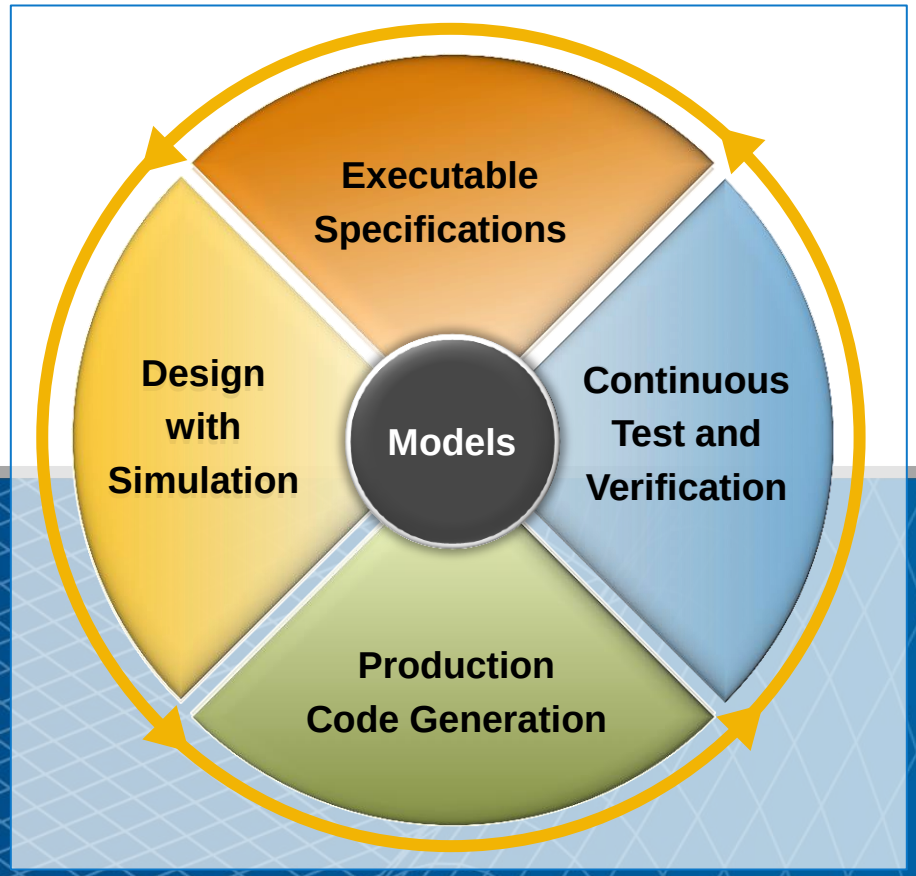
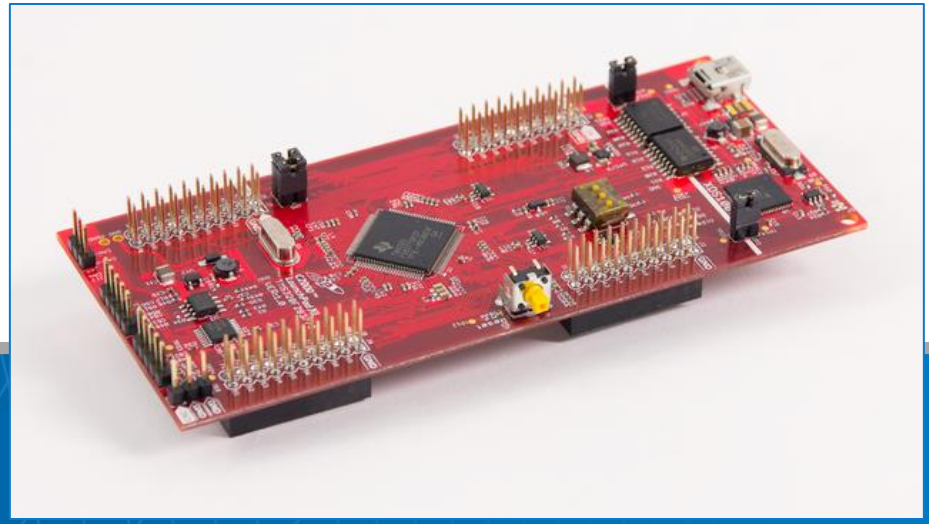
Motor Control with Embedded Coder and TI C2000™





Agenda

- TI C2000™ Microcontrollers
  - Matt Pate, Texas Instruments
- Production code generation with Embedded Coder
  - Brian McKay, MathWorks
- Demo: Running two 3-phase motors with F28069M LaunchPad
  - Antonin Ancelle, MathWorks

C2000™ Microcontrollers

Built for Real-Time, Closed-Loop Control

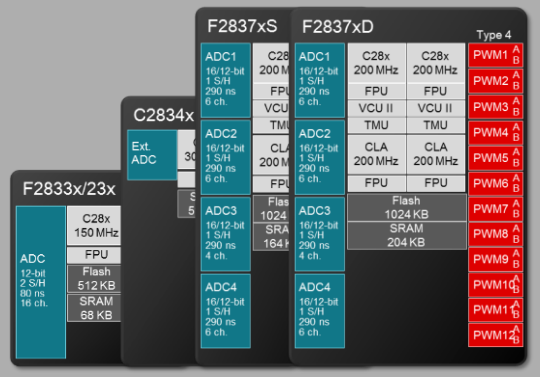
32-bit microcontrollers optimized for processing, sensing, and actuation to improve closed loop performance.

TI C2000™ MCU Platform

32-bit MCUs for Real Time Control

C2000™ Delfino™ MCUs

32-bit C2000 microcontrollers for the highest performance real-time, closed loop control applications



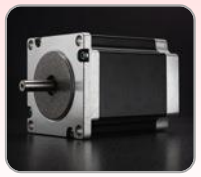
Up to 800 MIPS
512 KB – 1 MB Flash

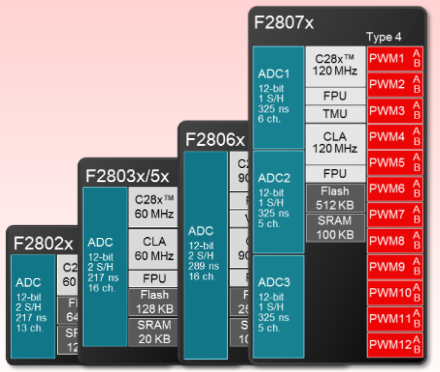
4x ADC, 12 – 16-bit, up to 14 MSPS, 4 S/H units

Up to 24 ch., 150ps high res. technology

C2000™ Piccolo™ MCUs

32-bit C2000 microcontrollers for broad real-time, closed loop control applications





Up to 240 MIPS
16 – 512 KB Flash

1-2 ADC: 12-bit, up to 7 MSPS, 2-3 S/H units,

Up to 24 ch., 150ps high res. technology

DNA of the C2000™ Microcontroller

Processing

- Single cycle execution of real-time control math
- Accelerated execution of application-specific code
- Independent multi-loop processing

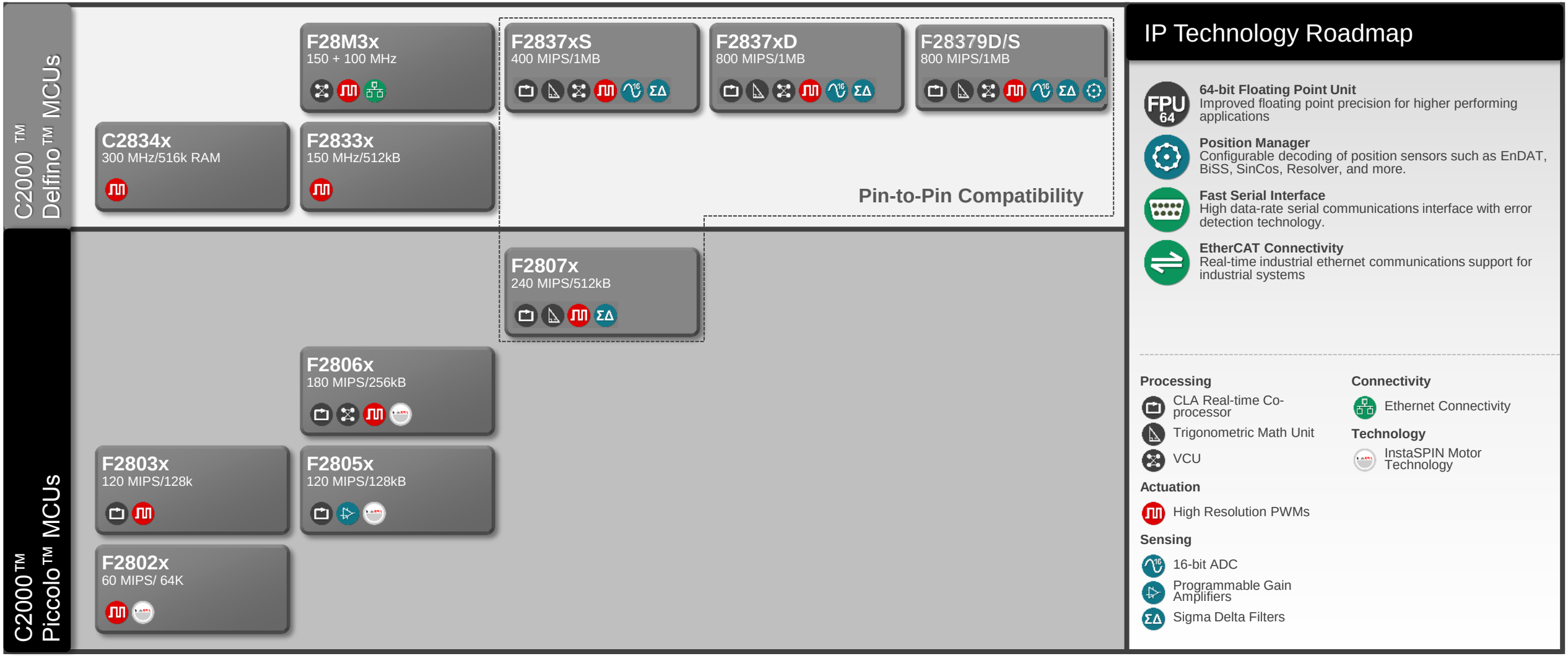
Actuation

- High resolution system control
- Flexible system interfacing
- Advanced system protection

Sensing

- Low latency, high accuracy, signal sampling
- High resolution, digital signal interfacing
- Asynchronous, system monitoring and response

TI C2000 MCU Portfolio



IP Technology Roadmap

64-bit Floating Point Unit
Improved floating point precision for higher performing applications

Position Manager
Configurable decoding of position sensors such as EnDAT, BiSS, SinCos, Resolver, and more.

Fast Serial Interface
High data-rate serial communications interface with error detection technology.

