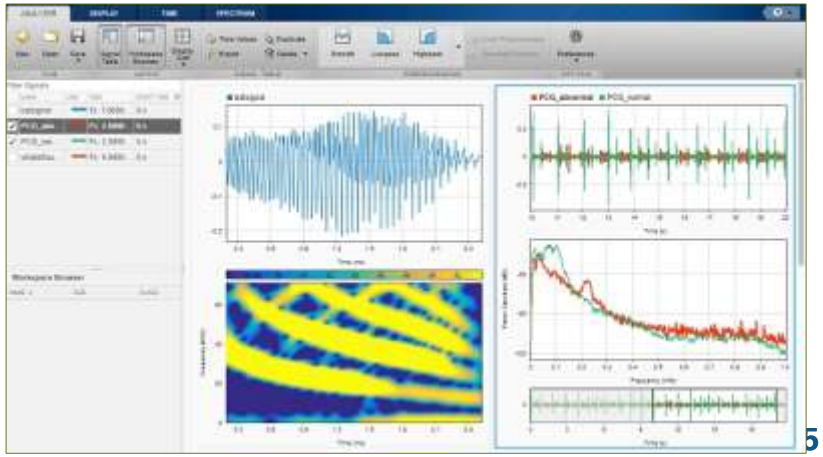
MATLAB App Designer
(standalone supported with MATLAB Compiler)

