Rapid multi-physics approach to the development of electric drive systems for hybrid and electric vehicles

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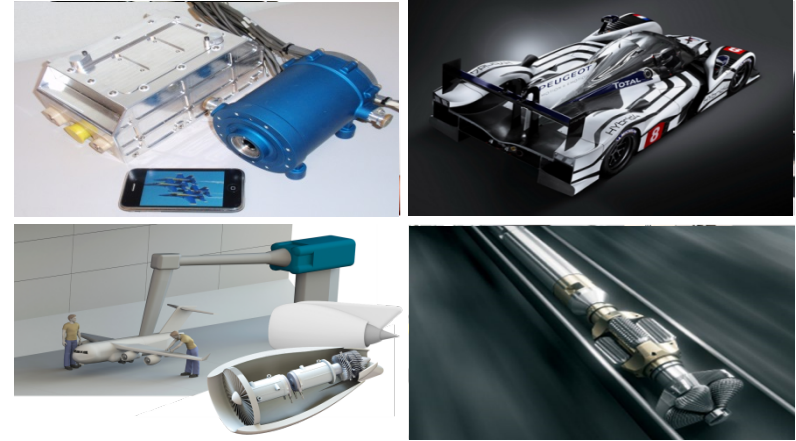**Automotive and Engine Technology**

Presentation Outline

- MTS Systems Corporation

- Electric Power Systems

- Development Cycle for Motors and Drive

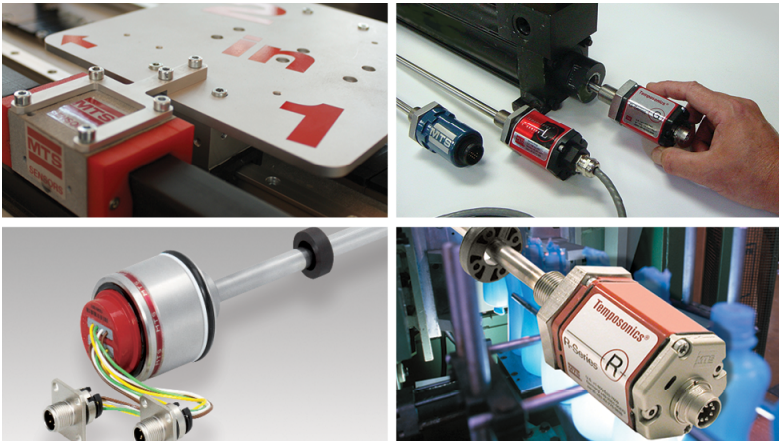- Applications

MTS Products, Systems and Services

Test Vehicles, Materials and Structures

Electric Power Systems Vehicles, Industrial

Sensors Liquid level and position

Services Consulting, Monitoring, Repair

EPS – Electric Power Systems

Develop and manufacture high performance electric motors and controls.
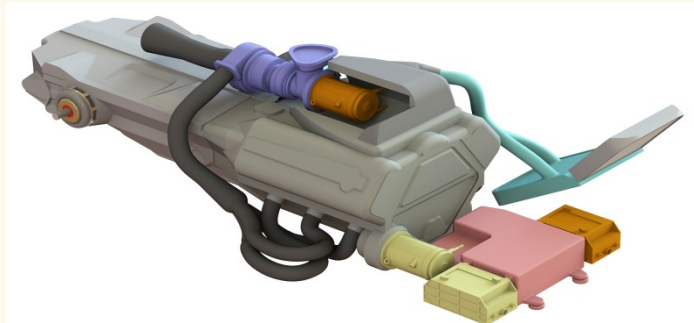
PORTFOLIO

» Traction motors
» ERS
» Dynos
» Industrial solutions
» Power generation
» Oil and gas exploration
» Aerospace applications