EtherCAT Connectivity
Real-time industrial ethernet communications support for industrial systems

Processing
- CLA Real-time Co-processor
- Trigonometric Math Unit
- VCU

Actuation
- High Resolution PWMs

Sensing
- 16-bit ADC
- Programmable Gain Amplifiers
- Sigma Delta Filters

Connectivity
- Ethernet Connectivity

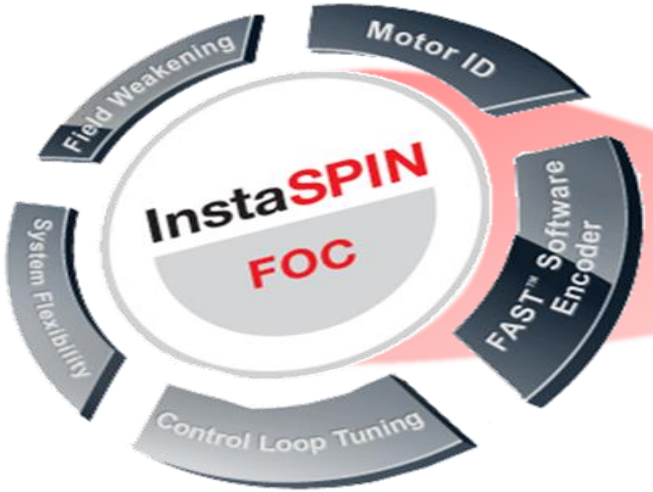
Technology
- InstaSPIN Motor Technology

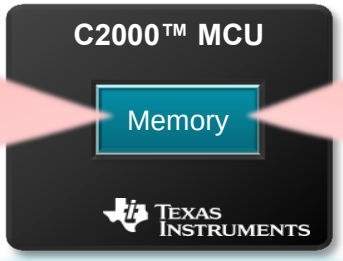
C2000 Solutions

powerSUITE	InstaSPIN	DesignDRIVE
		
Power Supplies	**Motor Control**	**Industrial Drives**
• Tools for power supply design • Software frequency response analyzer • Compensation designer • Adapt development kit software to your custom design	• Instantly spin any three phase motor • Automatic current loop tuning • Robust motion control • Software embedded on chip and ready to use	• Create designs for industrial drives applications • Support for various motor types, sensing technologies, encoder standards, and communications networks

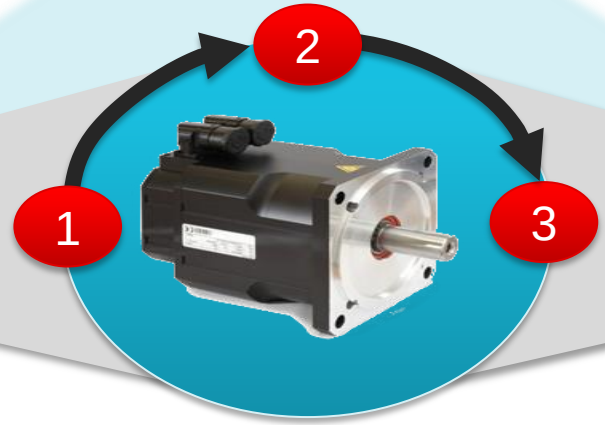
InstaSPIN™ Microcontrollers

C2000™ microcontrollers with embedded InstaSPIN™ motion control software to identify, tune, and fully control three phase motors in minutes.





Tune



Identify

Control

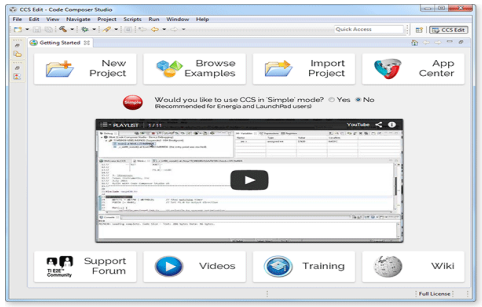
Any Three Phase, Variable Speed, Synchronous or Asynchronous Motor System

Optimized system **in minutes**.

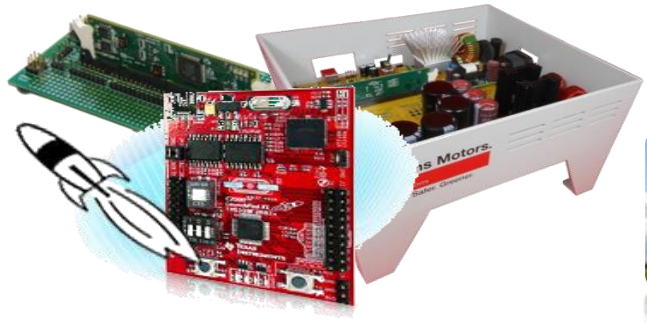
What Comes in the Box?

controlSUITE™ Software Suite

Code Composer Studio™ (CCS) IDE

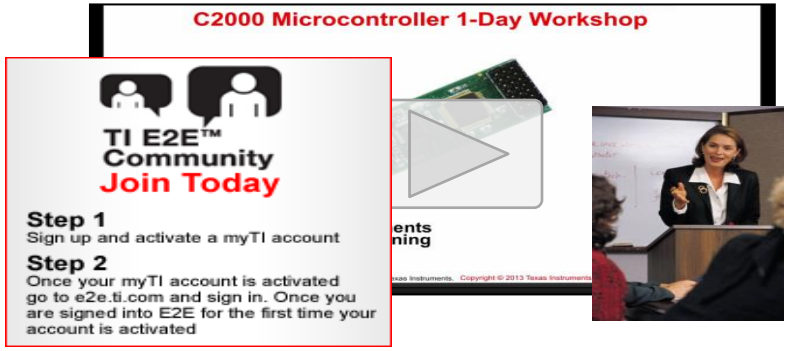


Hardware Development Kits



Application Expertise

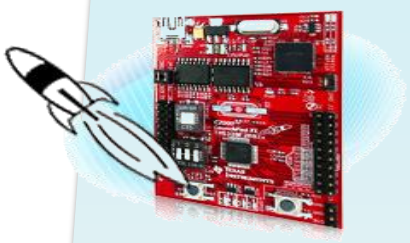
Training and Support



3rd Party Innovation and Support

Hardware Development Kits

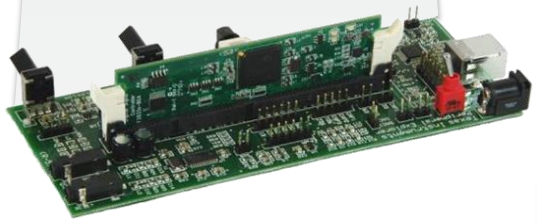
Starter Kits



Piccolo™/Delfino ™ LaunchPad

Fun, inexpensive, and powerful evaluation platform to dive into the world of real-time control programming with the C2000 platform.

View All LaunchPads

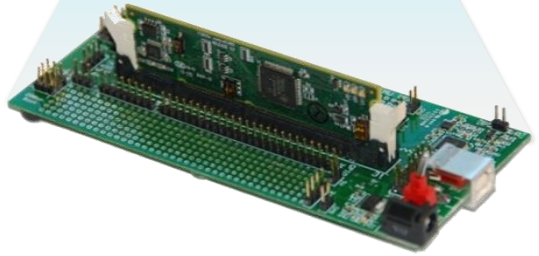


Peripheral Explorer

A great learning tool for new C2000 developers and university students with comprehensive introduction to C2000 peripherals. Based on the Delfino™ TMS320F28335 MCU.

View All Starter Kits

Prototyping Kits



Experimenter's Kits

Provide a hardware prototyping platform for application development..

View All Experimenter's Kits

Application Kits

Application Kits

Dive deep into specific application development hardware and software techniques.

Kits available for Motor Control, Digital Power, Solar, LED Lighting, and Power Line Communications applications

View All Application Kits

TI Design, Kits/Software Roadmap

TI Designs

Name	Application, TI devices	Est.Timeline
TIDA-00643	Drone UAV, F28027F, DRV8305	Now
TIDM-BIDIR-400-12	Bi-Directional DC/DC, F28035	Now
TIDM-HV-1PH-DCAC	High Voltage inverter (Solar & UPS), F28377D	Now
TIDM-1AXISMTR-PFC-5x	High Voltage Motor + PFC, F2805x	Now
TIDM-SERVODRIVE	Industrial Drives, F28377D	Now
F28377S LaunchPad + DRV8301/5 BoosterPack	High end motor control, F28377S, DRV8301 or DRV8305	Now

Kits and Software Roadmaps

Release/Kit name	What's new	Est.Timeline
TMDXIDDK28379	DesignDRIVES platform supporting development of many drive typologies. Support for F28379D silicon with Position Manager	Now
Motorware for InstaSPIN	Release 16: Dual Motor SW example for LAUNCHXL-F28069M, Hall sensor start-up, ease of use improvements (peripheral drivers)	Now
LAUNCHXL-F28379D	Performance dual-core LaunchPad with support for analog precision sensing. Also supports Position manager	3Q16

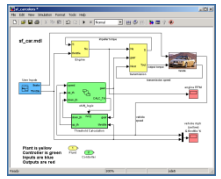
C2000 Training: www.ti.com/c2000training

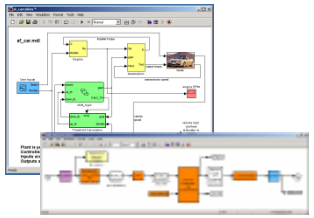
Series/Title	Application, TI device covered	Availability
C2000 MCU 1-Day Workshop – 8 Part Series	Intro to C2000 MCUs' features and functions	Now – Training Portal
C2000 InstaSPIN: From Evaluation to Production – 7 Part Series	TI InstaSPIN™ Motor Control Solutions - F2802x/5x/6x	Now – Training Portal
C2000 Digital Power Training Series – 5 Part Series	Digital Power – All C2000	Now – Training Portal
Designing with the C2000 F2807x and F2837x Microcontroller Family	Device Architecture – F2807x/37xS/37xD	Now – Training Portal
State Space Control Seminar – 4 Part Series	Control Theory – All C2000	Now – Training Portal
F28377S LaunchPad Technical Overview with a Demonstration of PWM Modulation	LaunchPad Tool – F28377S	Now – Training Portal
DesignDRIVE Training Video – 8 part series	Industrial Drive and Servo Control Systems TMS320F28379, TMS320F2837X	Now – Training Portal

Production Code Generation and Verification Using Simulink and Embedded Coder

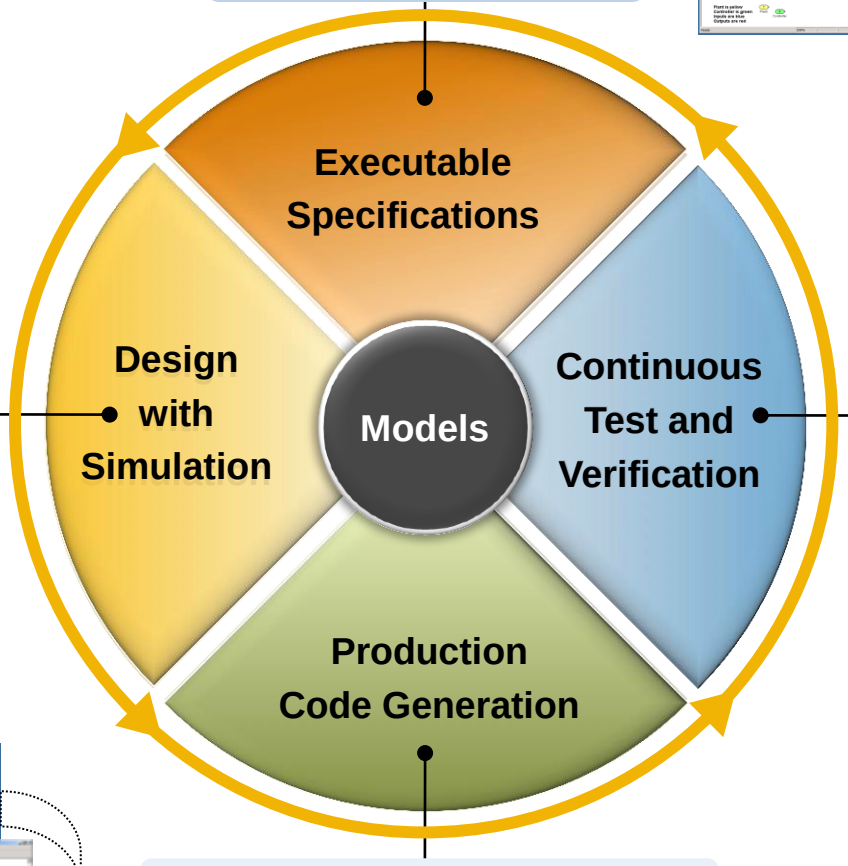
Model-Based Design with Production Code Generation