From Desktop to Real-Time Simulation and Testing

Extendable, Integrated and Interactive



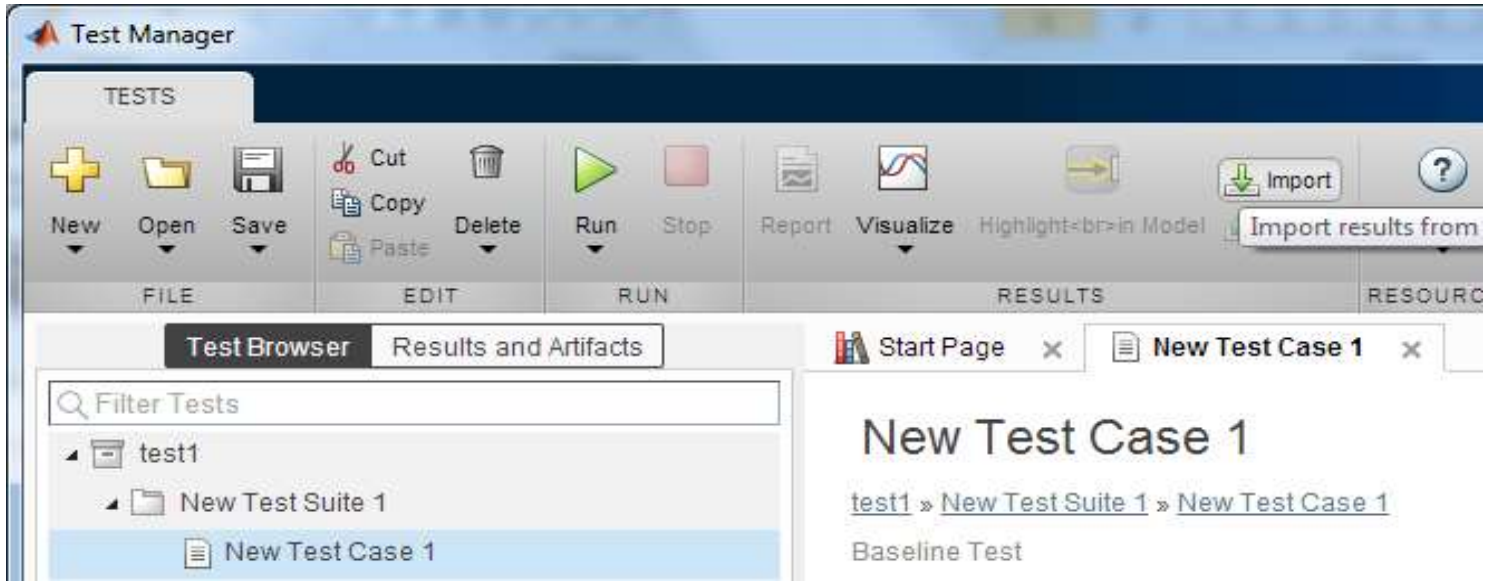


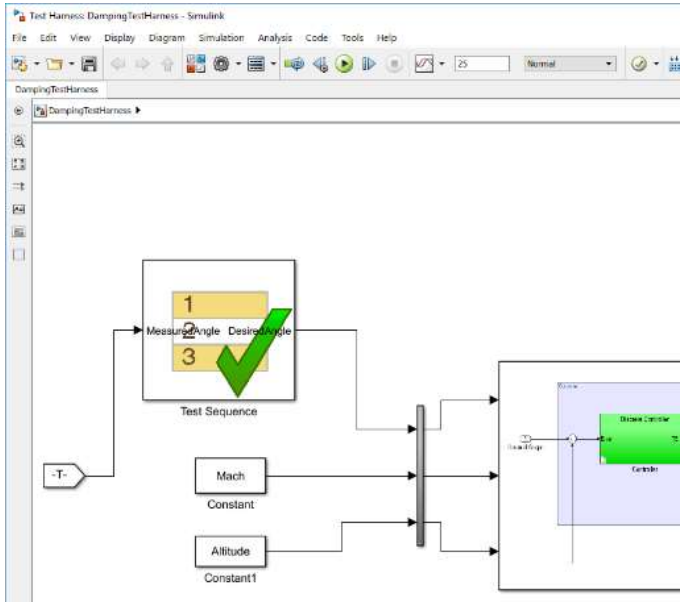


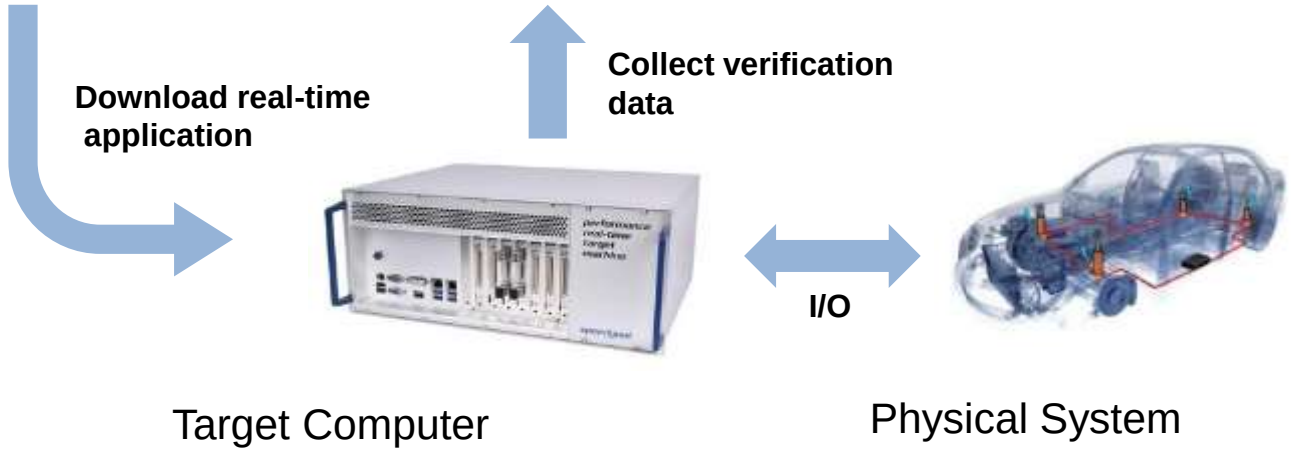
- Extensibility with other MathWorks products and third-party tools
- User interfaces for enhanced usability and standalone operation
- Data logging for offline analysis in MATLAB®

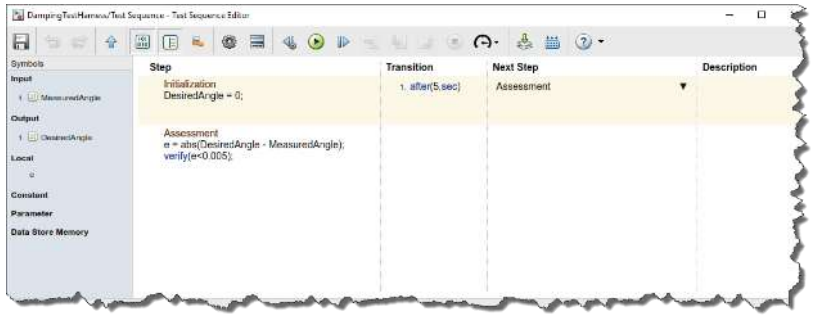
Automated Testing with Simulink Test

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









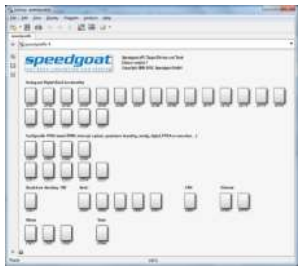
Real-time target machines, I/O, and protocols

Speedgoat Products and Services

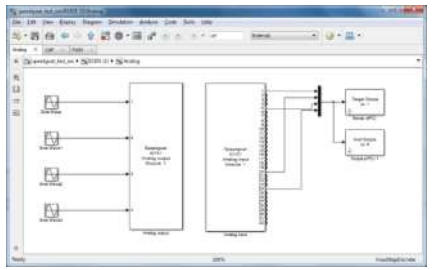
Made for Simulink, Tailored to Your Needs

Real-time target machine

I/O modules installed in target machine



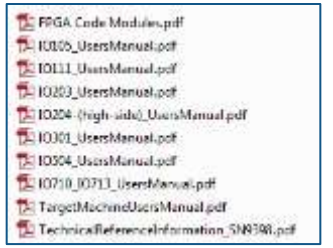
Simulink driver blocks



Simulink test models

I/O cables

Terminal boards



Documentation

Support, Training, Consulting, and Warranty Services

- Real-time target machines for office, lab, and field use
- 150+ commercial off-the shelf I/O modules
- Each target machine is configured to meet your sample rate, I/O, and environmental requirements
- Simulink Real-Time is expressly and exclusively designed to work together with Speedgoat hardware
- Most current MATLAB release always supported

Performance real-time target machine

Built for High Performance and Scalable

- Latest Intel CPUs with up to 8 cores
- Concurrent multicore CPU and FPGA real-time application execution
- Up to 50 I/O modules installable leveraging additional expansion chassis
- Built for Hardware-in-the-Loop testing and Rapid Control Prototyping
- Ideal for both, rack installation and desk use

Mobile real-time target machine

High Performance with Compact Form Factor

- Ideal for mobile and in-vehicle use
- Intel Core i7 2.5 GHz dual core CPU and FPGAs
- Rugged and fanless, extended temperature support
- Stackable: Up to 14 I/O modules supported
- With or without enclosure (openframe)
- 12+ years life cycle

Baseline real-time target machine

Compact and rugged yet Performant

- Ideal platform for applications requiring few channels, but a diverse set of I/O
- Intel Celeron 2.0 Quad Core CPU and optional FPGAs
- Over 100 compact miniPCIe, PMC, and XMC form factor modules supported
- For desk, field, and in-vehicle use
- Rugged compact design with extended temperature support
- Available with expandable enclosure and openframe

Unit real-time target machine

Small-scale Rapid Control Prototyping

- Intel® Atom® quad-core 1.6 GHz CPU
- For desk, field, and in-vehicle use
- Rugged compact design with extended temperature support
- Available with expandable enclosure and openframe
- Dimensions: H 60 mm x W 140 mm x D 100 mm

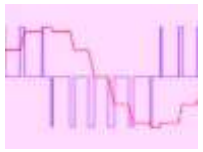
I/O Connectivity and Protocols Support

Vast range of I/O and protocols supported by over 200 I/O modules

Analog
A/D D/A 16-24 bit

Digital
TTL, RS422, LVDS

Communications
CAN, UDP, PROFINET…



Pulstrain/FPGA
PWM/Cap

Encoders
QAE, QAD, BiSS, SSI...