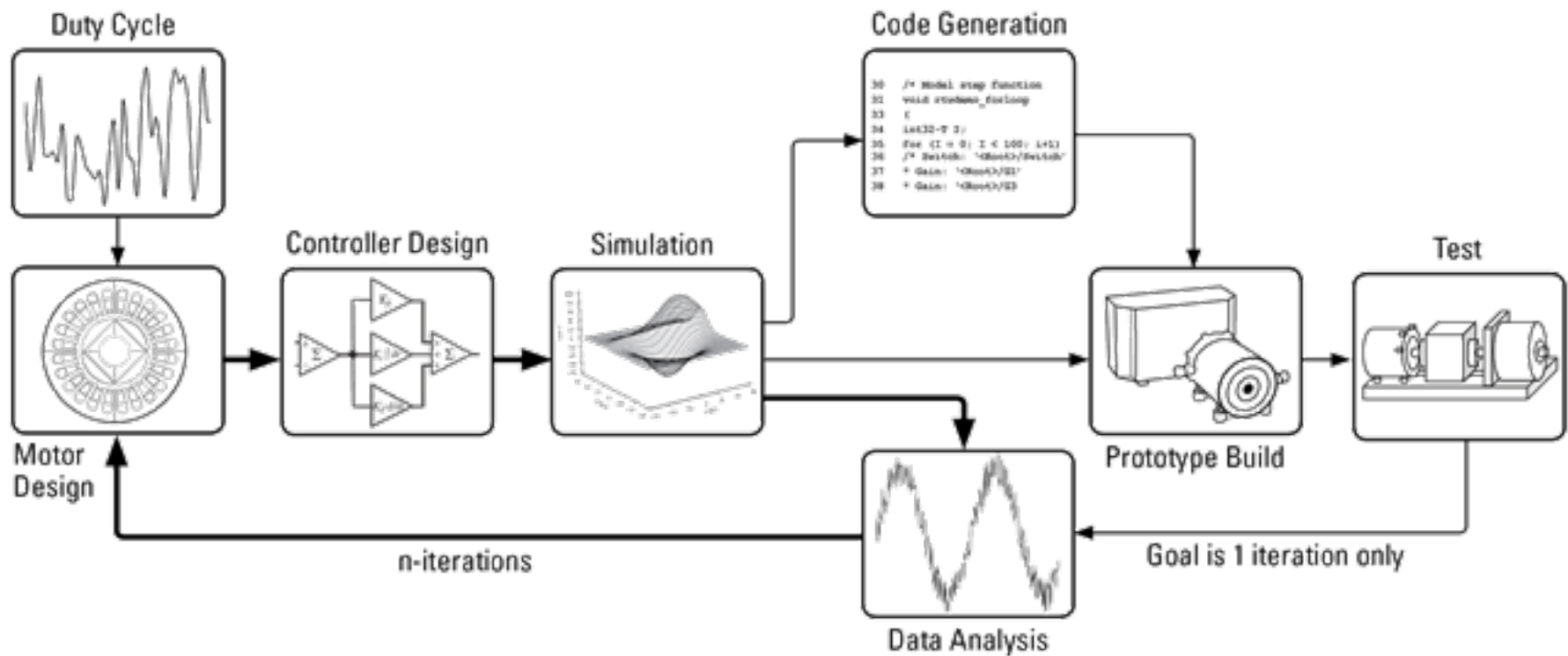Formula E drive System

» Traction drive
» Kinetic energy recovery

Formula 1 Energy Recovery System
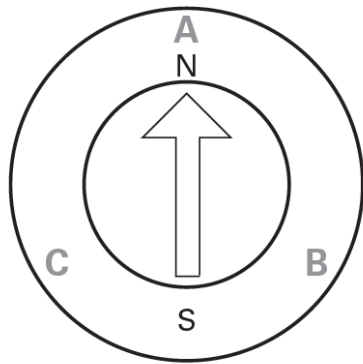

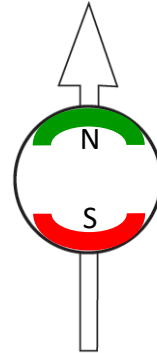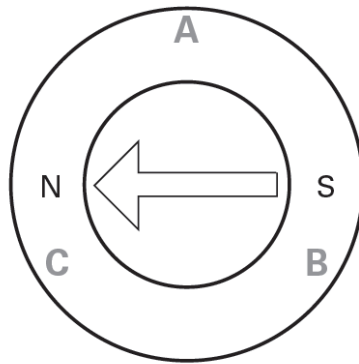» Kinetic energy recovery
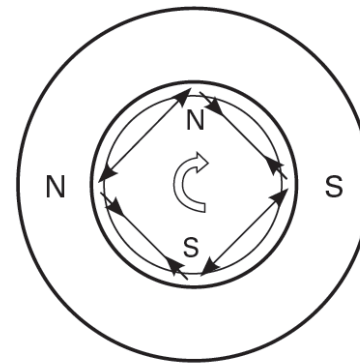» Heat energy recovery

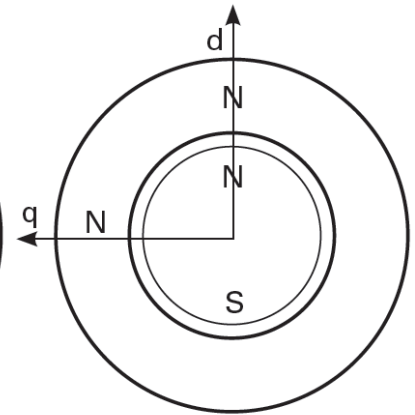# Development Cycle for Motors and Drives

Motor Principle

Stator
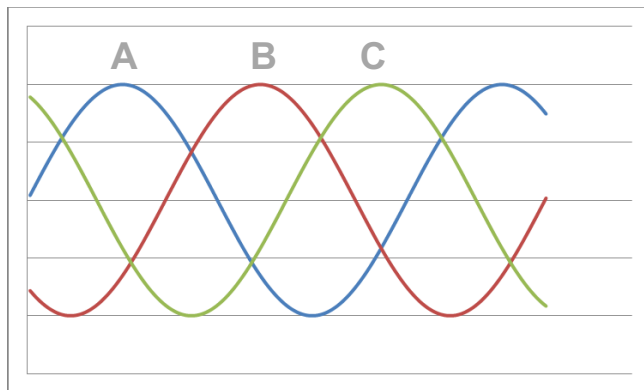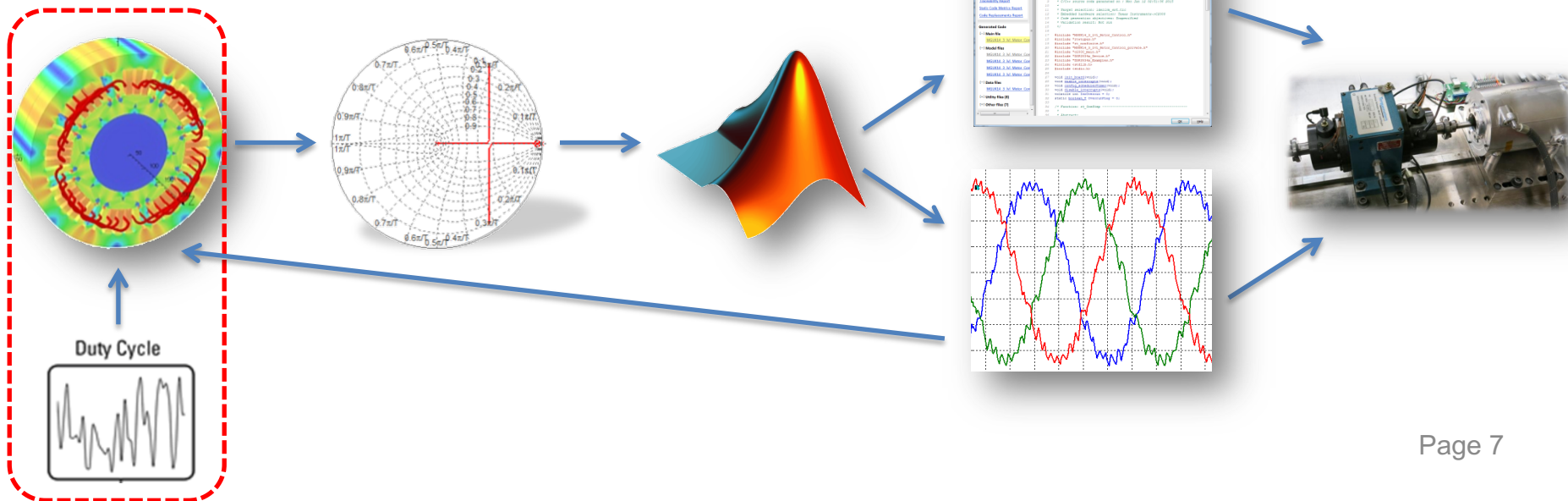
Rotor SPM