Executable models
-"one truth"

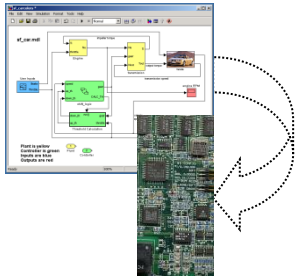


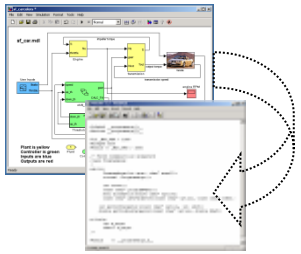


Simulation
-rapid iterations/prototypes
-convert float- to fixed point



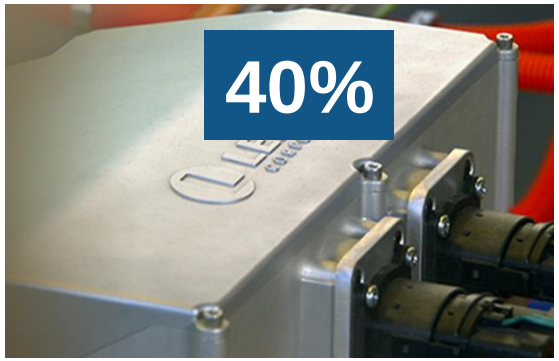
Test with Design
- detect errors earlier





Production code generation
-minimize coding errors

Production Code Generation – User Stories



Lear
Automotive ECUs

ell Aerospace USA
Control Systems

Development Time Savings

Weinmann Medical Germany
Transport ventilator

Alstom Grid UK
HDVC Power Systems

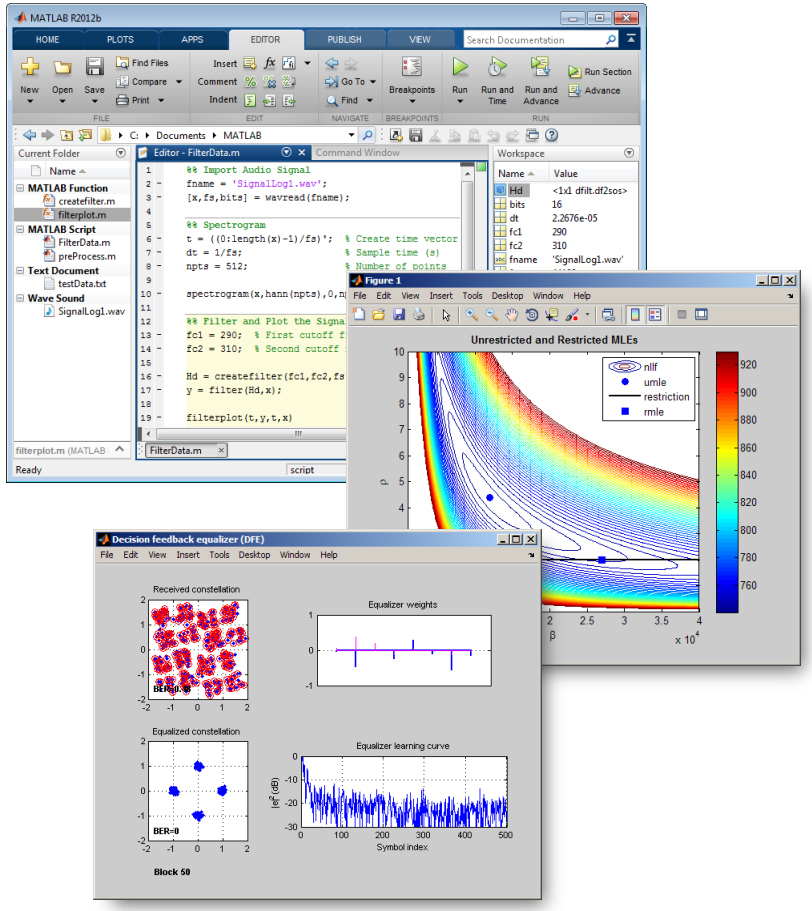
Elementary Schools
Project Based Learning

▪16

MATLAB®

Environment for technical computing

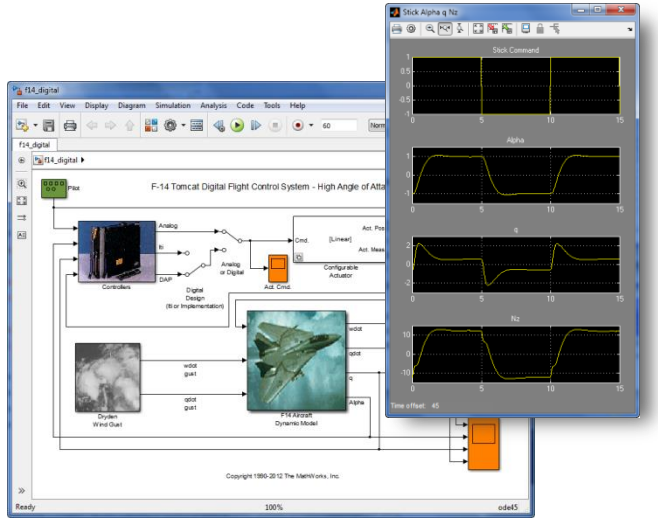
- High-level textual numeric language
- Data analysis and visualization
- Toolboxes for signal and image processing, statistics, optimization, symbolic math, and other areas
- Foundation of MathWorks products

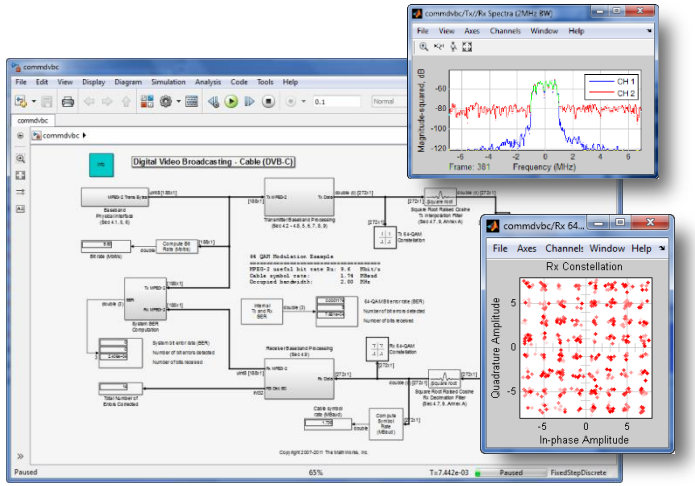


SIMULINK®

Environment for modeling and simulating dynamic systems

- Block diagrams and state machines (Stateflow)
- Linear, nonlinear, discrete-time, continuous-time, and multicore systems
- Blocksets for controls, signal processing, communications, physical modeling, and other system engineering areas
- Foundation for Model-Based Design



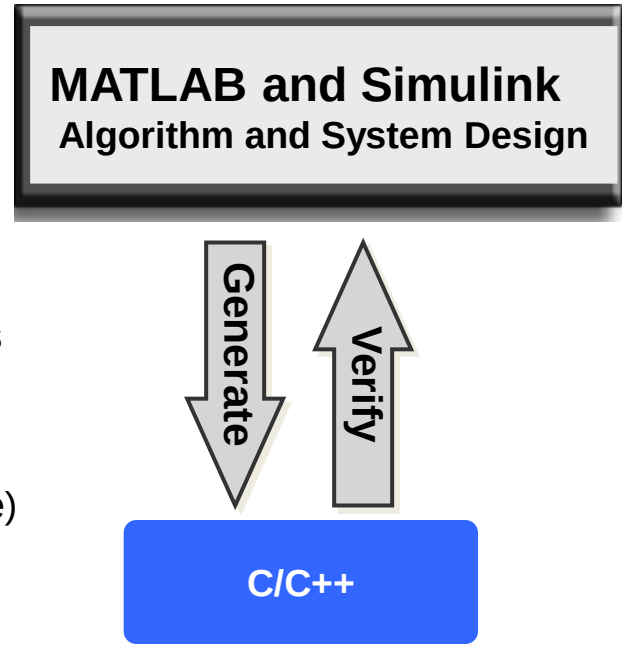


C/C++ Coders

MATLAB Coder - Code from MATLAB
- Portable code for numerical algorithms
- Desktop applications (standalone, library)

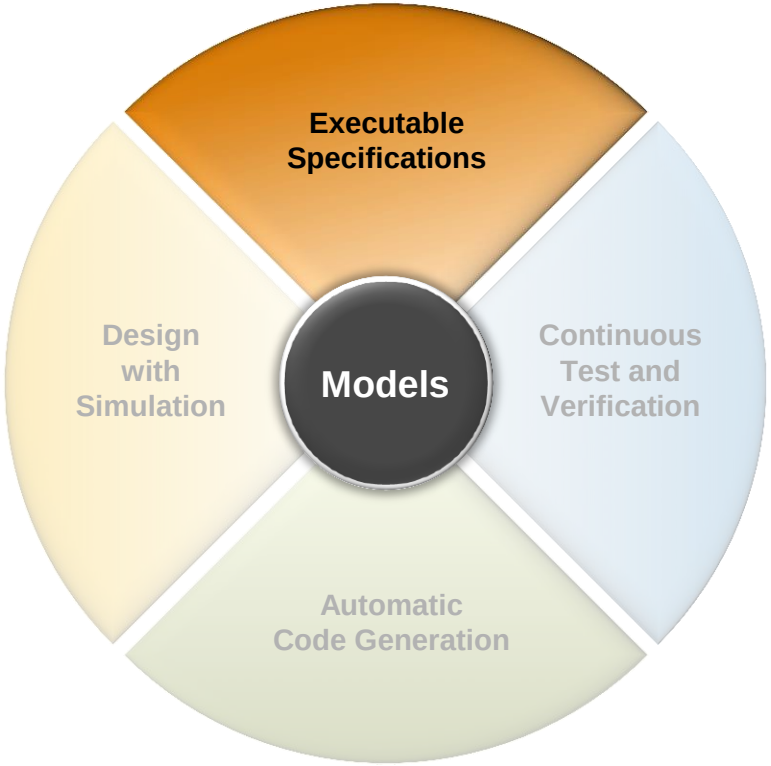
Simulink Coder - Code from Simulink
- Portable code for algorithms plus real-time framework
- Real-time machines for RP/HIL (e.g., Simulink Real-Time)

Embedded Coder – Production code
- Extends ML Coder and SL Coder for embedded processors
- MCUs and DSPs (from 8-bit devices to multicore SoCs)
  - Code optimization (portable code and processor-specific)
  - Code verification (software- and processor-in-the-loop, trace)
  - Code profiling (tasks and functions)
  - Code customization (data, functions, files)
  - Embedded targets (board initialization, I/O blocks, scheduler)
  - Certification (ISO-26262, IEC 61508, etc.)