Battery Management
emulation and simulation

Temperature & Strain
thermal sensors & strain gauges

Resistors
High Precision

Fault Injection
MOSFET switch

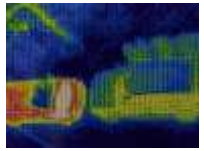
Audio & Speech
High performance analog modules

Relays
SPST, SPDT, DPST

LVDS/RVDT/ Synchro/Resolver
Measure and simulate

Vibration
IEPE/ICP

Shared Memory
2.5 Gbps



Video
Camera Link, USB

Timing
GPS, IRIG, PTP

Buses and Networks

Automotive

- CAN, CAN FD
- LIN
- FlexRay
- XCP, SAE J1939
- SENT
- PSI5
- Automotive Ethernet w/ SOME/IP

Aerospace

- ARINC (429,629,825)
- AFDX (ARINC 664 P7)
- SDLC/HDLC
- MIL STD 1553
- DShot

Automation

- Modbus (TCP, RTU)
- EtherCAT
- PROFIBUS
- PROFINET
- POWERLINK
- Ethernet/IP
- CANOpen

Energy

- DNP3
- IEC61850
- Modbus (TCP, RTU)

Railway

- MVB
- WTB

Multi-Industry

- UDP
- TCP/IP
- SPI, SSI
- I2C
- PTP
- Aurora

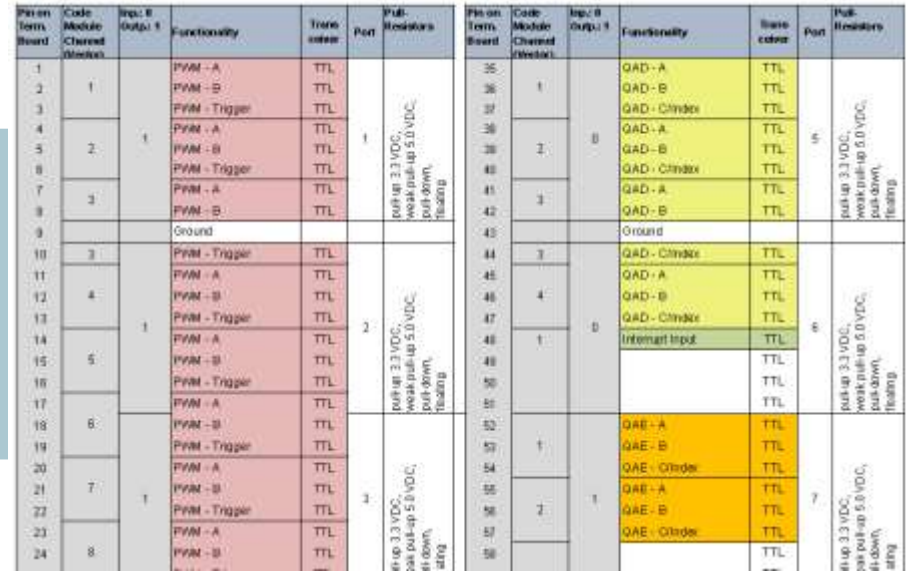
I/O Connectivity and Protocols Support

Two types of FPGA I/O modules

1. Configurable FPGA I/O Modules

- Cost effective hardware configurations
- Selectable configuration files with support for I/O requiring fast frequency support:
  - PWM generation and capture
  - Incremental and absolute encoders
  - SPI and I2C protocol support
  - …

For closed-loop sample rates below 20kHz

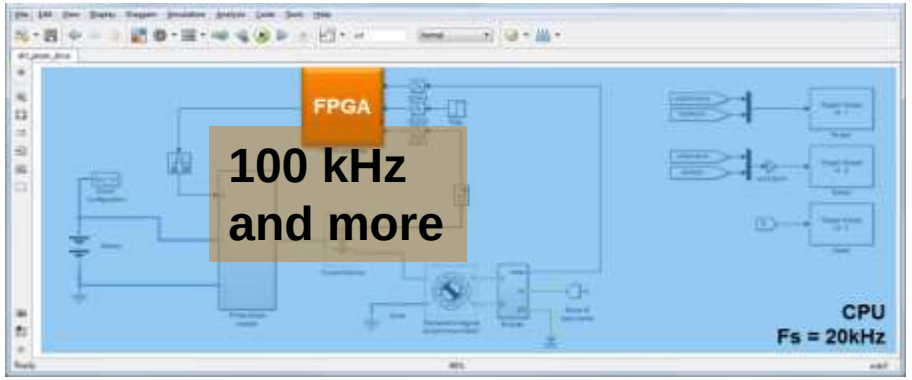


2. Simulink Programmable FPGA I/O Modules

- Large Kintex and Kintex Ultrascale FPGAs with fast analog, digital, and fiber optic I/O
- Implement Simulink designs using automatic VHDL code generation with HDL Coder
- To achieve fastest closed-loop rates