Torque Rotation

Control

Iq=torque
Id="correction"
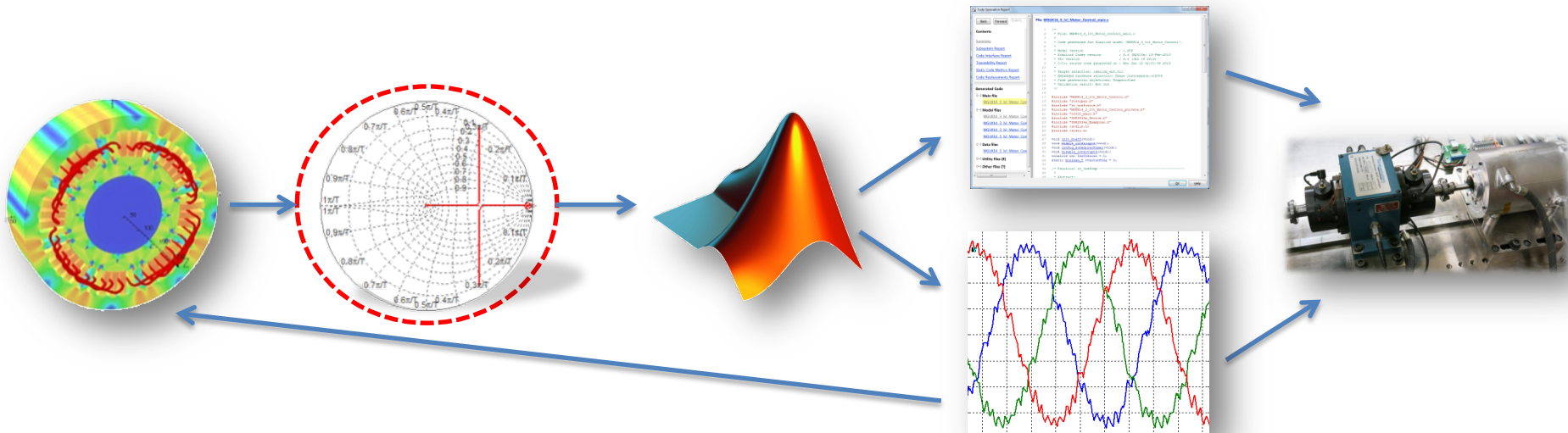
Motor/Drive System Design Process

- Duty Cycle drives base design, topology, etc.
- FEA of EM design
- Control Design
- Simulation
- Data Analysis/Hardware Design
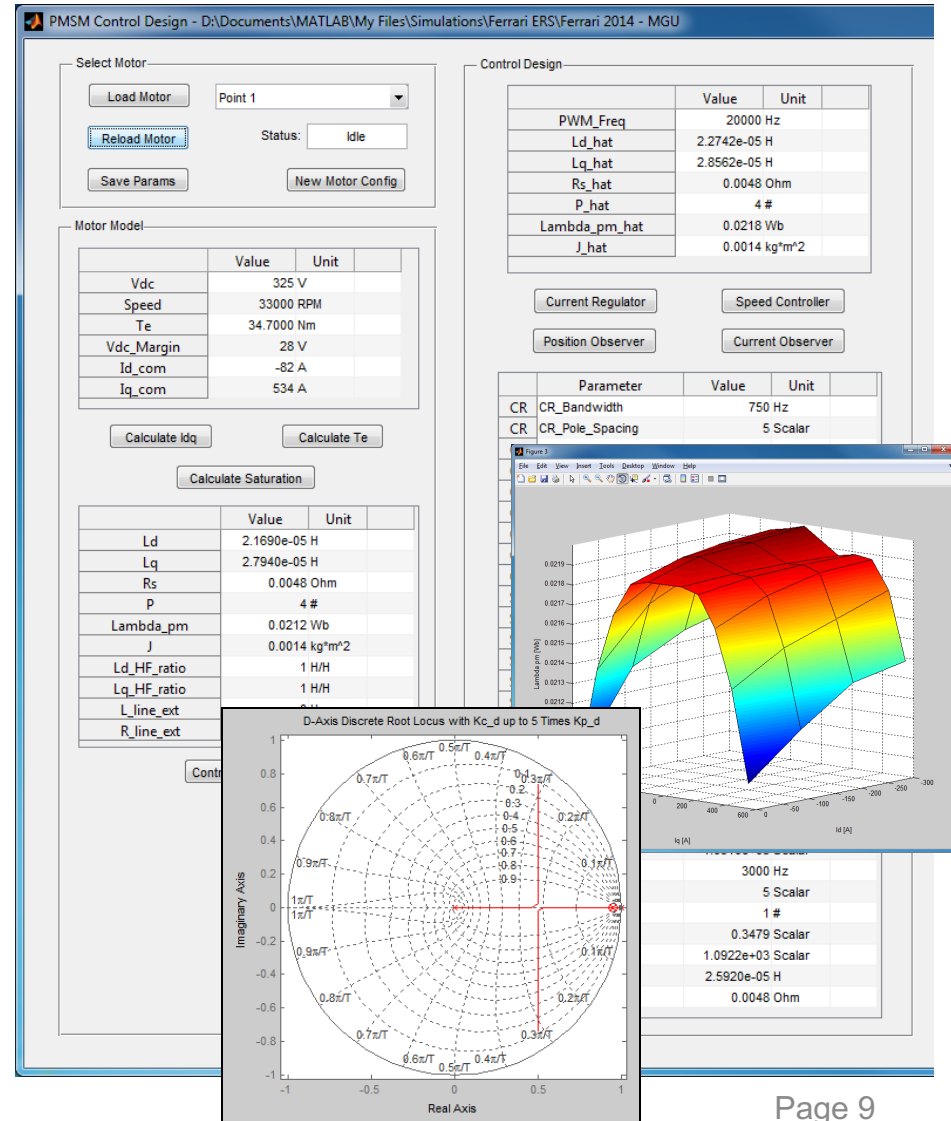- Code Generation
- Testing & Verification