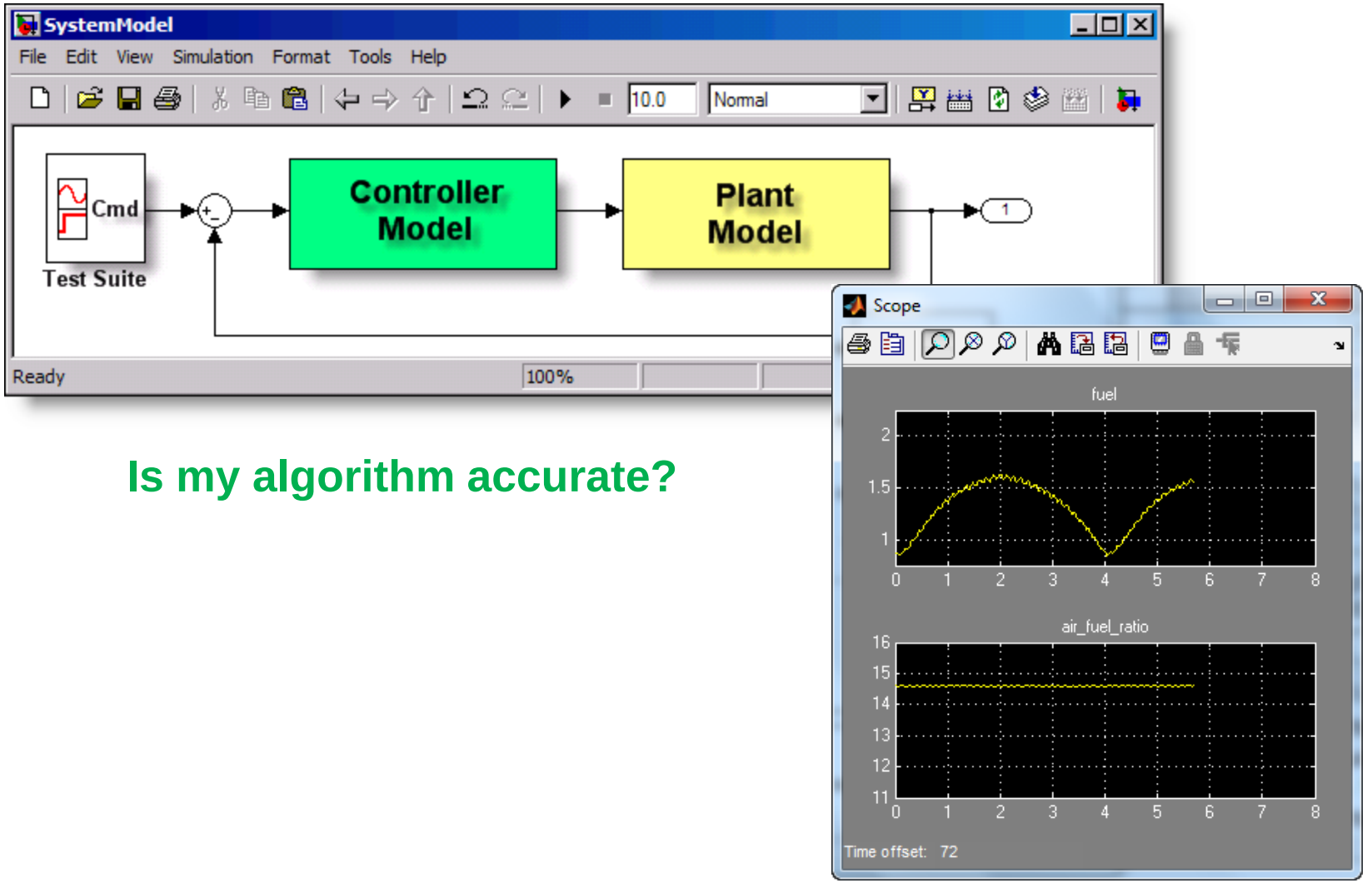


All coders generate portable code (ANSI/ISO C) by default.

Executable Specifications

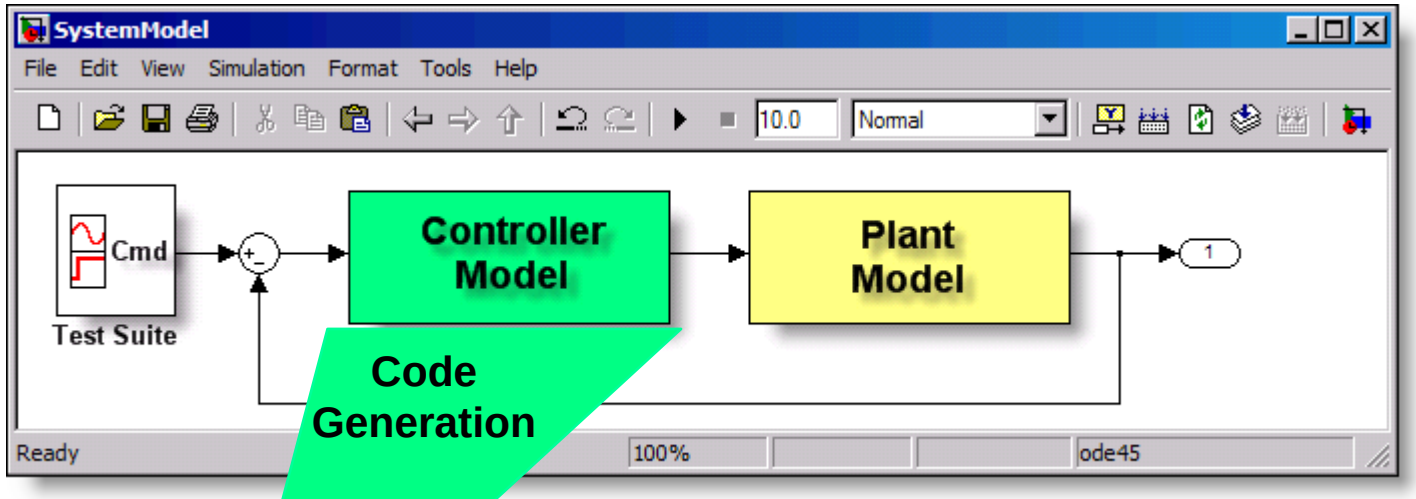


Simulation - Simulink

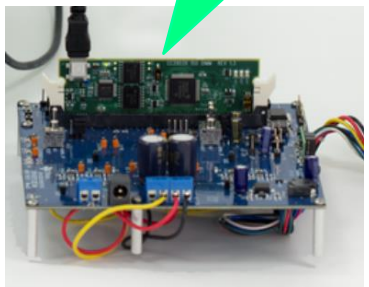


Is my algorithm accurate?

On-Target Rapid Prototyping – Embedded Coder



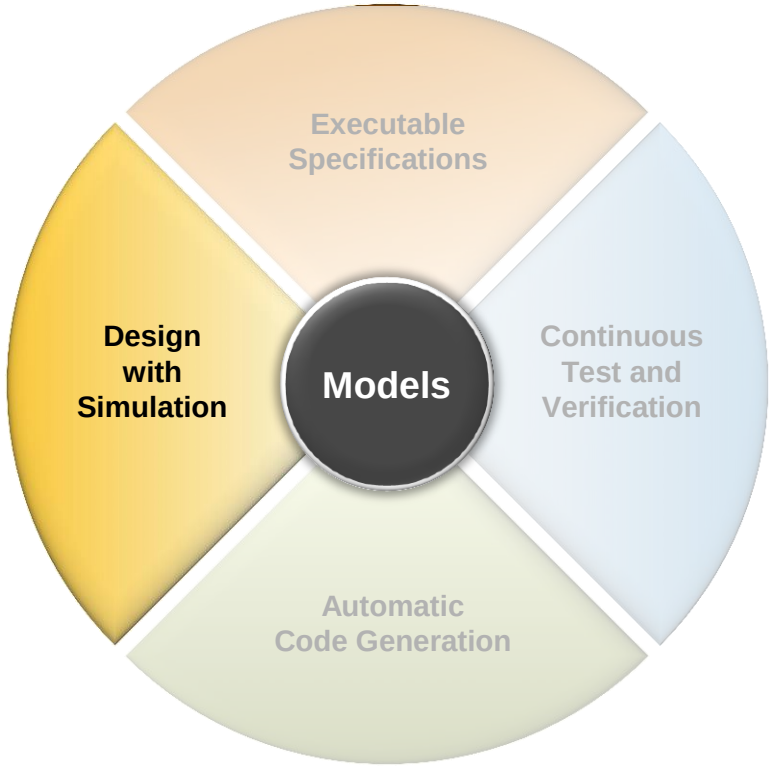
Is my algorithm practical?