For closed-loop sample rates above 20kHz

100kHz and more

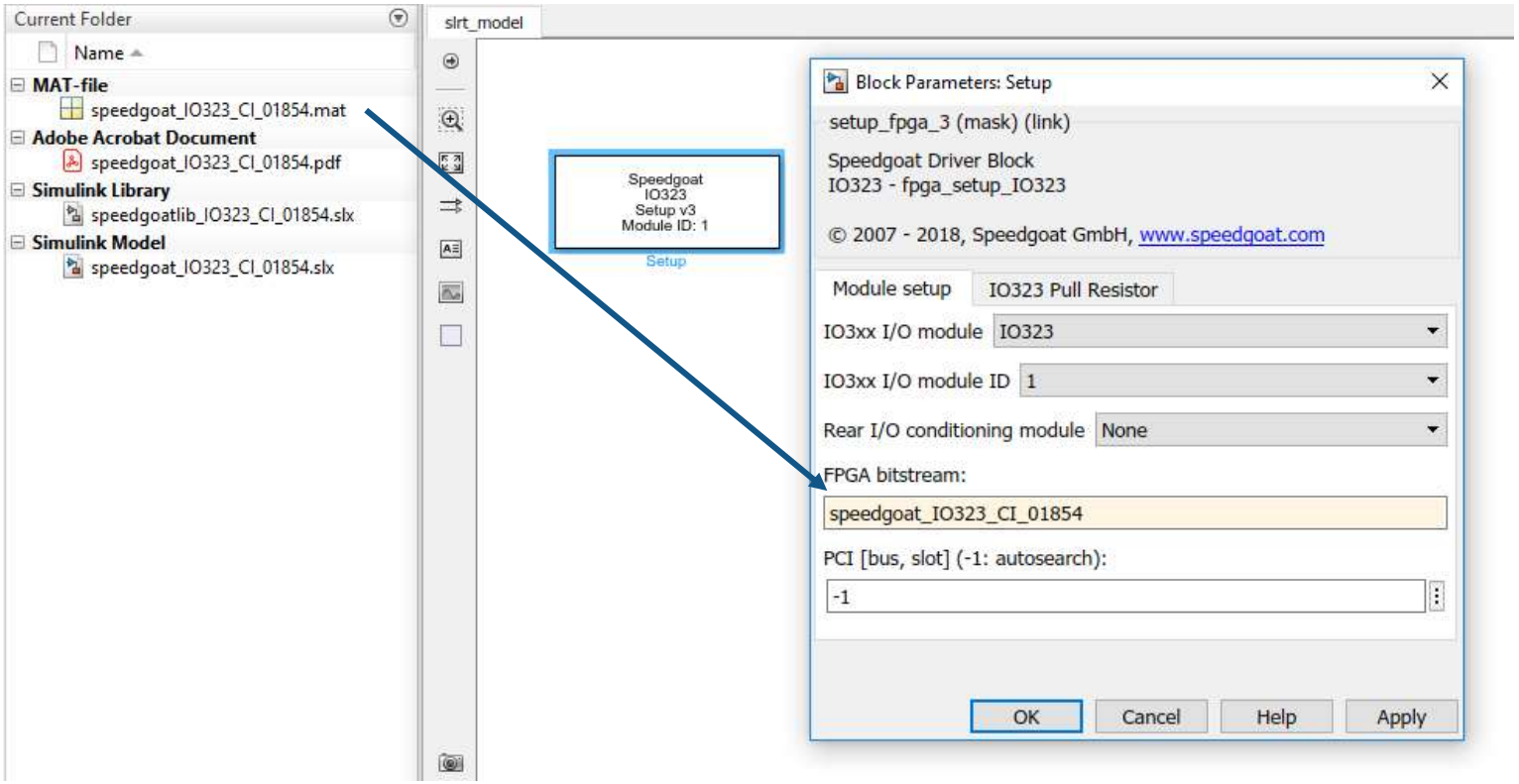


Configurable FPGA workflow

- The FPGA-based I/O module is configured by using a bitstream file provided by Speedgoat
- The available functionality and pin mapping is defined by the FPGA bitstream
- Users may have multiple FPGA bitstreams that can be used in different models depending on their application
- The Custom Implementation package includes:
  - FPGA bitstream
  - Documentation and pin mapping
  - Test model (example)
  - Simulink library

Configurable FPGA workflow

- Select the FPGA bitstream in the IO3xx Setup block
- The FPGA bitstream defines the pin mapping

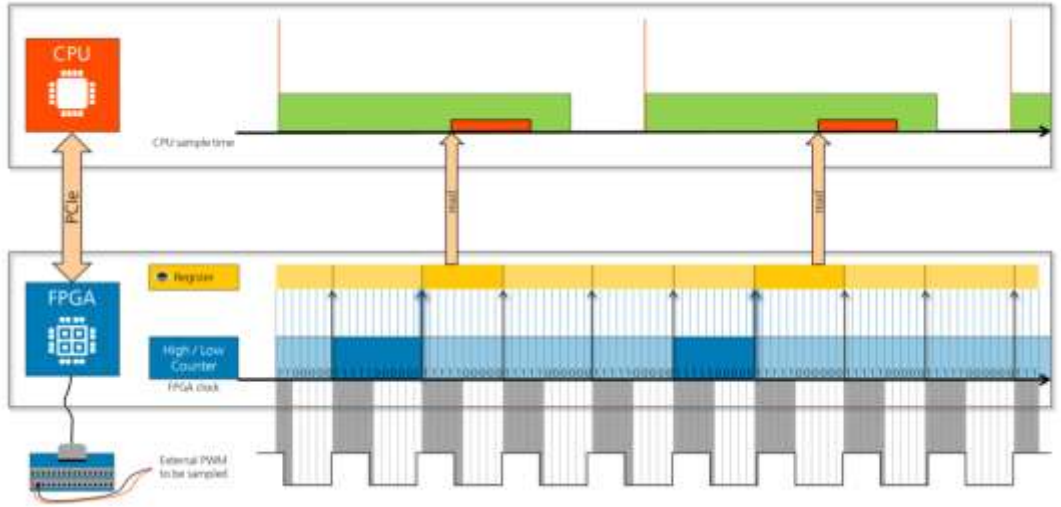


Pin	Code Module Channel	Functionality	Direction	Transceiver
1	1	PWM - A	OUT	TTL
2		PWM - B		TTL
3		PWM - Trigger		TTL
4	2	PWM - A	OUT	TTL
5		PWM - B		TTL
6		PWM - Trigger		TTL
7	3	PWM - A	OUT	TTL
8		PWM - B		TTL
9		PWM - Trigger		TTL
10	4	PWM - A	OUT	TTL
11		PWM - B		TTL
12		PWM - Trigger		TTL
13	1	CAP	IN	TTL
14		CAP -Trigger		TTL
15	2	CAP	IN	TTL
16		CAP -Trigger		TTL
17	3	CAP	IN	TTL
18		CAP -Trigger		TTL
19	4	CAP	IN	TTL
20		CAP -Trigger		TTL
21	1	SPI - CLK	IN/OUT	TTL
22		SPI - CS	IN/OUT	TTL
23		SPI - SDO	OUT	TTL
24		SPI - SDI	IN	TTL
25		Ground		

Configurable FPGA workflow

Summary

- The functionality is defined by the FPGA bitstream
- Very cost efficient HW and SW solution - New Custom Implementations can be ordered (lead time: 1-3 weeks)
- The Code Modules on the FPGA run at a faster rate and can generate or acquire signals with a higher frequency than the model sample time



