Plant and Signal Delivery Subsystem Modeling for Powertrain Control Design

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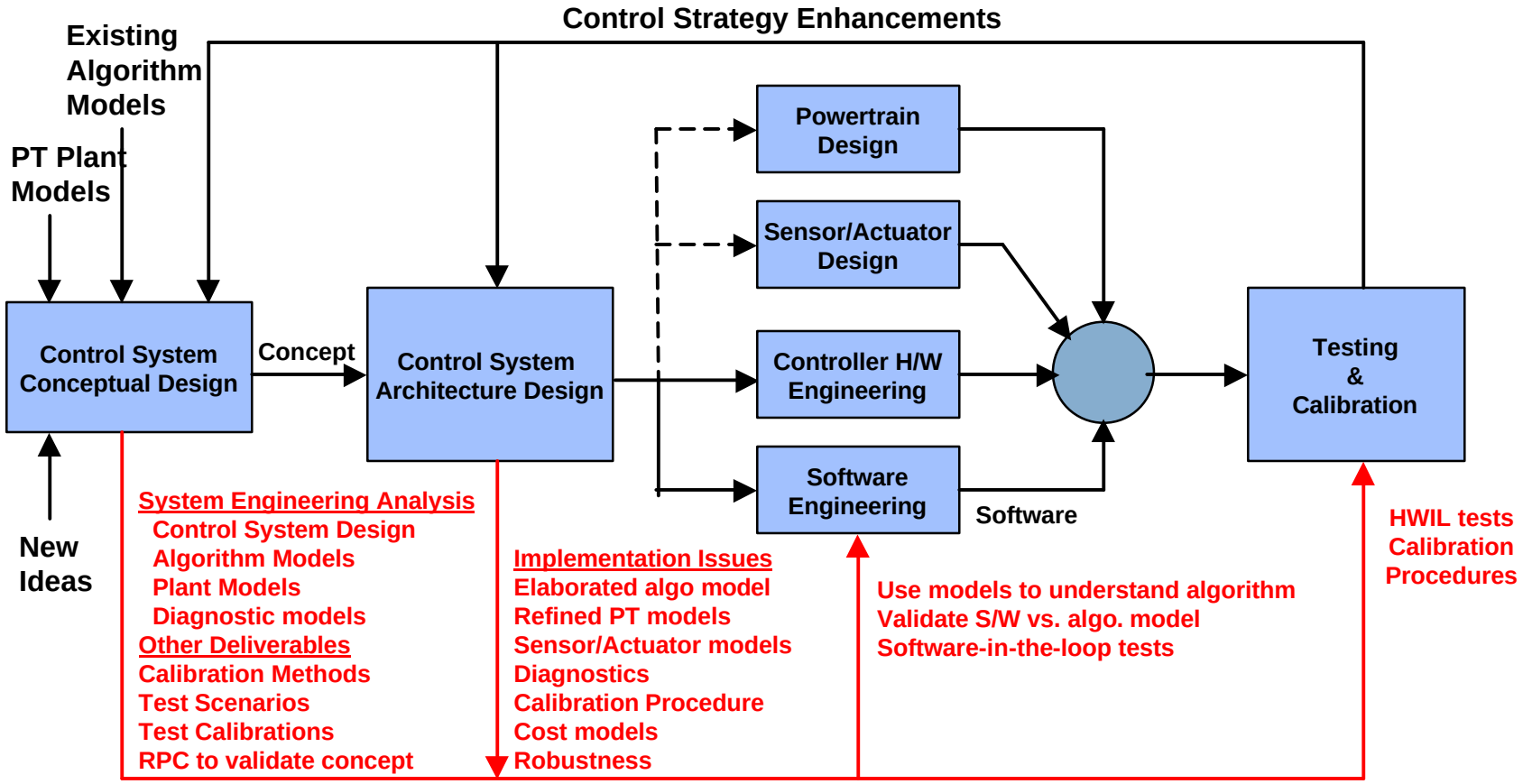
Challenges in PT Control System Design & Development

- Control System Design usually starts after hardware is available
- Time pressure to develop algorithm, write code and calibrate
- Minimum opportunity to influence hardware design
- Sensors & actuators may already be selected
- Signal Delivery Subsystem (SDSS) effects not always considered
- Cost is always a major factor

Model-Based PT Control Design Process



Why do Modeling & Simulation?

