Model-Based Design: Design with Simulation in Simulink

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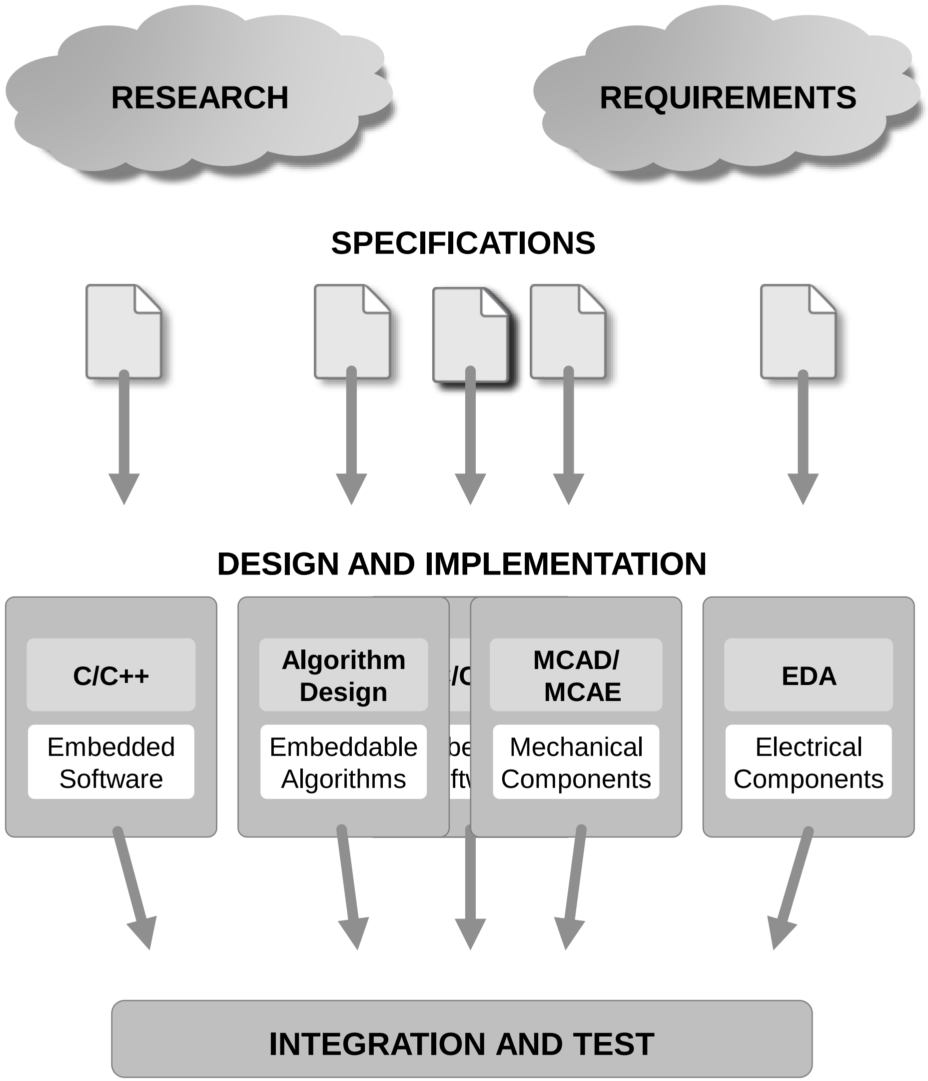
Application Engineer
MathWorks

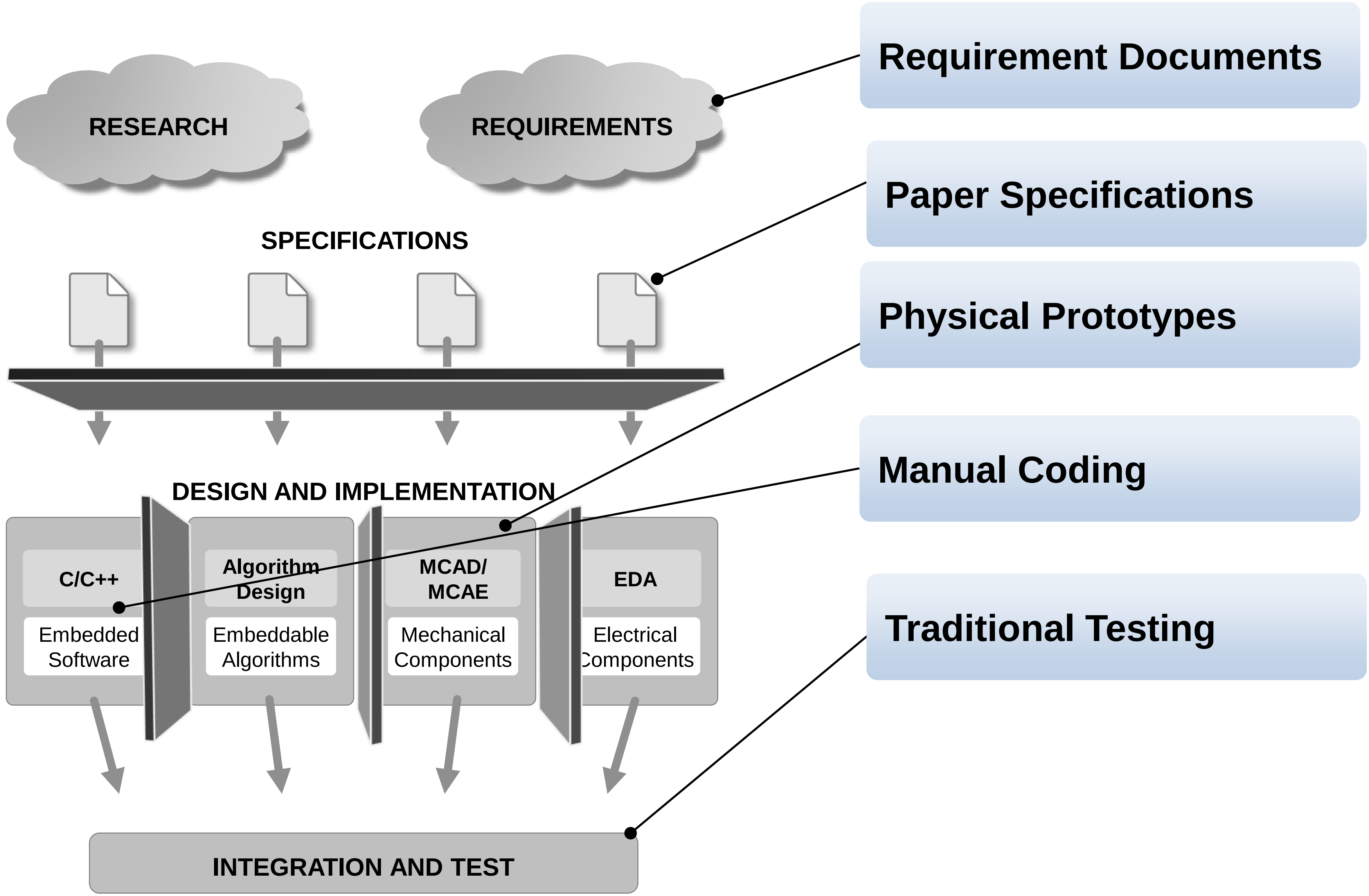
Outline

- Model-Based Design Overview
- Modelling and Design in Simulink
  - Modelling
    - Physical Systems
    - Control logic
  - Simulation
    - System-level optimisation
    - Verification of design changes
- Summary

Traditional Development Workflow



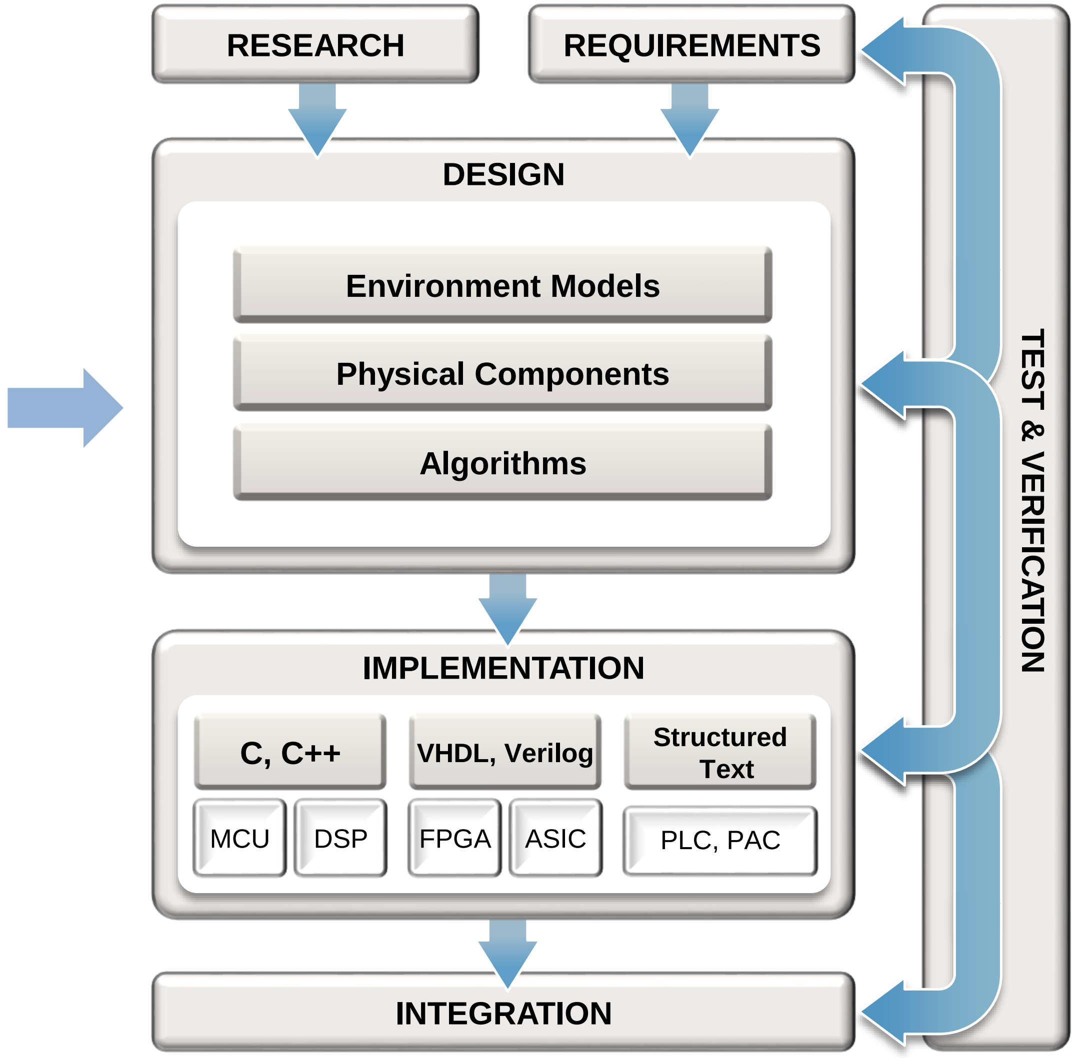
Problems in Traditional Development Workflow



