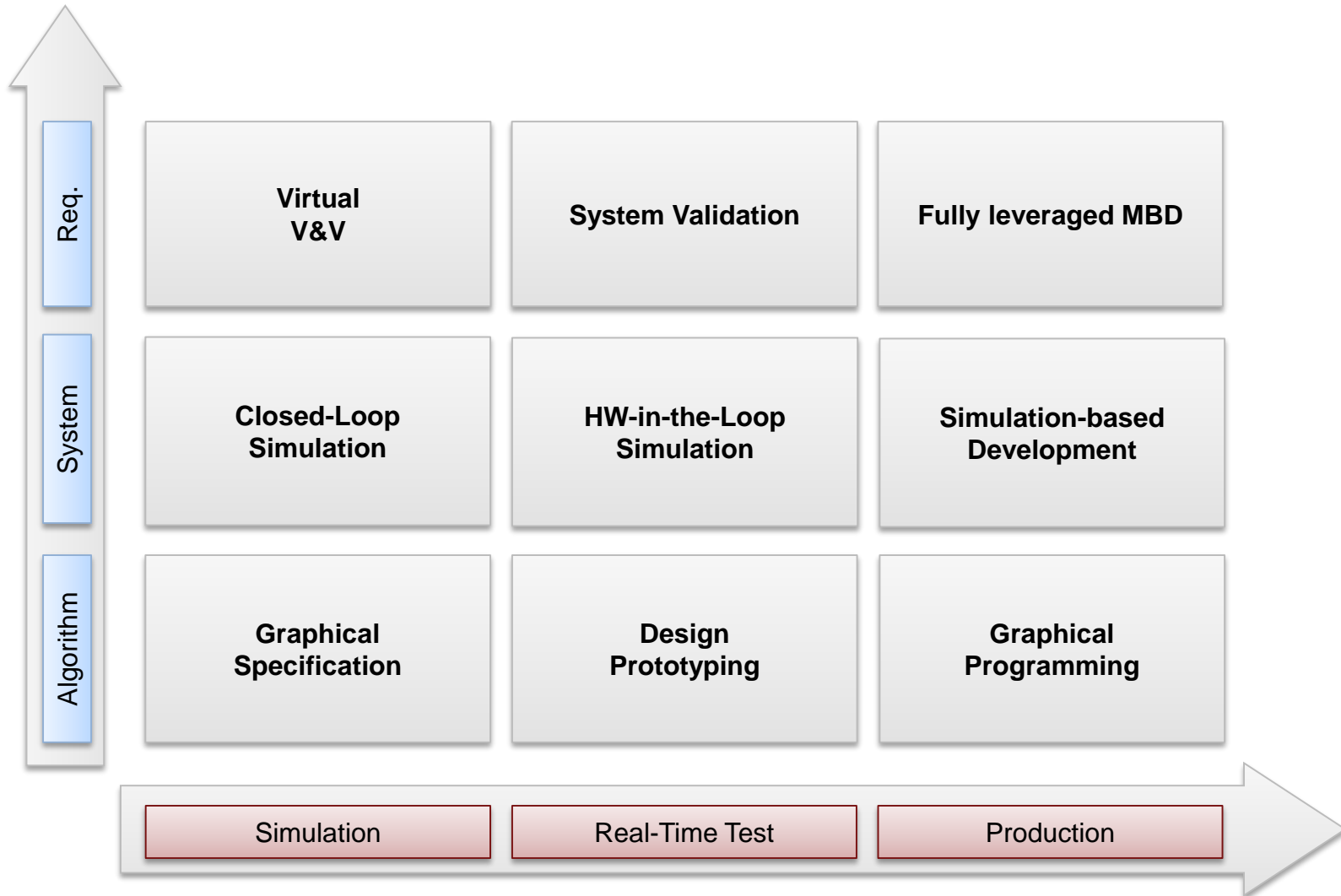


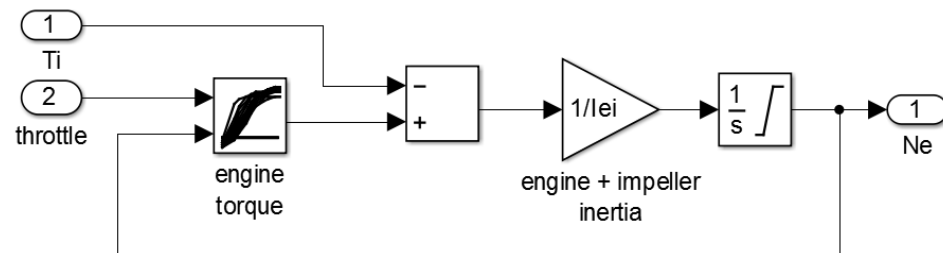
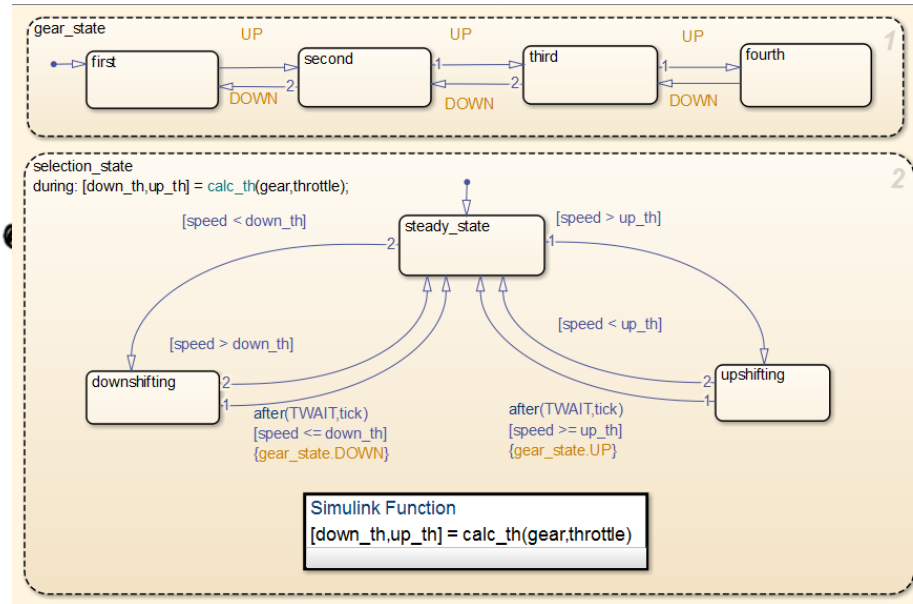
Model-Based Design of a Quadcopter