- Engineer a better performing system of higher quality, faster and more cost effectively
- Determine, analyze, and optimize a system's behavior without having to build it or before the hardware is available
- Be able to run tests that would be difficult, impossible or unsafe to run on the actual hardware
- Analyze the effects of variation on the system - DFSS
- Perform what-if studies - DFMEA, etc.

Types of Models

- Plant – physical system that is a major element of interest in a control problem, e.g., engine, transmission, EGR subsystem. It should include actuators, sensors, controller circuitry, wiring and environment (signal delivery subsystem)
- Plant Model – physics-based or behavioral math model built to understand the problem and represent the dynamics of the system being controlled
- Algorithm Model – executable representation of an algorithm - equations, data flow diagram, state charts
- Signal Delivery Subsystem Model – math model of the sensors, actuators, wiring, signal conditioning circuitry, A/D converters, PWM generators, etc. used to connect the controller to the physical quantity to be measured or controlled

Plant Models

- Hardware Design-oriented models – support design and analysis of hardware parts – fluid flow, structure, temperature distribution, etc. – FEA, CFD
- Control System Design-oriented models – support design and analysis of the control system (behavioral) – from sensor input to actuator output

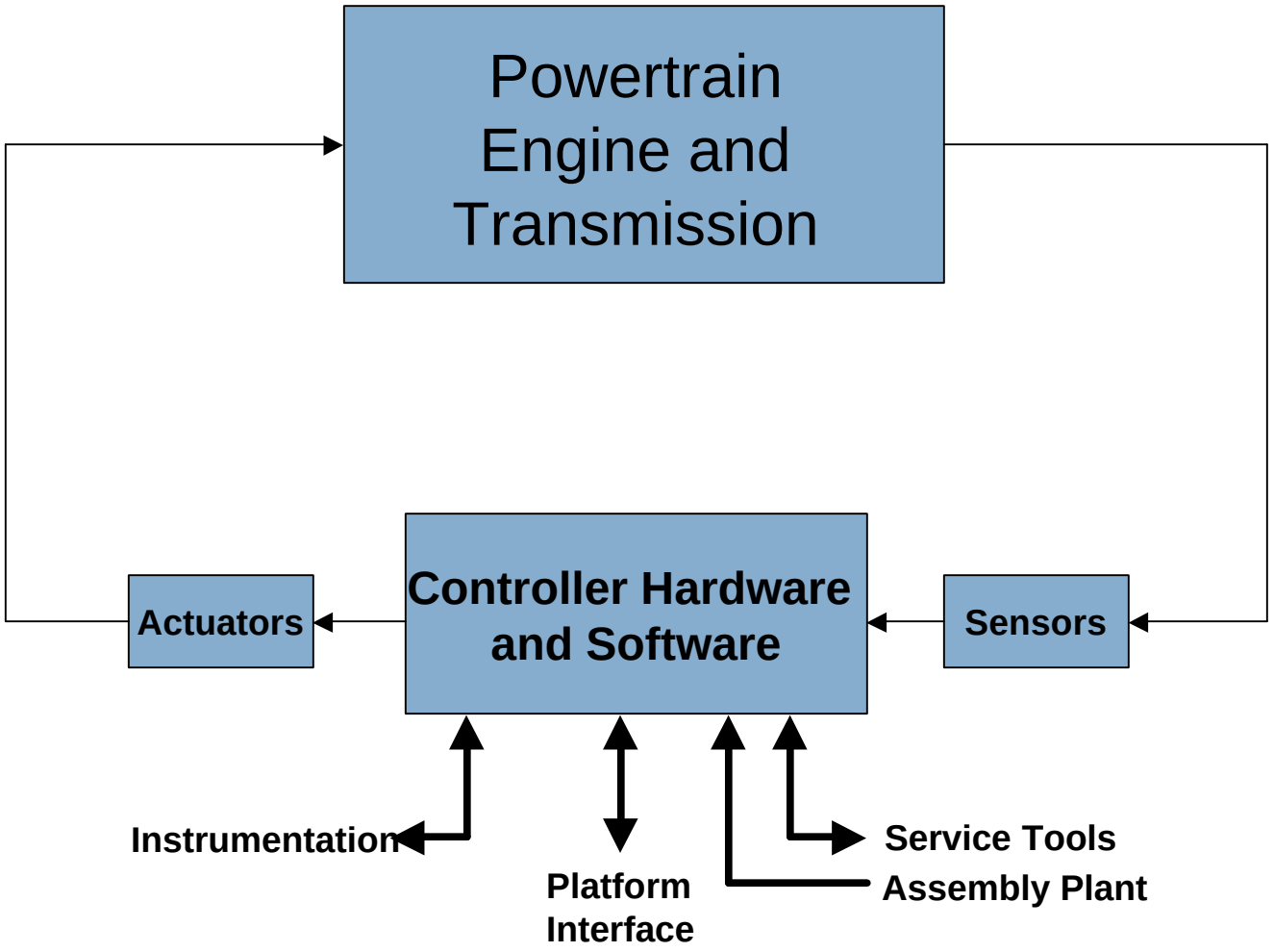
Control System Design-Oriented Plant Models

