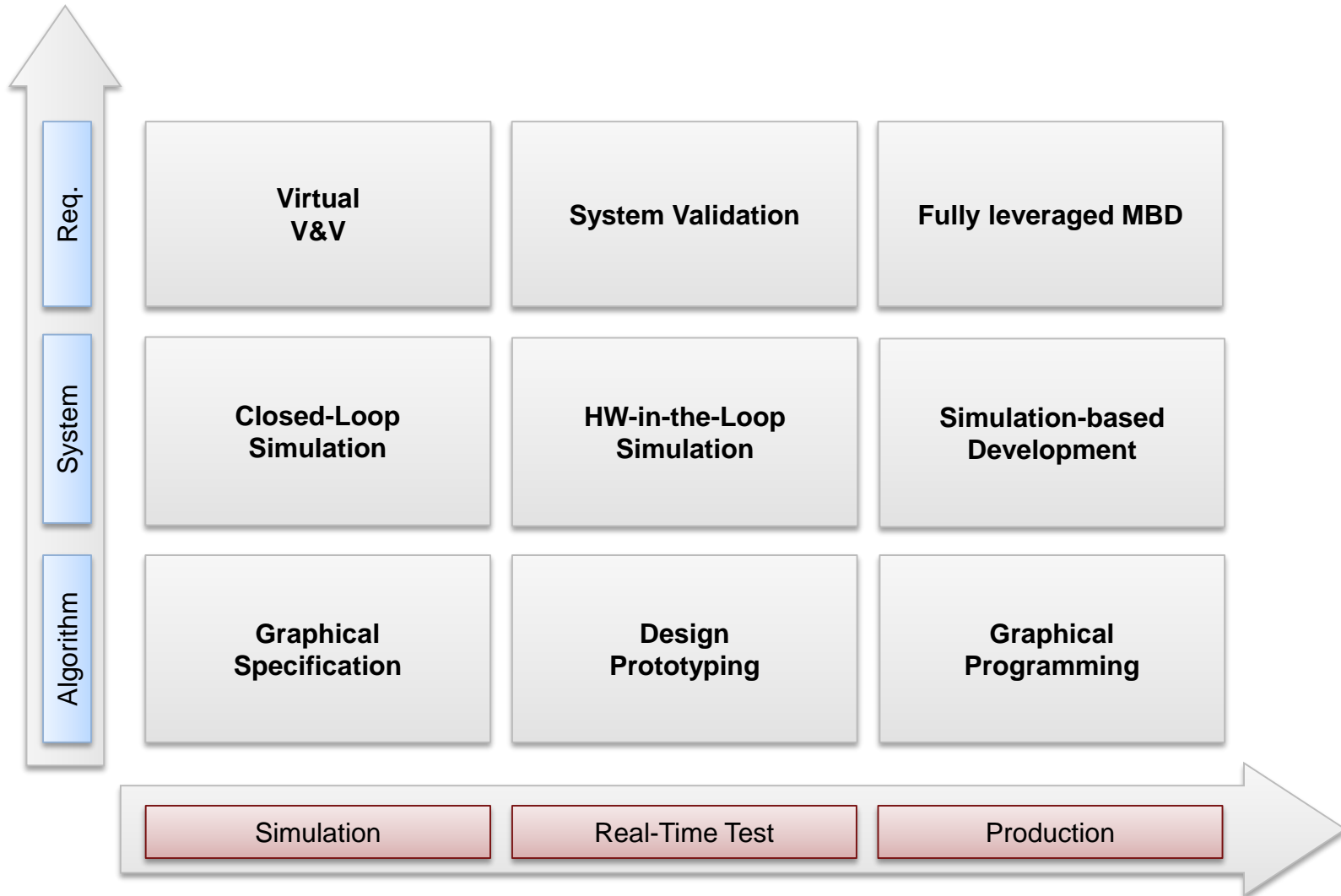


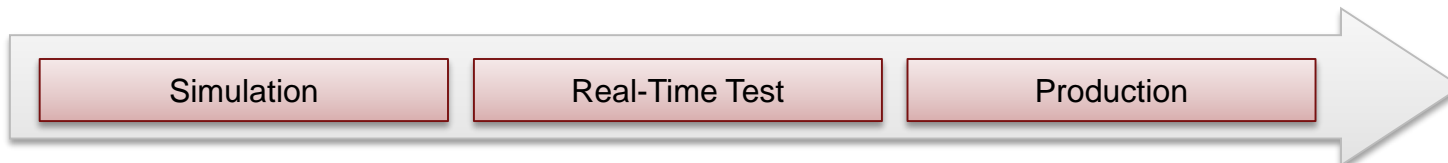
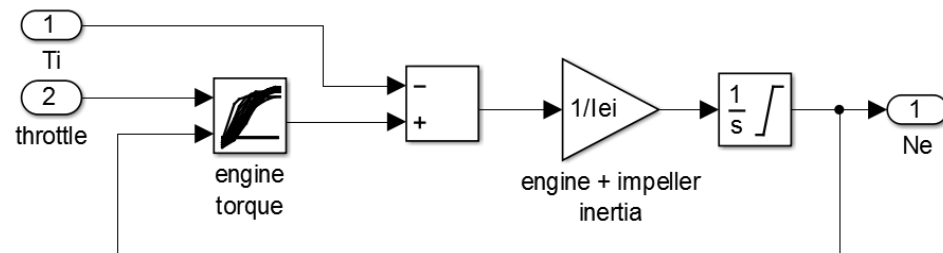
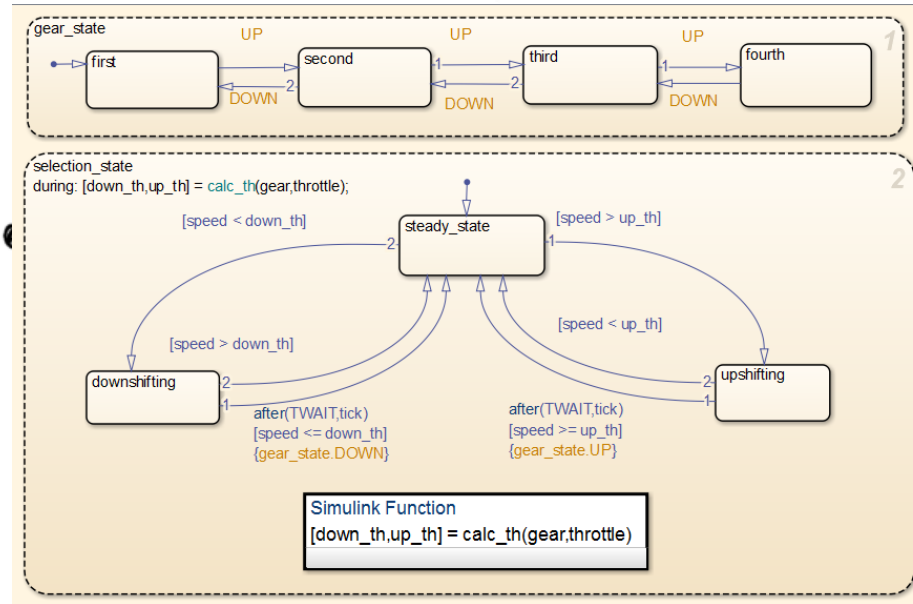
Model-Based Design of a Quadcopter