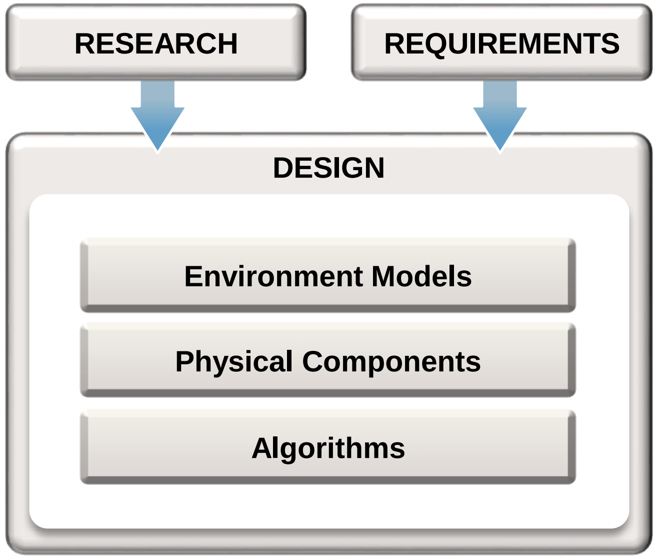
Model-Based Design Workflow

Traditional System Development Workflow

1. Research
2. Requirements and Specifications
3. Design
4. Implementation
5. Test and Verification



Model-Based Design: Specifications



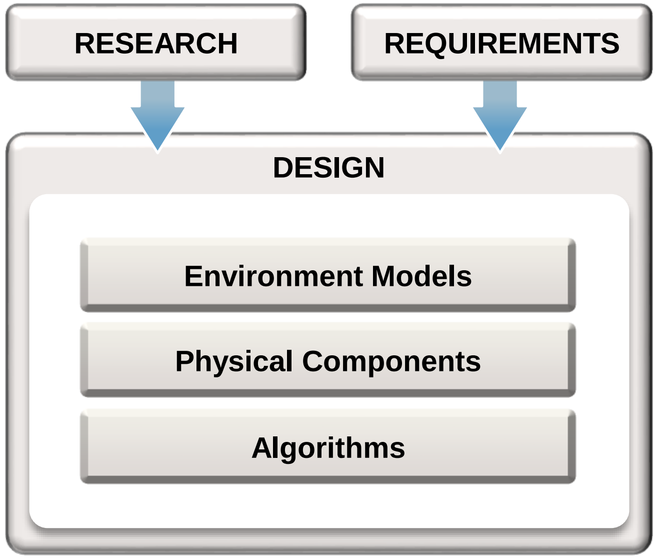
CAPABILITIES

- Executable specification
- Executable constraints
- Links to requirements

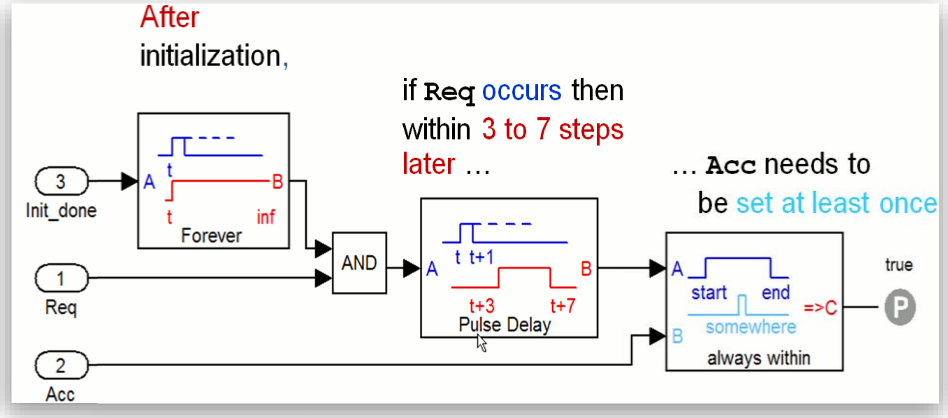
BENEFITS

- Early validation and test development
- Clear specification
- Simulate whole system, including environment
- Tight link to requirements

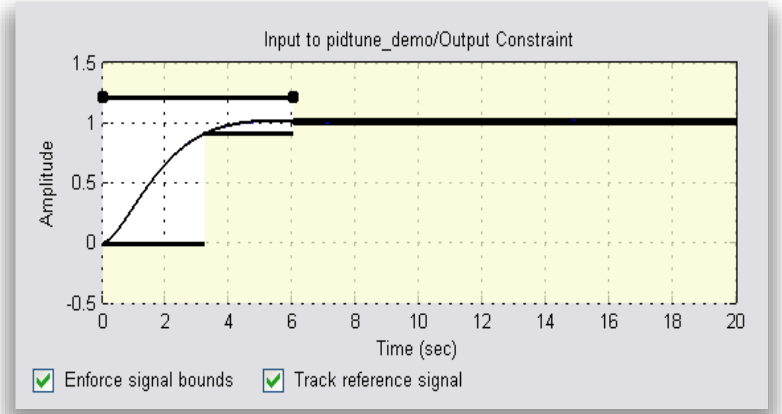
Model-Based Design: Requirements



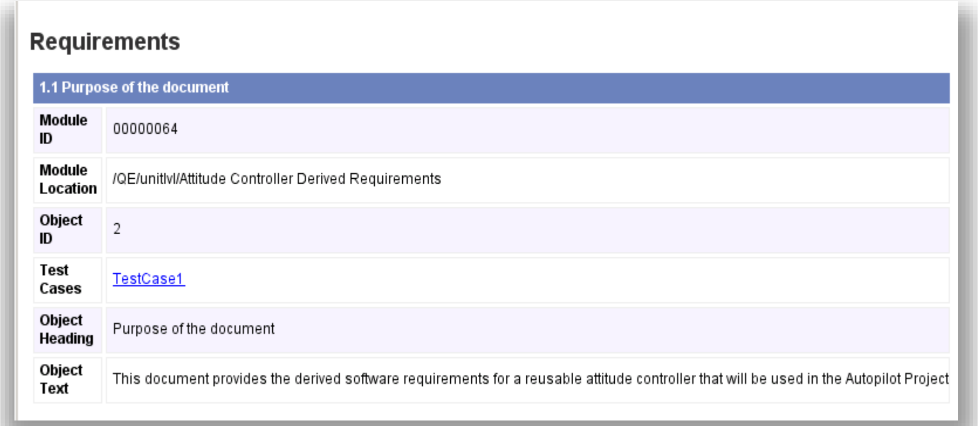
Formalize requirements as properties and objectives



Model system response bounds



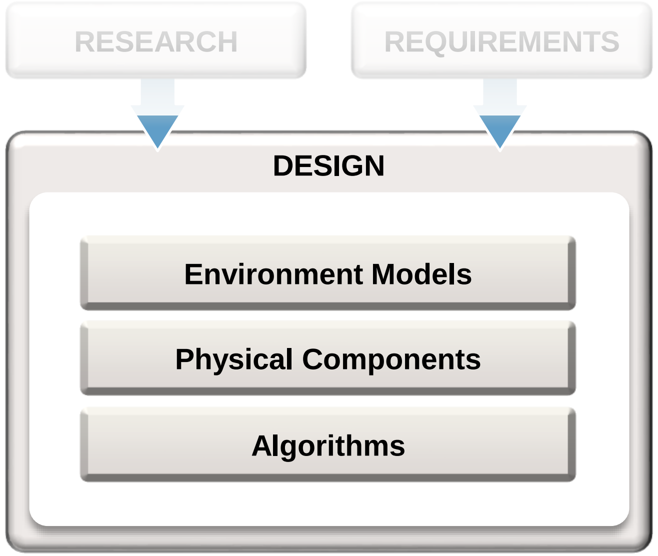
Trace to requirements in DOORS, Word, Excel, etc.



Requirements

1.1 Purpose of the document	
Module ID	00000064
Module Location	/QE/unitlvl/Attitude Controller Derived Requirements
Object ID	2
Test Cases	TestCase1
Object Heading	Purpose of the document
Object Text	This document provides the derived software requirements for a reusable attitude controller that will be used in the Autopilot Project

Model-Based Design: Design



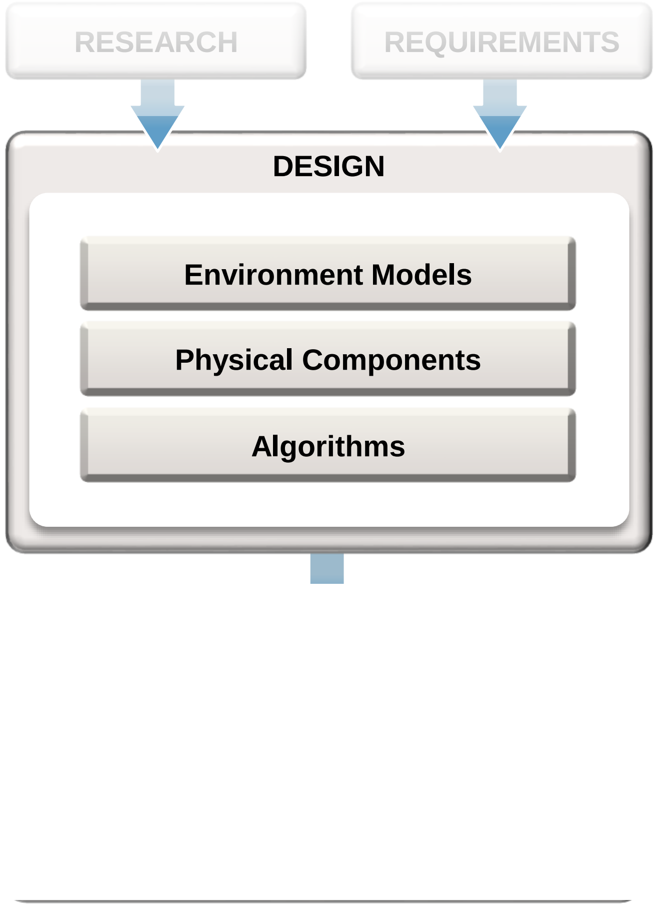
CAPABILITIES

- Refine model description
- Add fixed point, timing, component interface details