- Physics-based models – dynamic equations derived from physics and representing the system behavior (understanding)
- Physical models – math models of physical hardware, e.g., electrical, magnetic, mechanical, hydraulic
  - sensors, actuators, signal delivery subsystem
- Empirical models – characterized by measured data, requires hardware testing
  - regression analysis, Taylor series, etc.

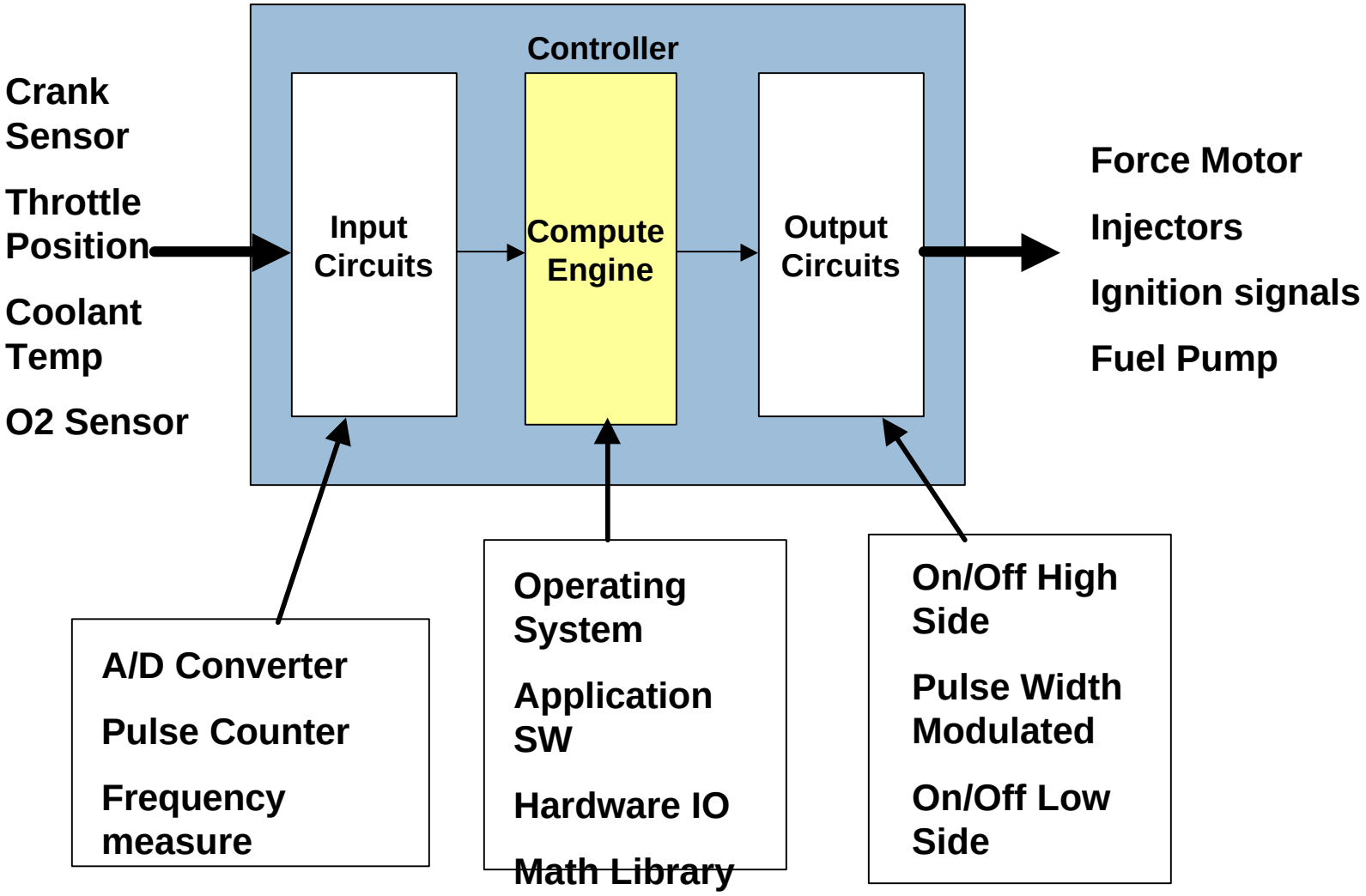
Plant Modeling Issues