Ryan Gordon

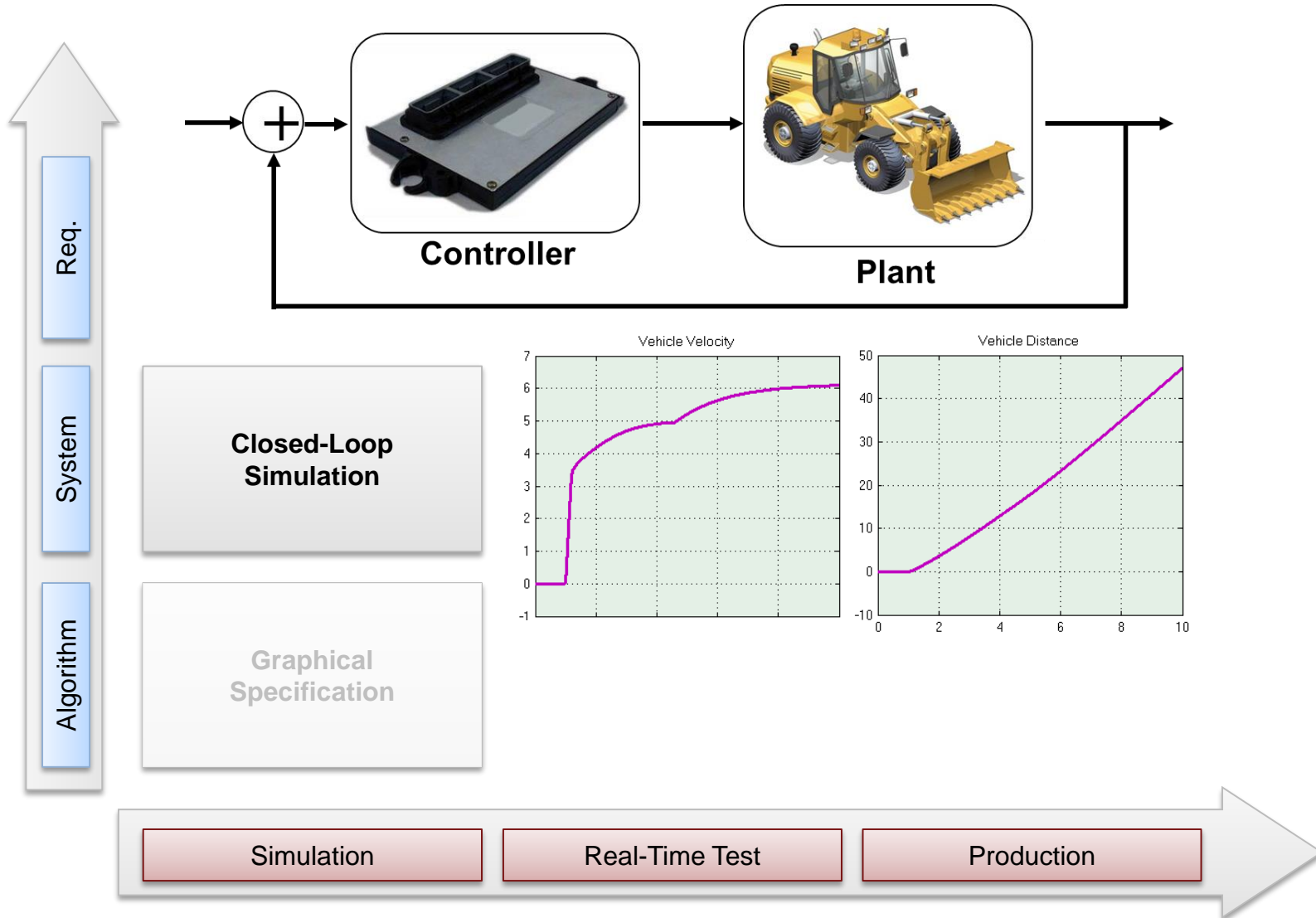
Model-Based Design Adoption Grid



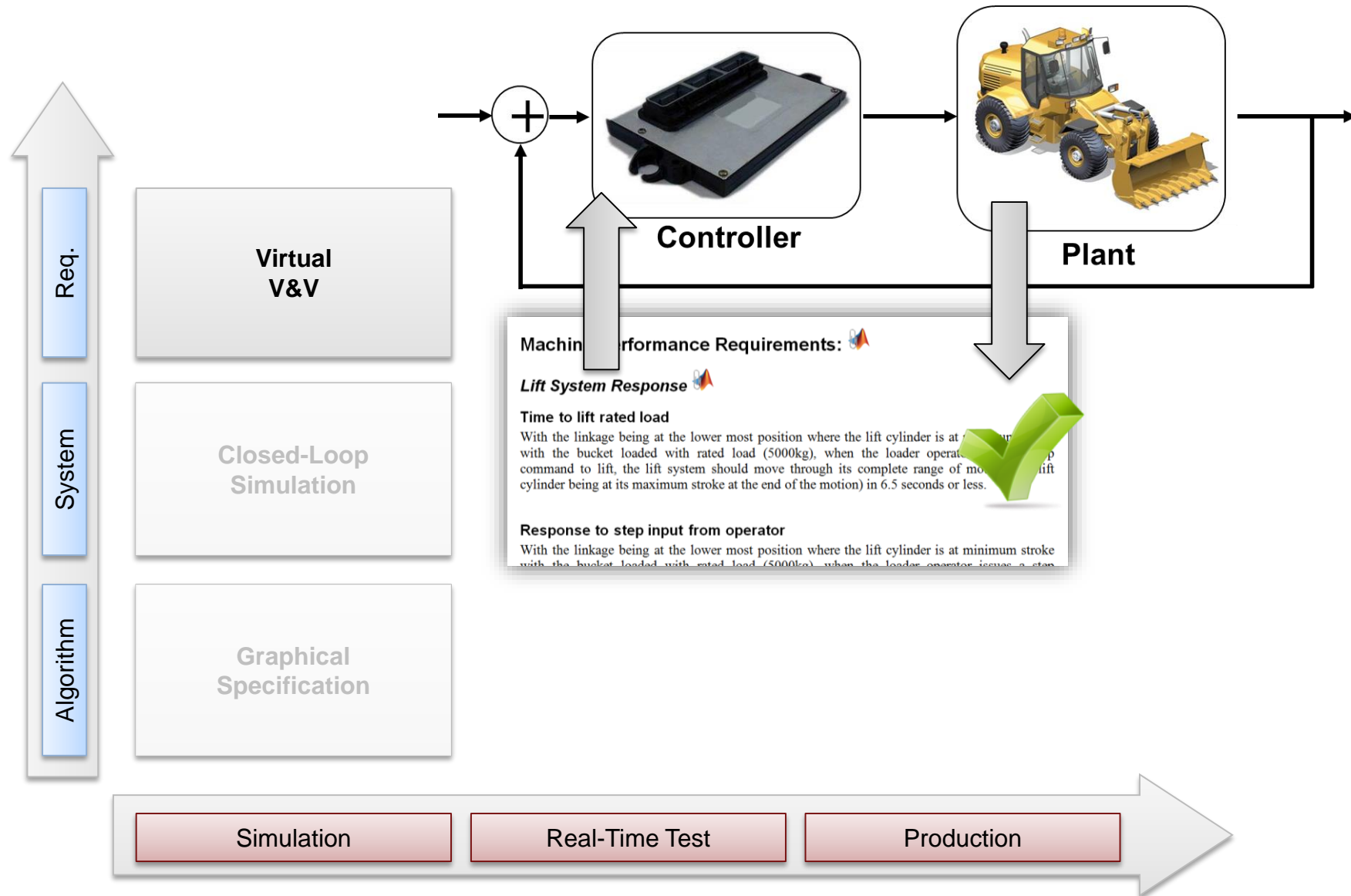
Model-Based Design Adoption Grid



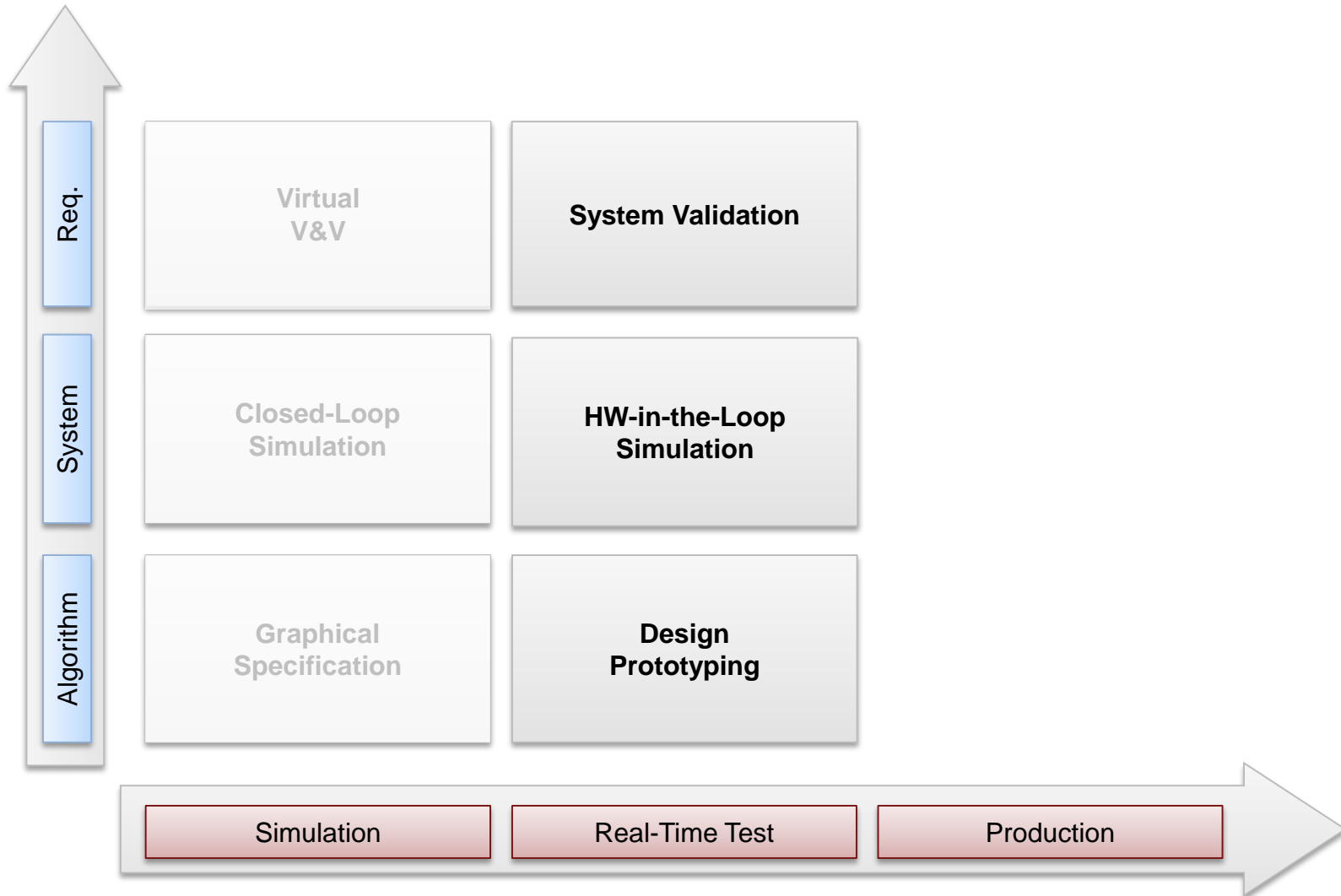
Model-Based Design Adoption Grid



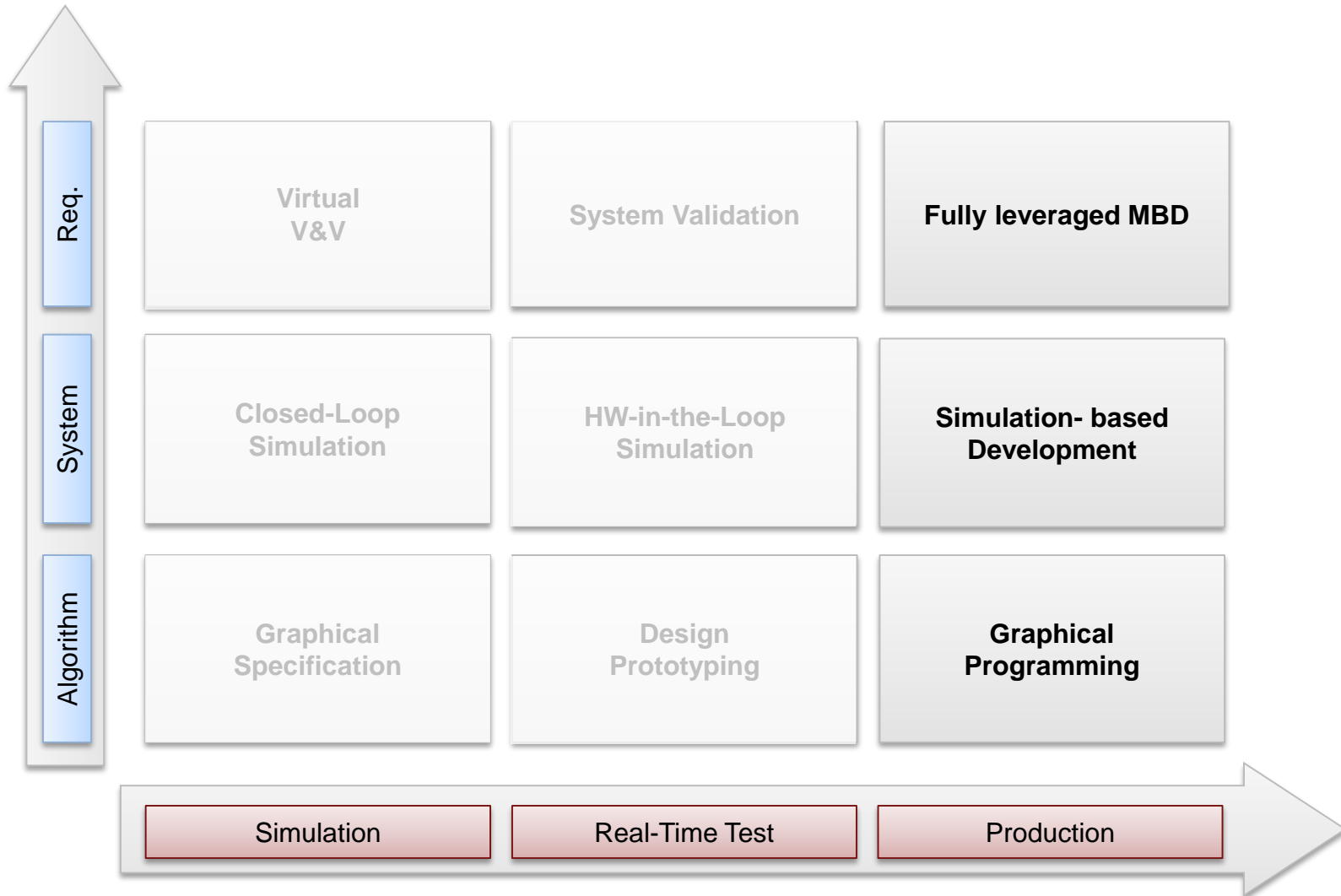
Model-Based Design Adoption Grid



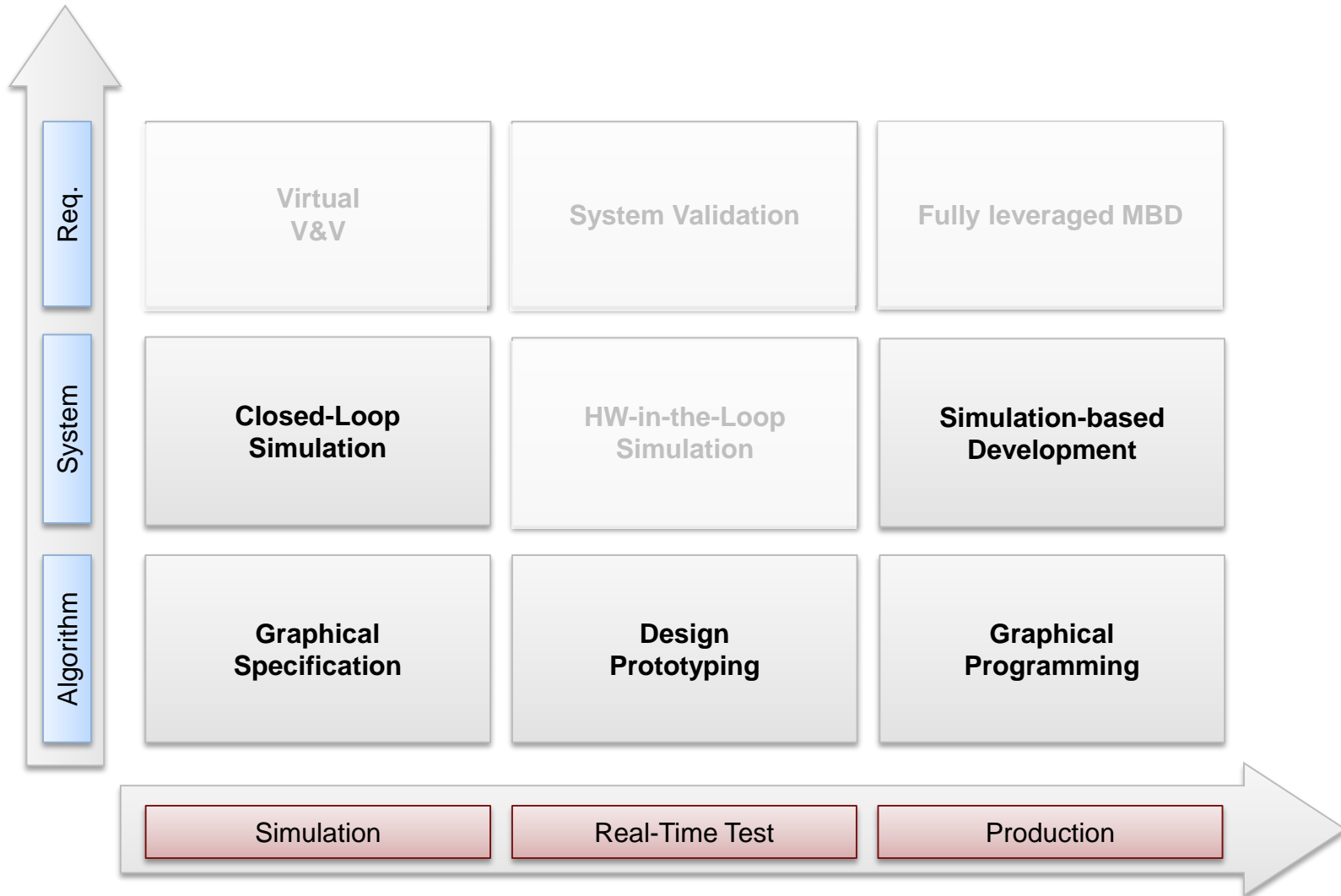
Model-Based Design Adoption Grid



Model-Based Design Adoption Grid

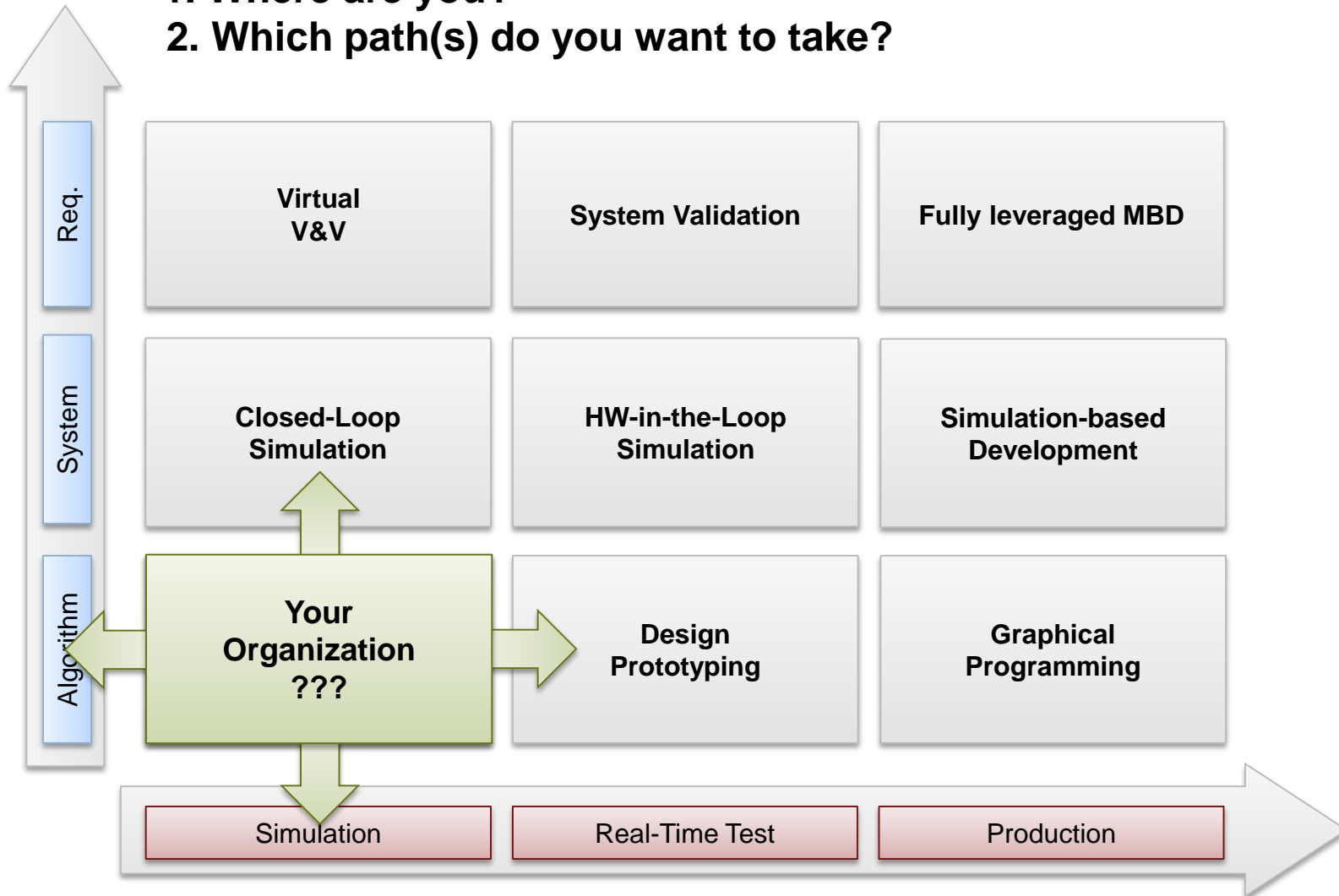


Model-Based Design Adoption Grid