Embedded Processor or ECU

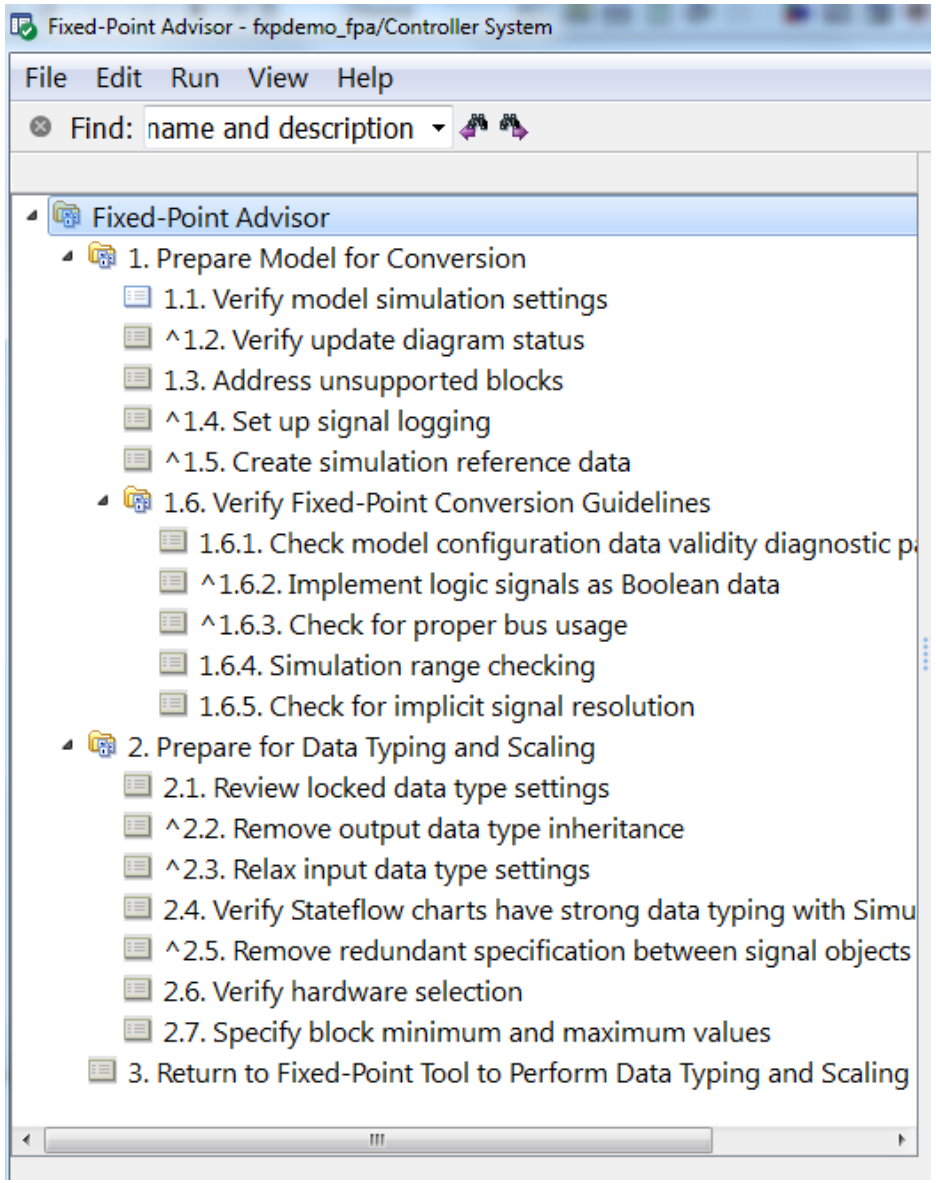
Harness

Design with Simulation



Float- to Fixed-Point Conversion

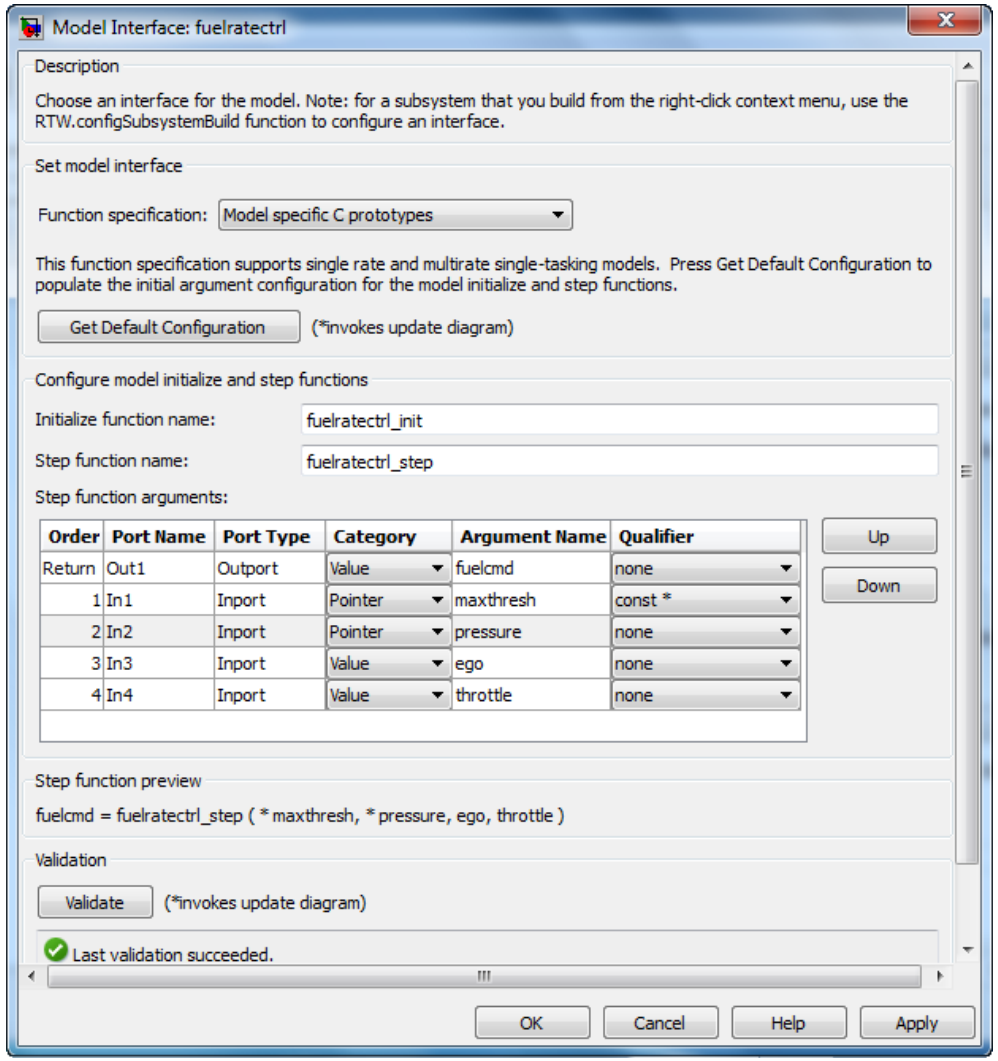
- Overflow/underflow
- Code optimizations
- Simulation ranges
- Derived ranges
  - Design-range scaling



>>fxpdemo_fpa

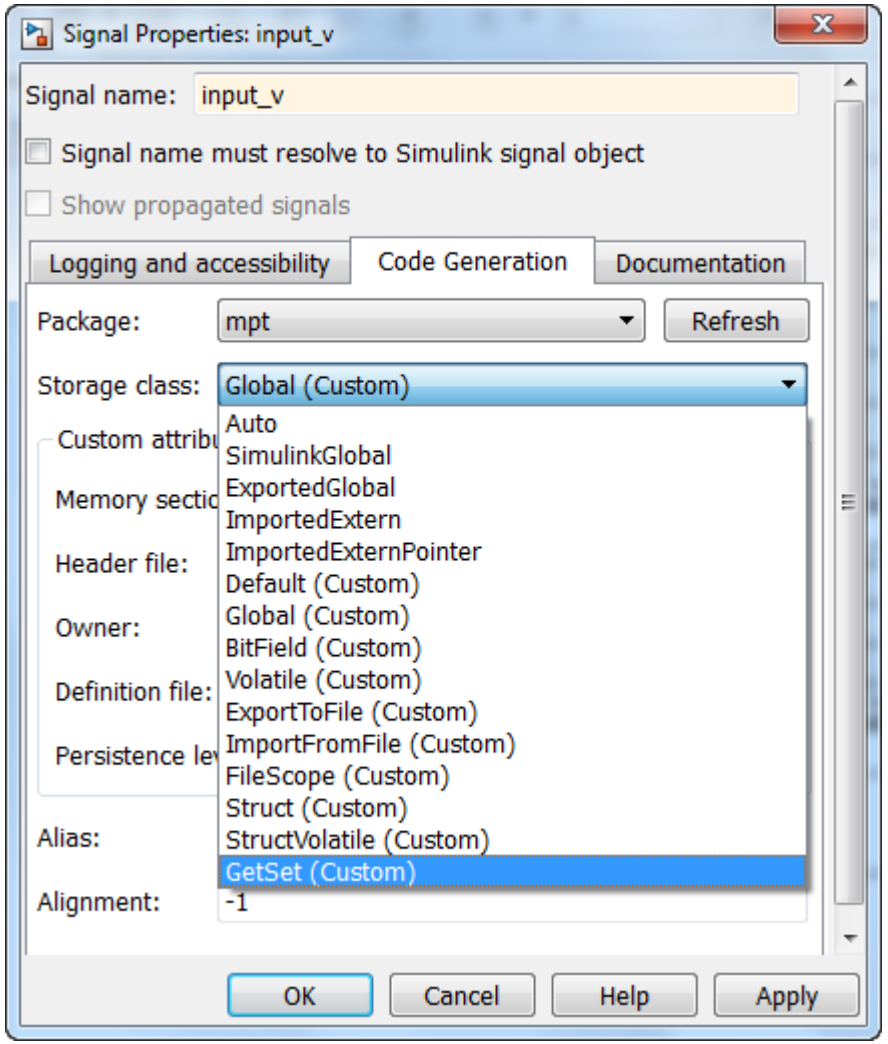
Function Interface Specification

- Function Name
- Argument Name
- Pass by value
- Pass by reference
- Qualifier

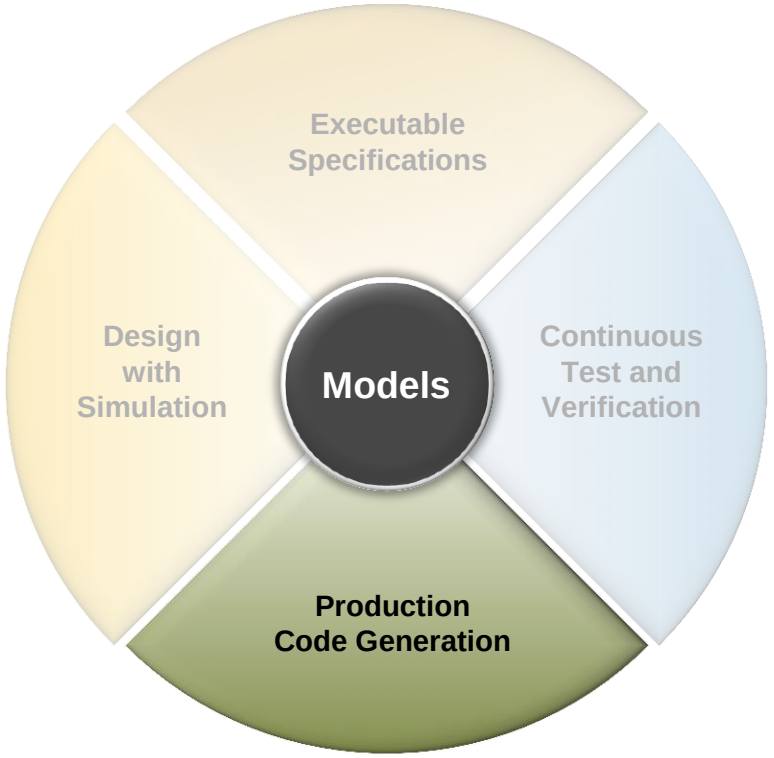


Data Specification

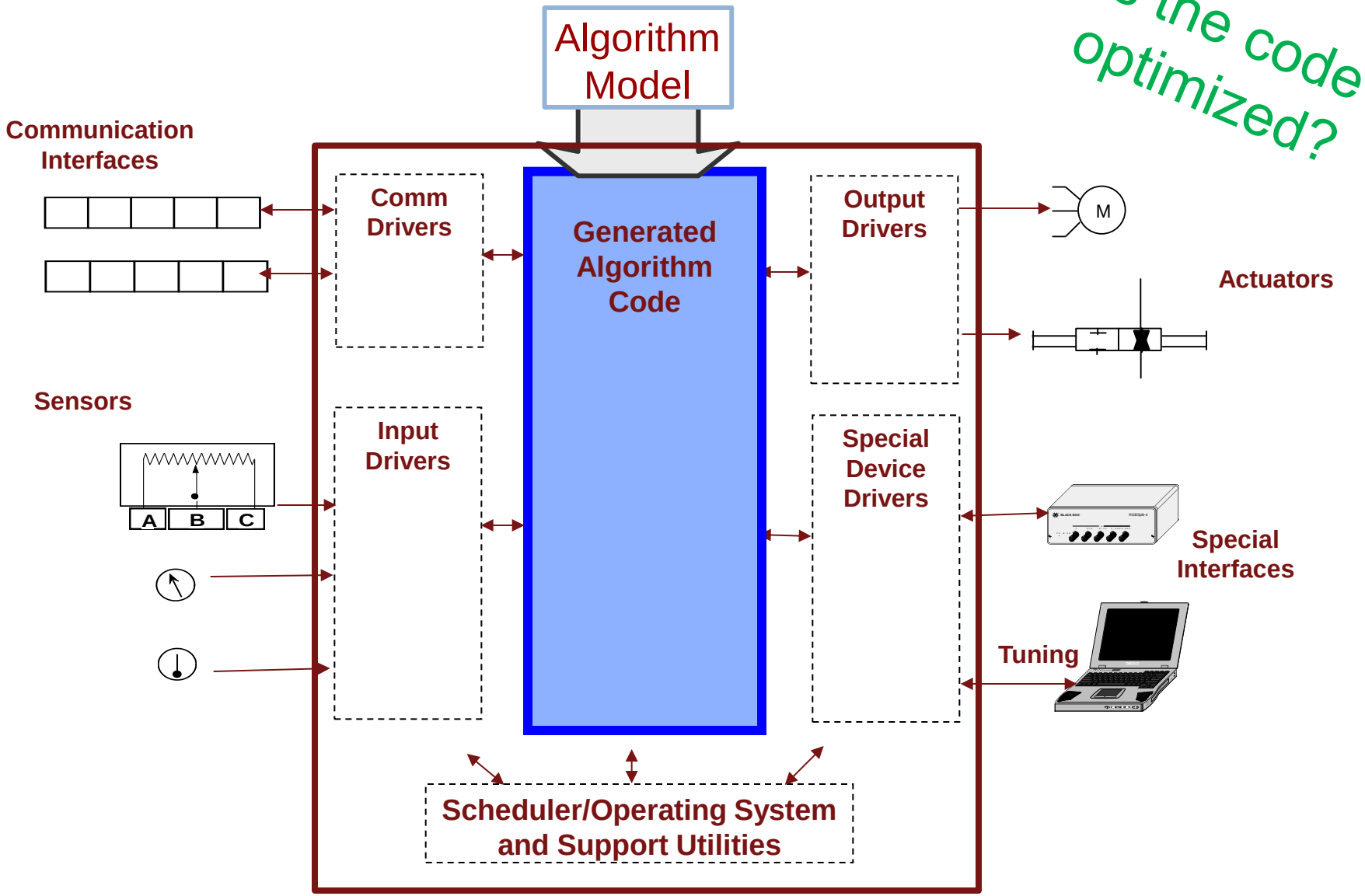
- Name
- Storage class
- Alias (typedef)
- Comments