- Plant models may take long to develop
- Many different models needed
  - Problem dependent
  - Fidelity and complexity
- No standard plant model architecture
- Need to validate model vs. hardware
- Desire to reuse models
- Different tools being used
- Sensors, actuators, signal delivery system must be included

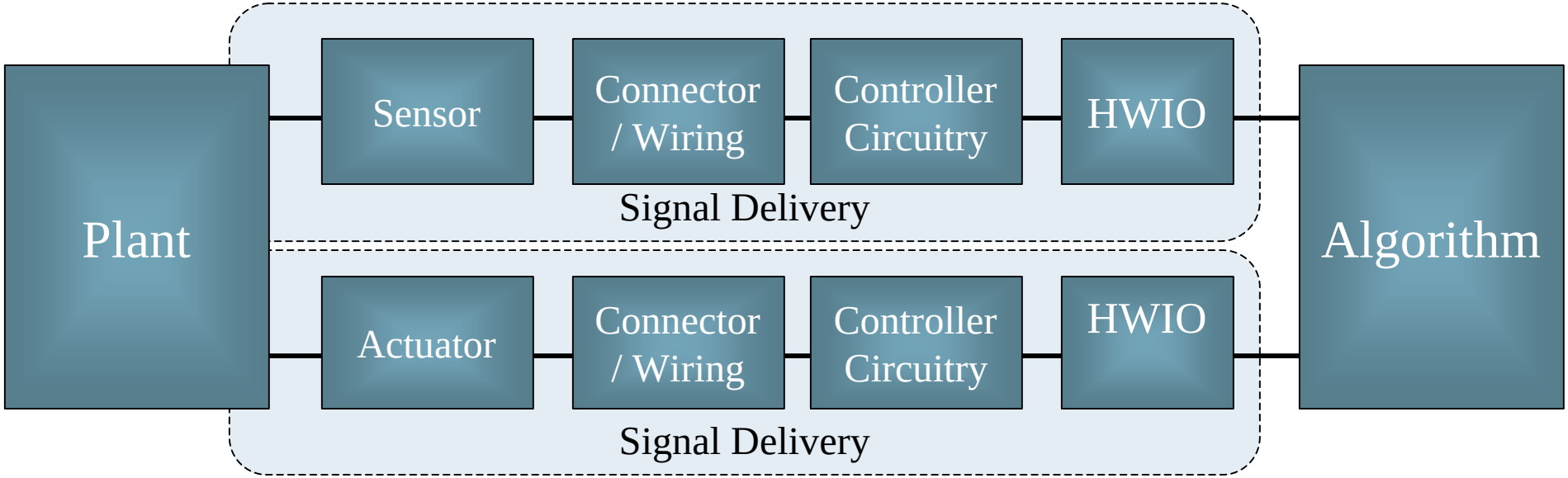
Powertrain Control System Block Diagram



Controller Hardware & Software



Signal Delivery Subsystem (SDSS)