Model-Based Design Adoption Grid

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



Demo Agenda

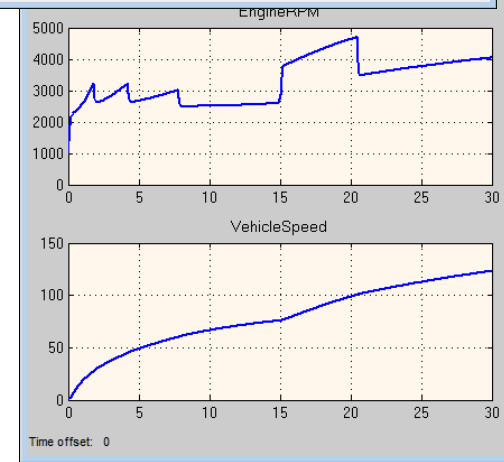
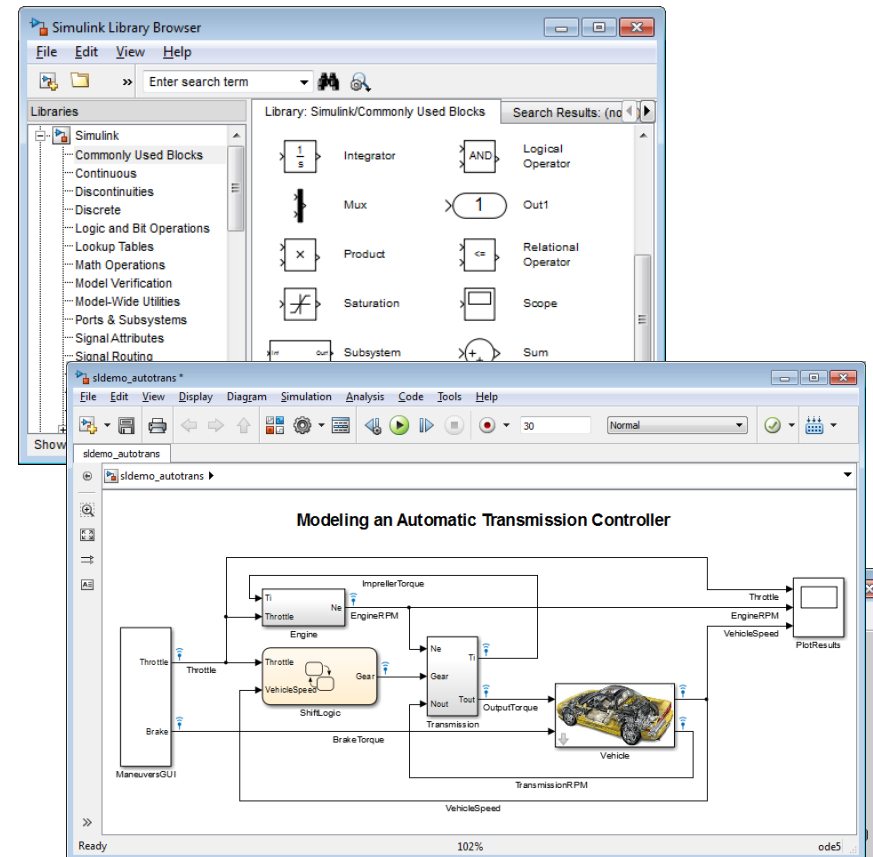
- Build Quadcopter Simulation with SimMechanics
- Build Control System with Simulink Control Design
- Deploy to Hardware with Embedded Coder and Custom Target

Demo Agenda

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

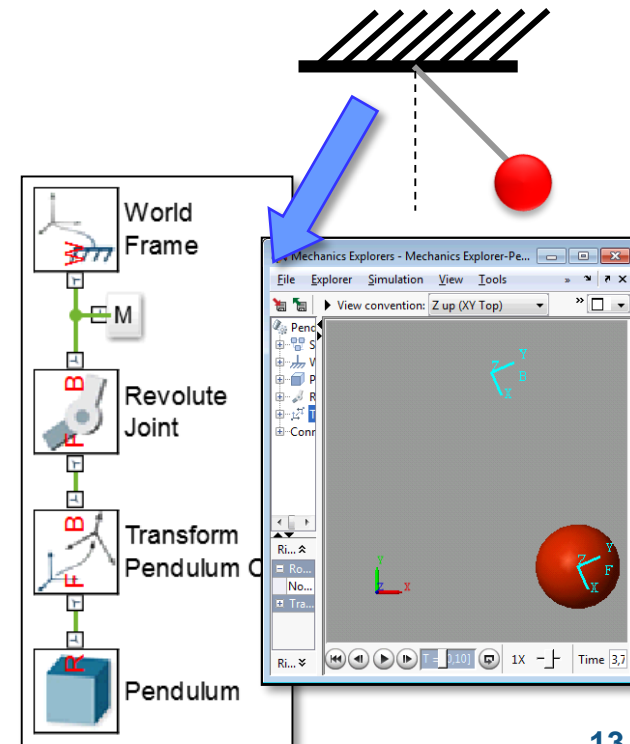
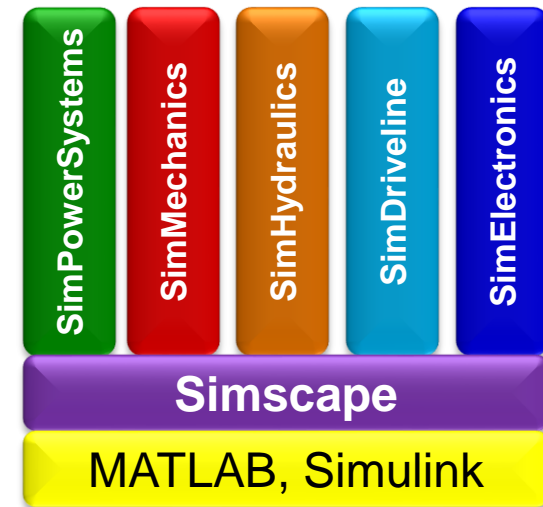
Introduction to Simulink®