Ryan Gordon

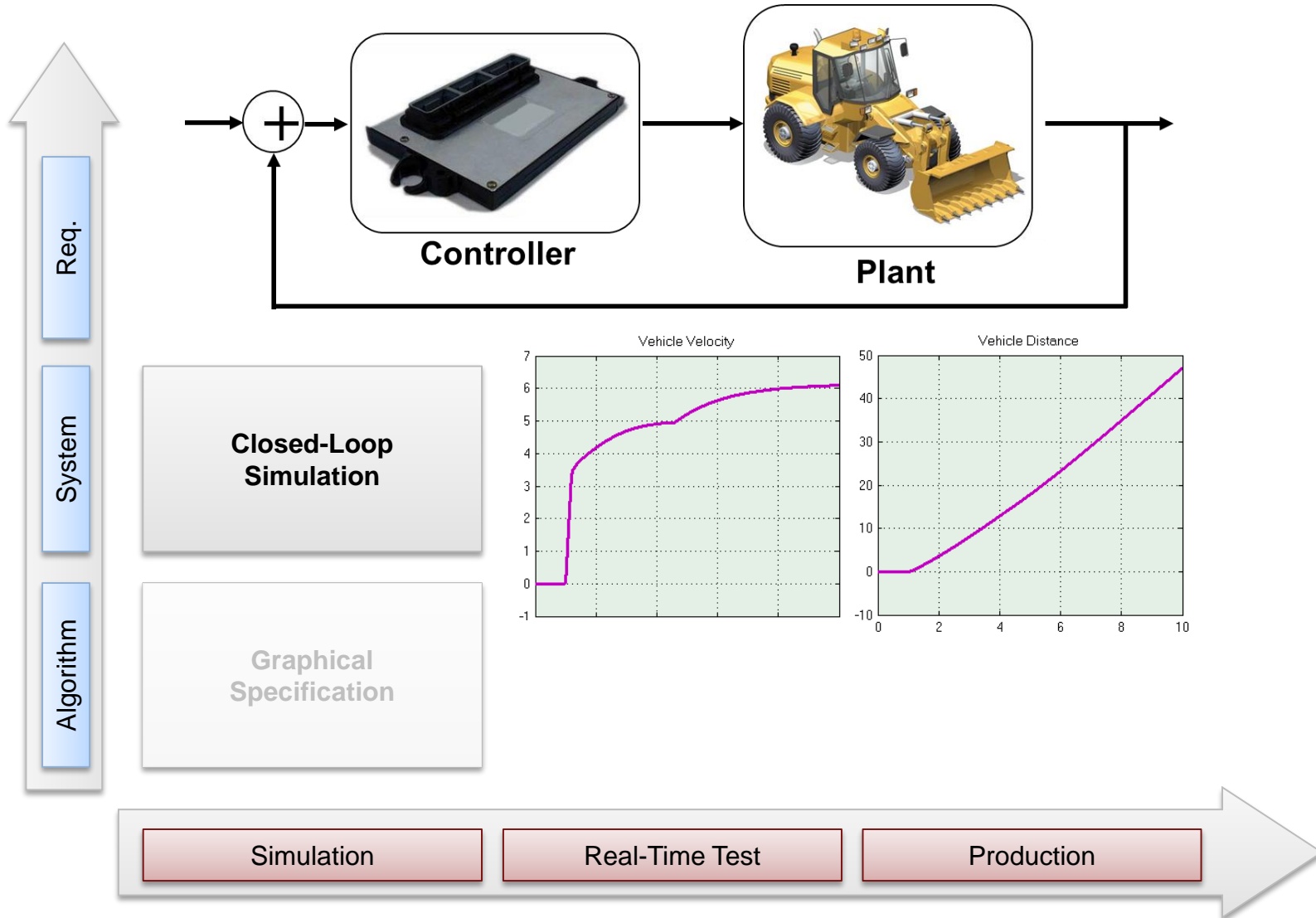
Model-Based Design Adoption Grid



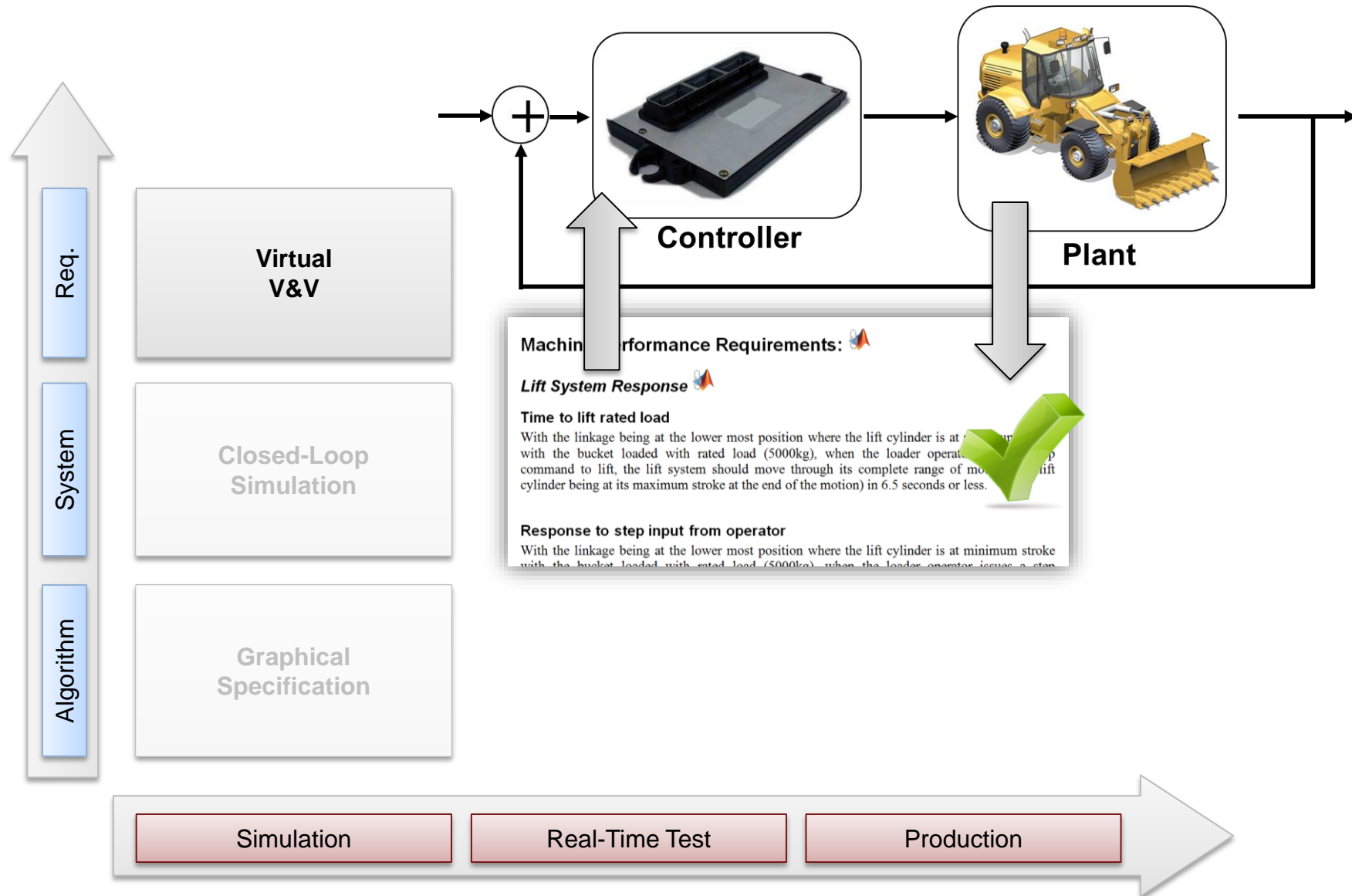
Model-Based Design Adoption Grid



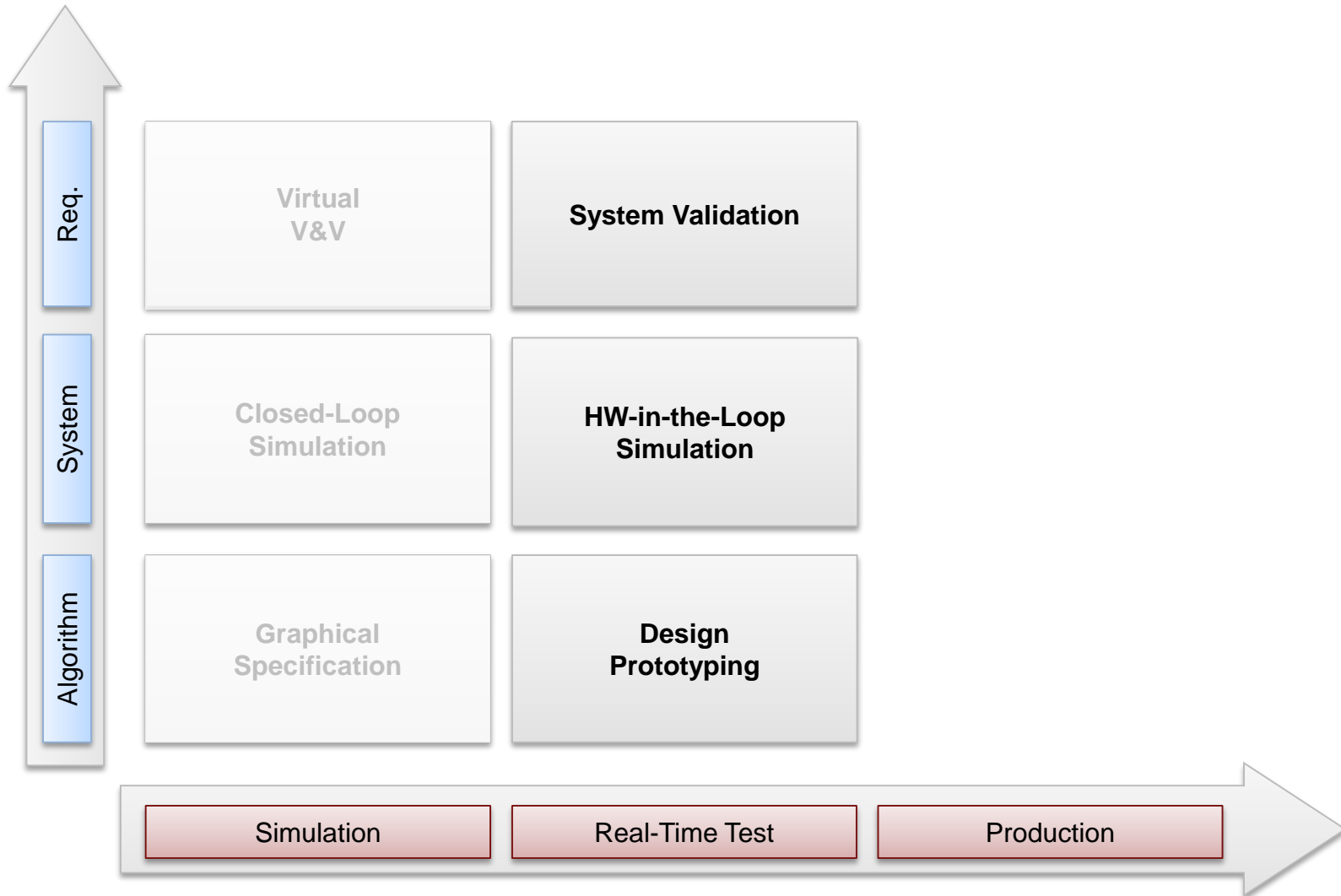
Model-Based Design Adoption Grid



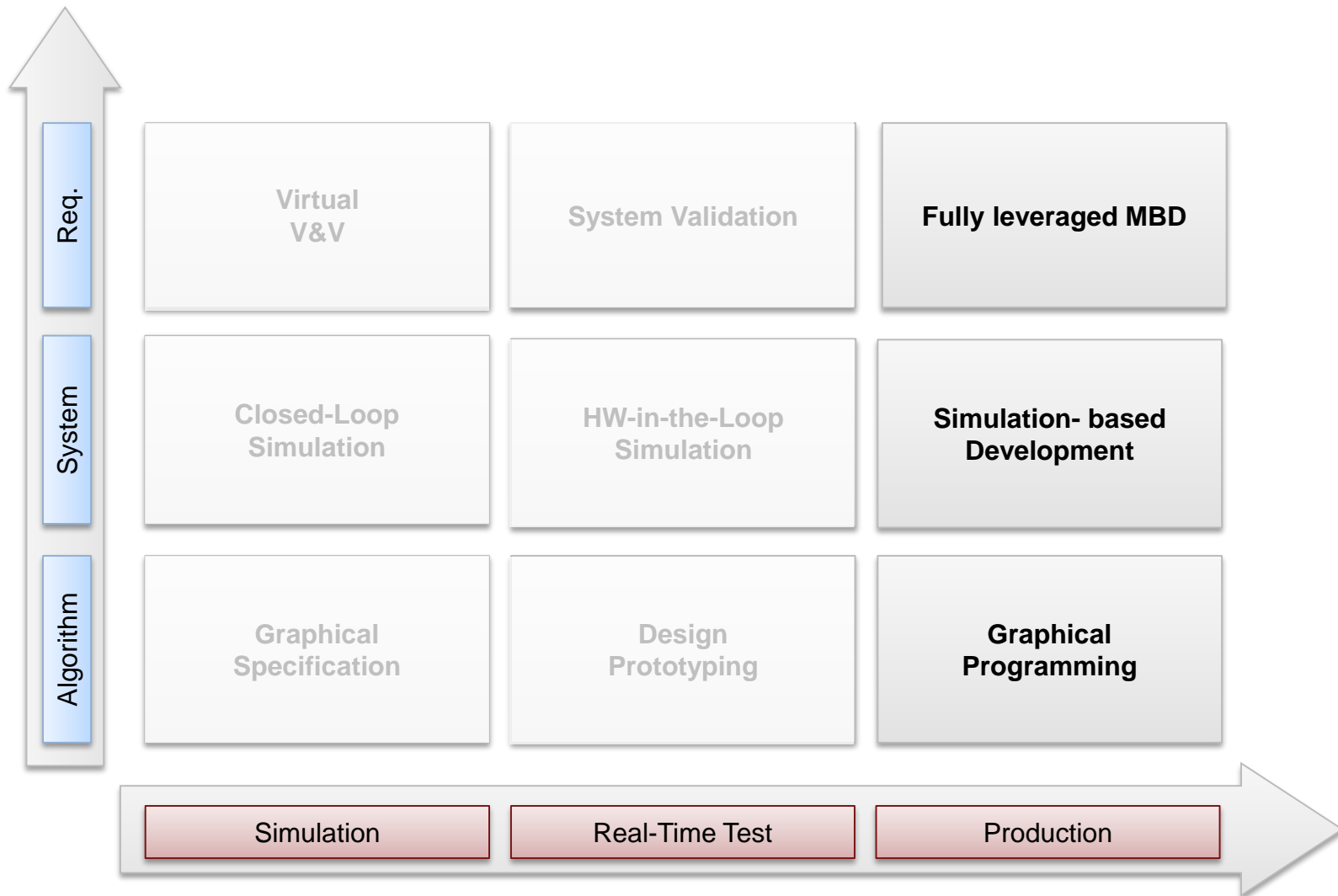
Model-Based Design Adoption Grid



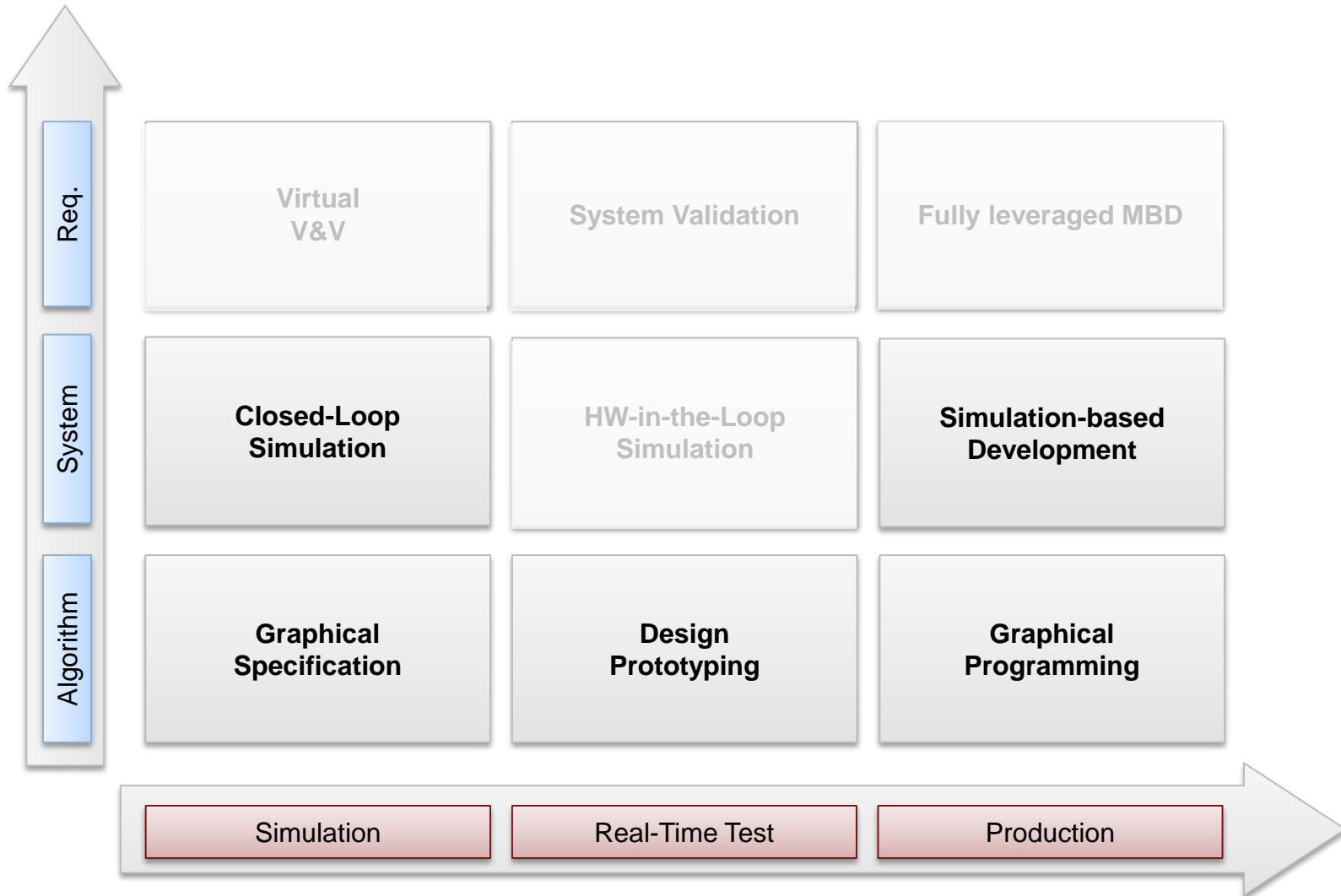
Model-Based Design Adoption Grid



Model-Based Design Adoption Grid

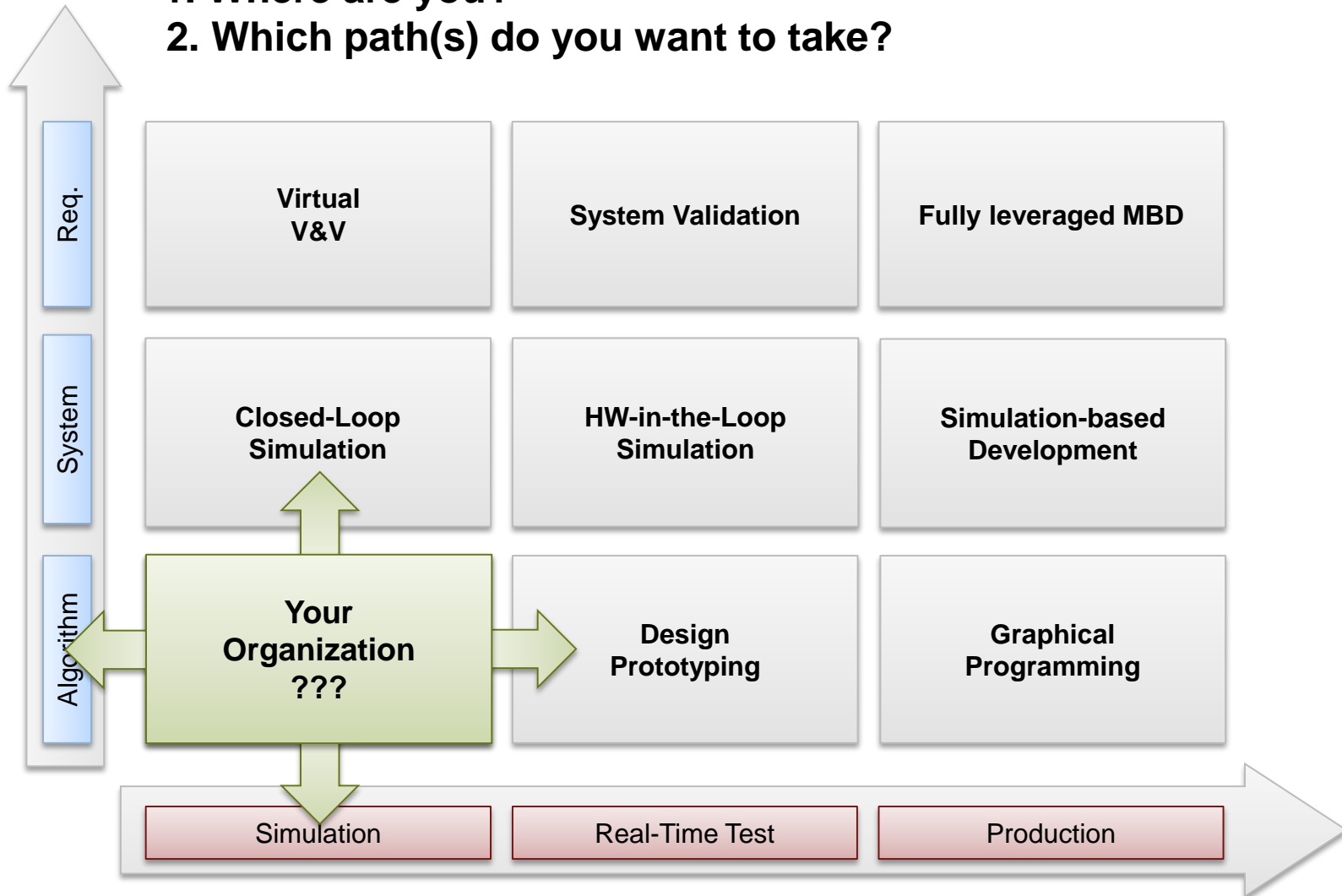


Model-Based Design Adoption Grid



Model-Based Design Adoption Grid

1. Where are you?
2. Which path(s) do you want to take?



Demo Agenda

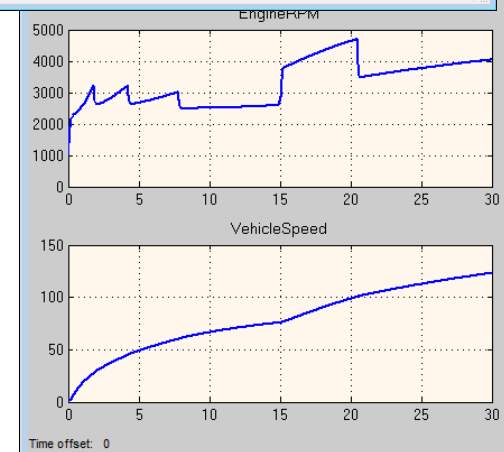
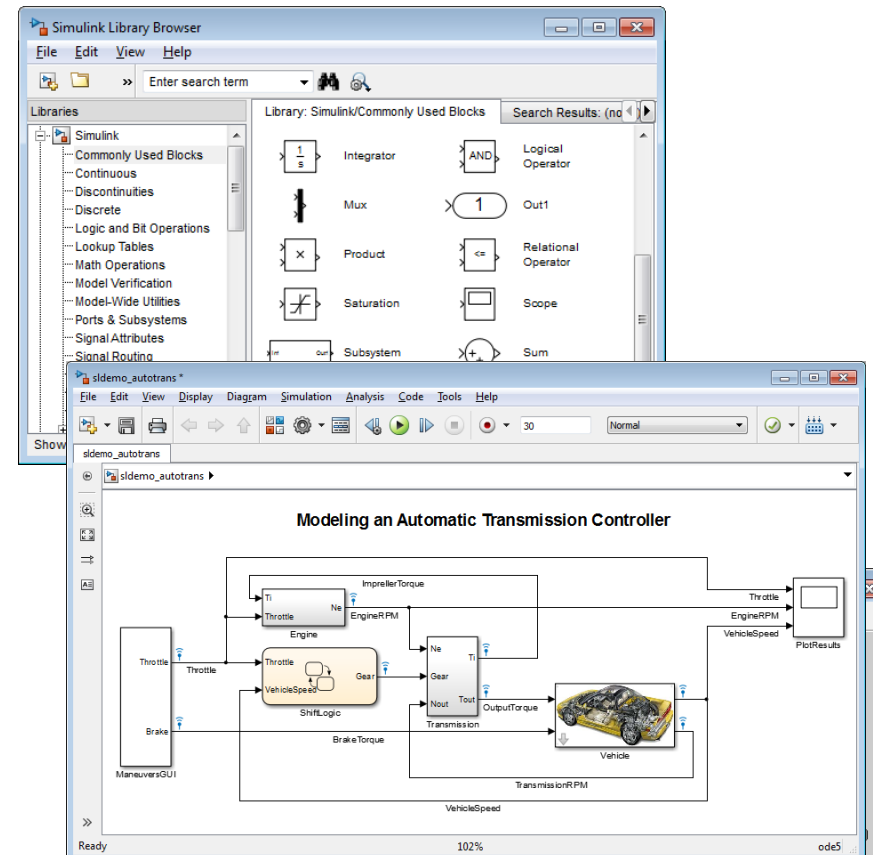
- Build Quadcopter Simulation with SimMechanics
- Build Control System with Simulink Control Design