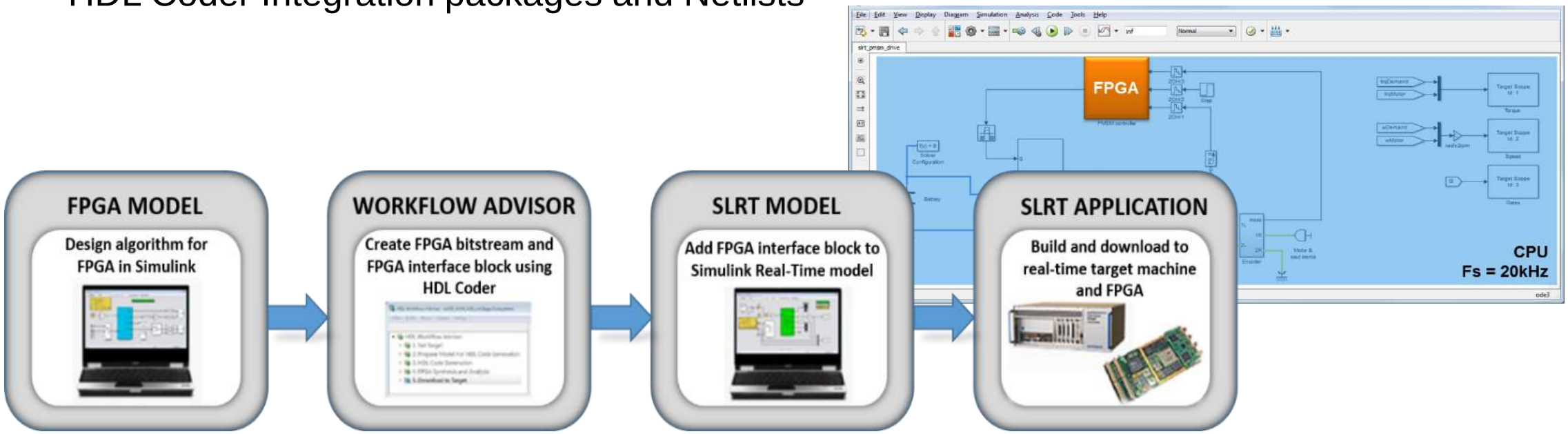
Programmable FPGA workflow

- The FPGA-based I/O module can be programmed by the end user
- The pin mapping is defined by the end user
- Algorithms can be implemented by using HDL Coder
- The HDL Coder Integration Package provides access to the hardware resources of the I/O module, such as analog and digital I/O pins, data transfer and buffers, etc.

Simulink Programmable FPGA I/O modules

Run Simulink designs at fastest closed-loop rates with automated VHDL code generation

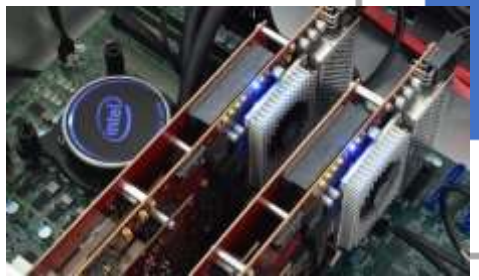
- Achieve closed-loop sample rates up to several MHz
- Immediate access to all I/O from within Simulink using HDL Coder Workflow Advisor
- Concurrently run real-time application designs in Simulink on FPGA(s) and multi-core CPU at different rates
- HDL Coder Integration packages and Netlists

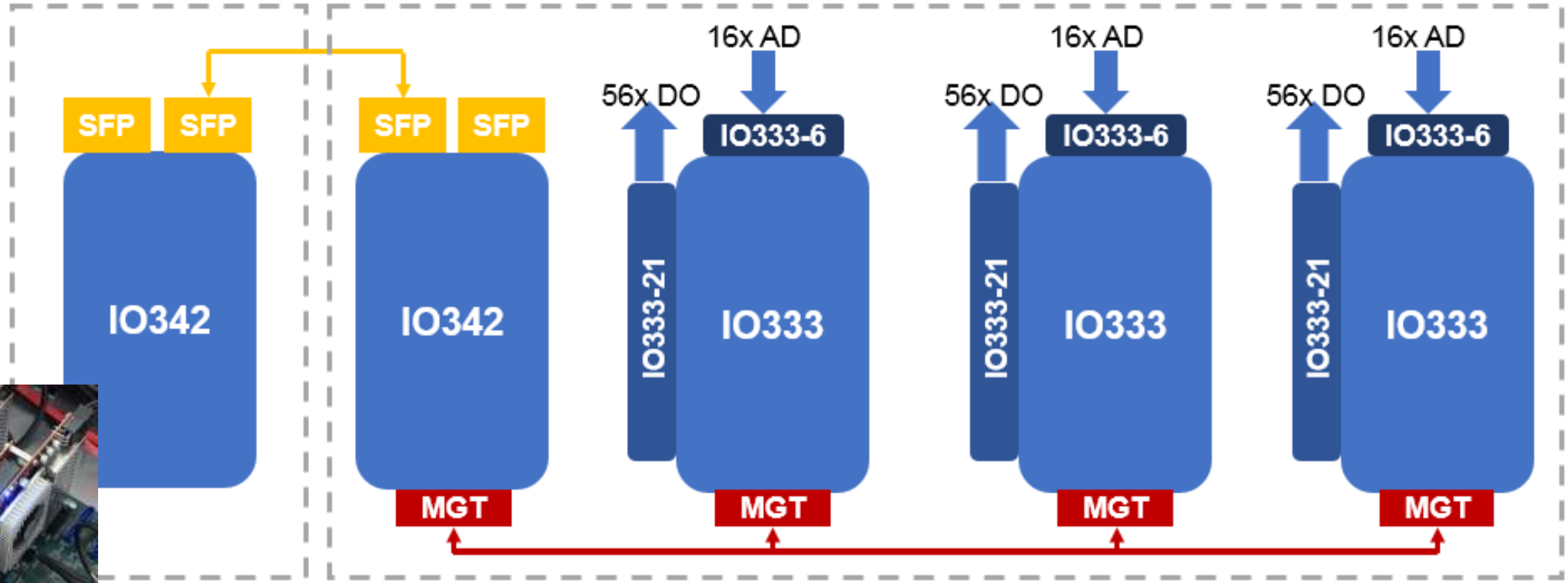


Simulink Programmable FPGA I/O modules

Interconnect many FPGA I/O modules with lowest latency link

- **Connect multiple F**lowest-latency inter-FPGA communication links and high throughput Aurora protocol using fiber optic **PGA I/O modules** with cabling
- Allows to achieve **fastest closed-loop rates** even in cases where hundres of analog and digital I/O lines, provided by multiple distributed target computers ar required

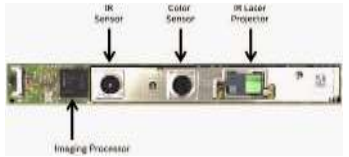




Simulink Programmable FPGA Prototyping Application

Examples

- **Controls: Plasma Control System for Fusion Reactor**
  32 inter-connected FPGAs with a total of 12.5 Mio logic cells, 700 analog I/O, and 74 high speed low latency fiber optic links exchanging data at 3.125 Gsps (231 Gsps aggregated)



- **Vision and Laser Controls: 3D Depth Sensing Camera for Augmented Reality**
  4 inter-connected FPGAs, fast analog I/O at 125 MHz, and digital I/O