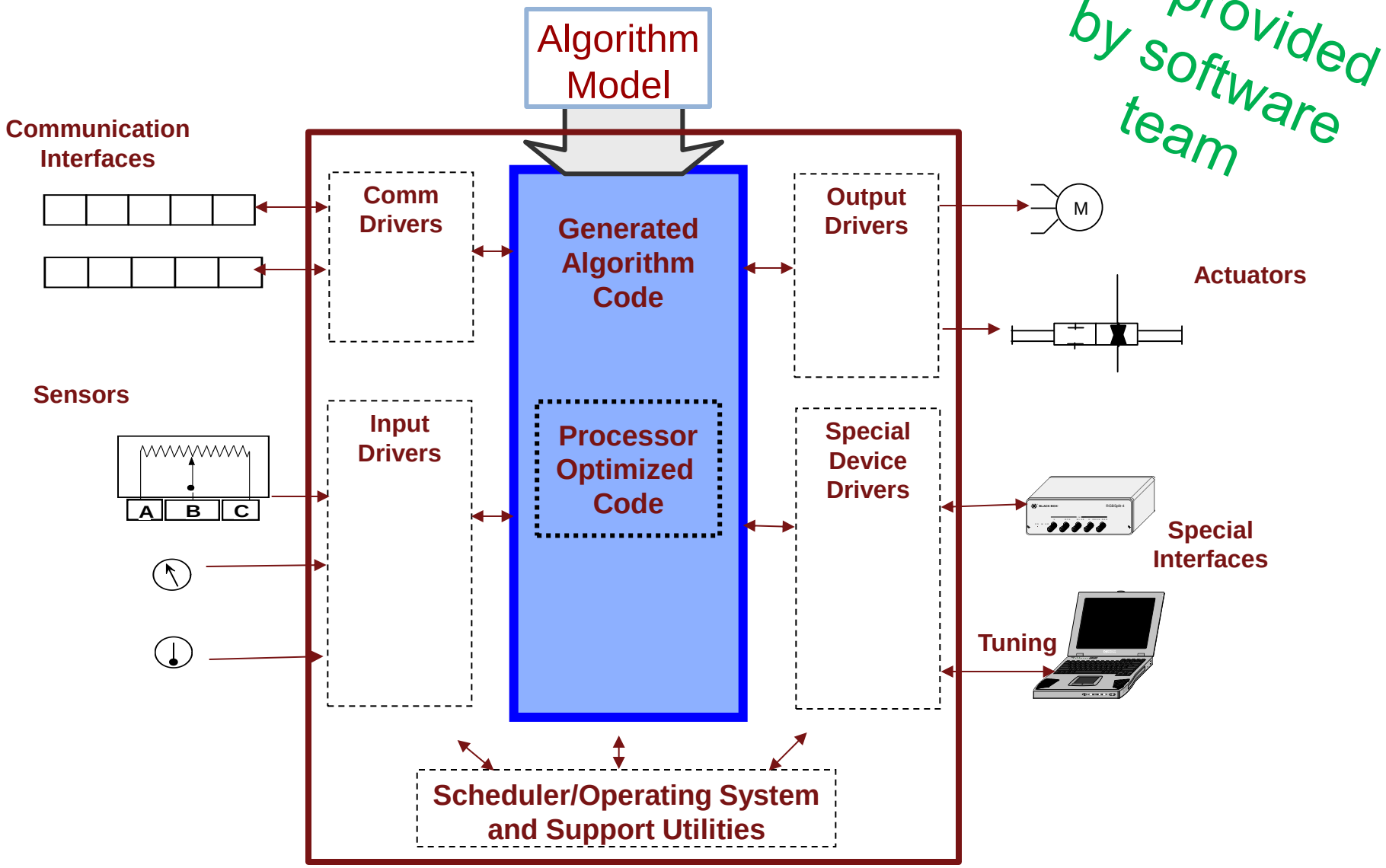
Production Code Generation



Algorithm Code (ANSI-C)

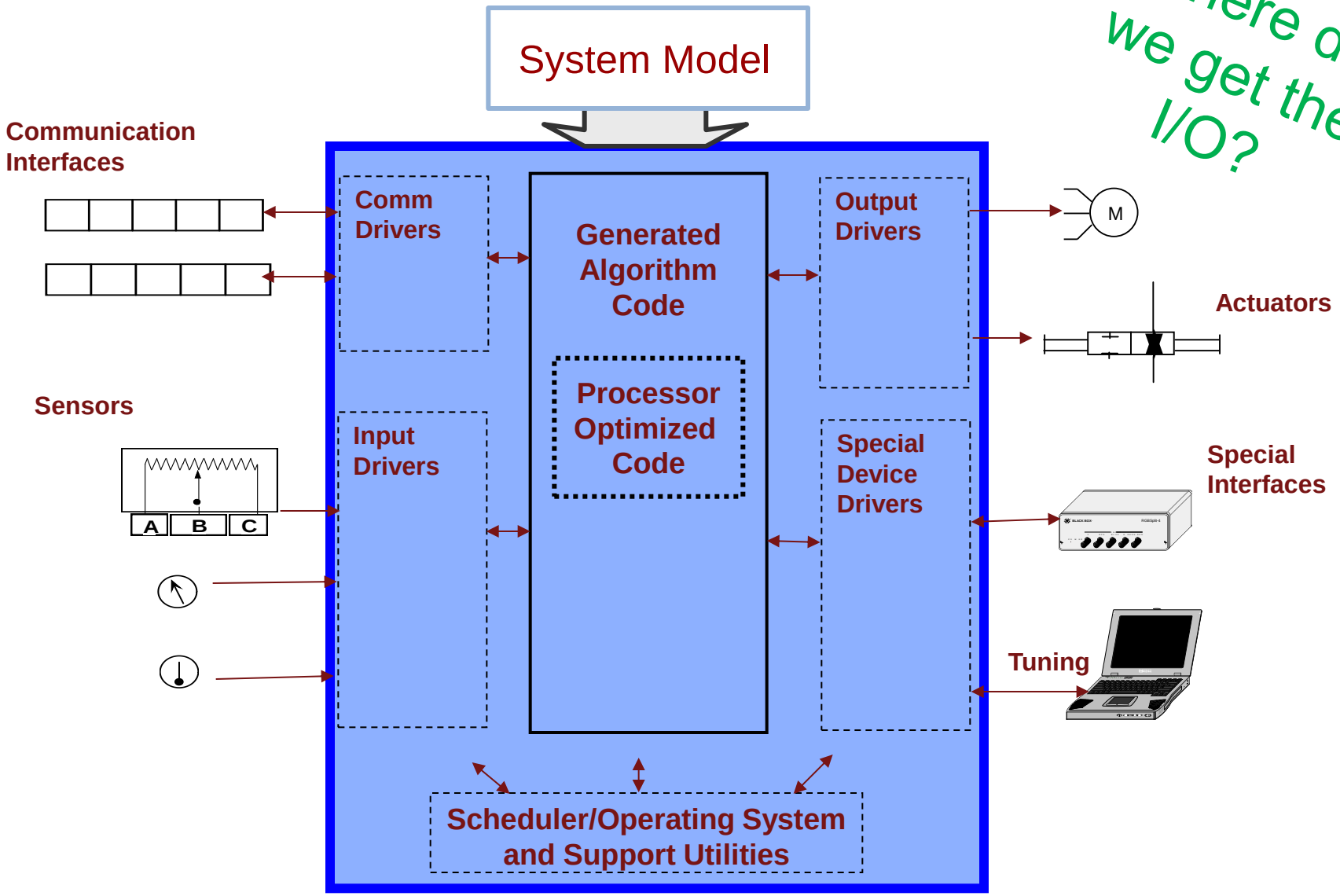


Algorithm Code (Processor-Optimized)



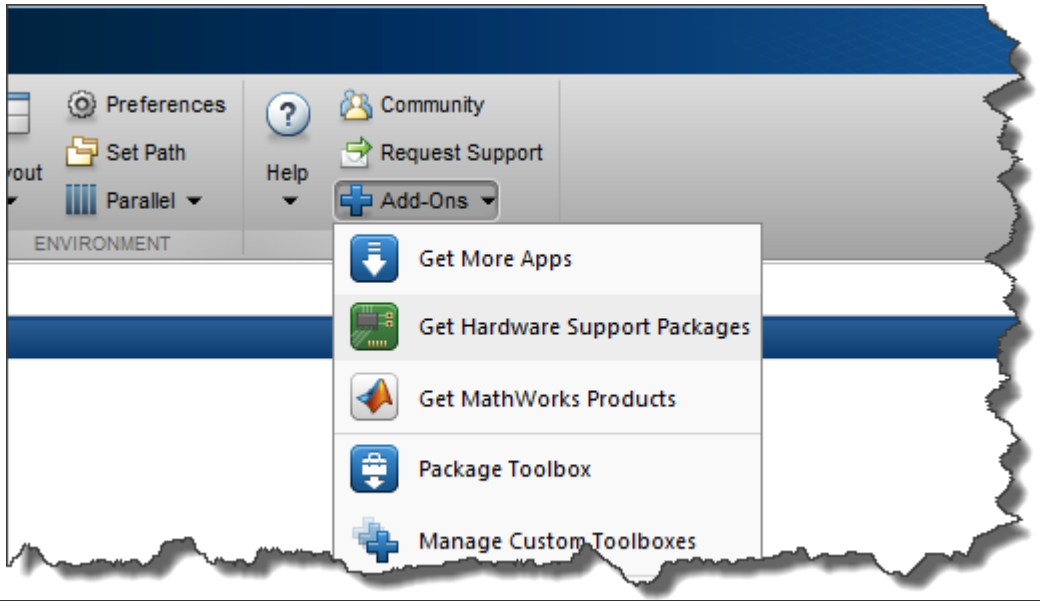
System Executable (Algorithm + I/O)

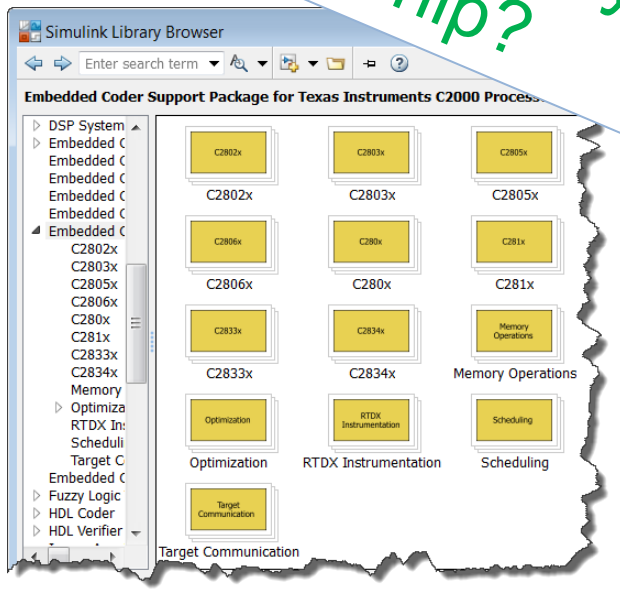
Where do we get the I/O?