- Deploy to Hardware with Embedded Coder and Custom Target

Demo Agenda

- **Build Quadcopter Simulation with SimMechanics**
- Build Control System with Simulink Control Design
- Deploy to Hardware with Embedded Coder and Custom Target

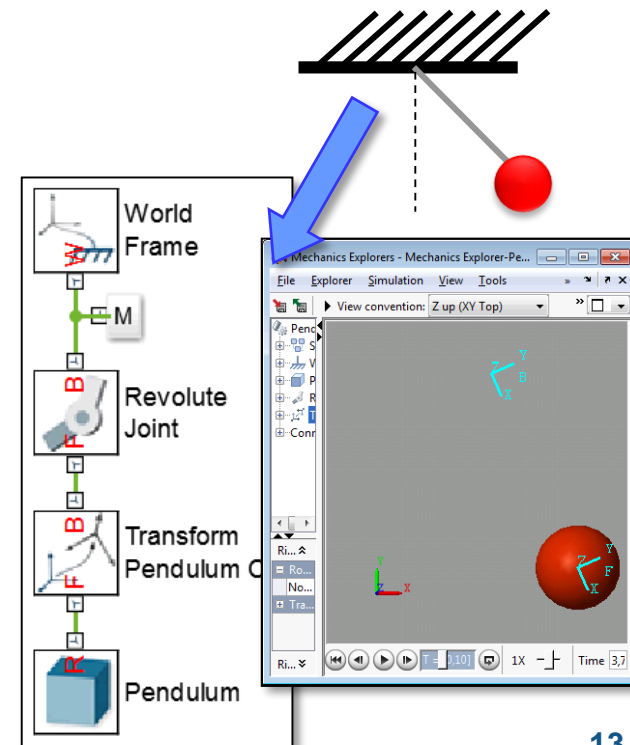
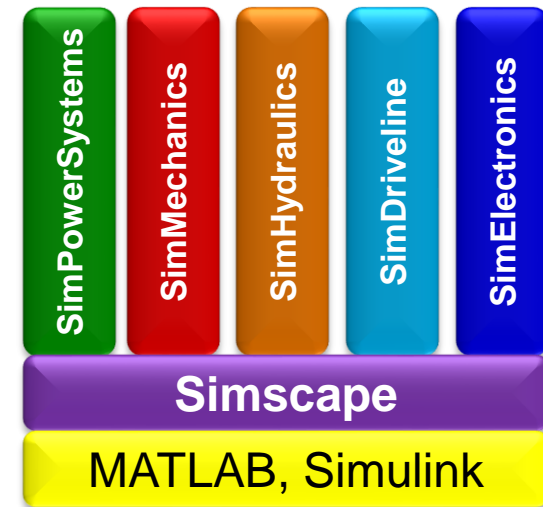
Introduction to Simulink®

- Block-diagram environment
- Model, simulate, and analyze multidomain systems
- Design, implement, and test:
 - Control systems
 - Signal processing systems
 - Communications systems
 - Other dynamic systems
- Platform for Model-Based Design



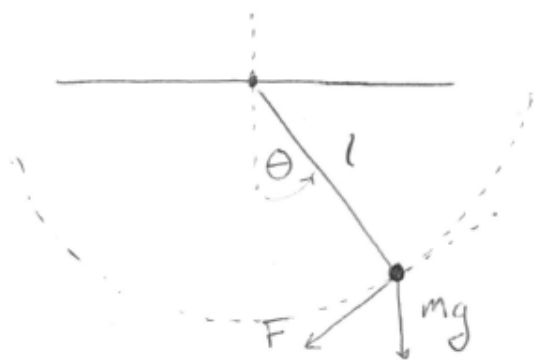
Introduction to SimMechanics

- Enables multibody simulation of 3D mechanical systems
- Construct model using bodies, joints, and forces
 - Model matches structure of system
 - No need to derive and program equations