Motor/Drive Design Process

- FEA
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Control Design

- Motor parameters lookup table
  - Generated with FEA
  - Ld, Lq, and Lambda vs Id and Iq
- Discrete control design
  - d-q current commands
  - Speed command
  - Speed observer
  - Current observer (Self Sensing)
- Operating point calculations
  - Including saturation
  - MTPA and Field Weakening
- Rapid and robust control design

Motor/Drive Design Process

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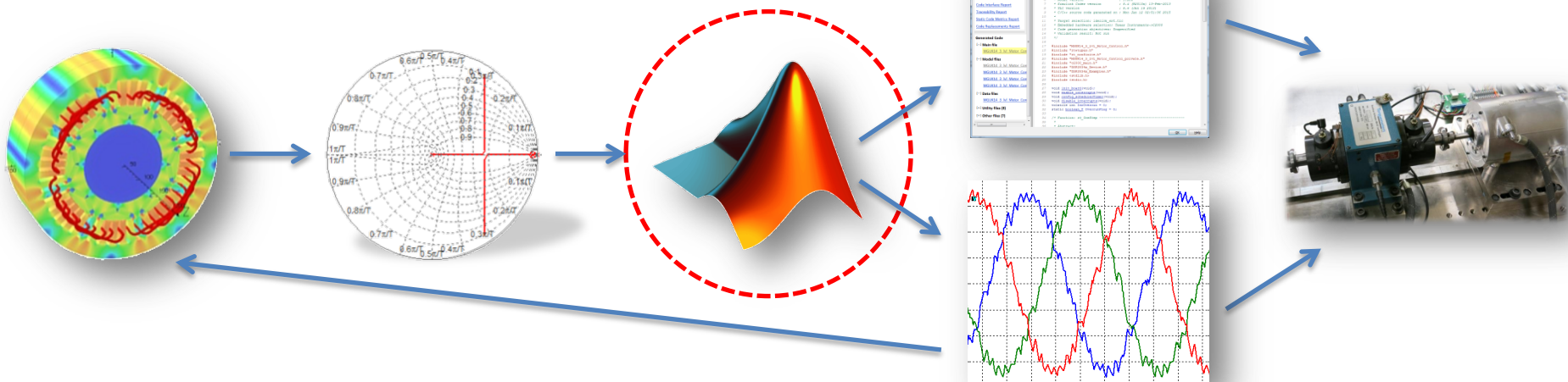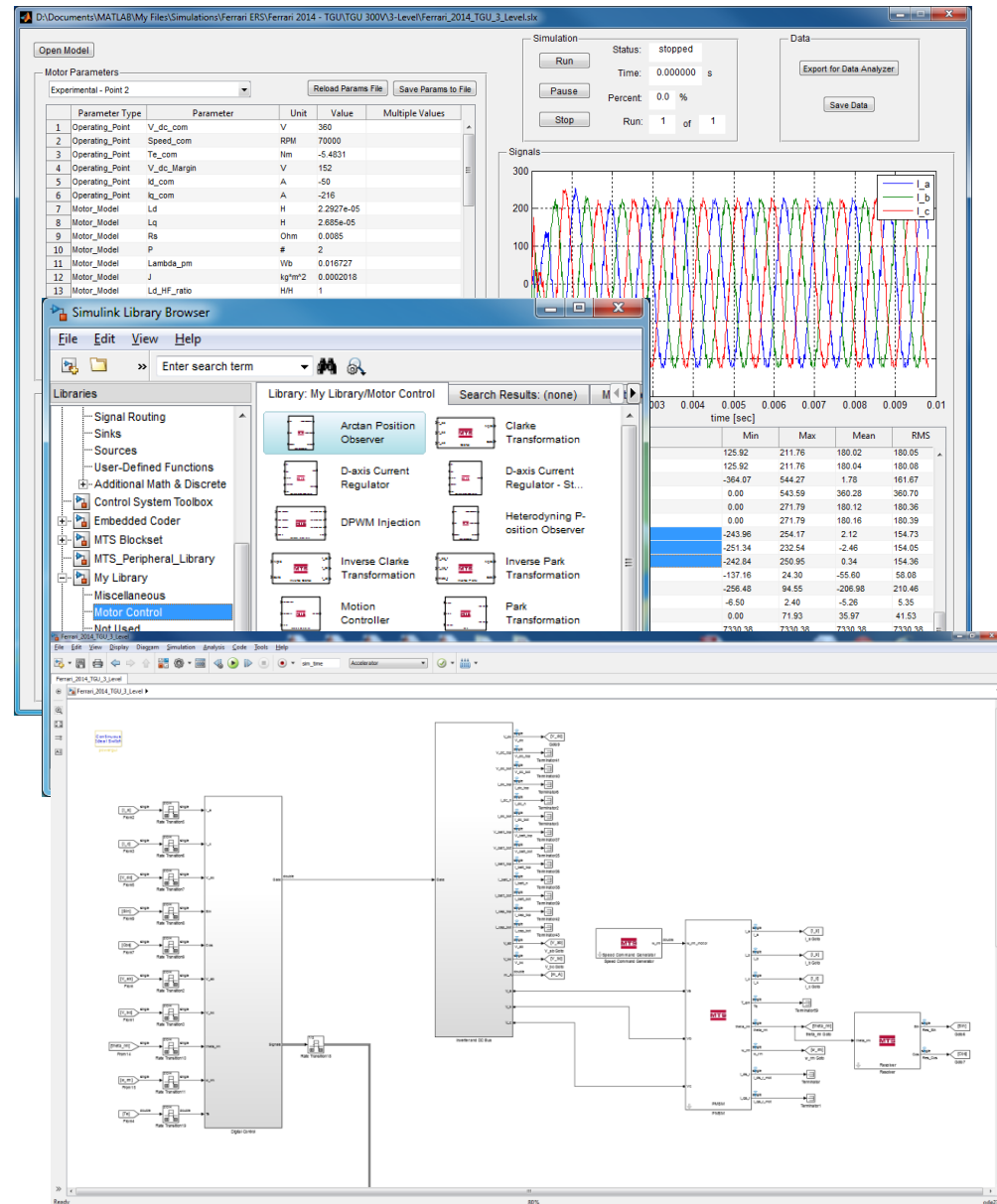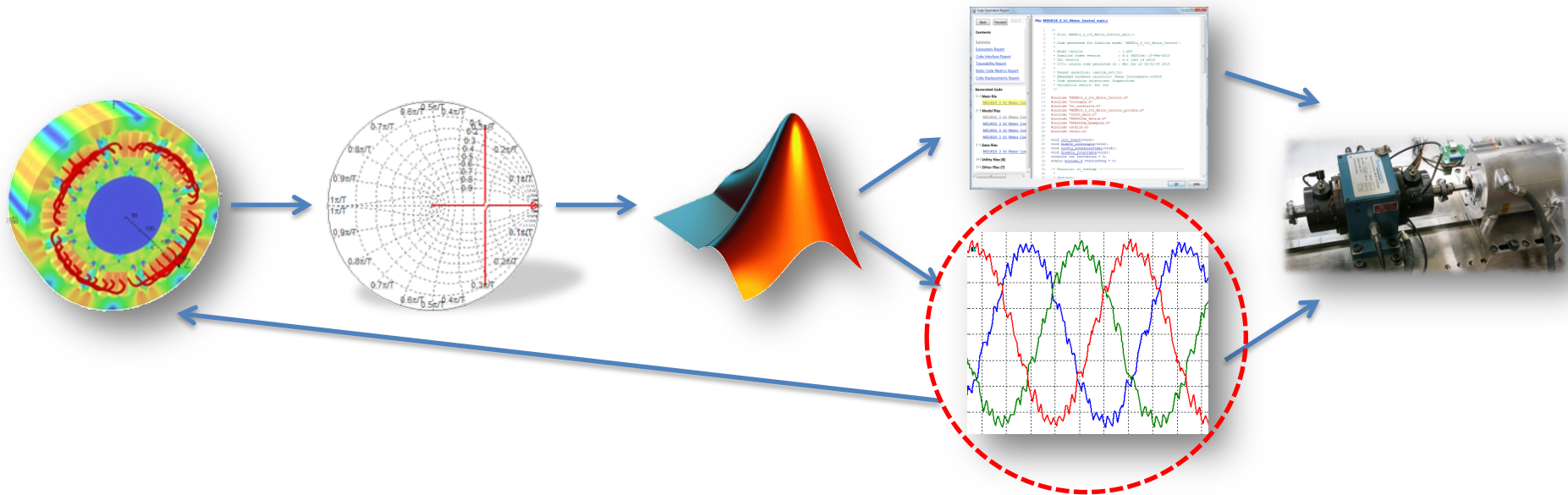# Simulation