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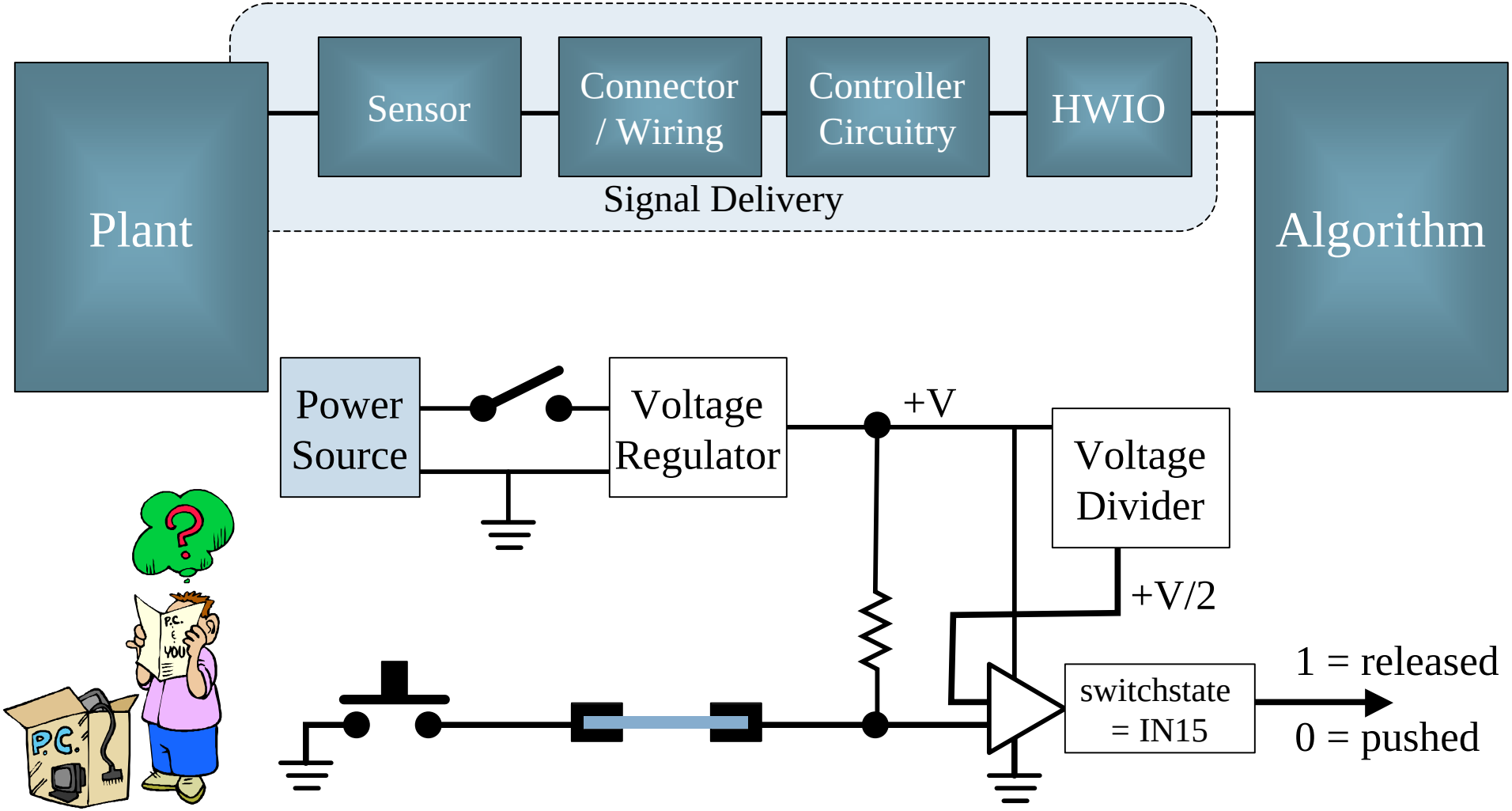
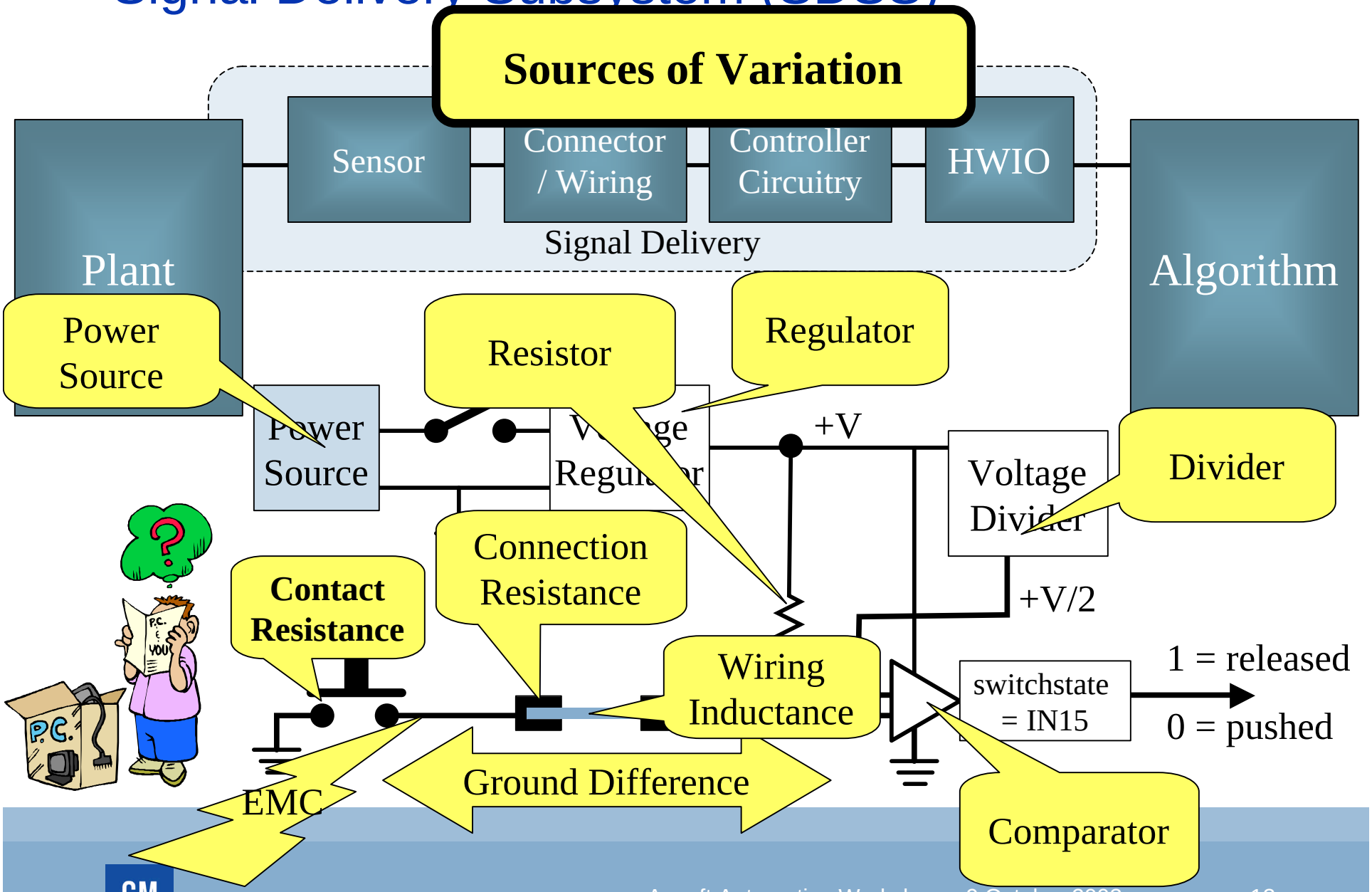


Signal Delivery Subsystem (SDSS)



Plant/SDSS Modeling Strategies

- Specific model for problem-at-hand
- One-size-fits-all model
- Reconfigurable models for levels of complexity
- Causal vs. a-causal models
  - Data flow diagrams
  - Topological models

Plant Modeling Tool Requirements

- Co-simulation with other tools
  - detailed engine & transmission models
  - algorithm models
  - sensor & actuator models
  - calibration tools
- Capable of real-time simulation for HIL
- Support for various levels of fidelity
  - e.g., model order reduction
- Modular structure
- Easily validated and correlated

Plant Modeling Tool Requirements (cont'd)

- Compatible with CM and version control tools
- Support for libraries of models
- Parametric configuration facilities
- Enterprise support
  - documentation, readability, portability
- Supports software-in-the-loop
- Scripting capability
- Web interface