BENEFITS

- Fast design exploration
- Design optimization
- Find flaws before implementation

Model-Based Design: Design



CAPABILITIES

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BENEFITS

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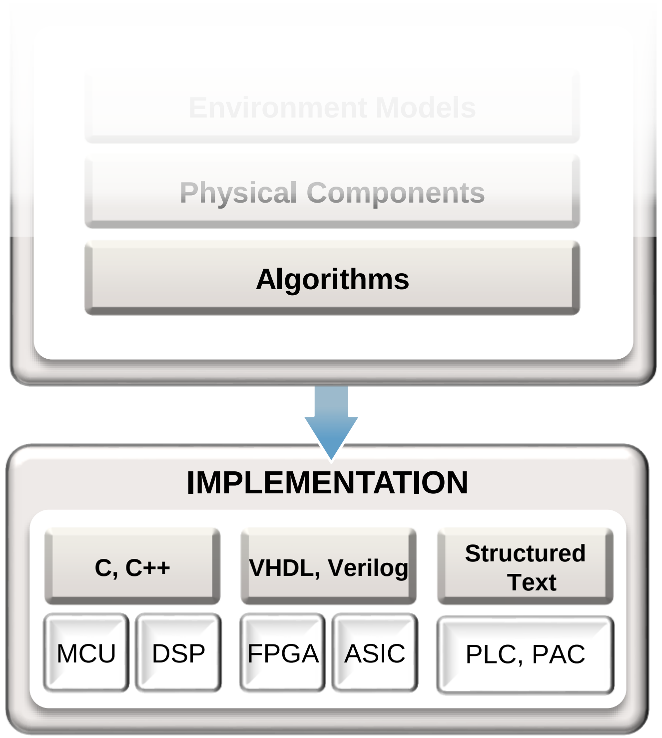
Model-Based Design: Implementation



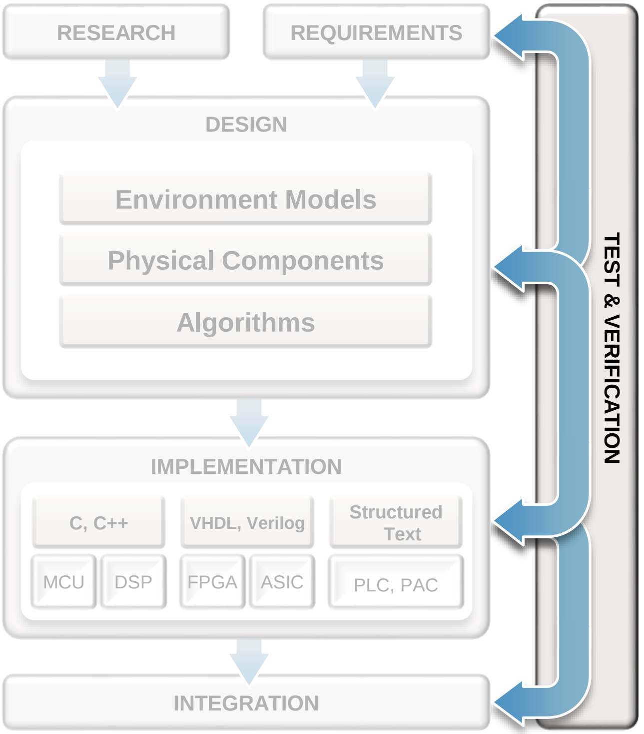
CAPABILITIES

- **Rapid Prototyping**
- **Automatic Code Generation:**
  - **C/C++**
  - **HDL**
  - **PLC**

BENEFITS

- **Eliminate hand-coding**
- **Eliminate hand-code errors**
- **Hardware target portability**
- **Better testability and reuse**
- **Bridge between domain, software, and hardware knowledge experts**

Model-Based Design: Test and Verification



CAPABILITIES

- Model Verification
- Software Verification
- Hardware-in-Loop
- Test and Measurement

BENEFITS

- Detect errors earlier
- Reduce use of physical prototypes
- Implementations that work first time
- Reuse tests throughout development stages

Building a Wave Farm with Model-Based Design

> “As engineering tools, MATLAB and Simulink provide **significant value.** They are just as valuable as innovation tools because they enable us to **quickly test ideas** that we would otherwise never try.”
>
> — *Jonathan Fiévez, Carnegie Wave Energy*

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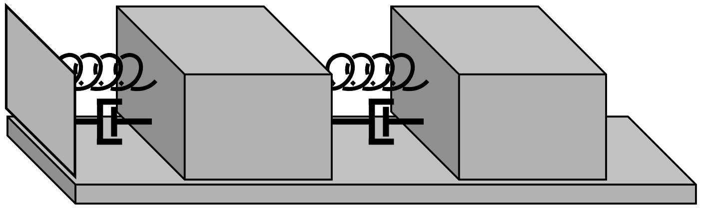
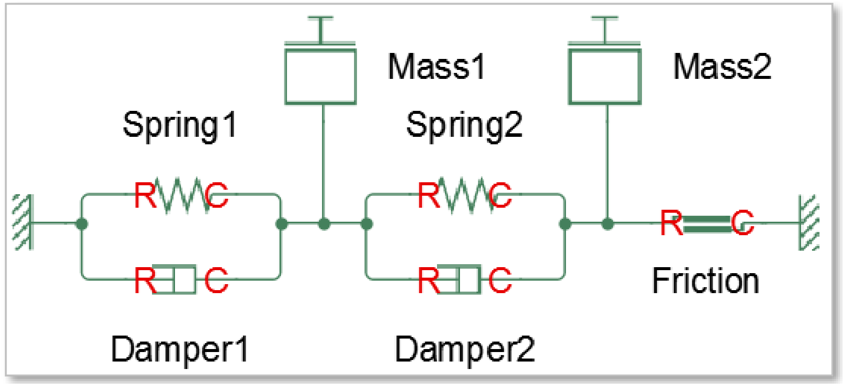
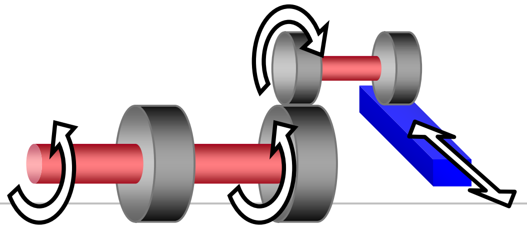
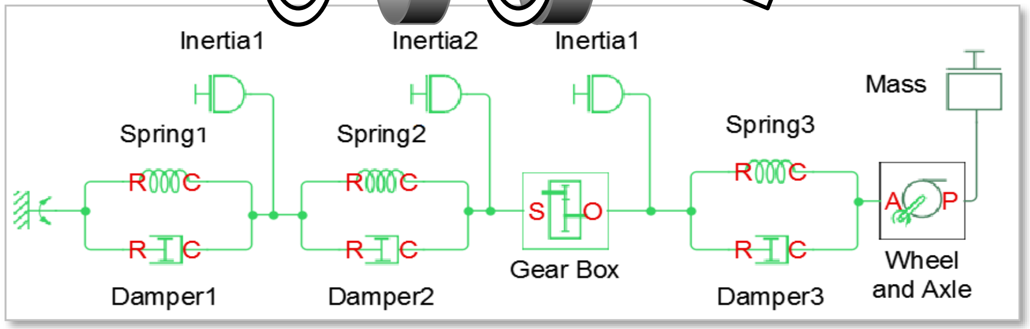
Mechanical System Modelling