- Parameters imported from motor control design

- Quick view of simulation results

- Custom motor control library
  - Design blocks
  - Easy to implement different control topologies

- Verify motor control
  - Gains from control design
  - Different control topologies

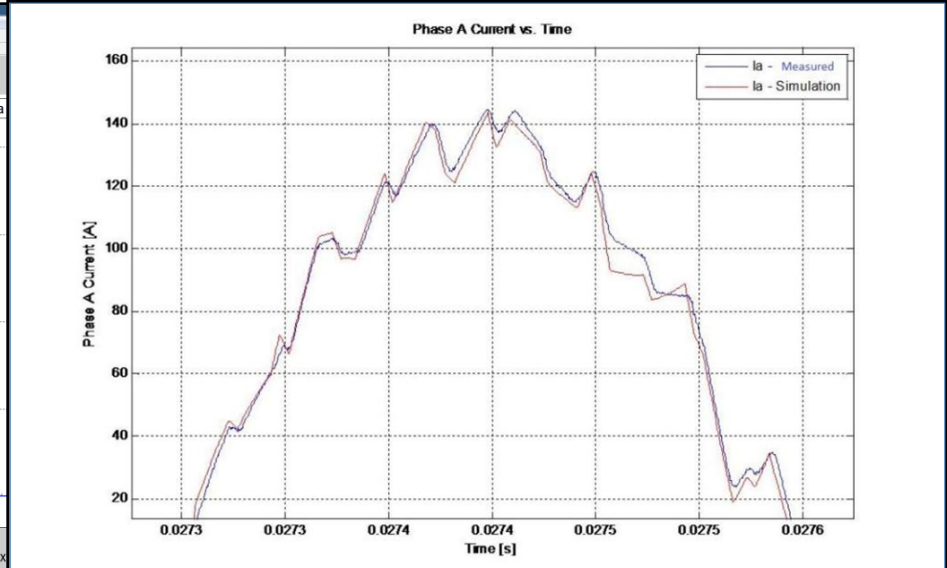