- Primary uses
 - System-level analysis
 - Control development in Simulink



Equations of Motion

$$\ddot{\theta} = -g/l \sin(\theta)$$



A diagram of a simple pendulum. A horizontal line represents the pivot. A solid line of length l is attached to the pivot and makes an angle θ with a vertical dashed line. A mass is at the end of the string. A force vector mg points vertically downwards from the mass. A force vector F points along the string towards the pivot. A dashed arc represents the path of the pendulum.

$$F = -mg \sin \theta = ma$$
$$a = -g \sin \theta$$

arc length is s

$$s = l\theta$$
$$v = \dot{s} = l\dot{\theta}$$
$$a = \ddot{s} = l\ddot{\theta}$$
$$l\ddot{\theta} = -g \sin \theta$$

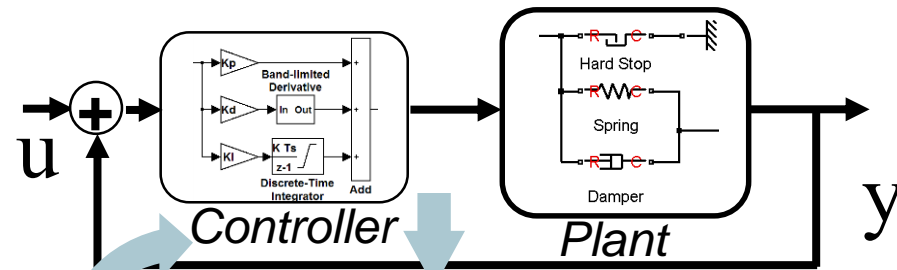
$$\ddot{\theta} = -\frac{g}{l} \sin \theta$$