- 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



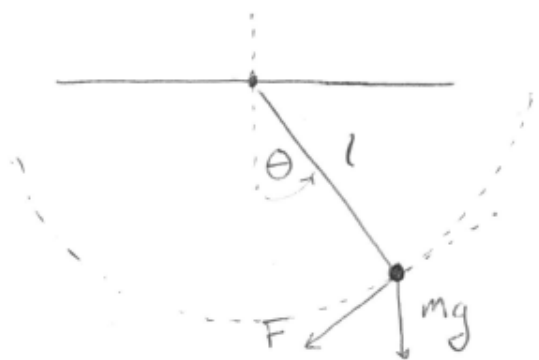
Introduction to SimMechanics

- 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 downward arrow is labeled mg . A dashed arc represents the path of the mass. A force vector F is shown pointing towards the pivot along the string.

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

arc length is s

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

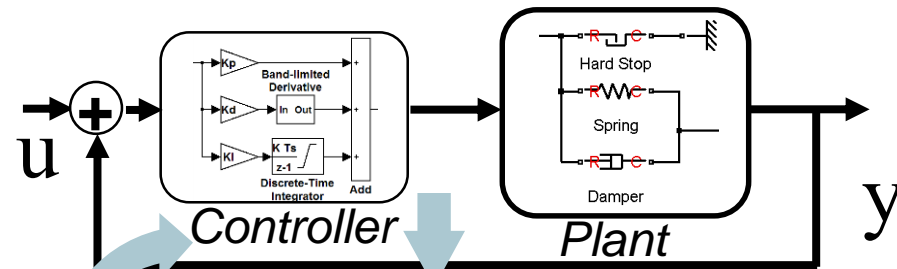
$$\ddot{\theta} = -\frac{g}{l} \sin \theta$$