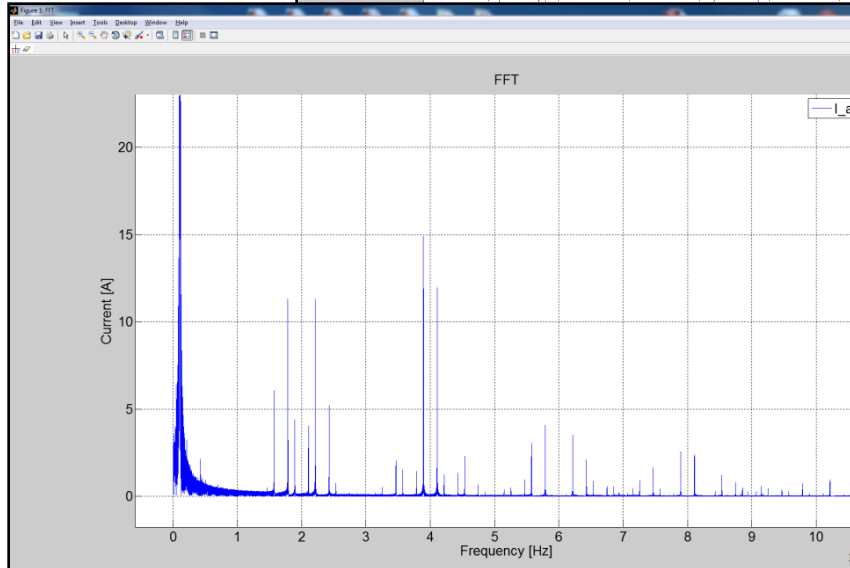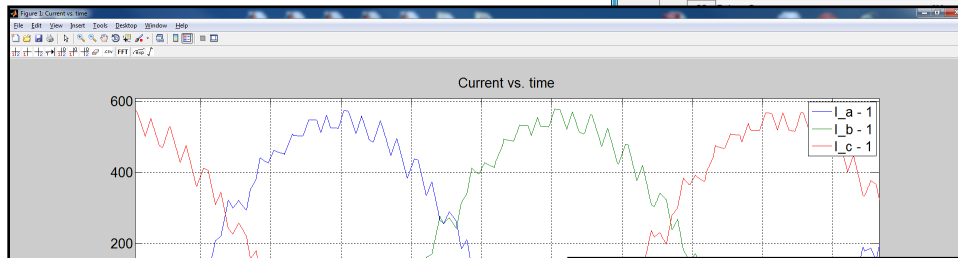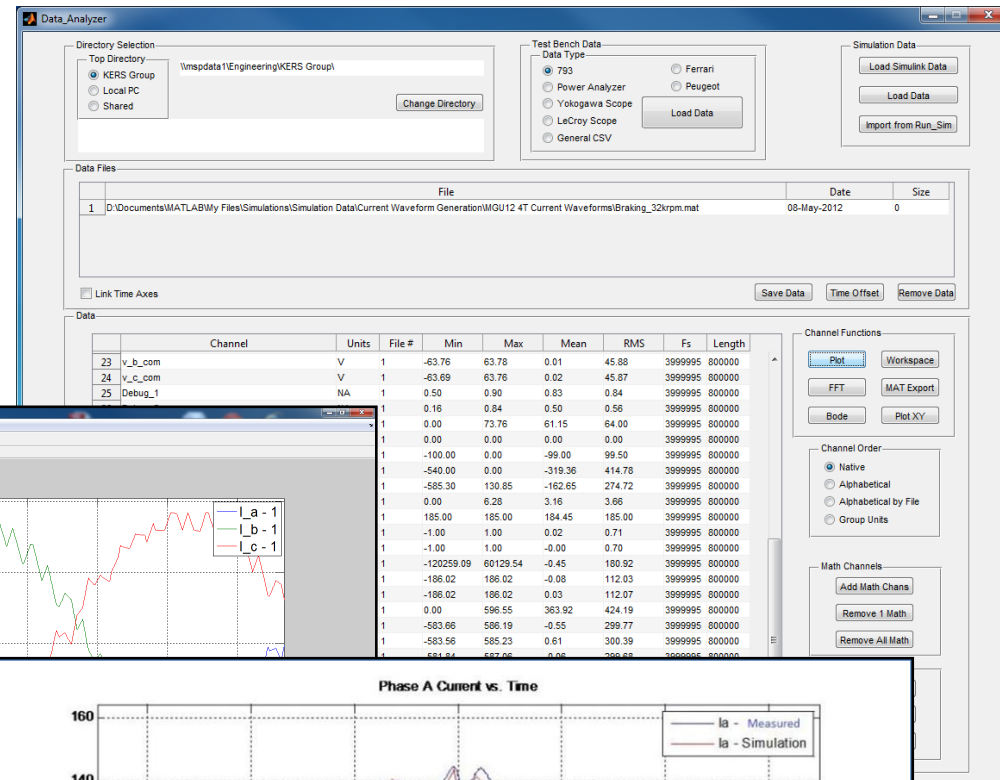- Data can be saved for further analysis

Motor/Drive Design Process

- FEA
- Control Design
- Simulation
- Data Analysis/Hardware Design
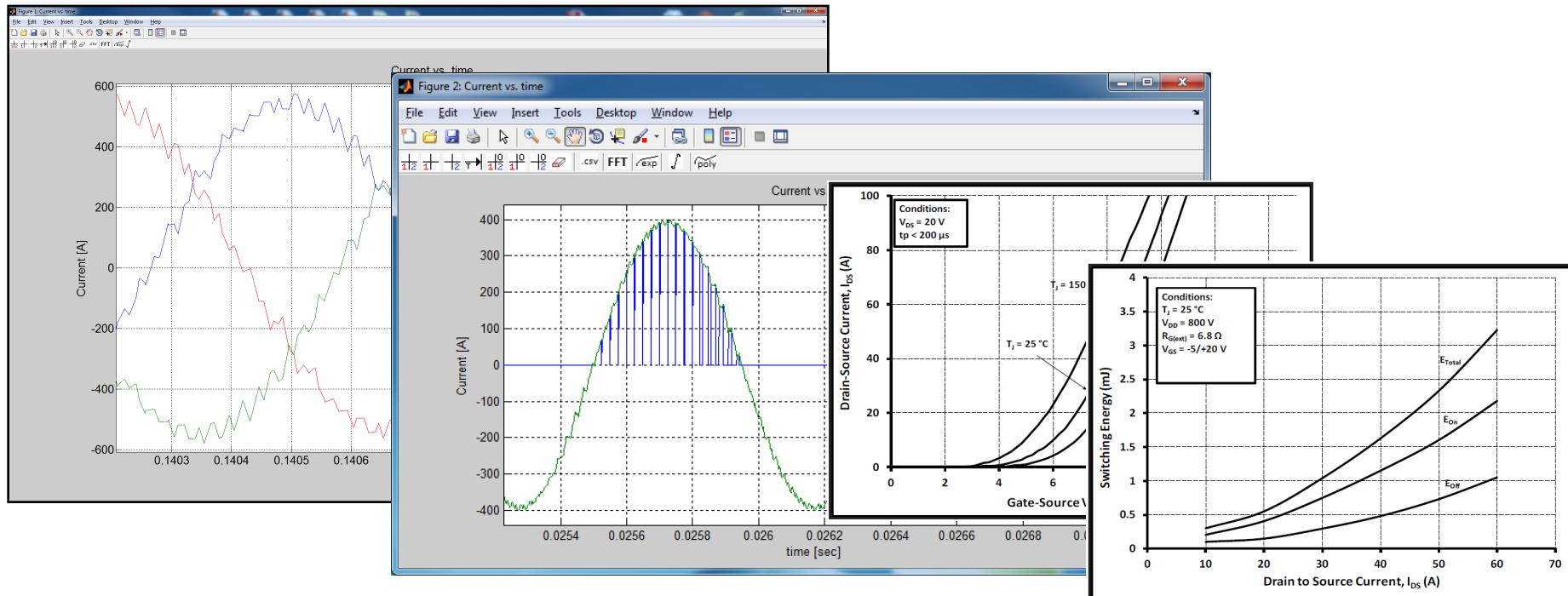- Code Generation
- Testing & Verification