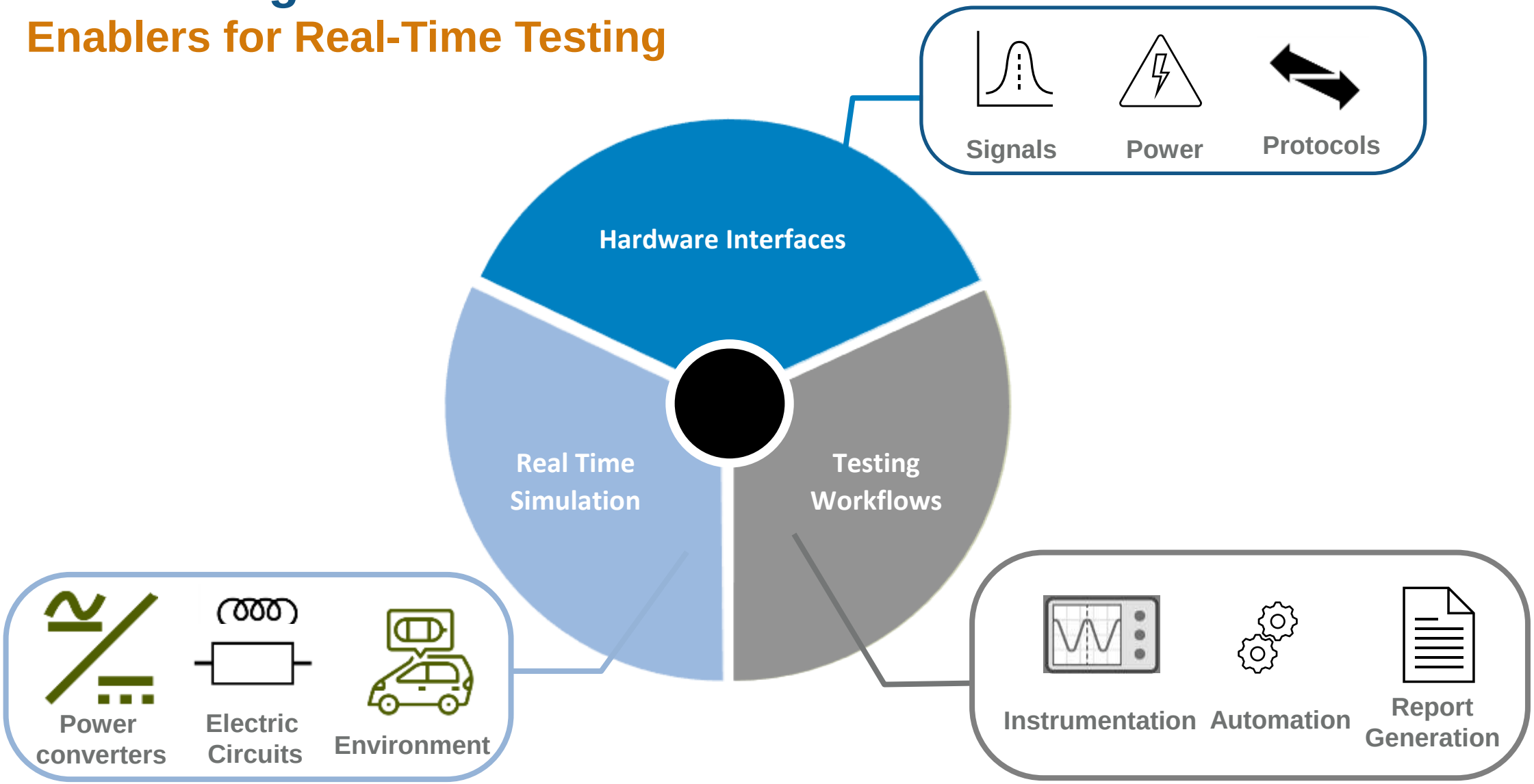
- **Very Fast Signal Acquisition and Generation: Vision Radar Development**
  2 x inter-connected Ultrascale FPGAs, and very fast analog AD/DA at up to 5 Gsps DMA transfer support for data logging to FPGA external RAM, x86 RAM drive, and for x86/FPGA lowest-latency data exchange using interrupt free polling mode

- **Very Fast Analog Signal Acquisition: Development of New Lidar (Light Imaging, Detection, and Ranging) Technologies for Autonomous Cars**
  Ultrascale FPGA with analog I/O up to 5 Gsps

Hardware-in-the-Loop Testing for Power Electronics

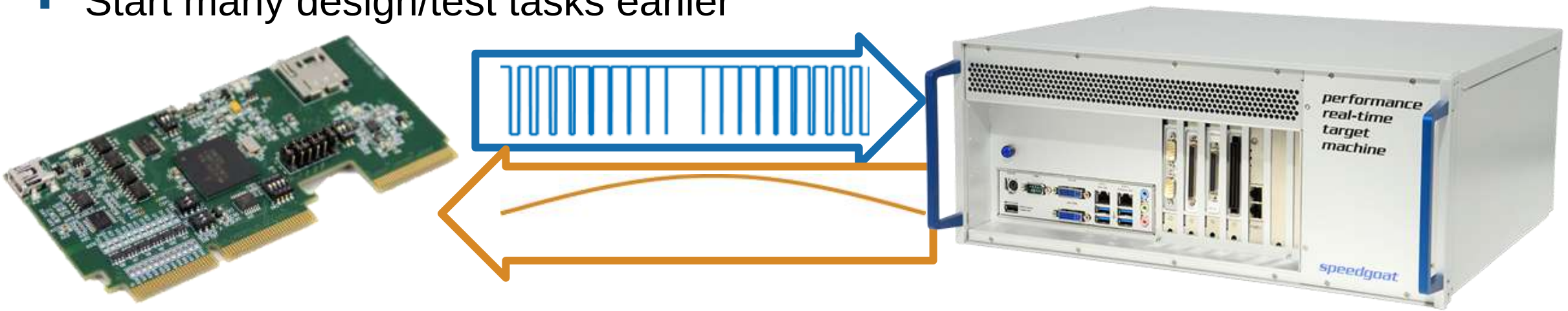
HIL Testing of Power Electronics

Enablers for Real-Time Testing



Advantages of Hardware in the Loop (HIL) Testing

- Can replace prototypes or production hardware with a real-time system
- Easier to automate testing
- Safer than most power electronics hardware
- Start many design/test tasks earlier



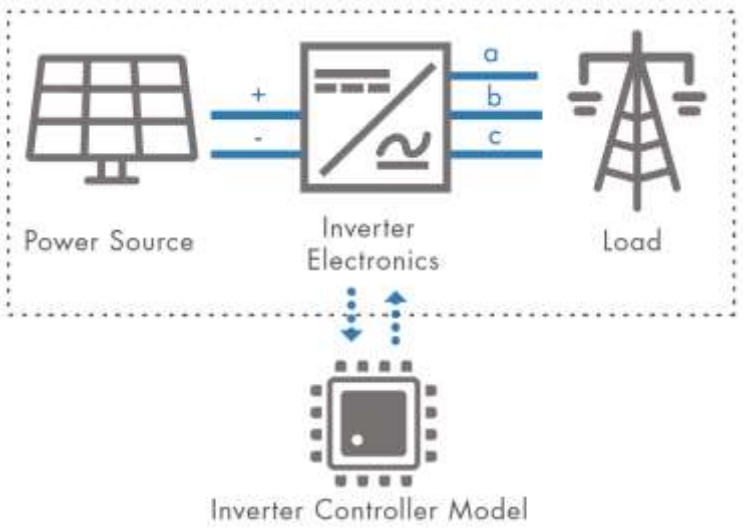
Controller

Virtual Simulation (Plant)