Demo Agenda

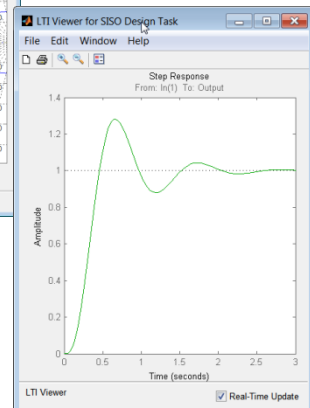
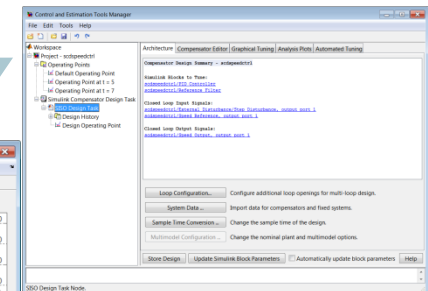
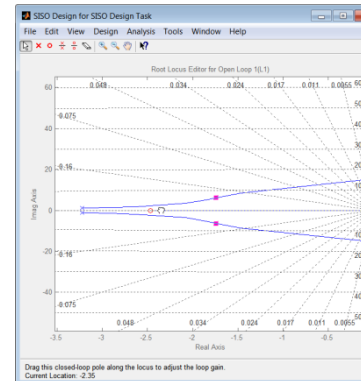
- Build Quadcopter Simulation with SimMechanics
- **Build Control System with Simulink Control Design**
- Deploy to Hardware with Embedded Coder and Custom Target

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

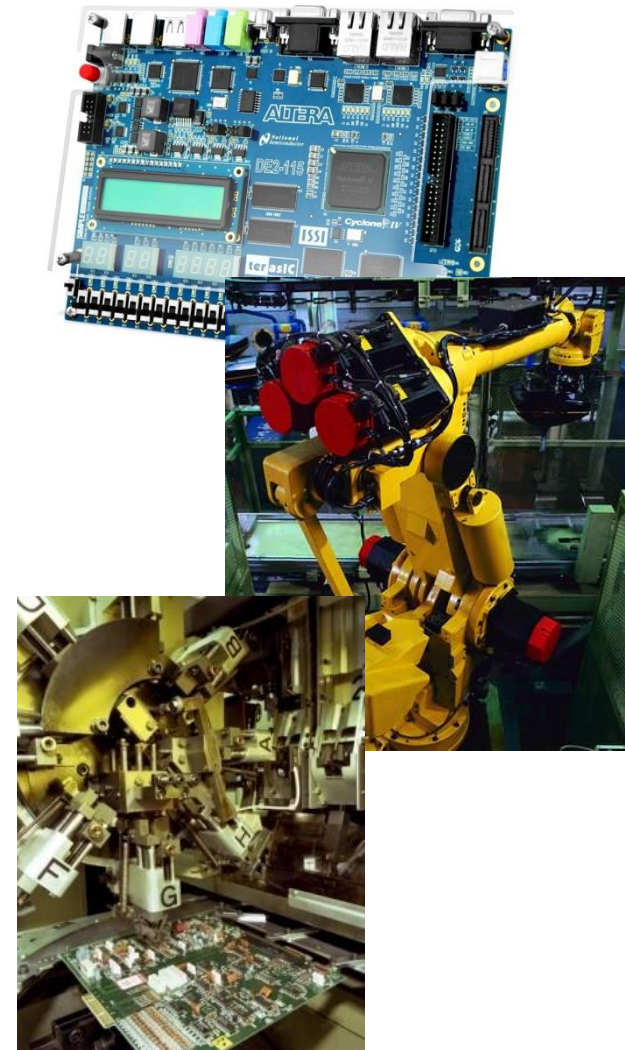
- Build Quadcopter Simulation with SimMechanics
- Build Control System with Simulink Control Design
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Intro to Automatic Code Generation

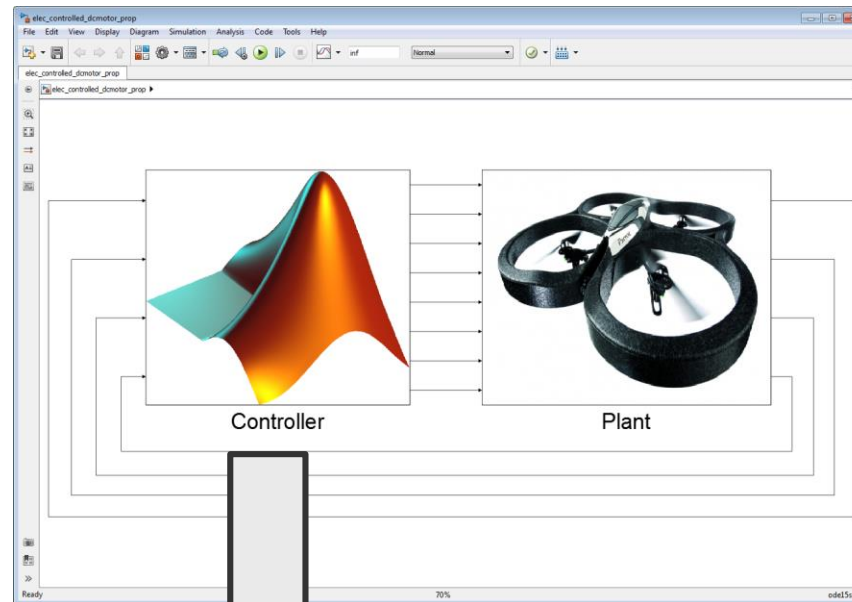
- ANSI-C Code generation for embedded microprocessors
 - MATLAB Coder
 - Simulink Coder
 - Embedded Coder

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

- PLC Code Generation
 - Simulink PLC Coder



Usage of Embedded Coder



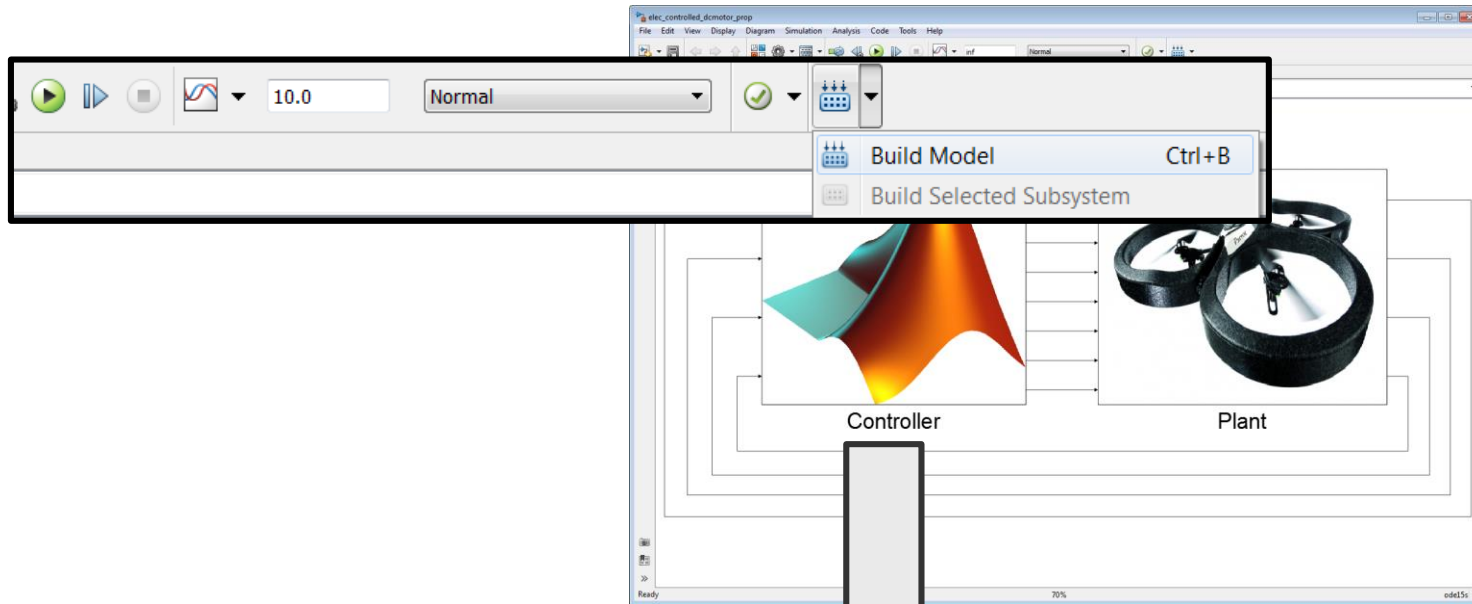
Generate C Code

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

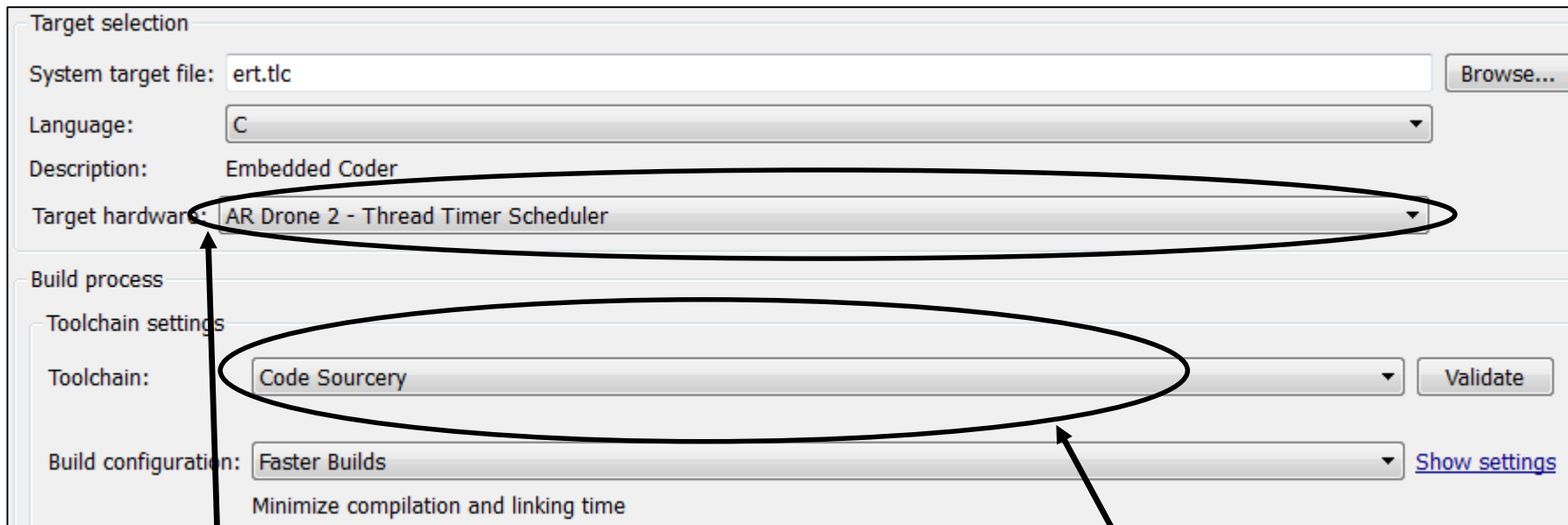
Merge with Existing Code-Base
(manual integration)