Demo Agenda

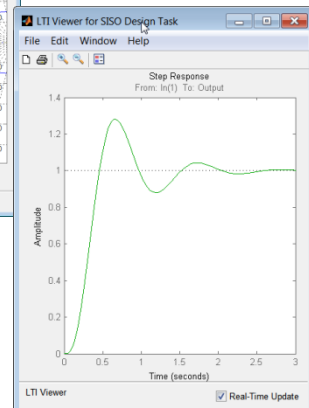
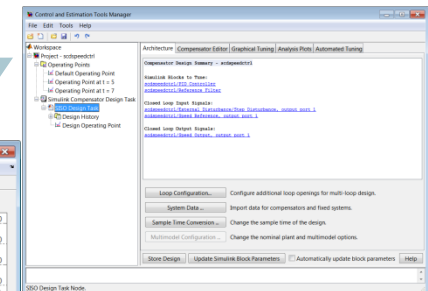
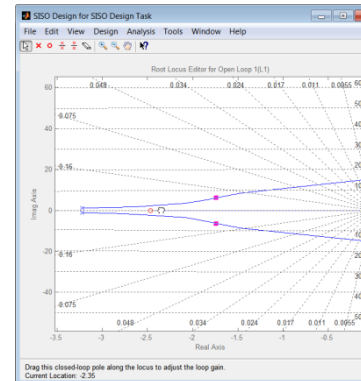
- Build Quadcopter Simulation with SimMechanics
- **Build Control System with Simulink Control Design**
- Deploy to Hardware with Embedded Coder and Custom Target

Introduction to Simulink Control Design

- Automatically tune gains of PID controllers
- Rapidly perform advanced linear analysis and control design for plants modeled in Simulink



$$\underline{\underline{A}} \underline{\underline{x}} + \underline{\underline{B}} \underline{\underline{u}} = 0$$



Demo Agenda

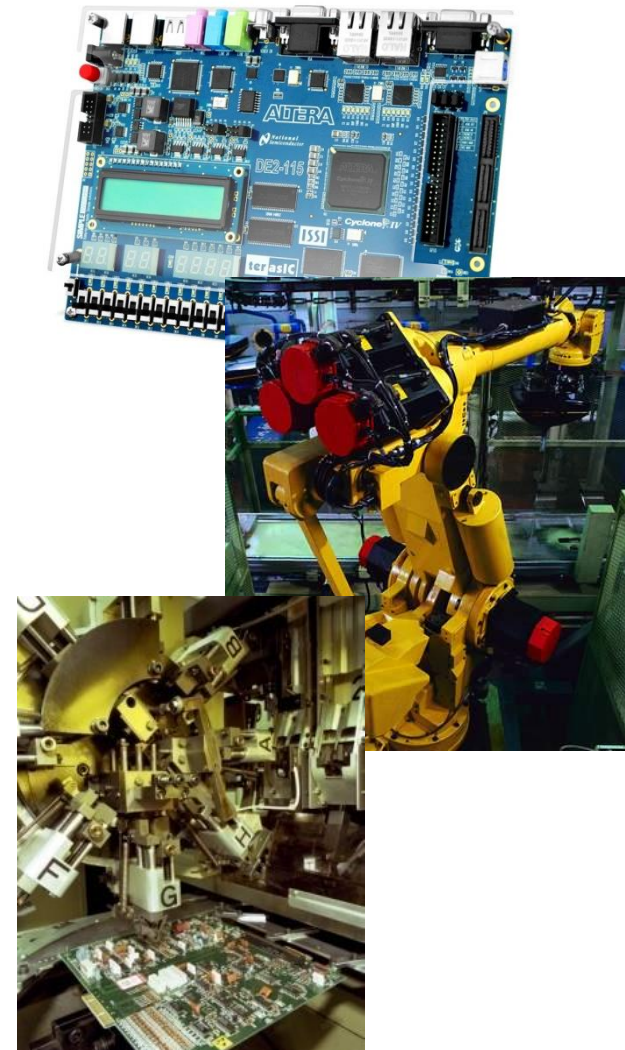
- Build Quadcopter Simulation with SimMechanics
- Build Control System with Simulink Control Design
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Intro to Automatic Code Generation

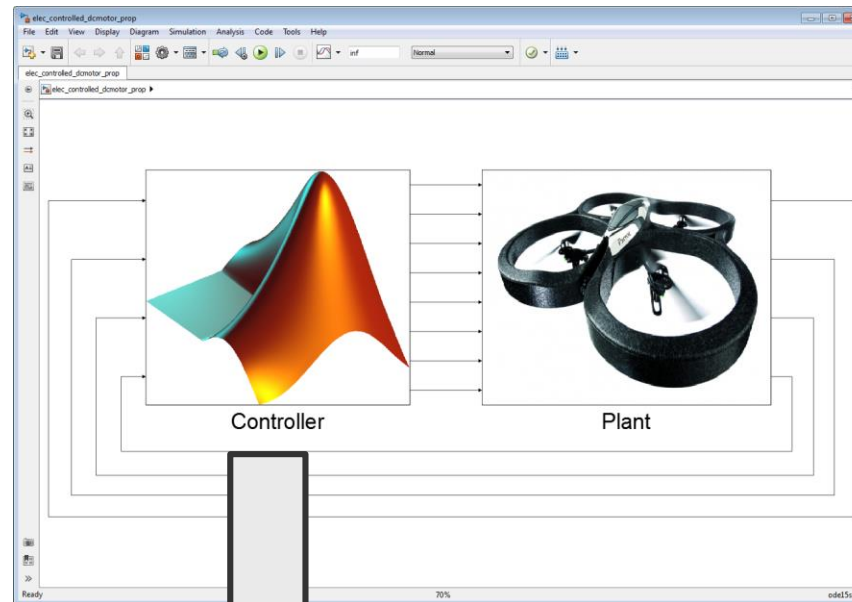
- ANSI-C Code generation for embedded microprocessors
 - MATLAB Coder
 - Simulink Coder
 - Embedded Coder

- HDL Code Generation for FPGAs and ASICs
 - HDL Coder
 - HDL Verifier

- PLC Code Generation
 - Simulink PLC Coder



Usage of Embedded Coder



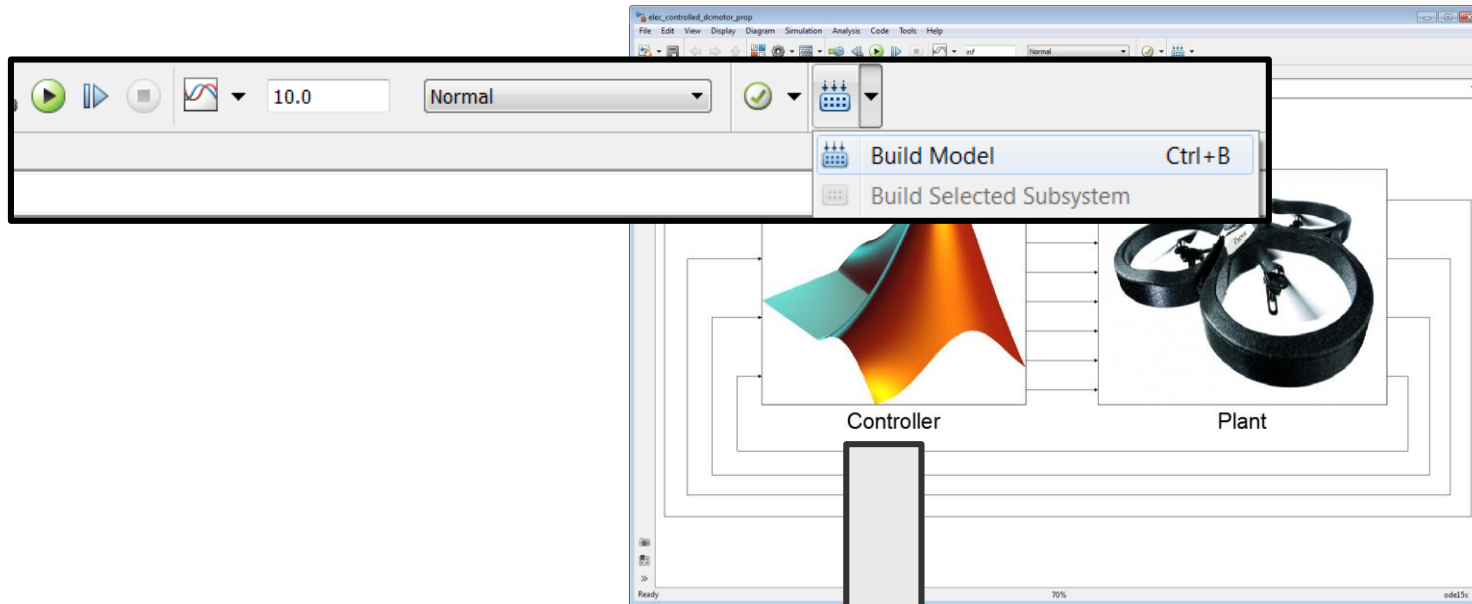
Generate C Code

Merge with Existing Code-Base
(manual integration)

Shared Library / DLL
(ie: integrating with another application)

Target specific platform,
stand-alone execution

Usage of Embedded Coder



Generate C Code

Merge with Existing Code-Base
(manual integration)

Shared Library / DLL
(ie: integrating with another application)

Custom-Target

Target specific platform,
stand-alone execution

What the user sees: Build-Tool Chain Interface

Target selection

System target file:

Language:

Description: Embedded Coder

Target hardware:

Build process

Toolchain settings

Toolchain:

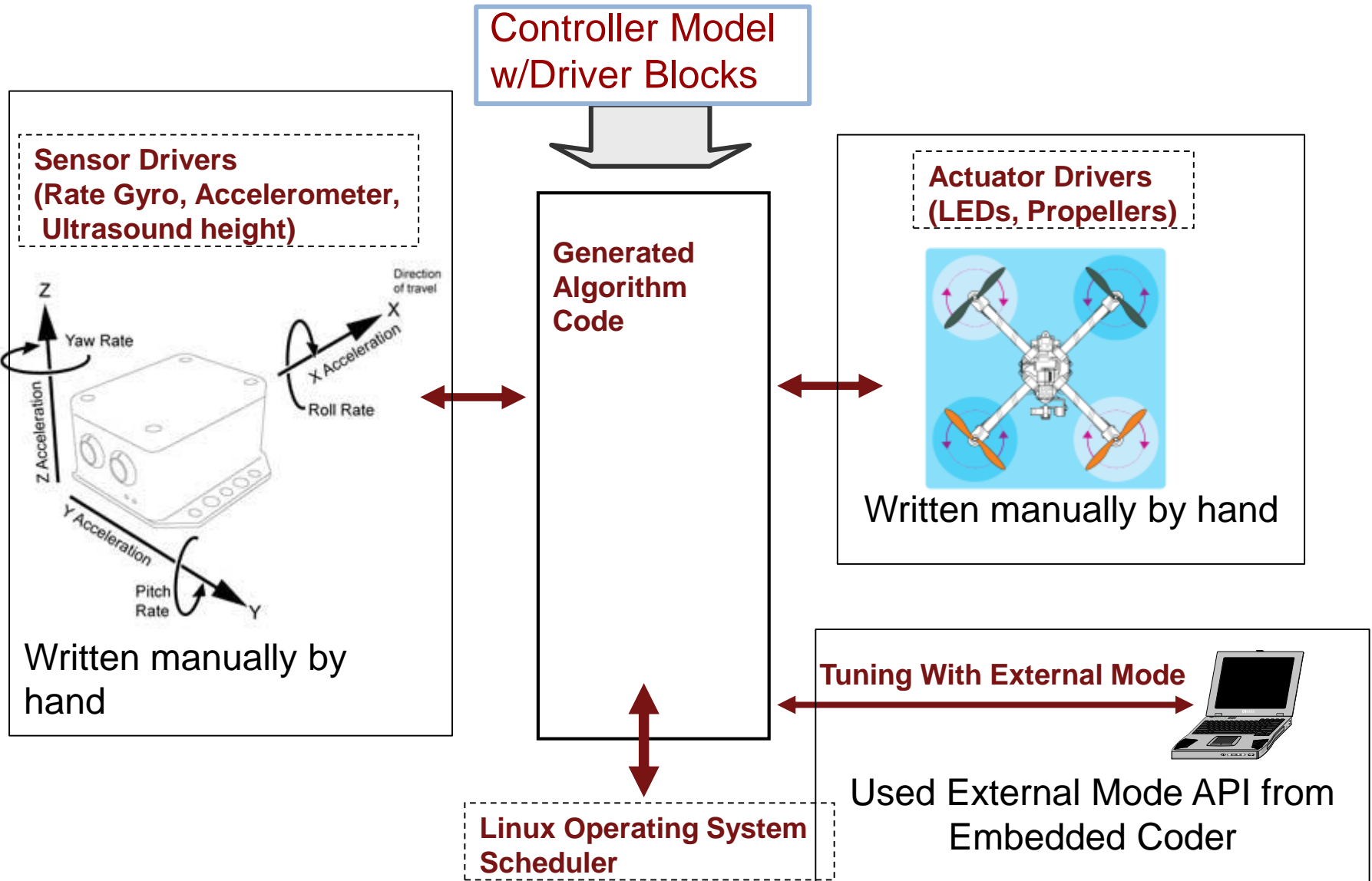
Build configuration: [Show settings](#)

Minimize compilation and linking time

Custom Hardware

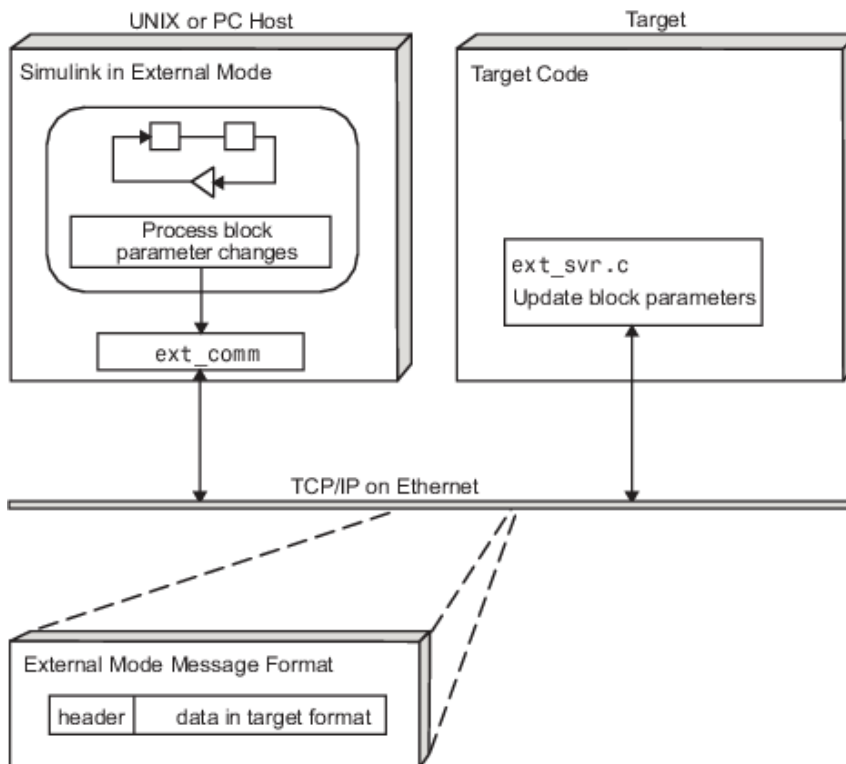
Custom Compiler/Toolchain

How we generated a full program executable



External Mode

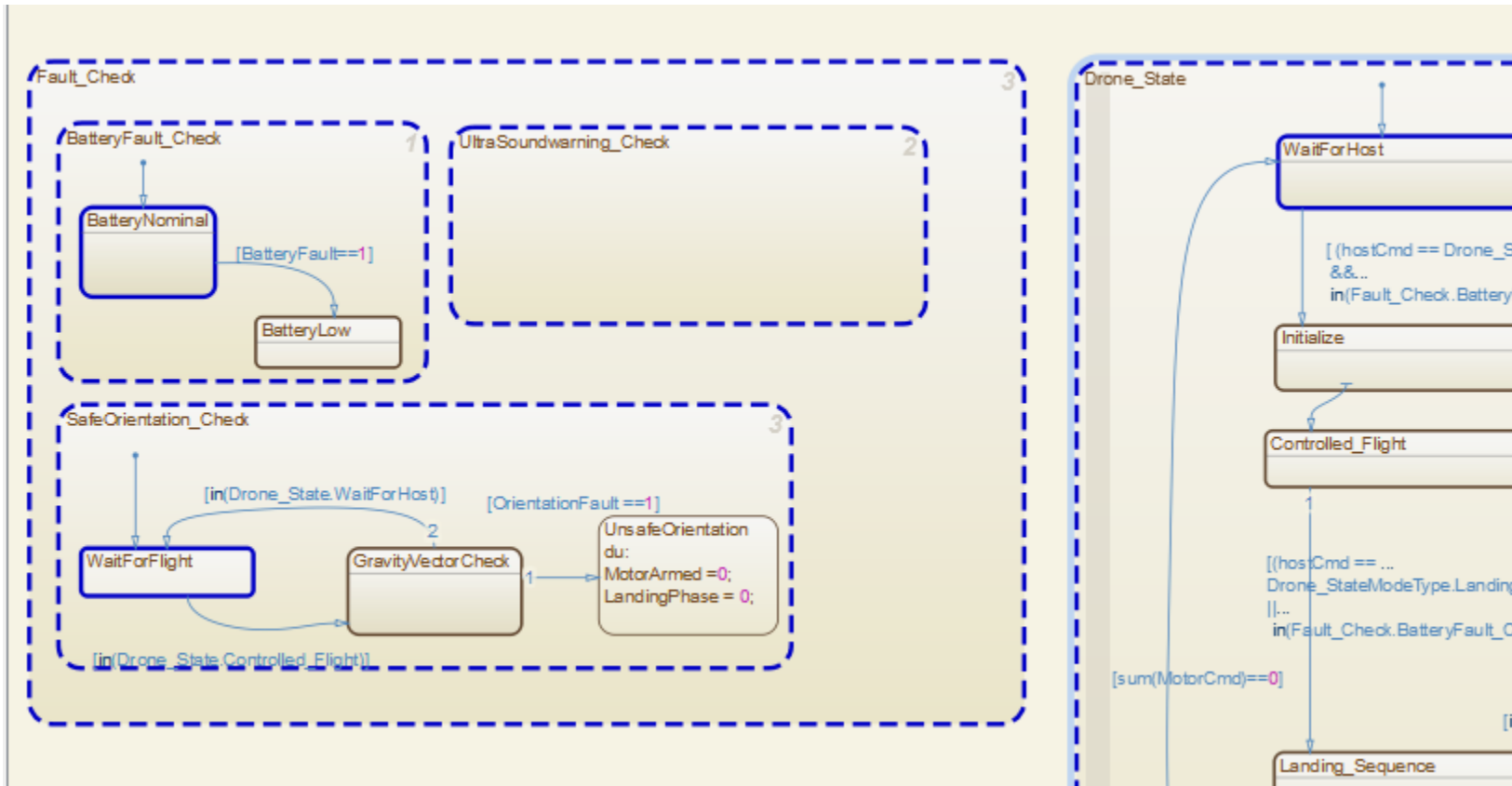
- a) Visualize signals/values of generated code in Simulink as executable is running
- b) Change values of parameters in real-time.
No re-compilation to change a single gain value