Hardware-in-the-Loop for Power Electronics

Workflow

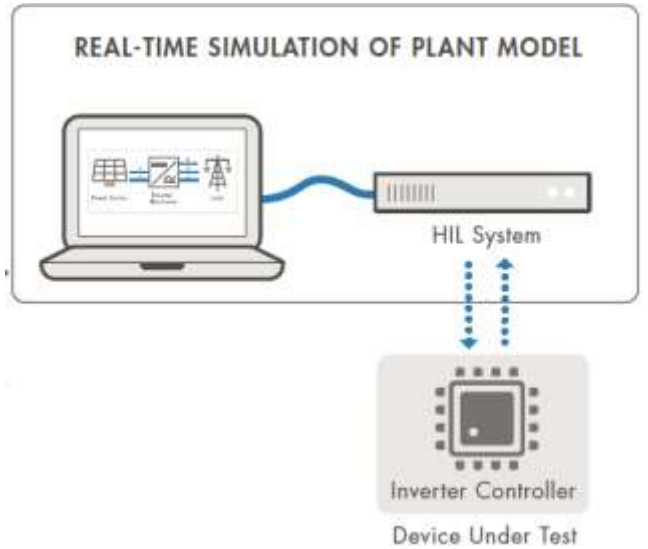
Design and optimize controls using electrical systems simulation



Generate embedded code for the plant

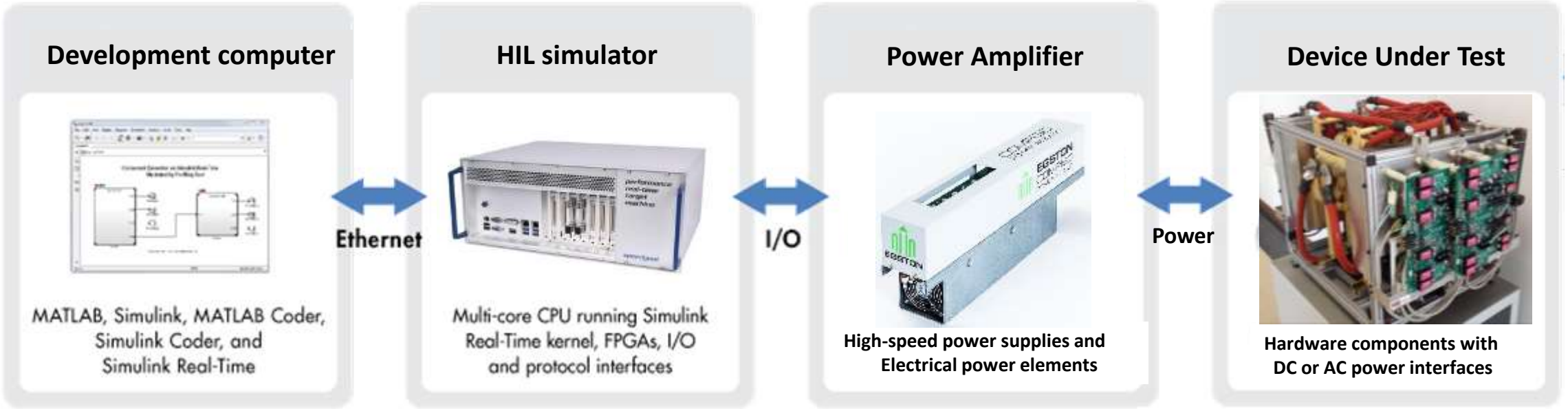
and the plant

Test the control hardware using HIL simulation



Power HIL Solution

- Target applications like grid, battery pack, AC/DC coupling emulators
- Power amplifier from various partners (from 300 W to 2 MW)