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

Custom-Target

Target specific platform,
stand-alone execution

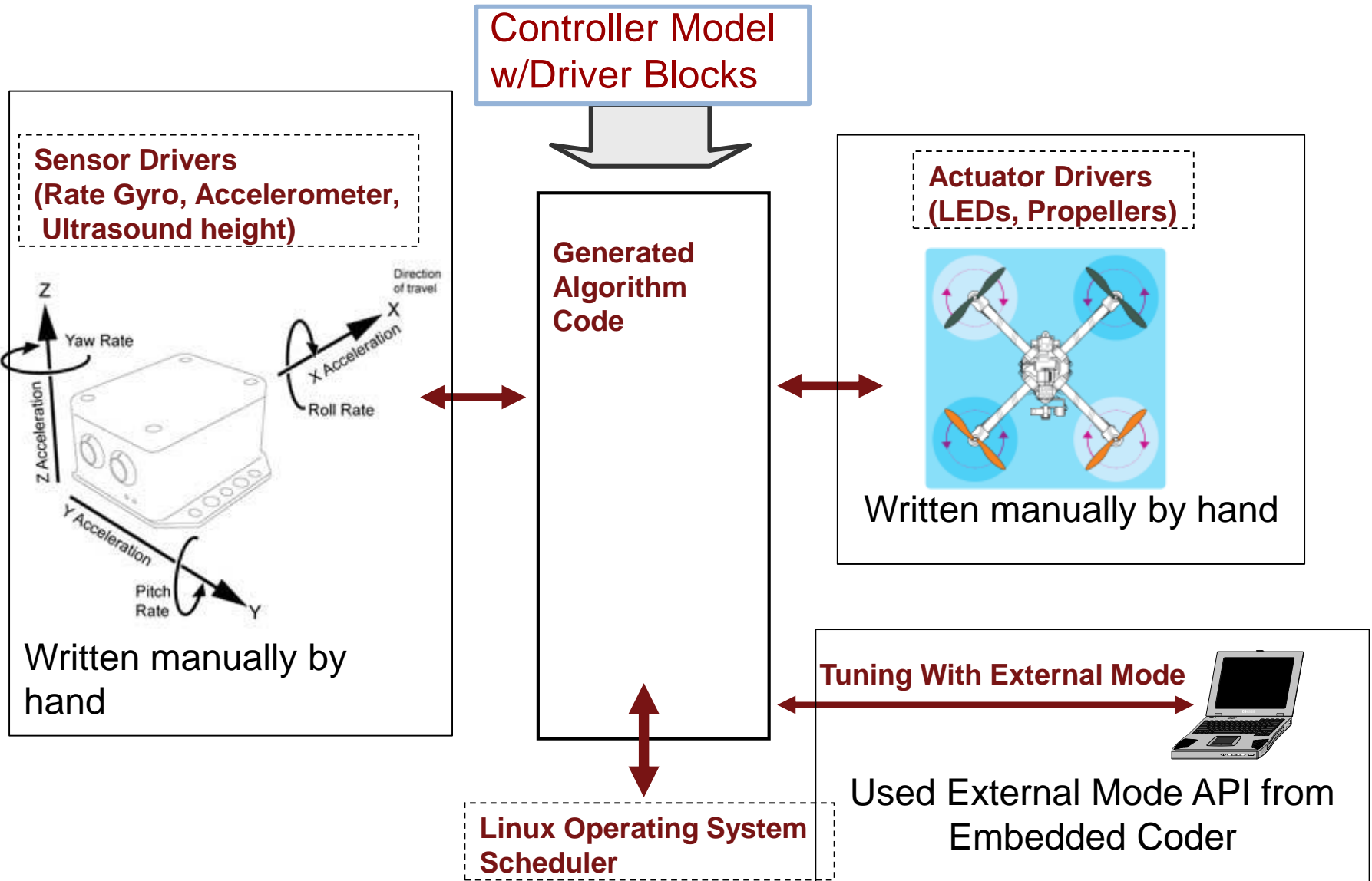
What the user sees: Build-Tool Chain Interface



Custom Hardware

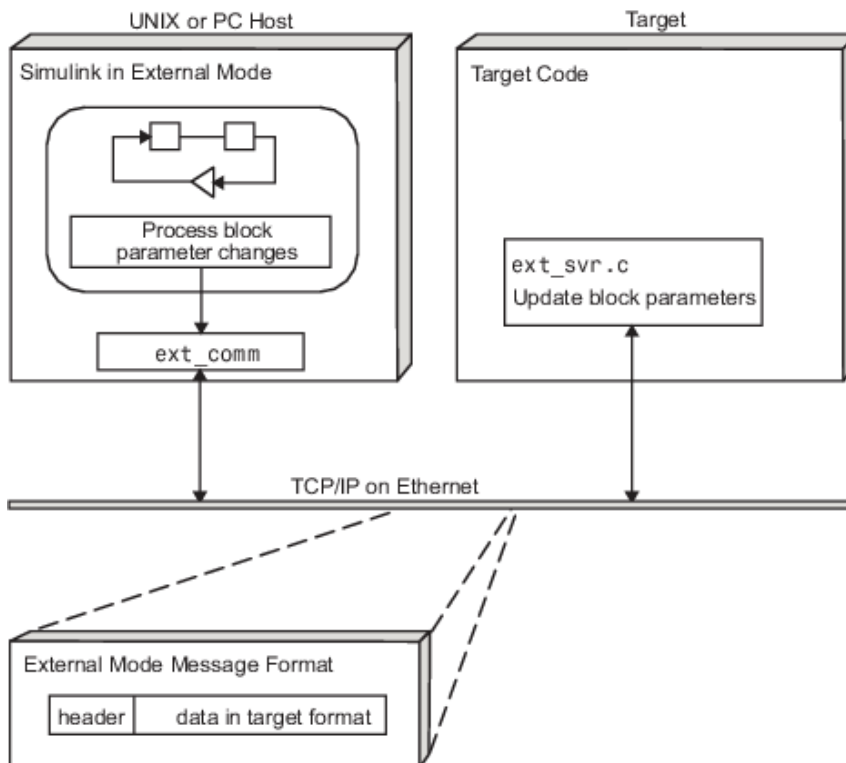
Custom Compiler/Toolchain

How we generated a full program executable



External Mode

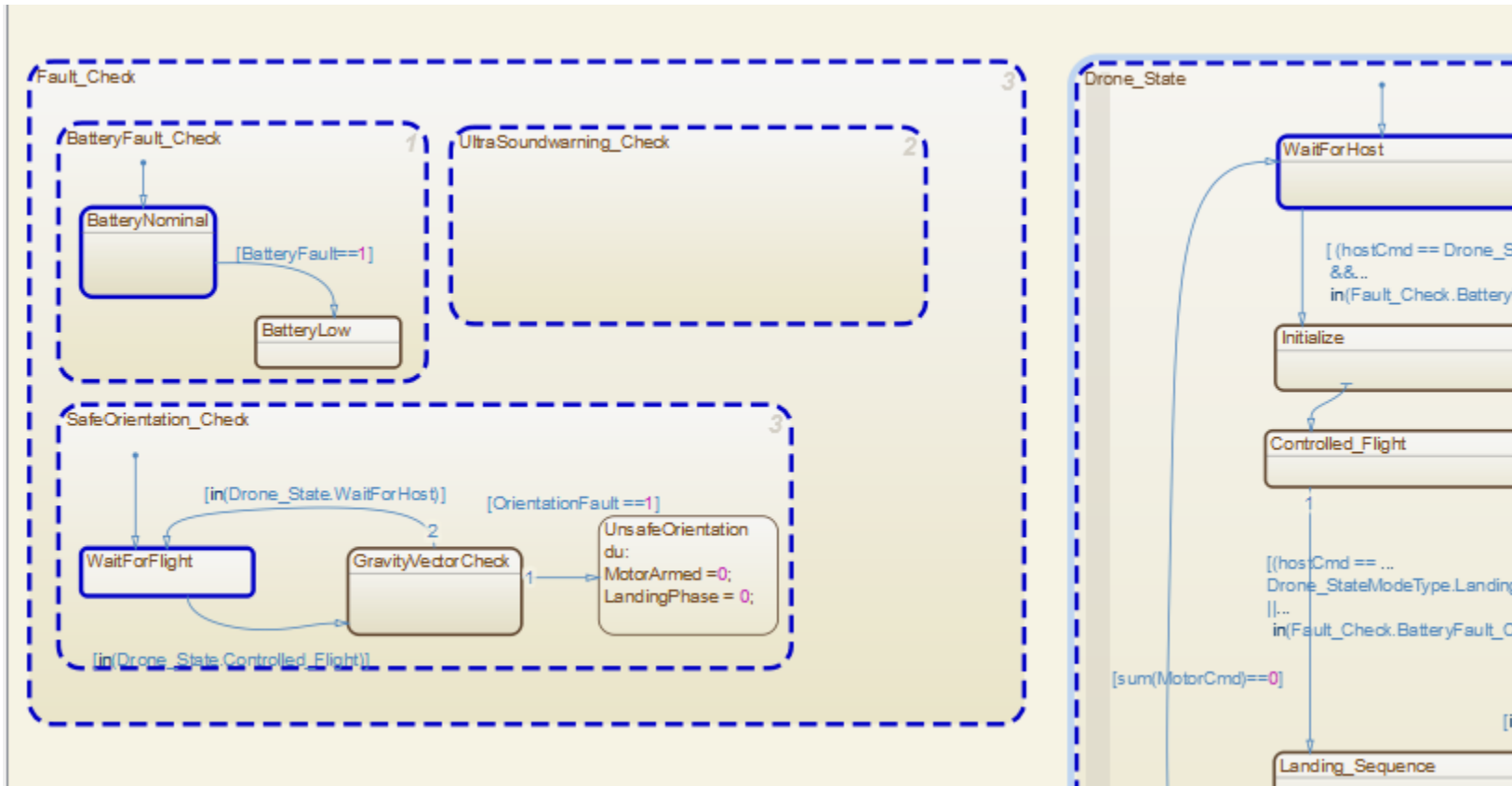
- a) Visualize signals/values of generated code in Simulink as executable is running
- b) Change values of parameters in real-time.
No re-compilation to change a single gain value