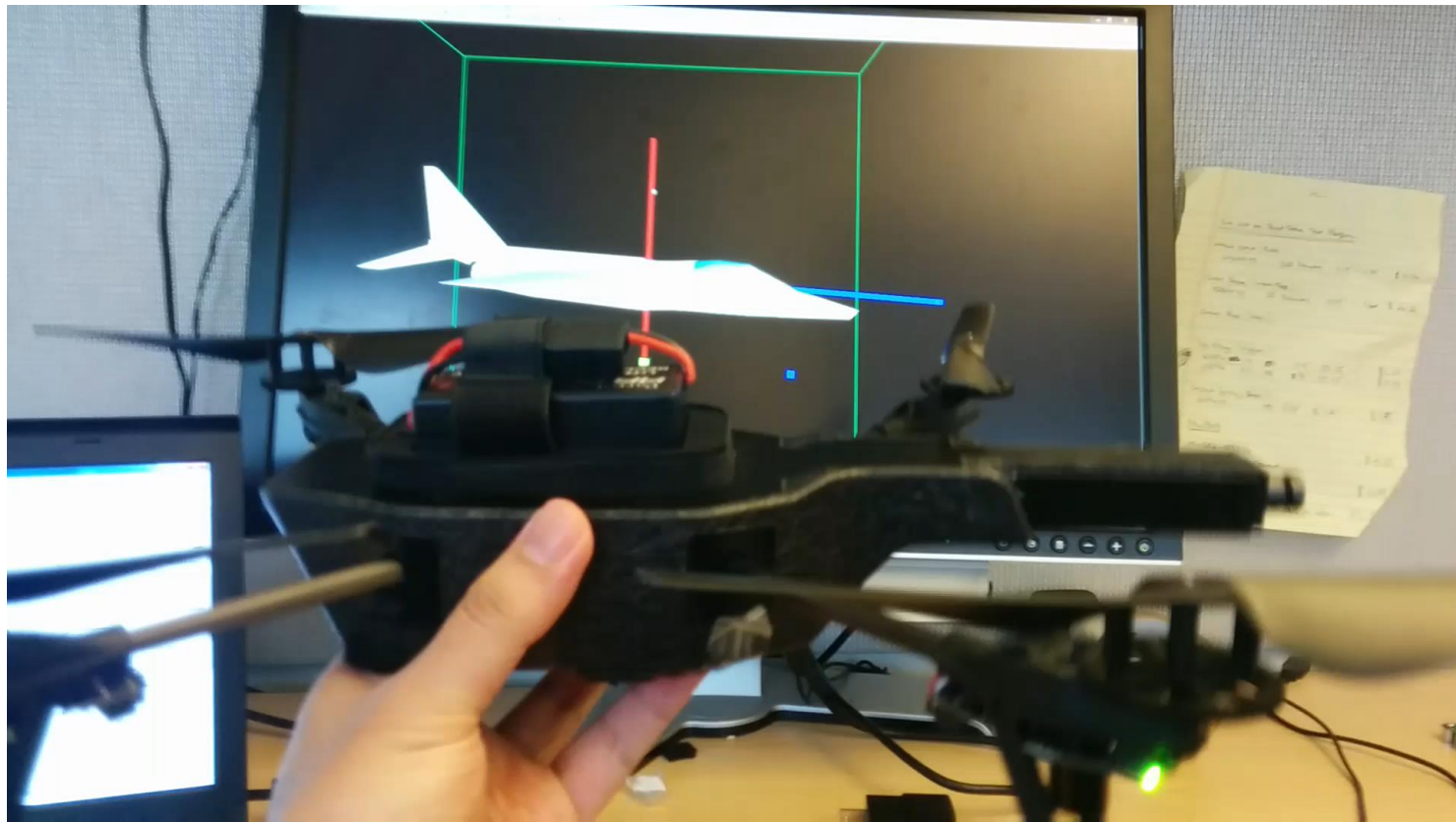
Out-of-the-box support:

- Support for UNIX / Windows PC and WindRiver VxWorks
- Transport layers included:
Serial RS-232, TCP/IP
- Can customize your own transport layer, API available for this

External Mode Demo



Video of External Mode



HW connectivity support

The image shows the MATLAB R2020a ribbon menu with the 'Add-Ons' dropdown menu open. The 'Get Hardware Support Packages' option is highlighted, and a red arrow points to it. The ribbon categories include VARIABLE, CODE, SIMULINK, and ENVIRONMENT.

The Support Package Installer window is open, showing a list of support packages. The 'Update' checkbox for the first package is checked. The window title is 'Support Package Installer'.

Select support package to install

Show: All (69)

Support for:

- ARM Cortex-A
- ARM Cortex-M
- ARM Cortex-based VEX Microcontroller
- AUTOSAR Standard
- Altera FPGA Boards
- Altera SoC
- Analog Devices DSPs
- Android Sensors
- Arduino
- BEEcube miniBEE Platform
- BeagleBoard
- BeagleBone Black
- Classification Learner
- DCAM Hardware
- Data Translation Frame Grabbers
- Digilent Analog Discovery
- DirectSound Audio
- Freescale Kinetis Microcontrollers
- GenICam Interface
- GigE Vision Hardware
- Hamamatsu Hardware
- Kinect for Windows Sensor
- Kvaser CAN Devices
- LEGO MINDSTORMS EV3

Support packages:

	Action	Installed Version	Latest Version	Description	Required Base Product
1	<input checked="" type="checkbox"/> Update	14.2.0	14.2.1	Generate code optimized for Cortex A processors.	Embedded Coder
2	<input type="checkbox"/> Reinstall	14.2.0	14.2.0	Generate optimized DSP algorithm code for Cortex-A.	DSP System Tool...

Pixhawk Target

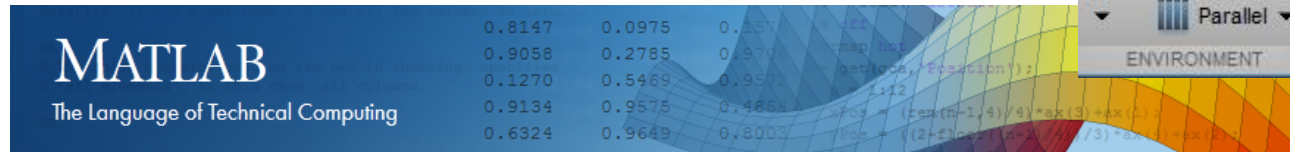
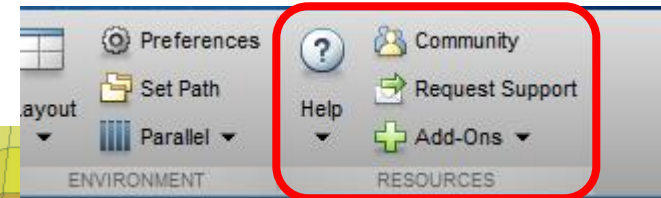


- Open source hardware for all sorts of the amateur/commercial micro-UAVs
- Highly customizable hardware. Can be used with quad-copter, hexa-copter or fixed wing UAVs
- Runs a Real-Time Operating System (NuttX) on ARM Cortex-M.
- Simulink code generation target written by Steve Kuznicki (Pilot Engineering). Tested with a hexa-copter
- AR Drone and Pixhawk Target Support package coming soon!

Resources

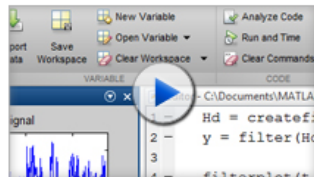
Community, Support, and Add-Ons

<http://www.mathworks.com>



- Overview
- Videos
- Code Examples
- Webinars

MATLAB® is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, you can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java™.



Product Overview 2:05

You can use MATLAB for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology. More than a million engineers and scientists in industry and academia use MATLAB, the language of technical computing.

TRY OR BUY

- [Contact Sales](#)
- [Product Trial](#)
- [Pricing and Licens](#)

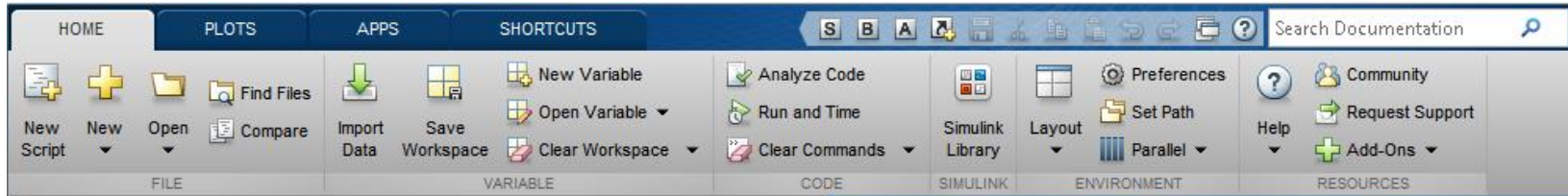
R2014a

Download the Latest Relea

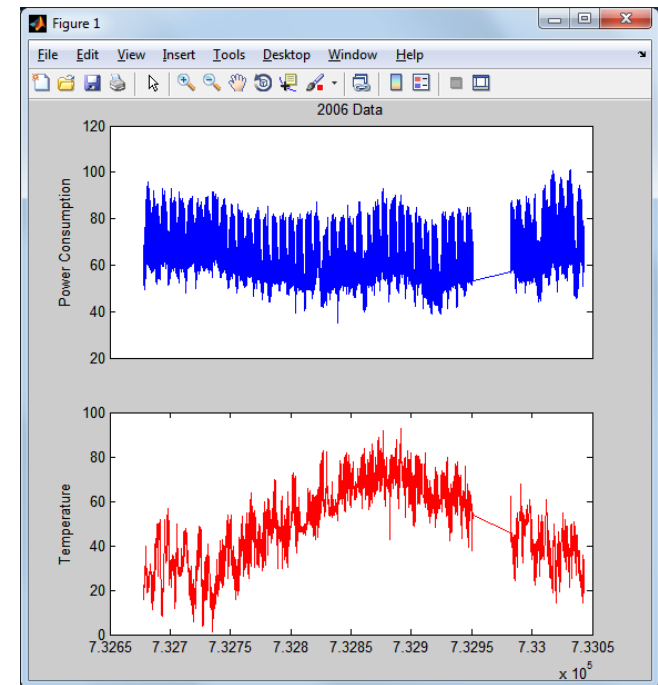
Getting Started with (5:06)