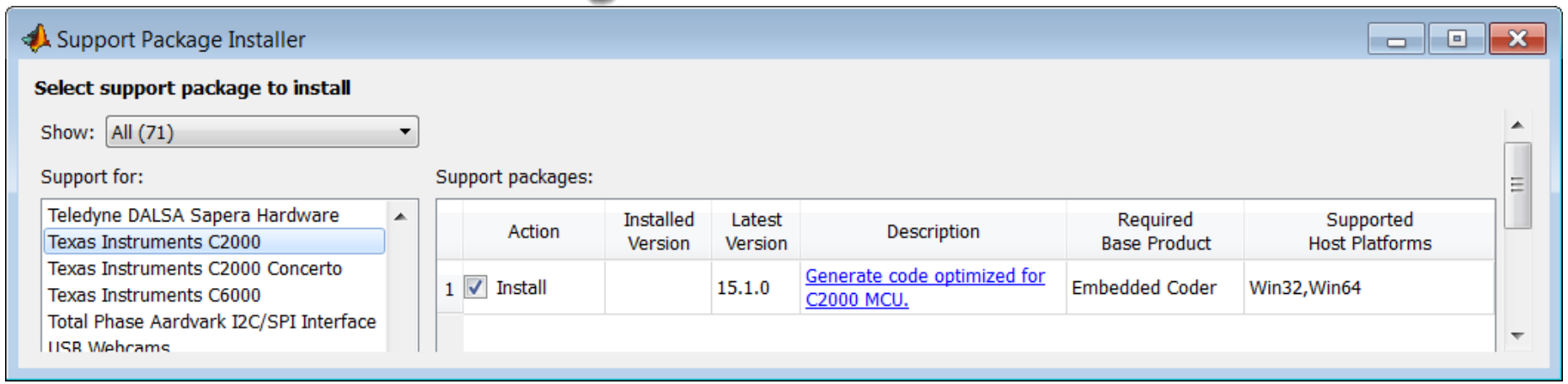


Embedded Coder Hardware Support Packages

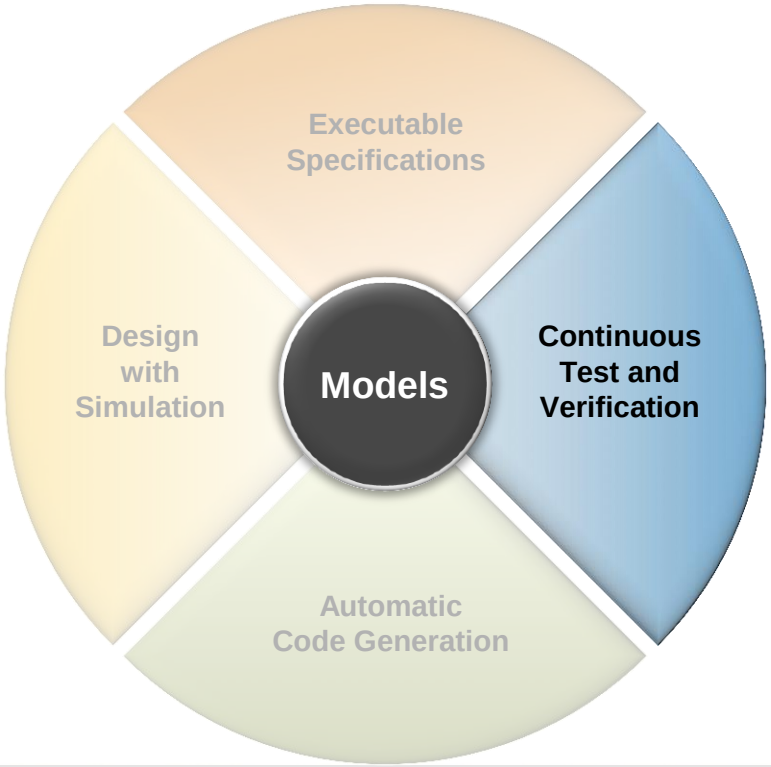
Are we ready to ship?





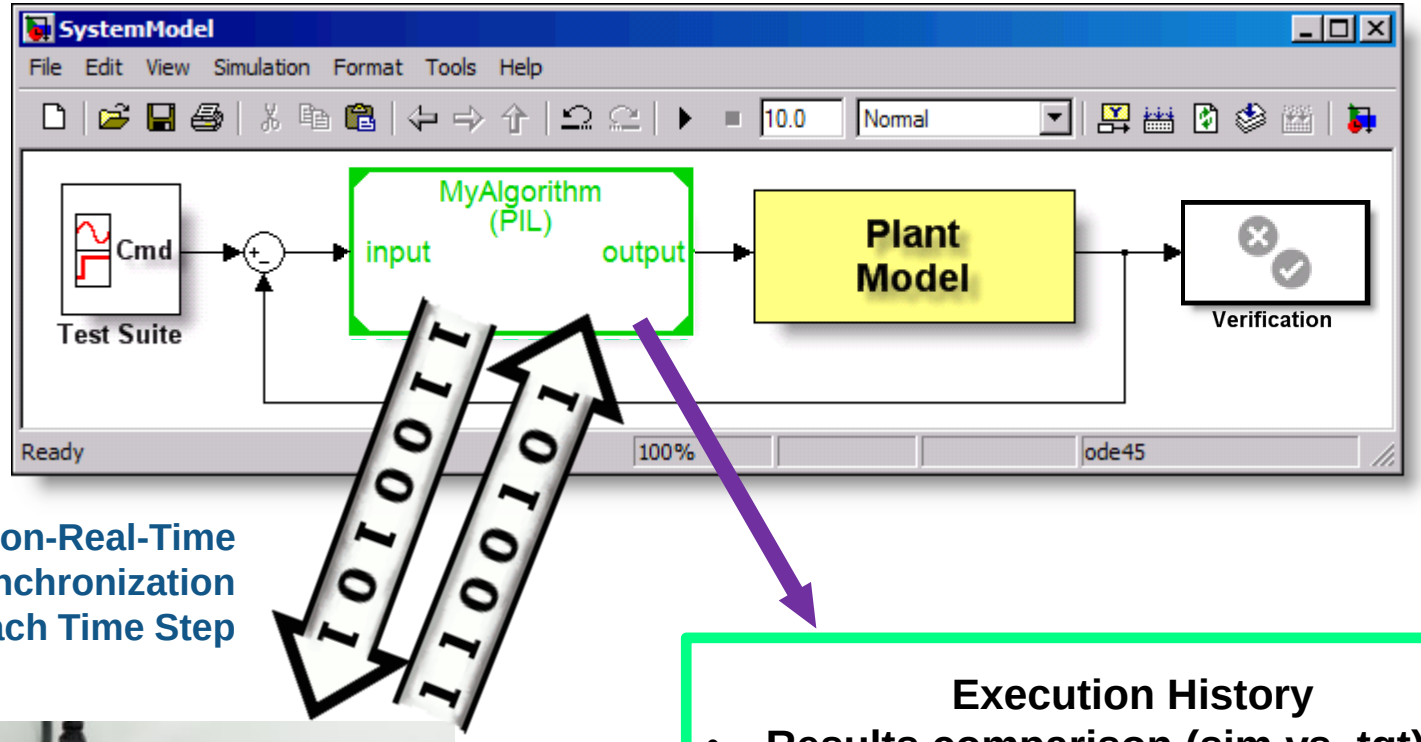


Continuous Test and Verification (PIL)

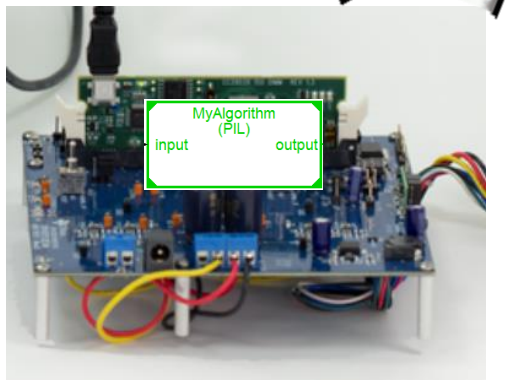


Processor-in-the-Loop (PIL)

Verify algorithms



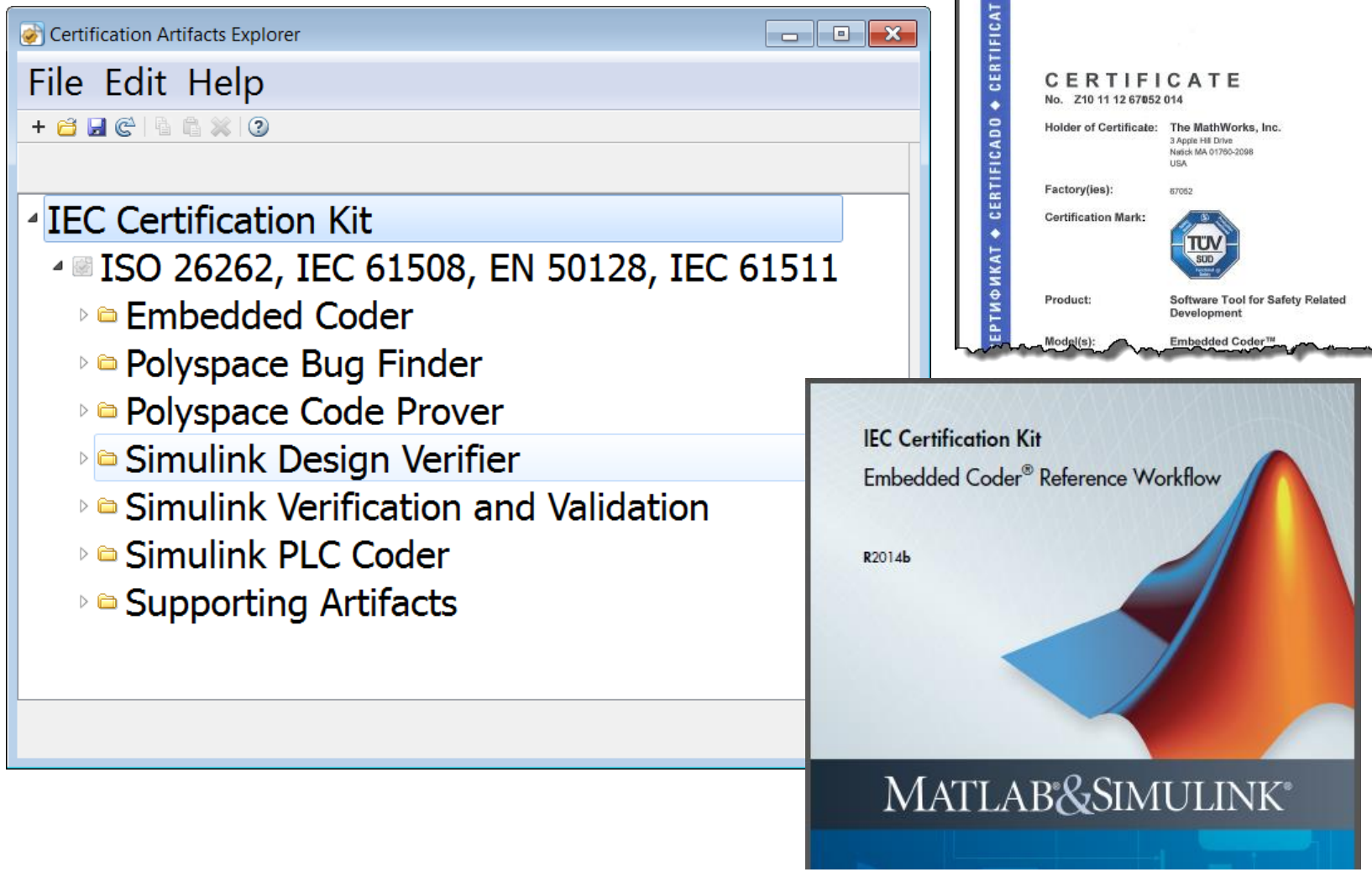
Non-Real-Time Synchronization with Host at Each Time Step