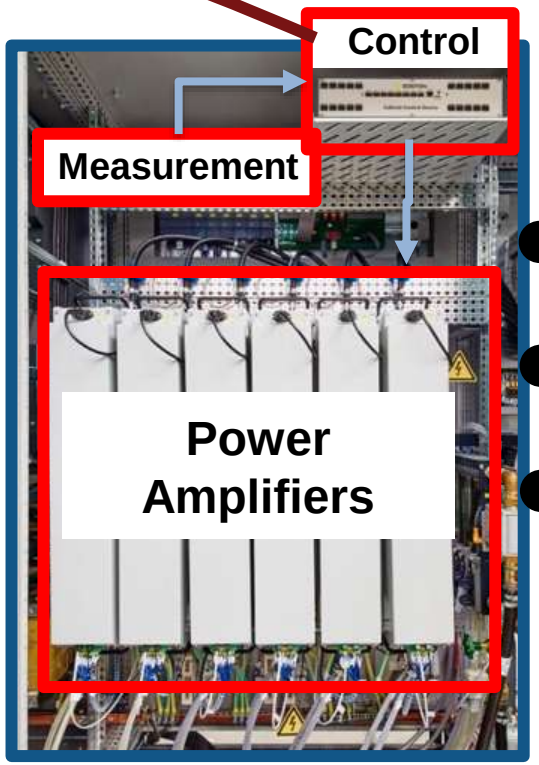


Power HIL Test Setup Example

Speedgoat target computer

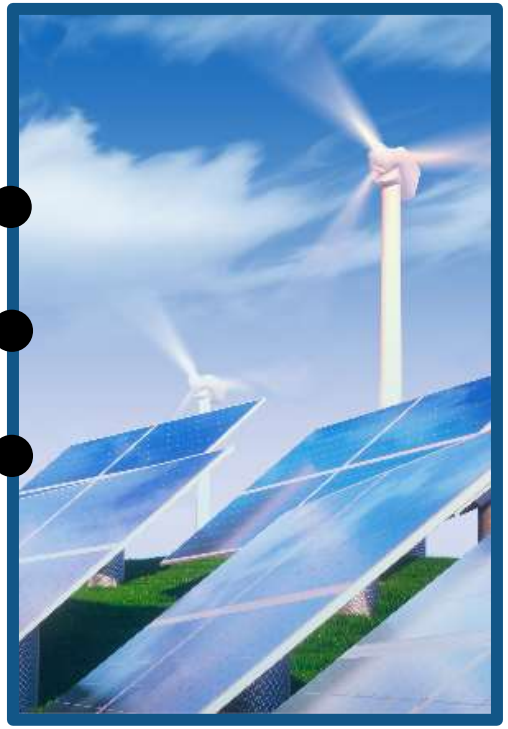
fiber optic
4µs

EGSTON power amplifier



electric
power

Device Under Test



Success Story: SuperGrid Institute, France

Rapid Controller 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

SuperGrid Institute
Powering the electrical grid of the future

> "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

Success Story: Leonardo DRS

FPGA-Based HIL Testing of Shipboard Power Electronics Systems

Challenge

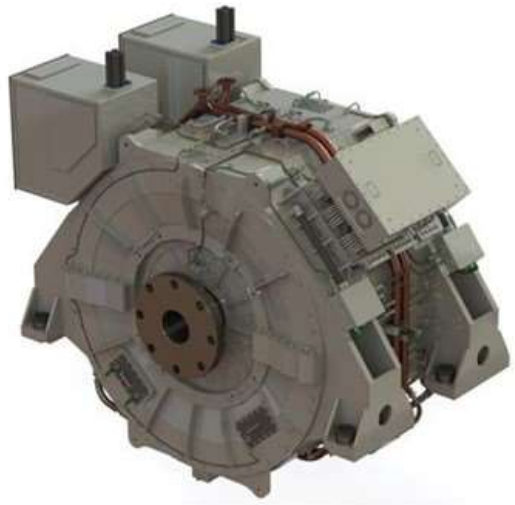
- Small-scale prototypes and hardware testbeds are simplified and do not represent the complexity of the actual hardware
- Testing time with the full-scale hardware is limited
- Not all tests are conducted with the actual hardware to avoid damaging the equipment

Solution

- Use Simulink, Simscape, and Speedgoat products to model the plant on different levels of fidelity
- Implement hardware-in-the-loop testing, including automated fault testing

Results

- Reduced design iteration from days to hours
- Saved cost, time, and lab space
- Reused simulation models for HIL testing



LEONARDO DRS

> "With Simulink, Simscape, and HDL Coder, we can develop plant models and deploy them directly to an FPGA for HIL tests; it's a no-nonsense, no-compromise way to simulate large-scale power electronics systems."
>
> Henry Brengel,
> Leonardo DRS

Success Story: German Aerospace Center - DLR

Real-Time Simulation Environment for Electrical Distribution Grids

Challenge

- Researching the robust operation of power grids that can facilitate the change to decentralized infrastructure and renewable sources of energy
- Combining of digital simulation and field testing on actual power hardware, integrating technologies from electrical, heat, and transportation (or mobility) domains
- Collaboration with groups at several other labs, both within DLR and at other institutions

Solution

- Run simulations in real-time with Speedgoat that incorporate real-world power hardware
- Model, test and optimize control strategies and grid-in-the-loop
- Use Speedgoat FPGA I/O modules to emulate current and voltage signals from grid nodes
- Study Quarter Energy Management Systems (QEMS) by recreating the voltage at a node within a grid model
- Co-simulation environment that enables DLR to link two or more laboratories via a UDP connection

Result

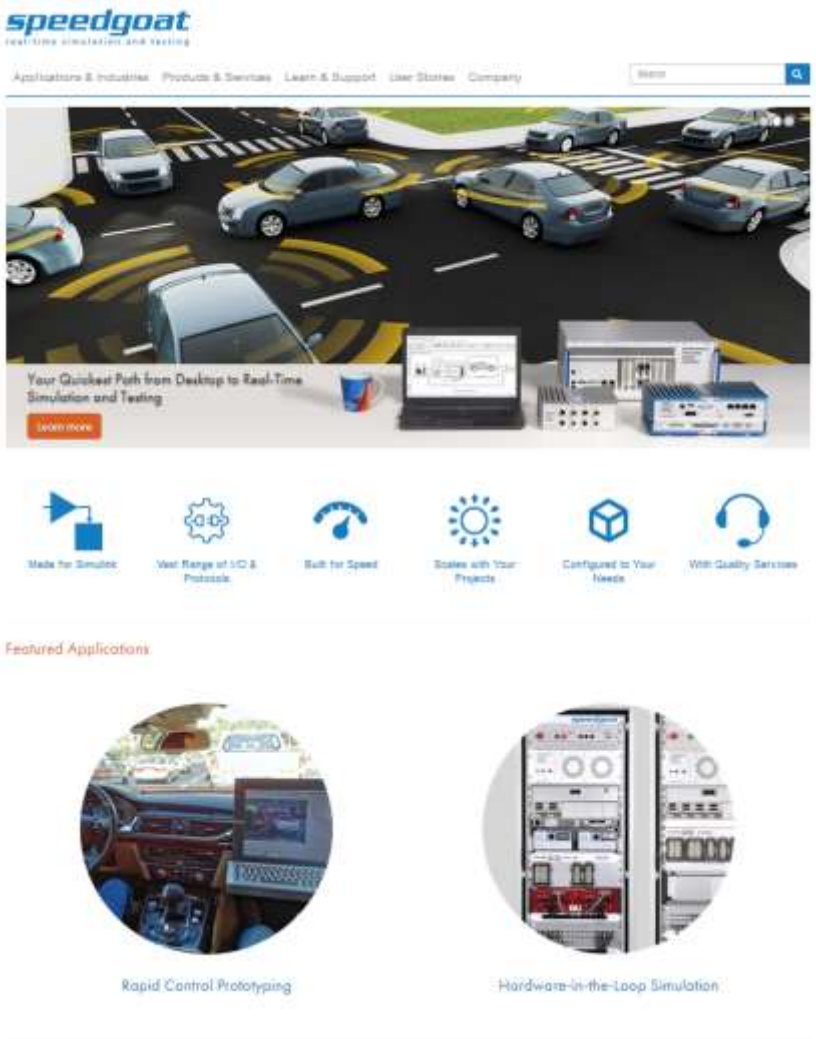
- DLR can explore scenarios that would be too costly or dangerous to test on real equipment
- Pushing processes outside their nominal operating conditions
- Efficient and effortless collaboration with other laboratories

DLR

> "The testing environment lets us rapidly validate new ideas and control algorithms that we develop in house with real-time tests"

Online Resources

Visit the Speedgoat, and the MathWorks Simulink Real-Time webpage to learn more



www.speedgoat.com

www.mathworks.com