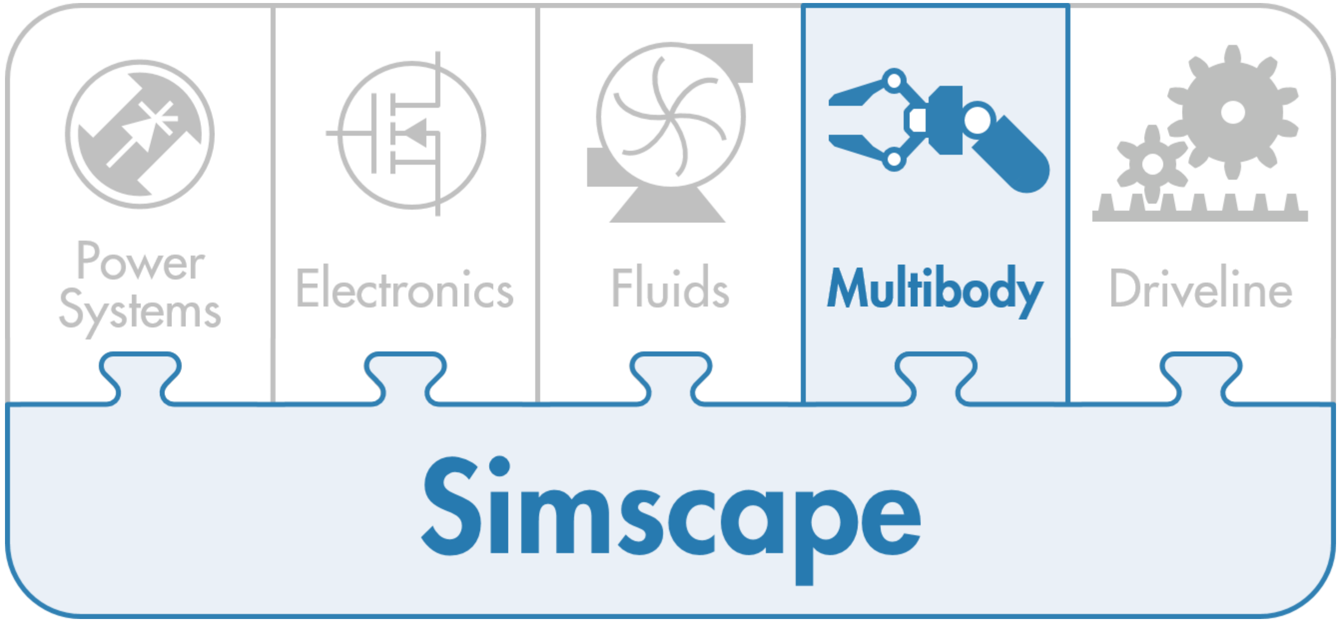


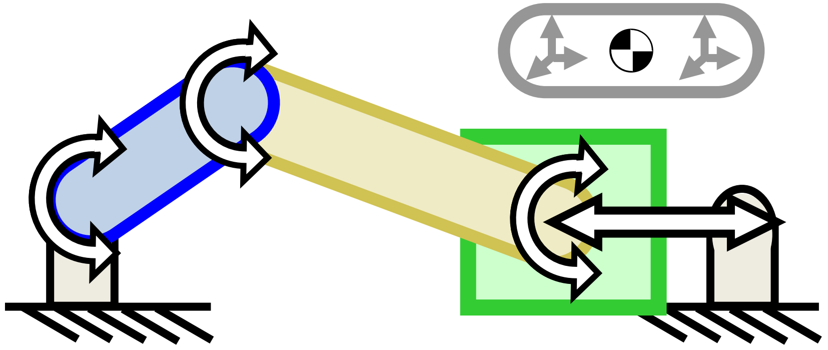
Simscape

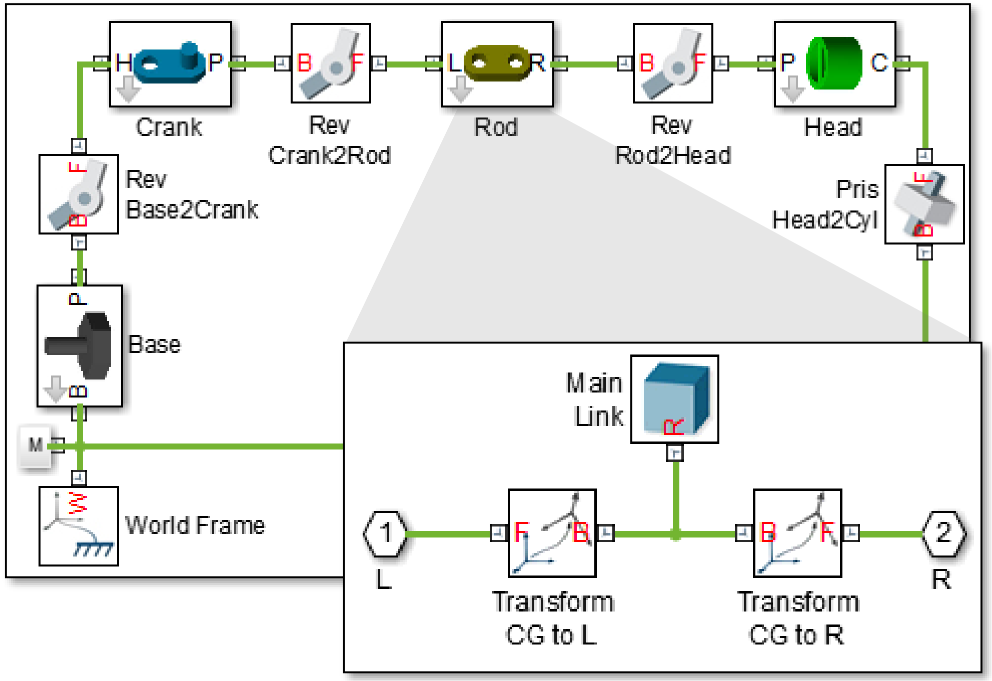




Mechanical System Modelling







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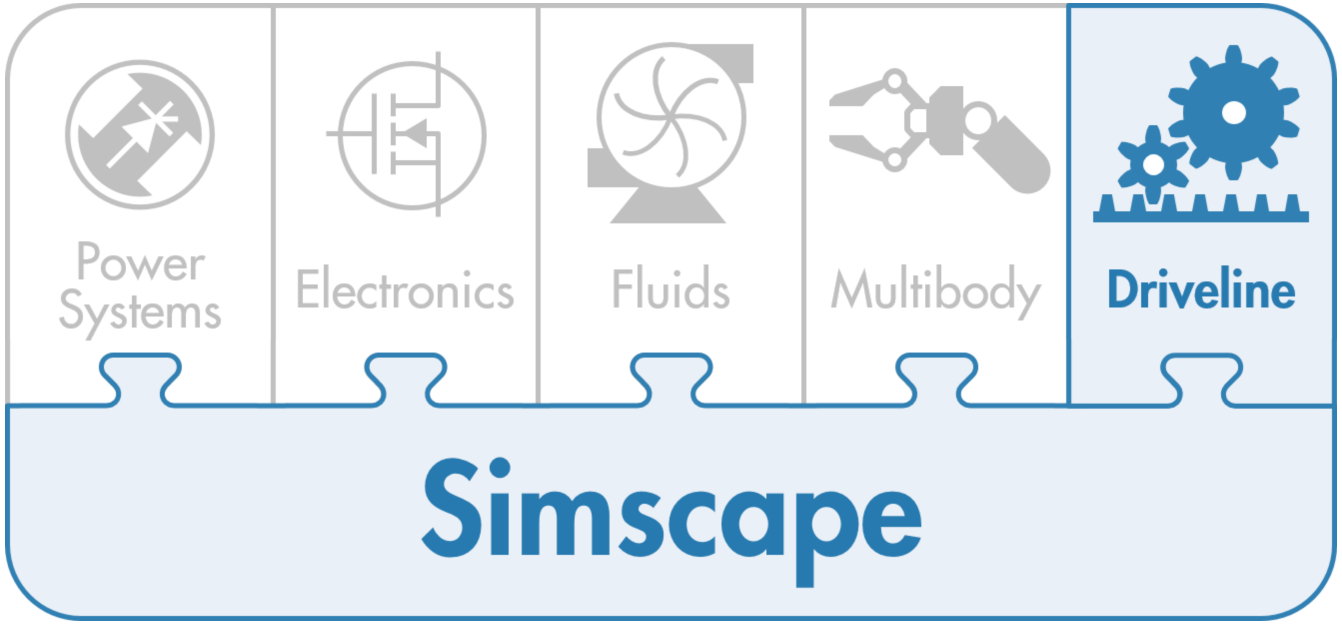
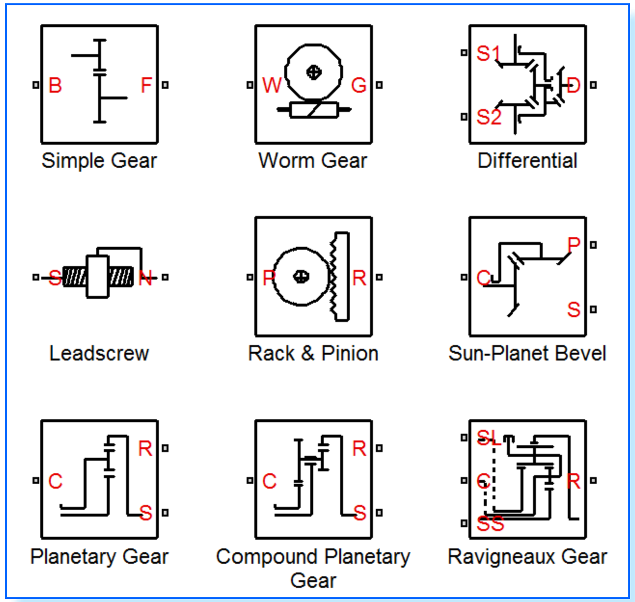
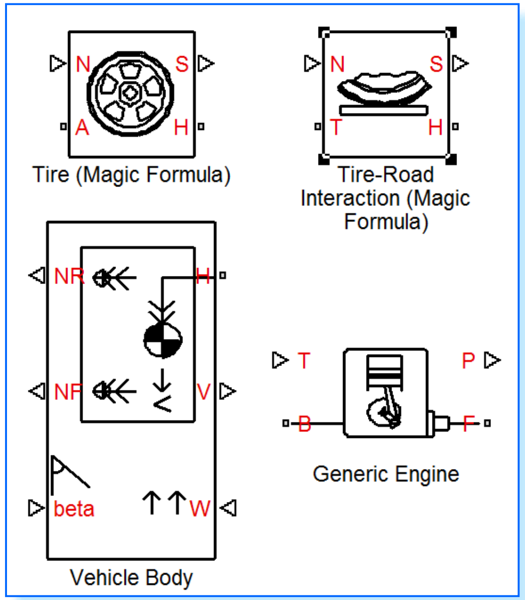
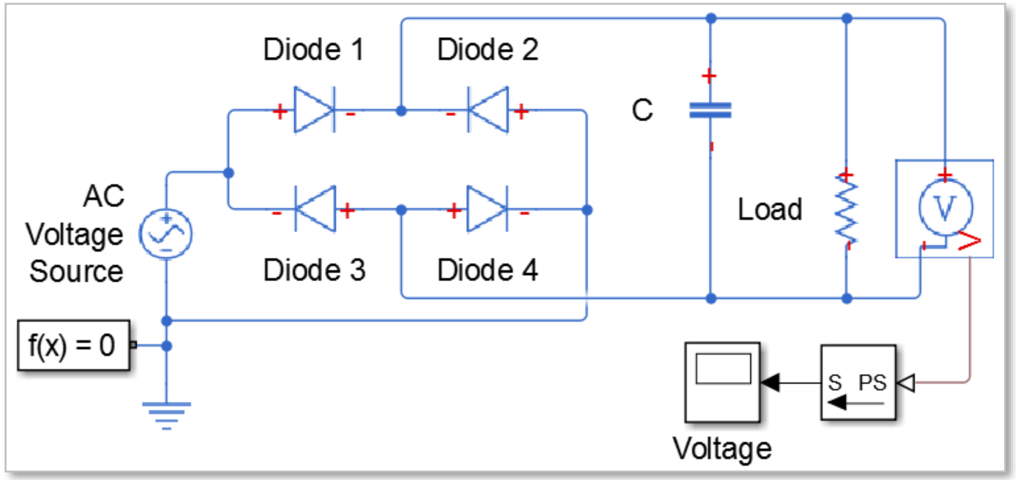