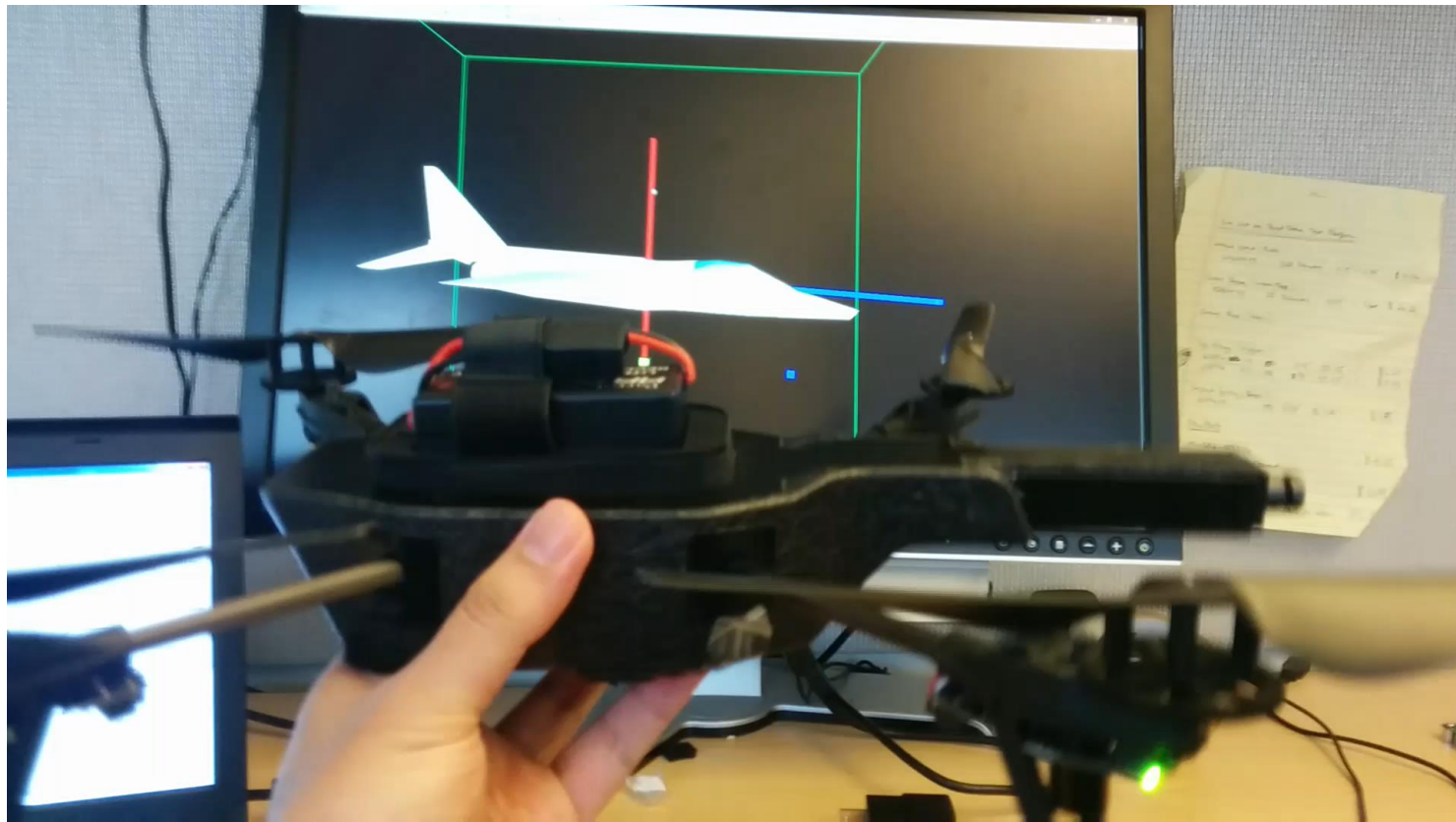
Out-of-the-box support:

- 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 interface. The 'ADD-ONS' tab is selected, and the 'Get Hardware Support Packages' option is highlighted. A red arrow points to this option.

The Support Package Installer dialog box is open, showing a list of support packages on the left and a table of installed and latest versions on the right.

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

	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

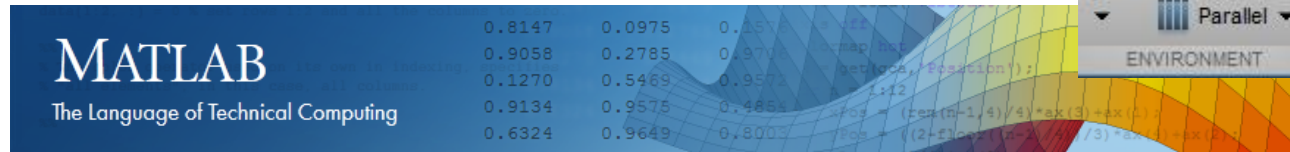
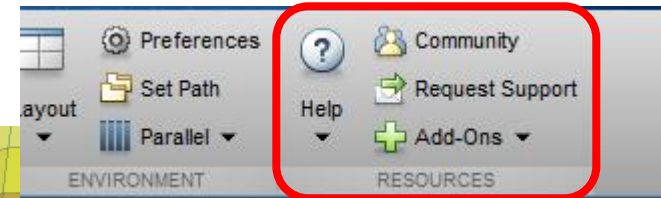


- Open source hardware for all sorts of the amateur/commercial micro-UAVs
- Highly customizable hardware. Can be used with quad-copter, hexa-copter or fixed wing UAVs
- Runs a Real-Time Operating System (NuttX) on ARM Cortex-M.
- Simulink code generation target written by Steve Kuznicki (Pilot Engineering).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

Resources

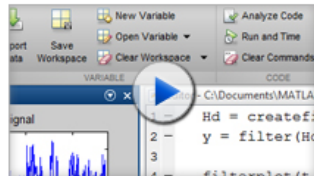
Community, Support, and Add-Ons

<http://www.mathworks.com>



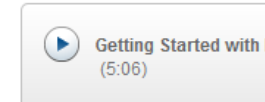
- Overview
- Videos
- Code Examples
- Webinars

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™.



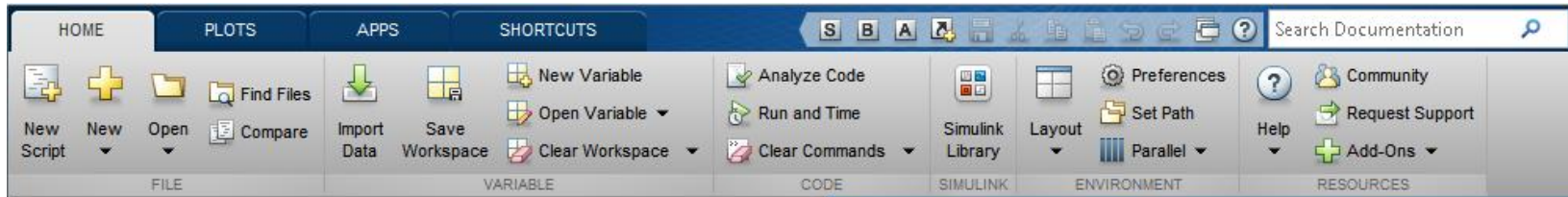
Product Overview 2:05

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.