Data Analysis

- Import simulation and experimental data

- Compare data

- Functions to analyze data

Hardware Design

- Phase currents fed back into FEA to estimate motor losses
- Device currents used to calculate power electronics losses and heating
- DC RMS current and voltage ripple used for capacitor sizing
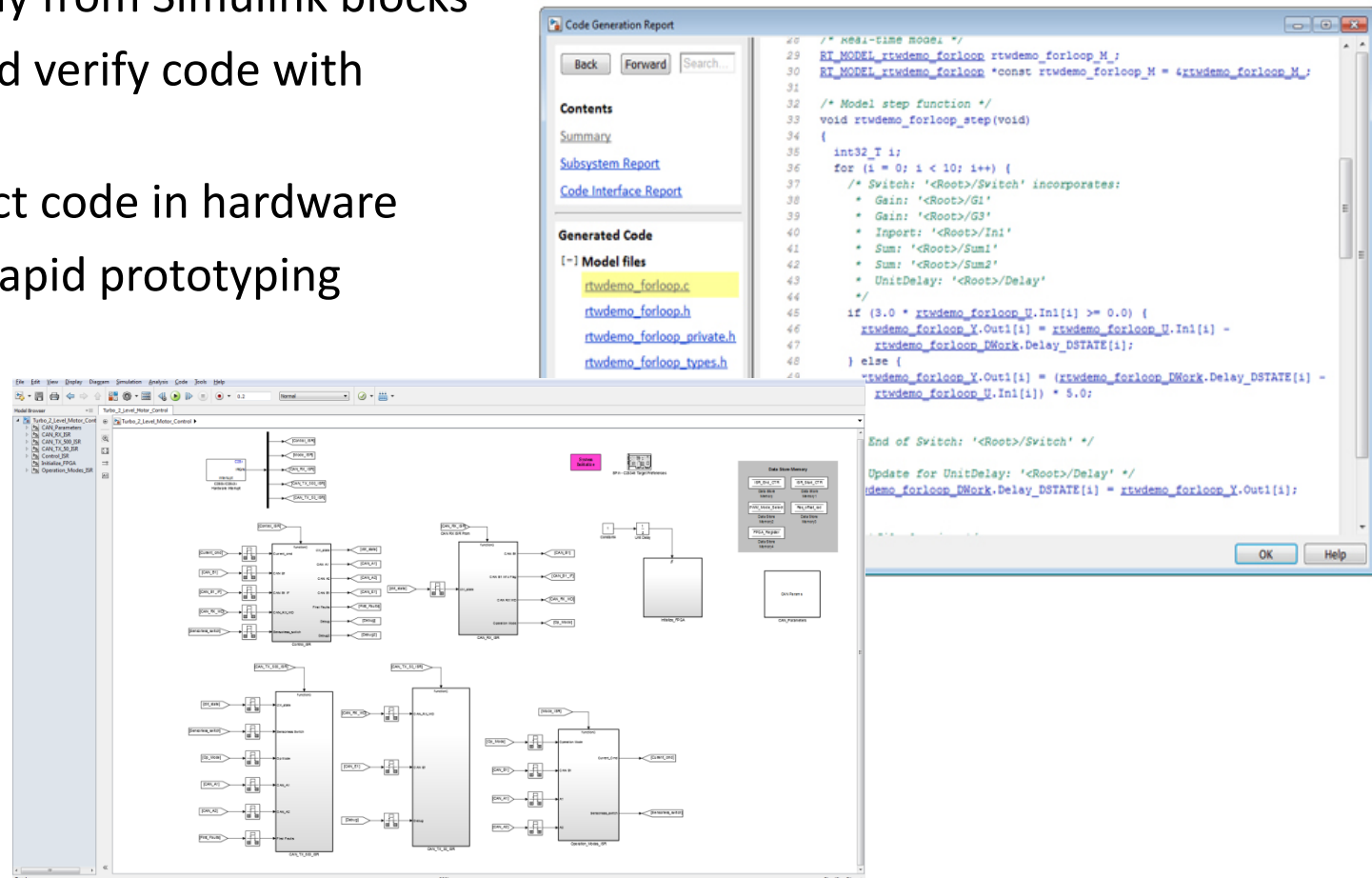- RMS currents used for bus bar sizing