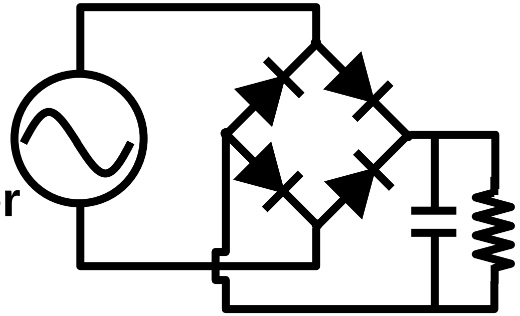


Electrical System Modelling

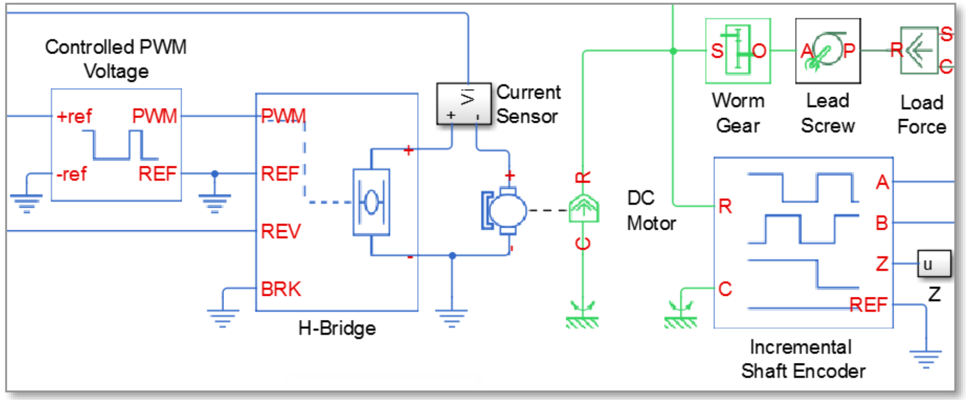


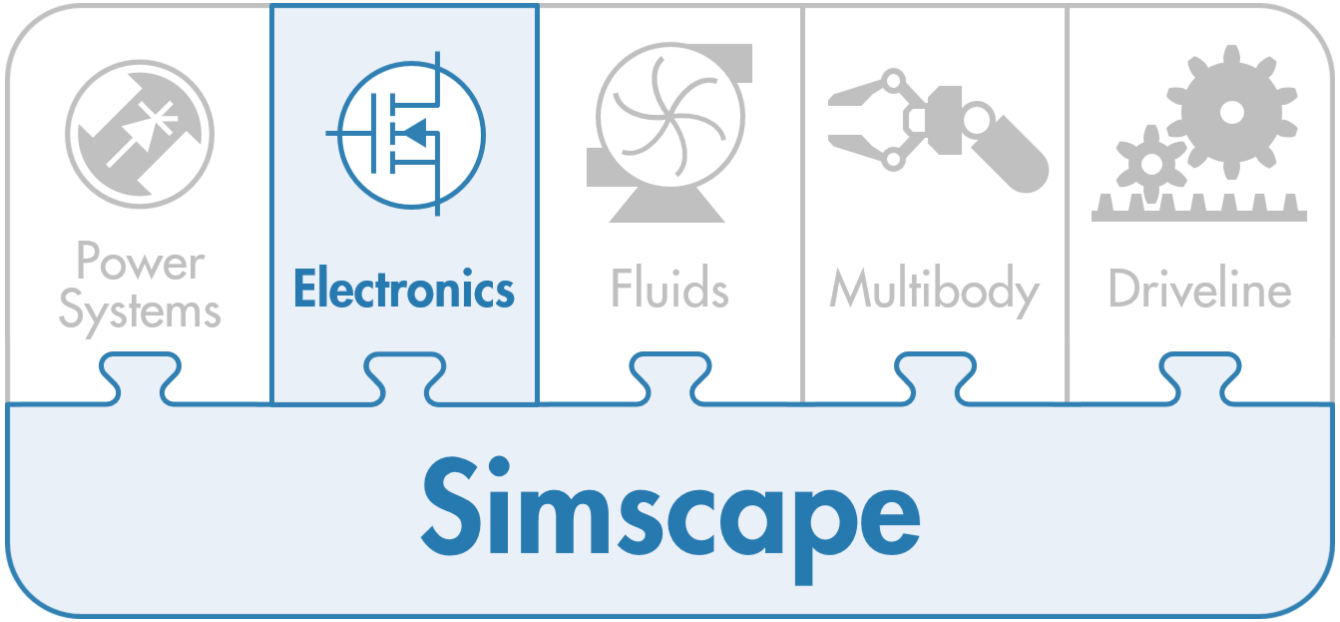
Simscape

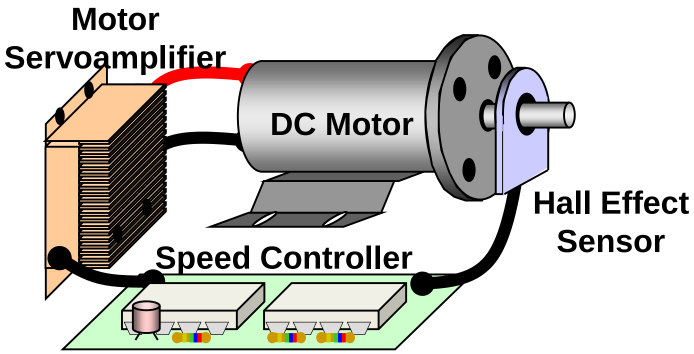
Bridge Rectifier
(AC to DC)