- Seminars
- Webinars
- Workshops
- Videos
- Examples
- Technical Support
- Pilot Engineering
- Training
- Consulting
- Book Program
- File Exchange
- MATLAB Answers
- Apps
- Hardware support packages

Improved productivity and effectiveness



- Accessing data
- Exploring, analyzing, and visualizing data interactively
- Automating common tasks
- Debugging and optimizing code
- Sharing results
- Discovering new features and capabilities



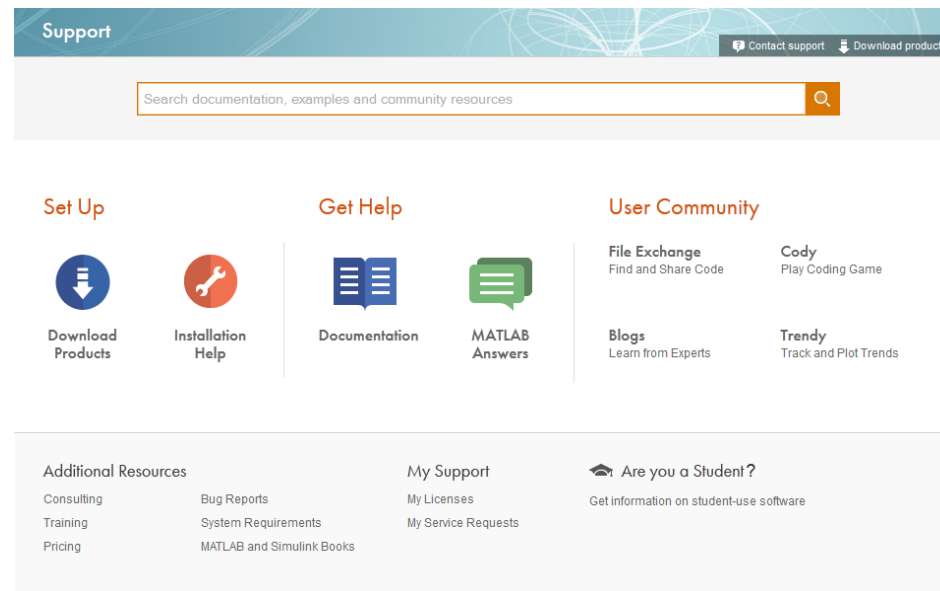
Technical Support

Resources

- support@mathworks.com
- Over 100 support engineers
 - All with MS degrees (EE, ME, CS)
 - Local support in North America, Europe, and Asia
- Comprehensive, product-specific Web support resources

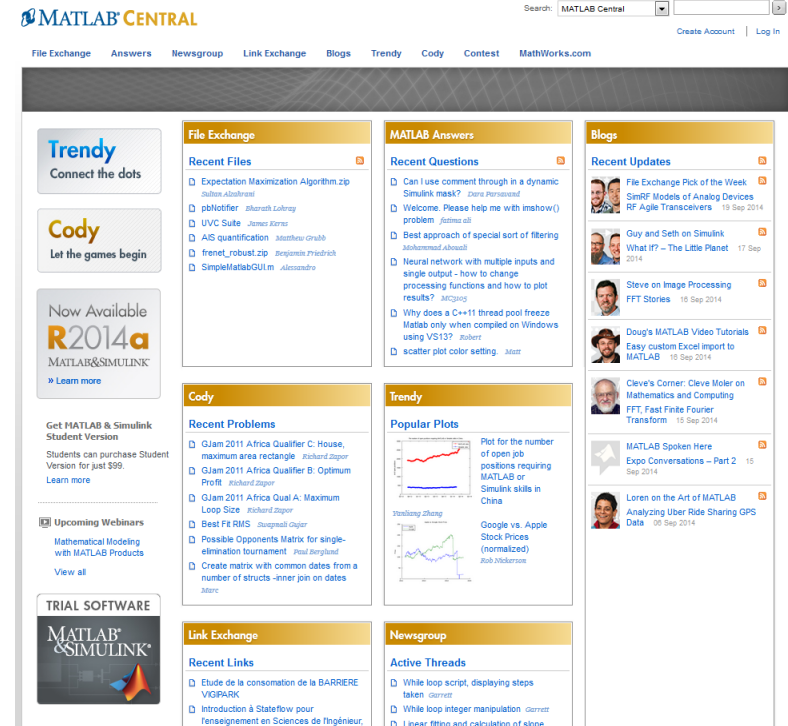
High customer satisfaction

- 95% of calls answered within three minutes
- 70% of issues resolved within 24 hours
- 80% of customers surveyed rate satisfaction at 80-100%



MATLAB Central

- Open exchange for the MATLAB and Simulink user community
- 70,000 visits per day
- File Exchange
 - Access more than 10,000 free files, including functions, apps, examples, and models
- MATLAB Answers
 - Ask MATLAB questions or search more than 18,000 community-answered questions.
- Newsgroup
 - Web forum for technical discussions about MATLAB and Simulink
 - 1,400 posts per day



- Blogs
 - Read commentary from engineers who design, build, and support MATLAB and Simulink.

Training Services

Exploit the full potential of MathWorks products

Flexible delivery options:

- Public training available worldwide
- Onsite training with standard or customized courses
- Web-based training with live, interactive instructor-led courses
- Self-paced interactive online training



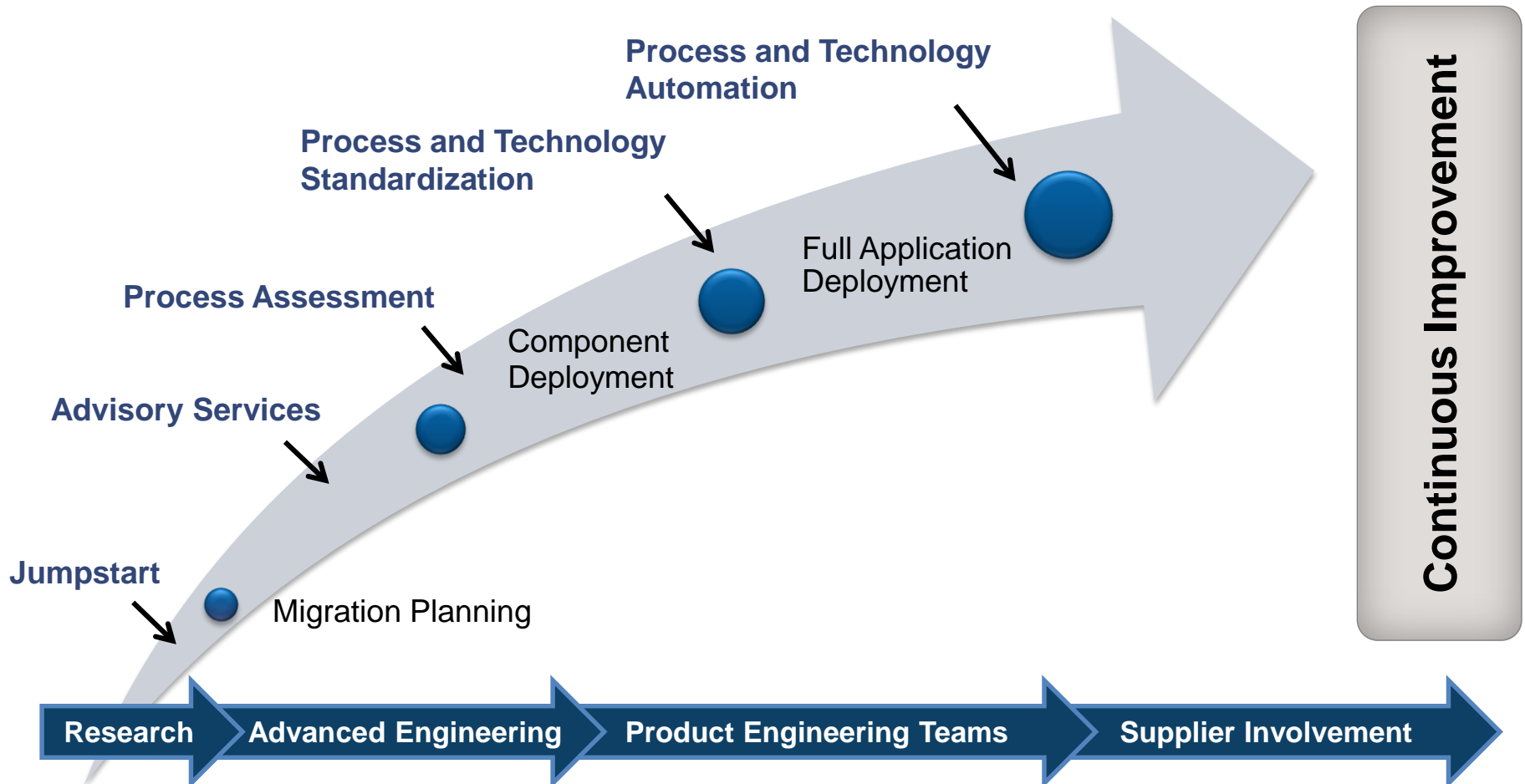
More than 30 course offerings:

- Introductory and intermediate training on MATLAB, Simulink, Stateflow, code generation, and Polyspace products
- Specialized courses in control design, signal processing, parallel computing, code generation, communications, financial analysis, and other areas

Consulting Services

Accelerate your return on investment

A global team of experts supporting every stage of tool and process integration



Questions?