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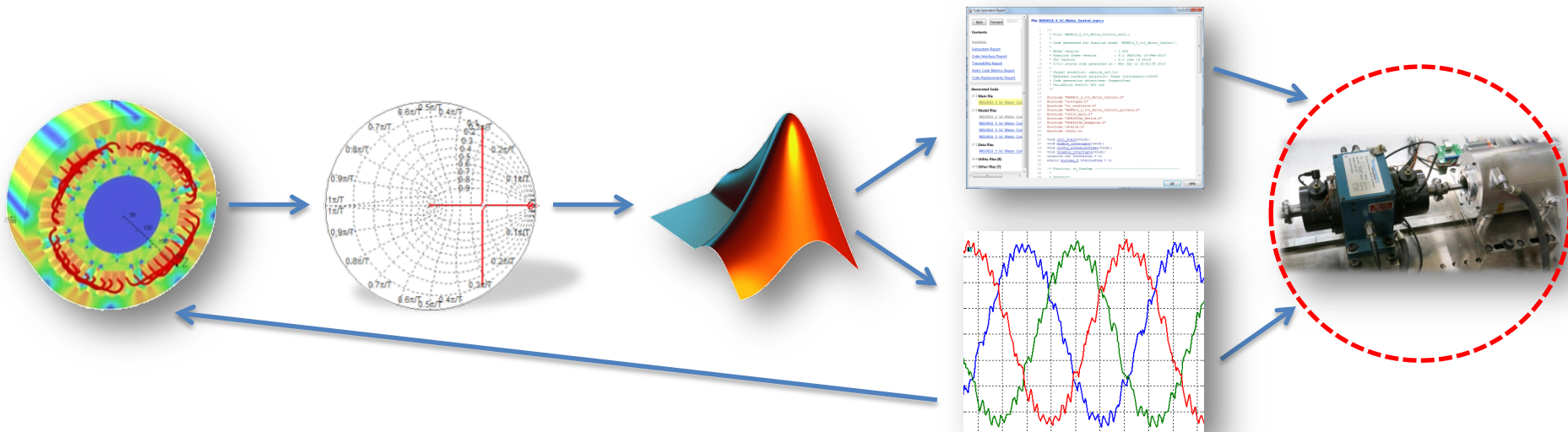- Code Generation
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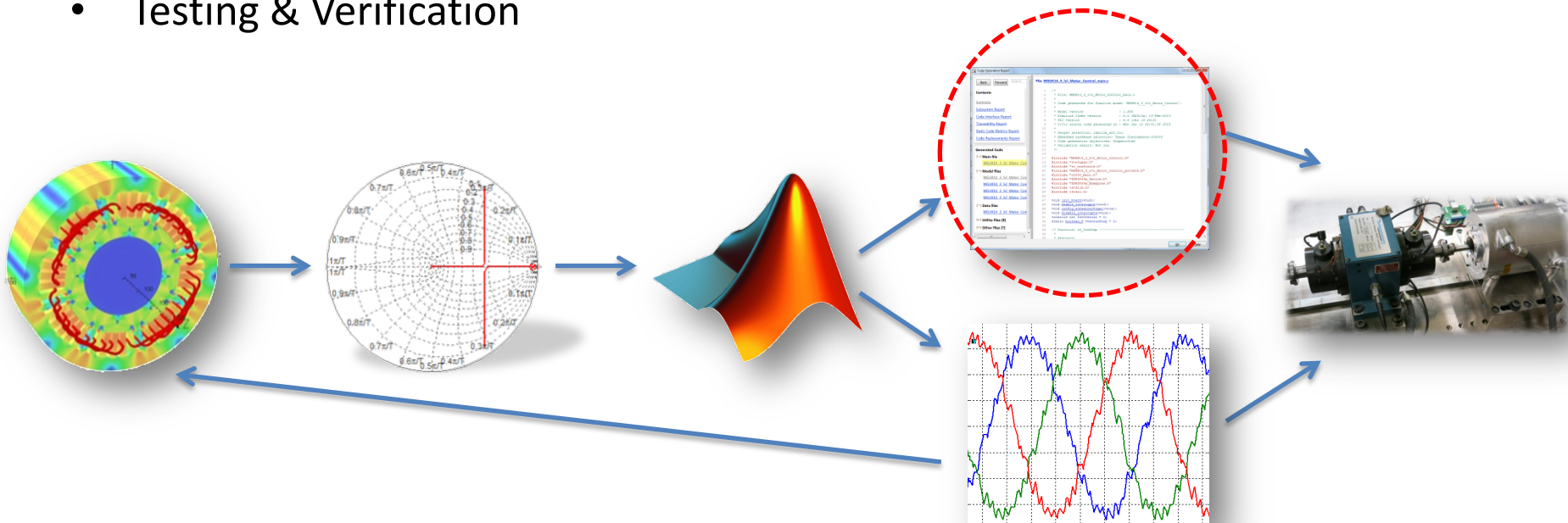
Code Generation

- Simulink Coder builds DSP/FPGA code directly from Simulink blocks
- Develop and verify code with simulation
- Deploy exact code in hardware
- Allows for rapid prototyping

Motor/Drive Design Process

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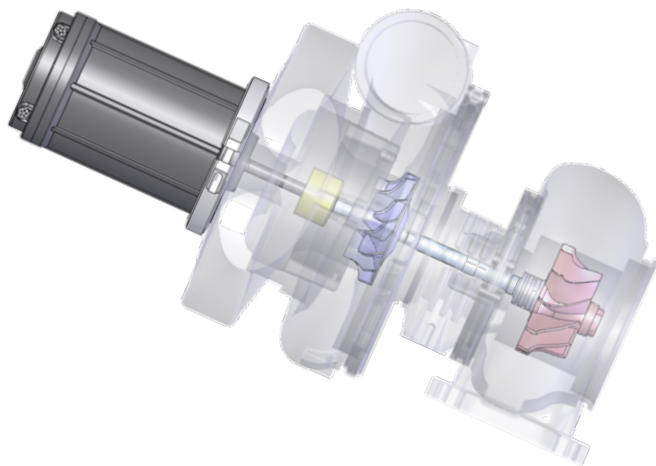- Code Generation
- Testing & Verification

Testing & Verification

- Calibrate drive
- Verify back-emf
- Bearings break-in
- Verify control
  - DQ current regulators
  - Field weakening, Id, Iq
  - Torque accuracy
  - Tune sensorless control
  - Run motor to full speed and torque
- Measure motor and drive efficiency
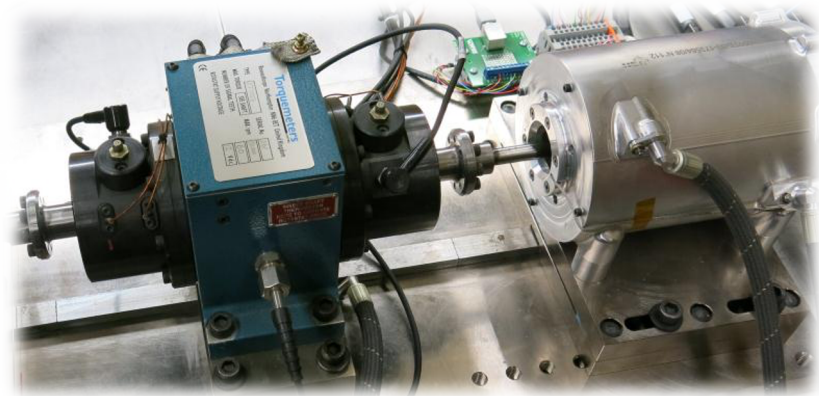
Applications …

Questions Please ?

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