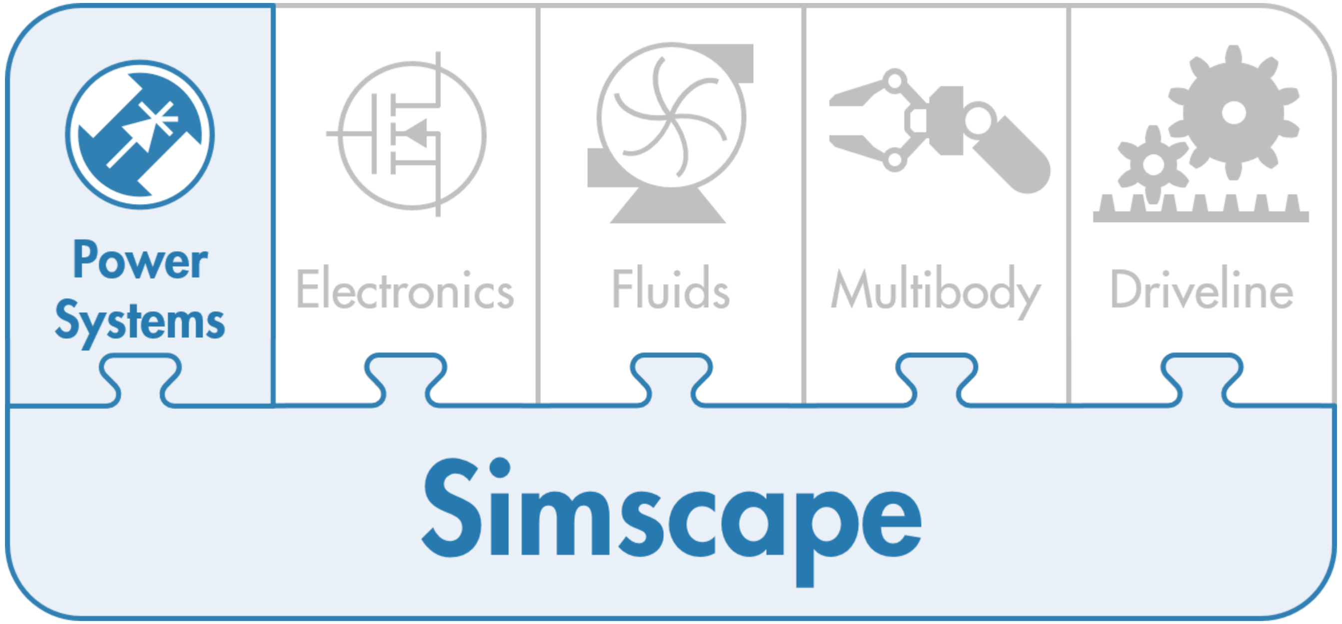
Electrical System Modelling

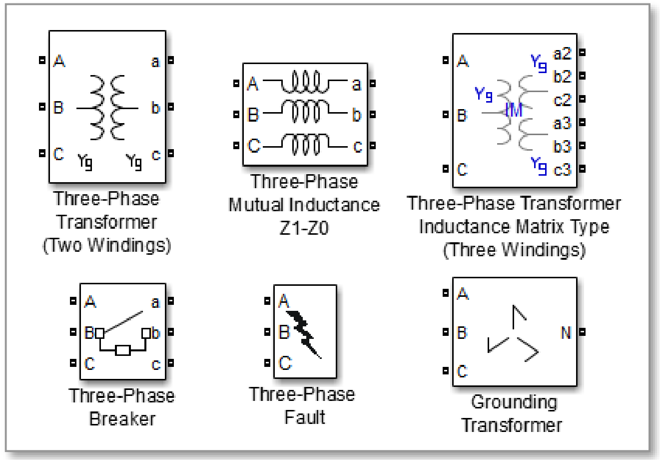


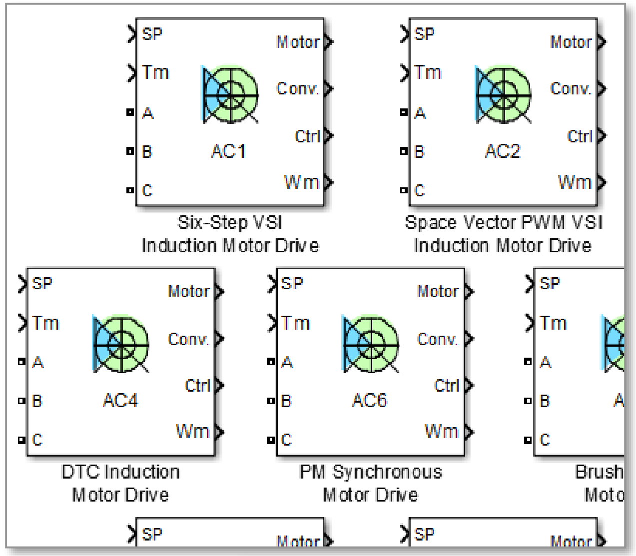


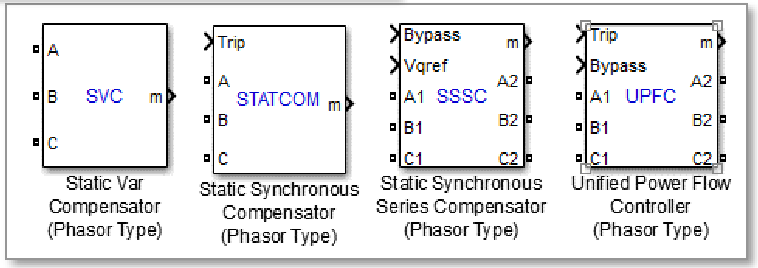


Electrical System Modelling

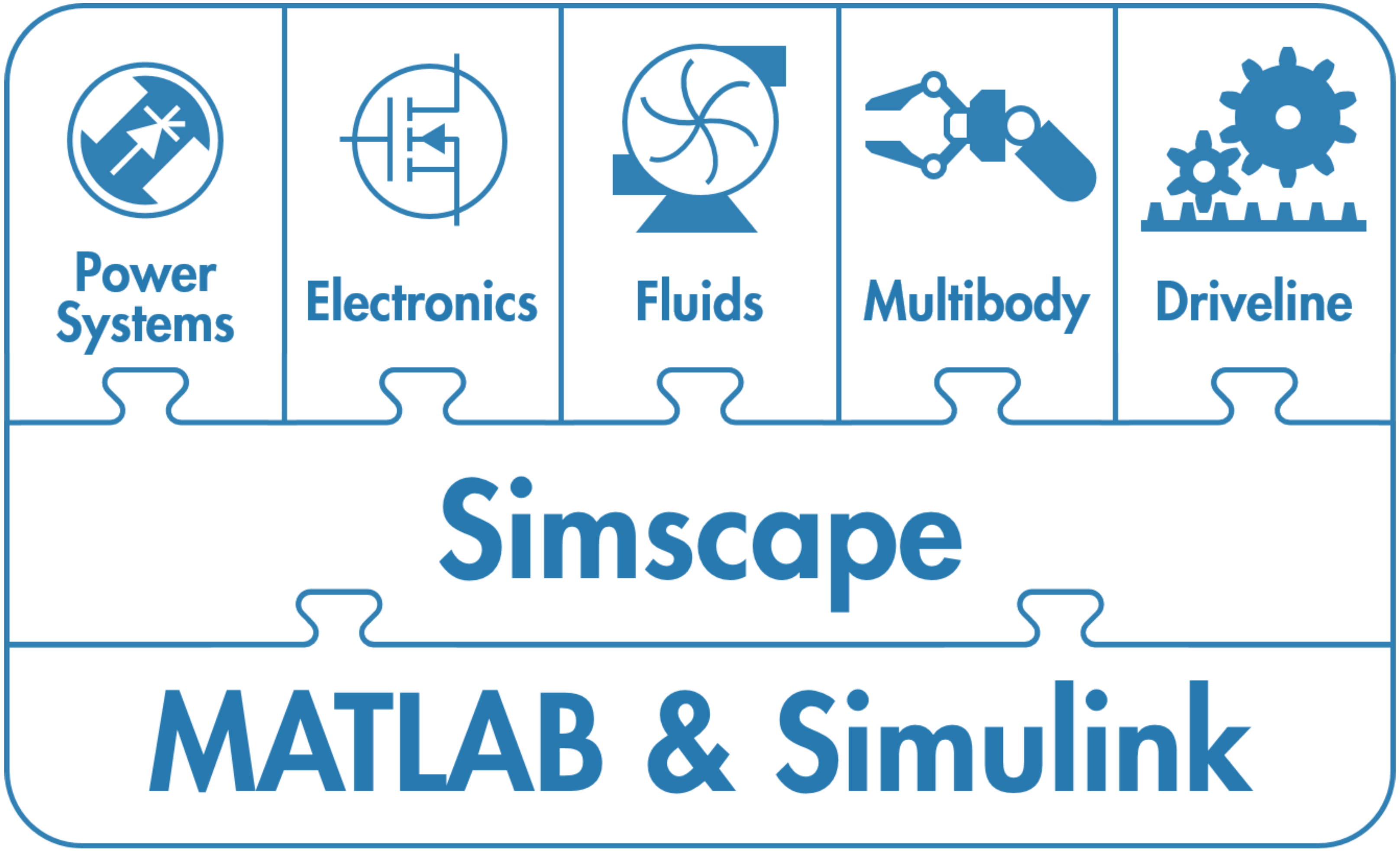




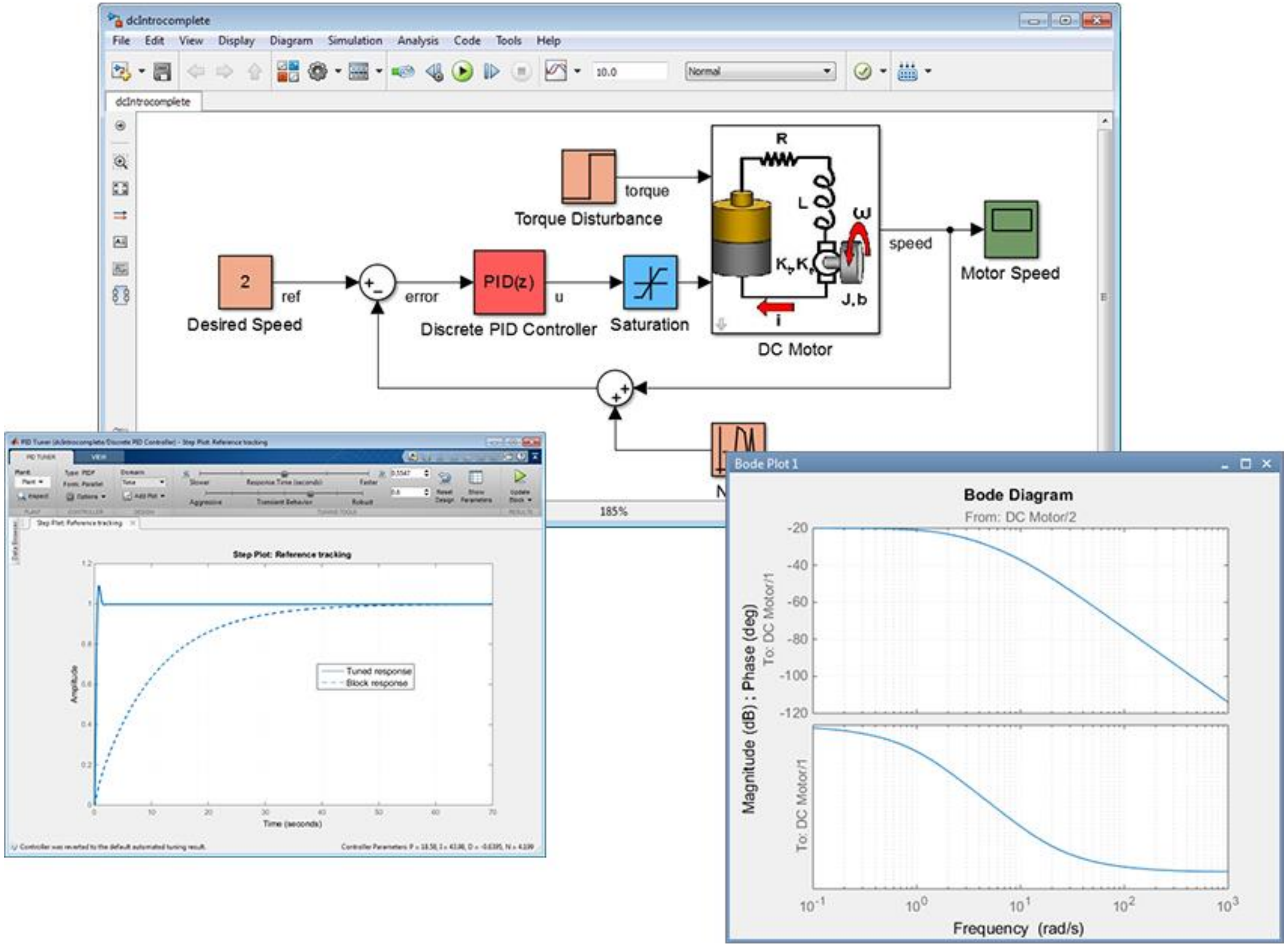




Multi-Domain Modelling of Physical Systems



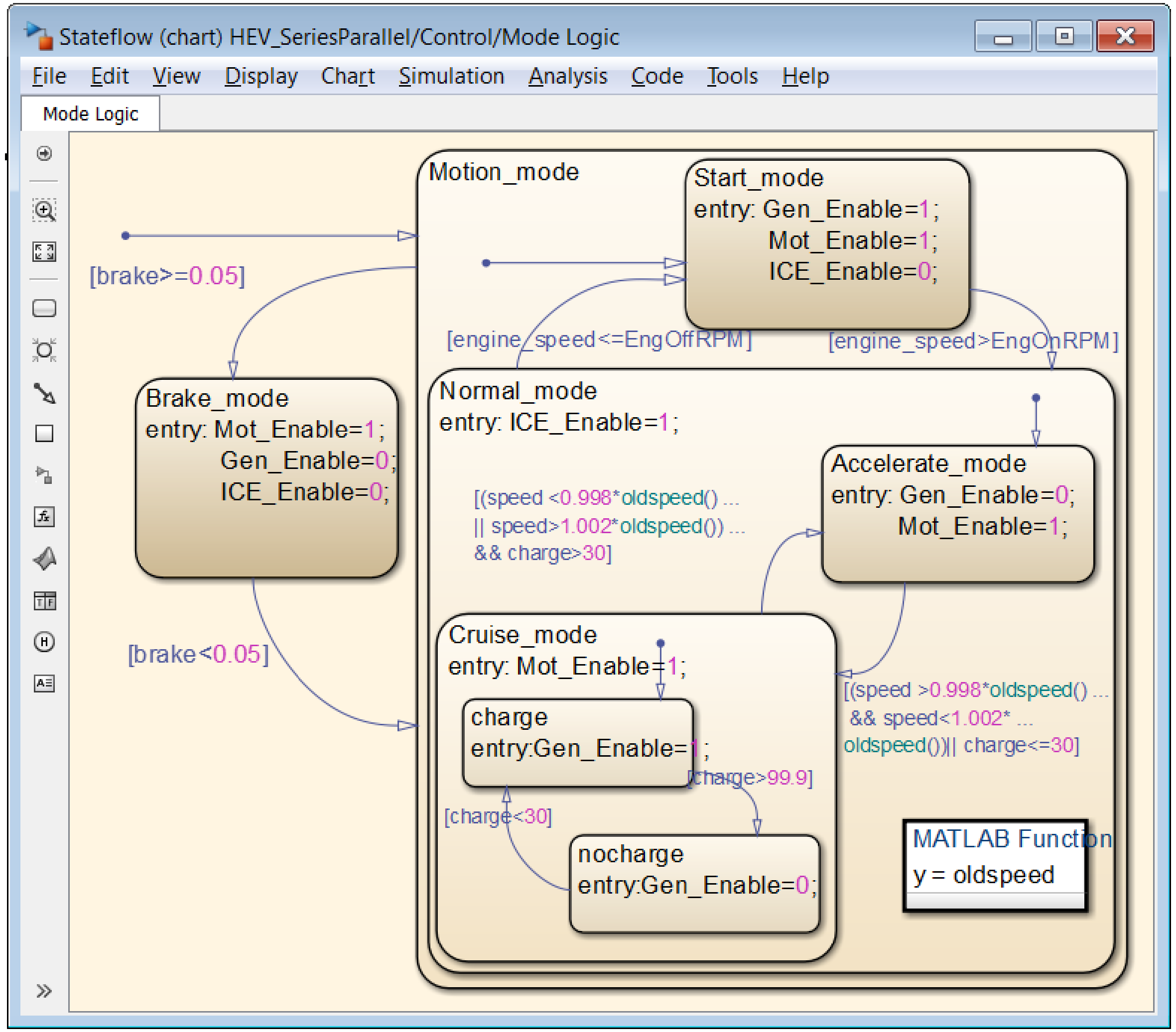
Control System Design



Defining System Mode Logic

- Define mode logic using state machine in Stateflow

- Generate production code directly from model



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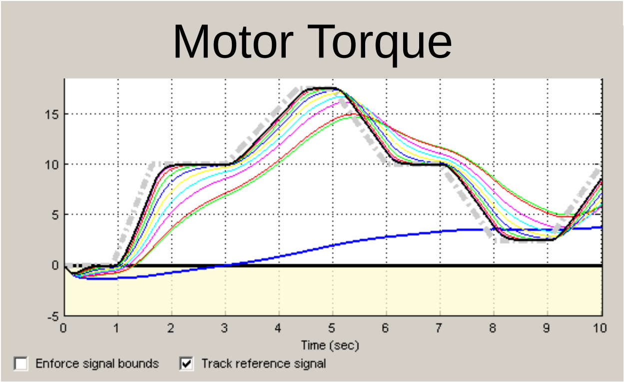