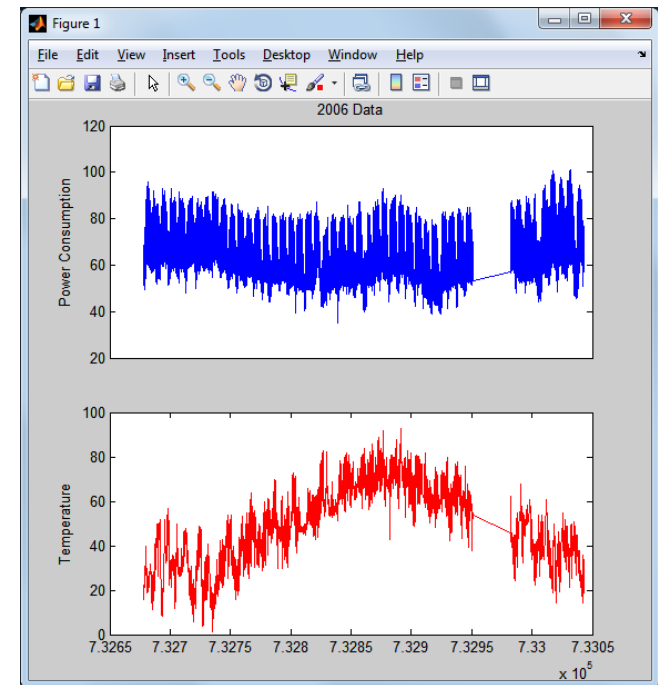


- Seminars
- Webinars
- Workshops
- Videos
- Examples
- Technical Support
- Pilot Engineering
- Training
- Consulting
- Book Program
- File Exchange
- MATLAB Answers
- Apps
- Hardware support packages

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



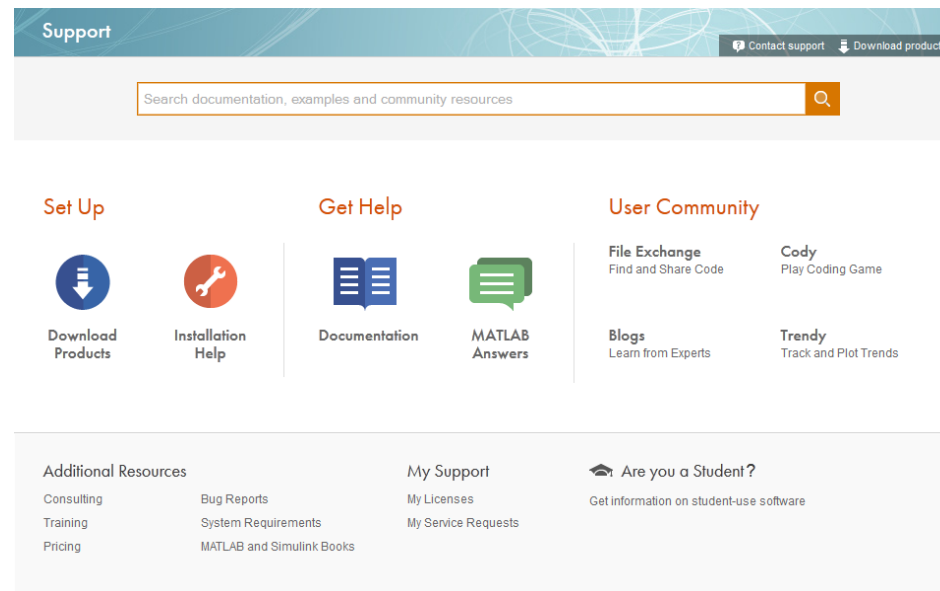
Technical Support

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

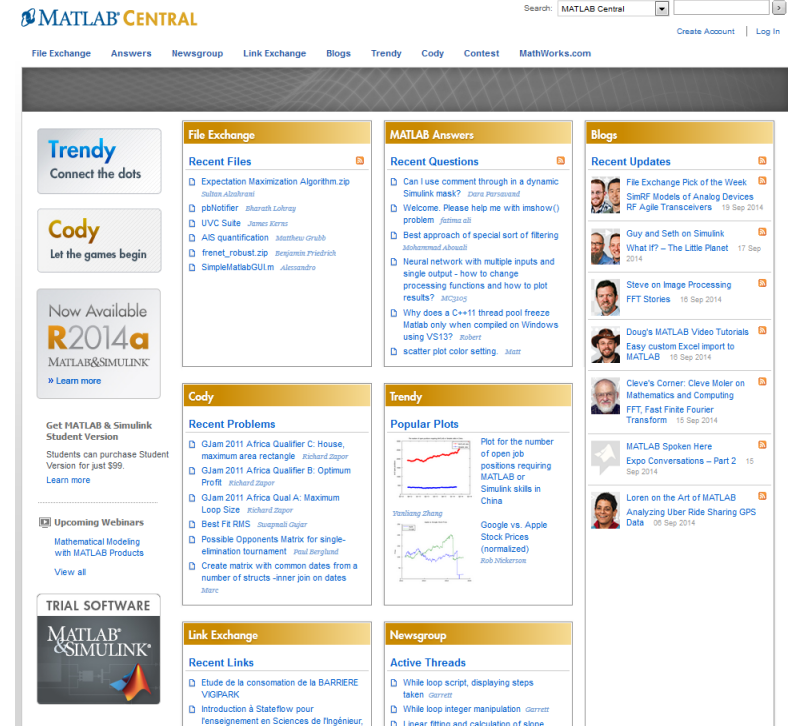
High customer satisfaction

- 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



The screenshot shows the MATLAB Central homepage with a search bar at the top right and navigation links. The main content area is divided into several sections:

- Trendy:** "Connect the dots" section.
- Cody:** "Let the games begin" section, featuring a "Now Available R2014a" banner and "Upcoming Webinars" for "Mathematical Modeling with MATLAB Products".
- File Exchange:** "Recent Files" section listing items like "Expectation Maximization Algorithm.zip" and "SimpleMatlabGUI.m".
- MATLAB Answers:** "Recent Questions" section with questions such as "Can I use comment through in a dynamic Simulink mask?".
- Blogs:** "Recent Updates" section featuring articles like "File Exchange Pick of the Week: SmRF Models of Analog Devices".
- Cody:** "Recent Problems" section listing challenges like "Glam 2011 Africa Qualifier C: House, maximum area rectangle".
- Trendy:** "Popular Plots" section showing a line plot and a bar chart.
- Link Exchange:** "Recent Links" section with links like "Etude de la consommation de la BARRIERE".
- Newsgroup:** "Active Threads" section with threads like "While loop script, displaying steps taken".

- 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



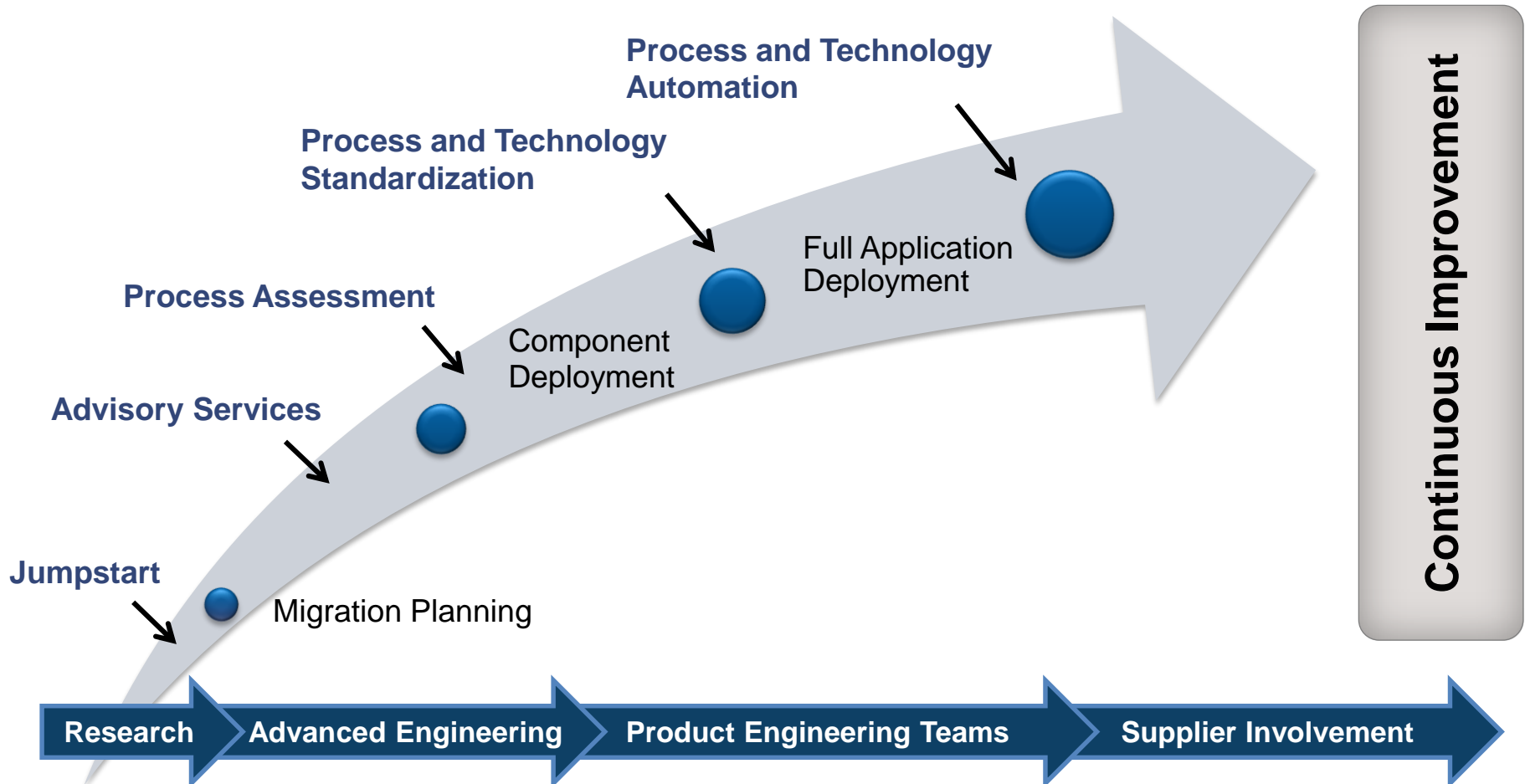
More than 30 course offerings:

- 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?