Execution History

- **Results comparison (sim vs. tgt)**
- **Code coverage**
- **Execution timing**

Certification Support (IEC Certification Kit)

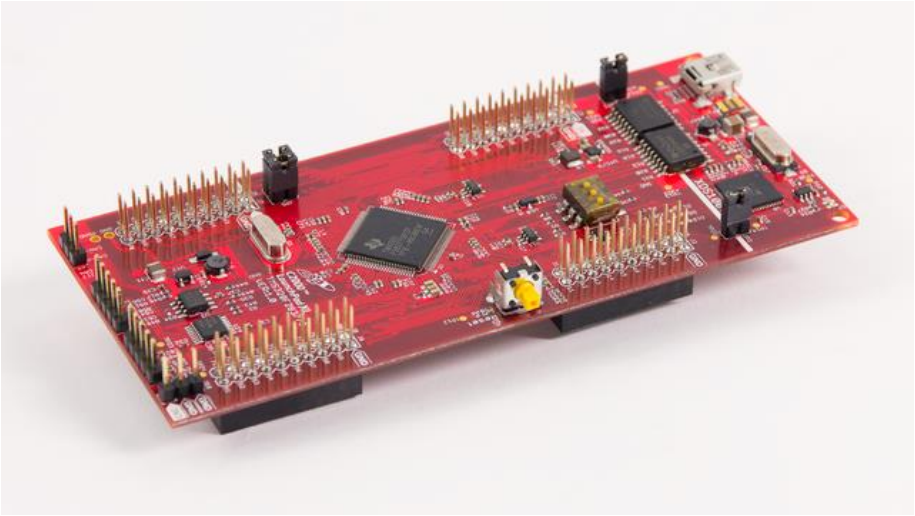



```
>>certkitiec
```

MathWorks TI C2000 Support Package for Embedded Coder

Supported devices:

- Piccolo F2802x/3x/5x/6x/07x
- Delfino F2833x/32x/37xS/37xD
- Fixed-point F280x/1x



F28377S LlaunchPad

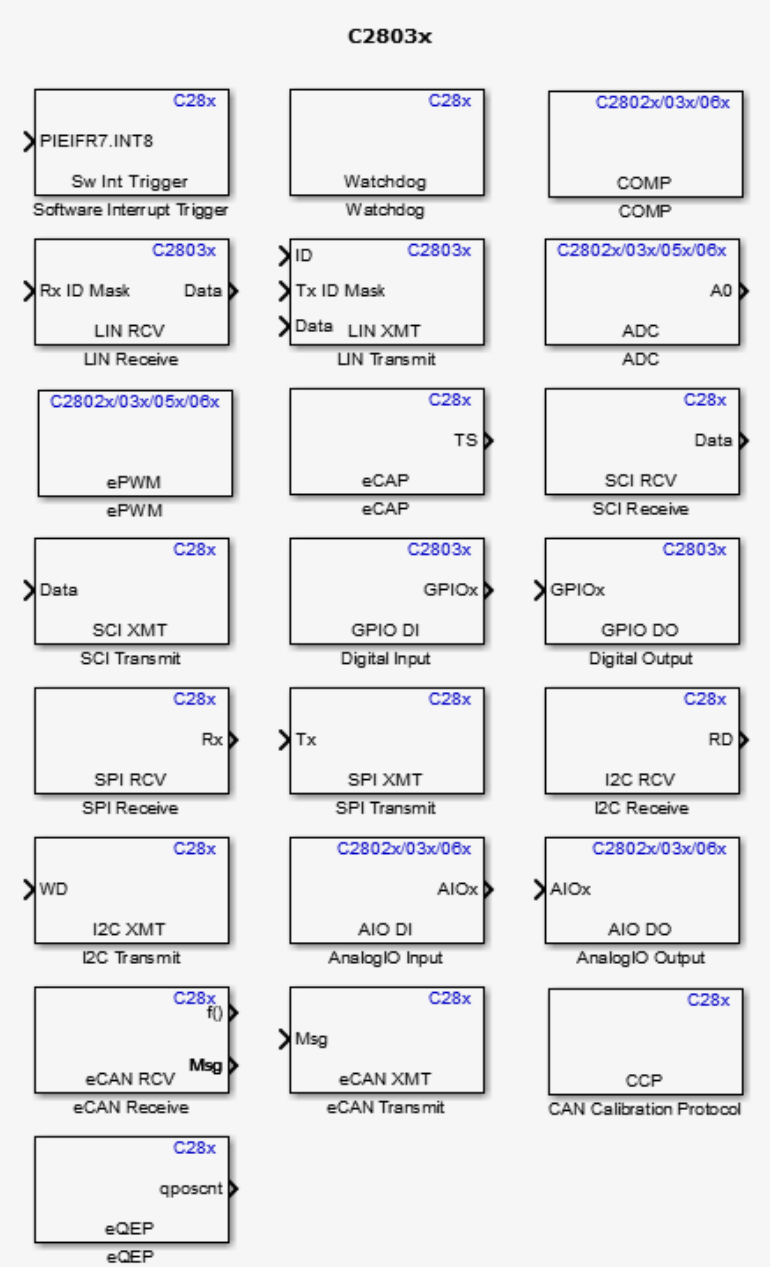
Scheduling the generated code:

- Periodic tasks
- Interrupts (Hardware, Software)
- Idle tasks
- Advanced concepts:
  - Pre-emptive rate-monotonic Scheduler.
  - Base rate interrupt replacement
  - Peripheral triggers (launch A/D conversion from PWM)
  - Running on the CLA
  - Loading in Flash, running in RAM.
  - Using DMA

Supported TI C2000 drivers

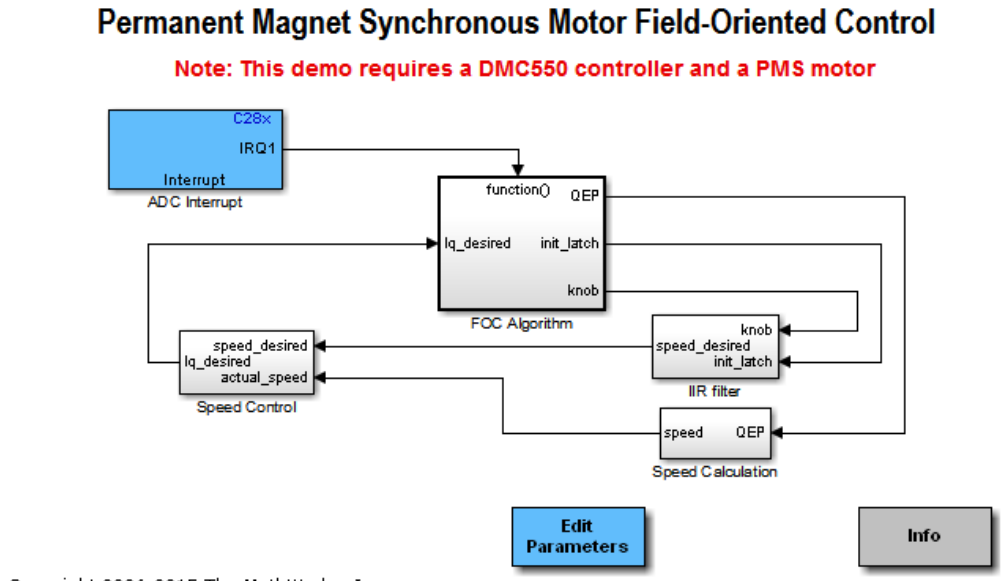
- ADC, AIO, Comparator,
- GPIO, eQEP, ePWM, eCAP,
- eCAN, I2C, SCI, SPI, LIN
- Watchdog, DMA.

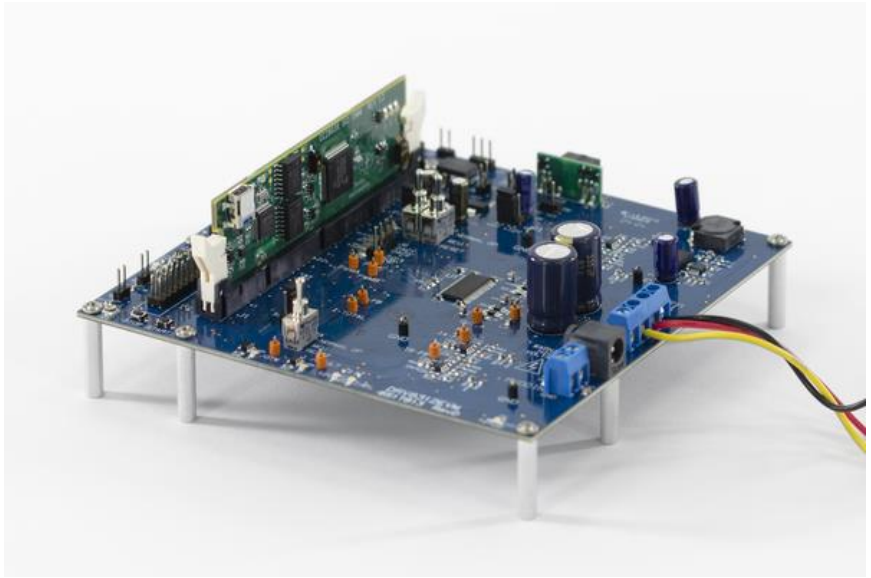
- Motor control position sensing
  - Optical encoder (using eQEP)
  - Hall sensors (using eCAP)
  - Sensorless (Using SMO)



Embedded Coder support for TI C2000 Motor Control kits

- TI F28027 Launchpad + DRV8301 (FX + Video)
- TI F28069 Launchpad + 2 x DRV8301 (FX + Video)
- ControlCard + DRV8312 (Shipping example)
- DM550 + eZdsp (Shipping example)
- High voltage motor control kit (available on demand)





Takeaways

- The Model is at the center
  - You can simulate and test your system at every step
- Customize the generated code for your C2000 MCU
  - Configure production code for your software and data architecture
- Use the code to test directly on your C2000 MCU
  - Run on hardware early in the design process