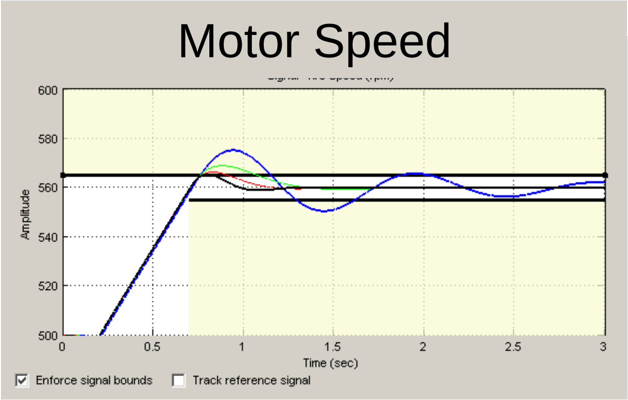
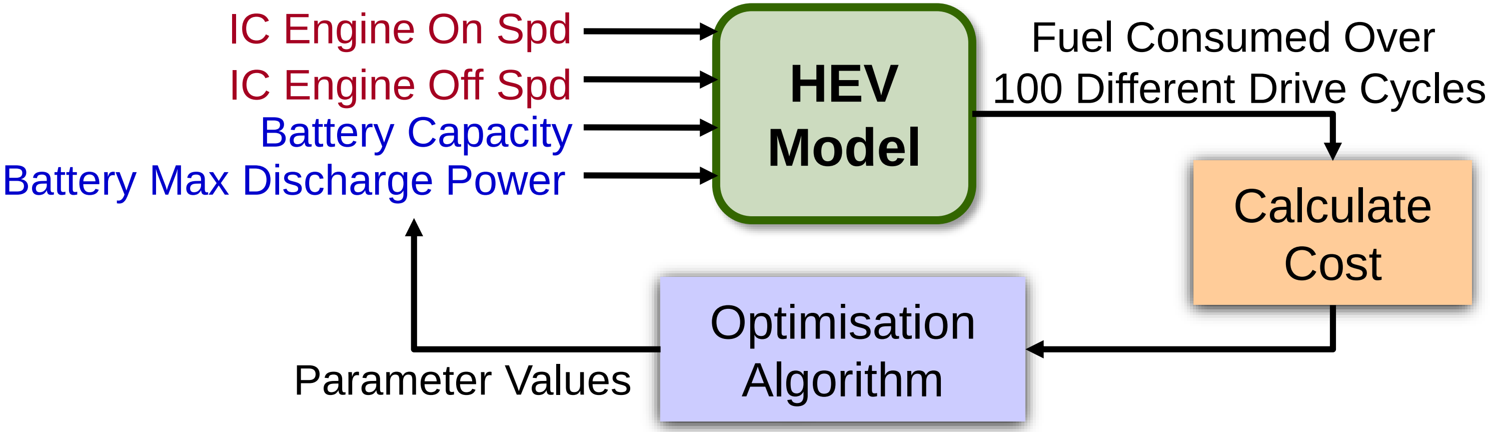
Optimise Entire System





- Use optimisation algorithms to automatically tune parameter values
  - Match response
  - Meet requirements

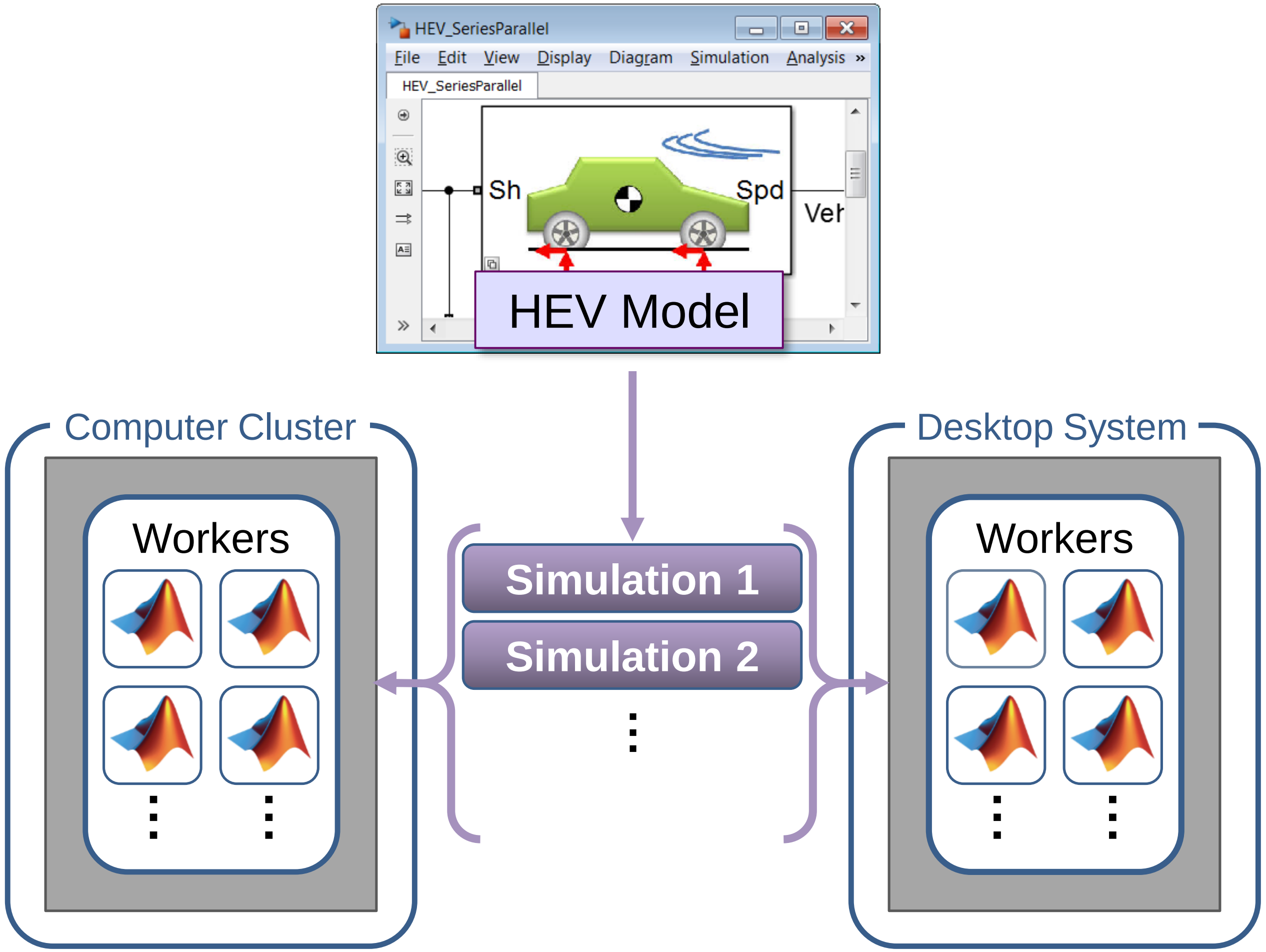
- Optimise <u>system</u> performance (controller and physical system)



Distributing Simulations with Parallel Computing

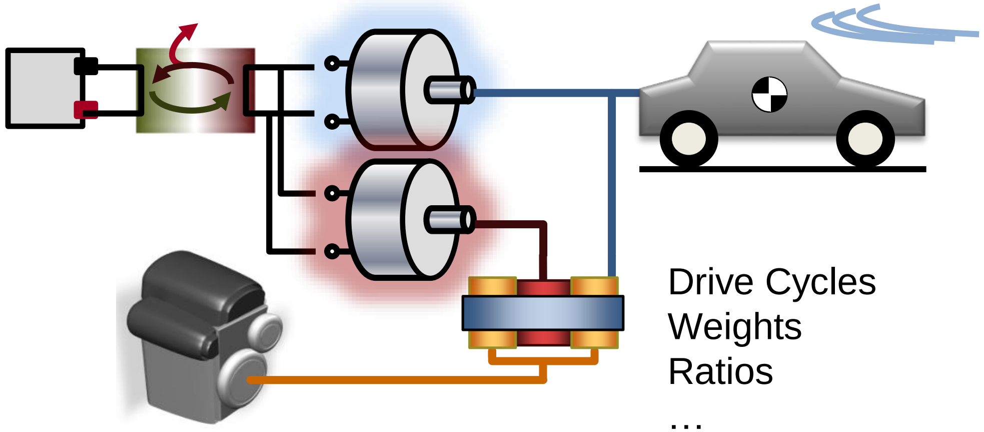
- Simulating in parallel
  - Distribute simulations to multiple cores/processors
  - Dramatic speedup for sets of simulations (parameter sweeps, flight cycles optimisations, and more)

`for` → `parfor`

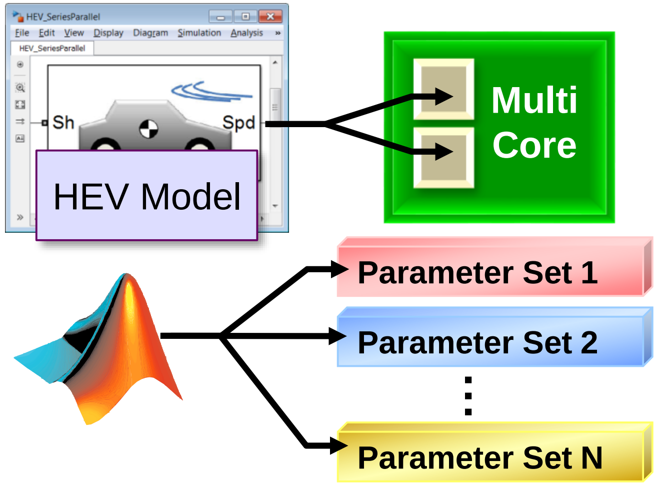


Shorten Simulation Times With Parallel Computing

Model:



Drive Cycles
Weights
Ratios
…



Problem: Minimize simulation time to run a parameter sweep on the HEV model

Solution: Use Parallel Computing Toolbox to speed up the sweep

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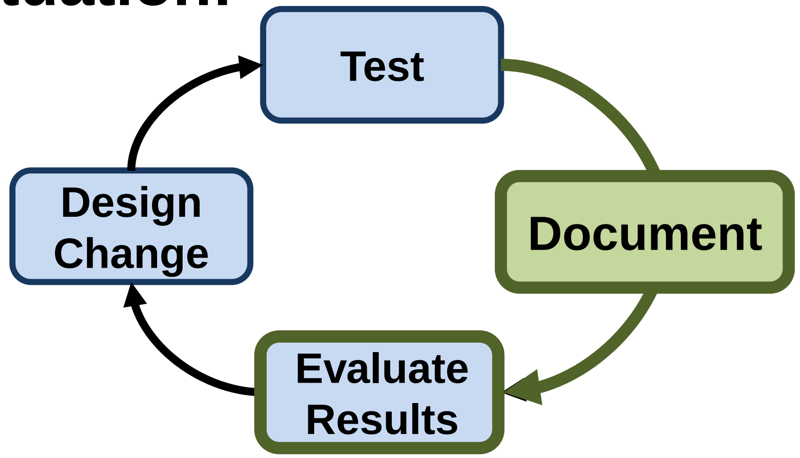
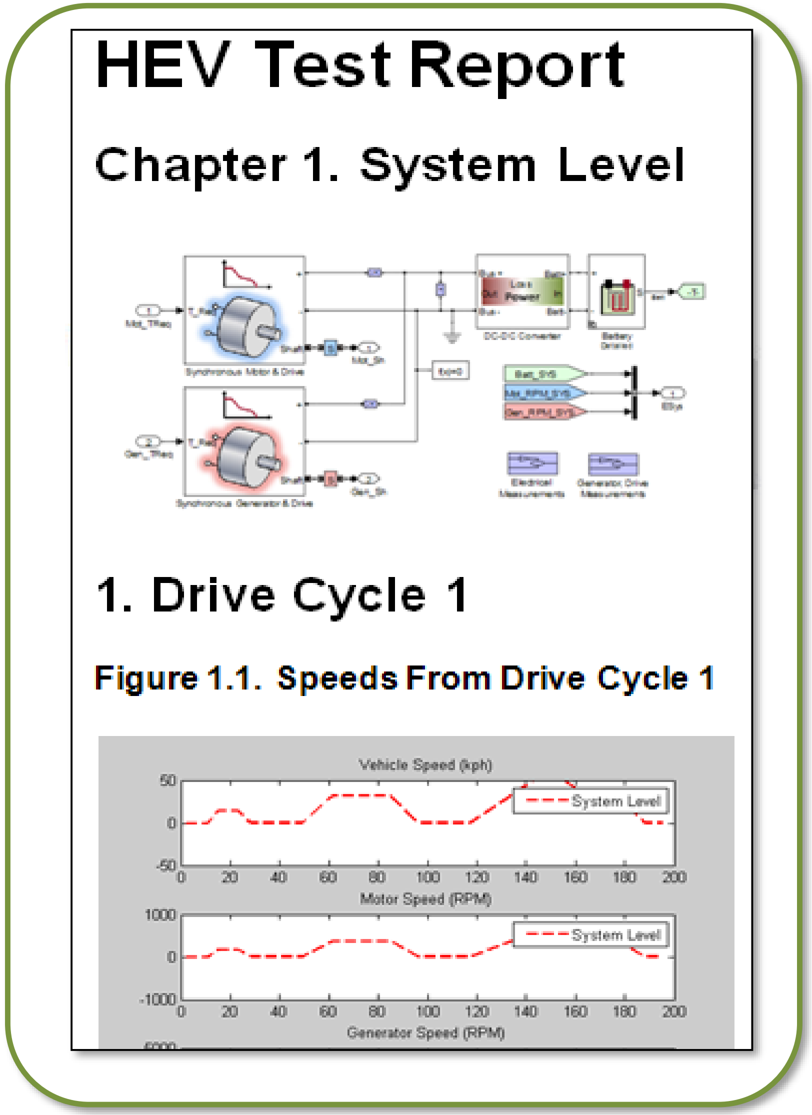
Automatically Run Tests And Document Results

Situation:



Problem: Evaluate test results quickly to make design changes and document the results

Solution: Use Simulink Report Generator to automatically document tests and results



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Key Points

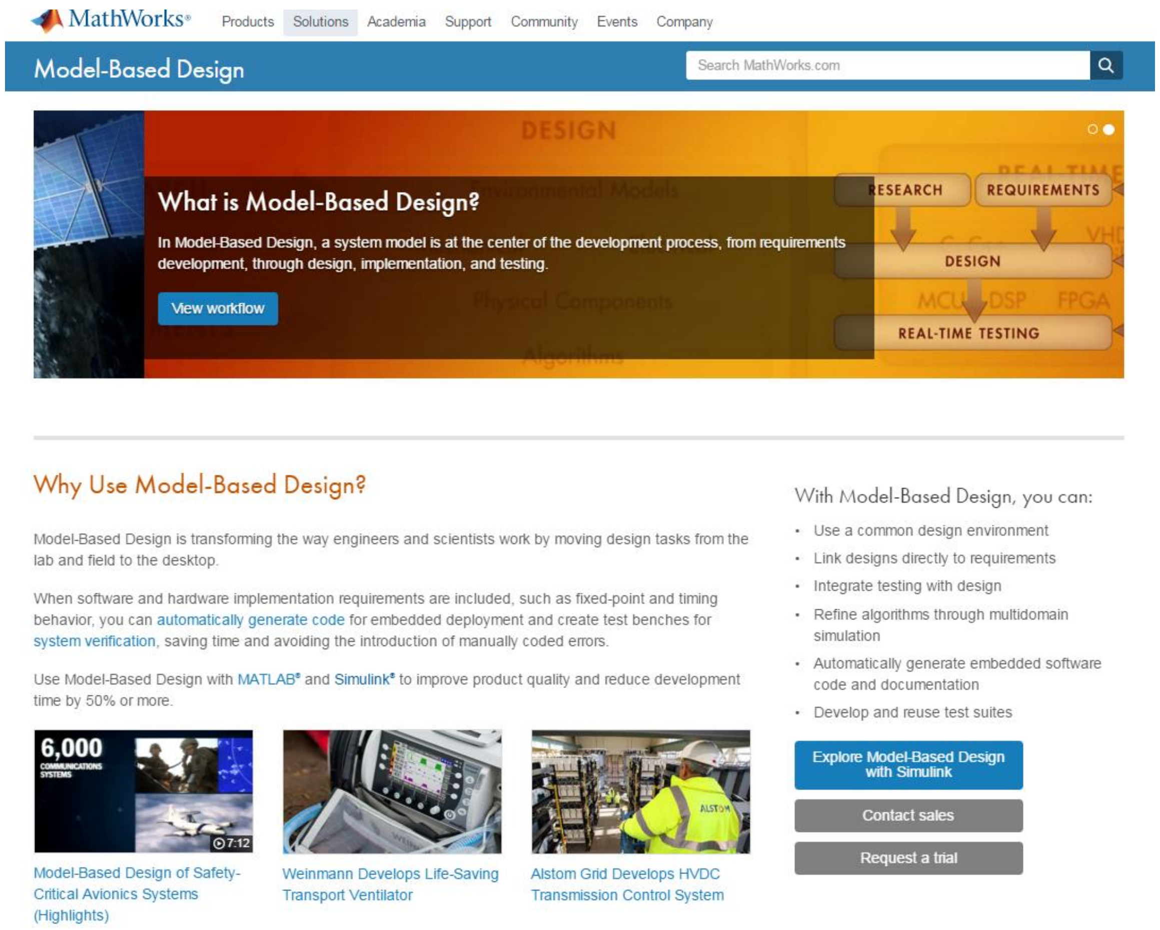
- Simulink is a multi-domain modelling and simulation environment facilitating Model-Based Design
- Optimise the system-level performance
- Accelerate your development
  - Speed up simulations using Parallel Computing Toolbox
  - Speed-up processes using Simulink Report Generator

Call to Action

Learn more about Model-Based Design with Simulink

- Explore our [website](au.mathworks.com)
  - au.mathworks.com

- Contact me:
  - Ruth-Anne Marchant
    - ruth-anne.marchant@mathworks.com.au



Q & A