Lecture 3 - Model-based Control Engineering

- Control application and a platform
- Systems platform: hardware, systems software. Development steps
- Model-based design
- Control solution deployment and support
- Control application areas

Generality of control

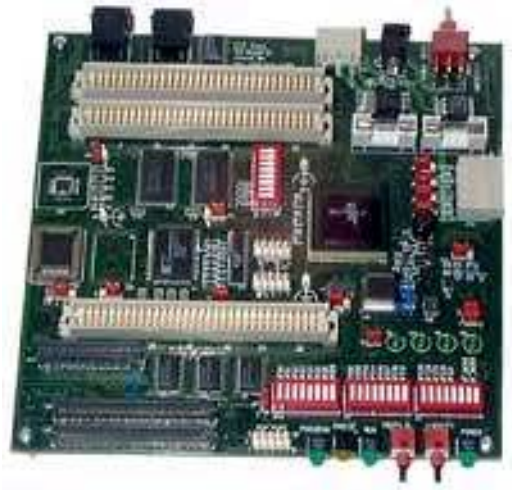
- Modeling abstraction
- Computing element - software
- System, actuator, and sensor physics might be very different
- Control and system engineering is used across many applications
  - similar principles
  - transferable skills
  - mind the application!

System platform for control computing

- Workstations
  - advanced process control
  - enterprise optimizers
  - computing servers (QoS/admission control)
- Specialized controllers:
  - PLC, DCS, motion controllers, hybrid controllers

System platform for control computing

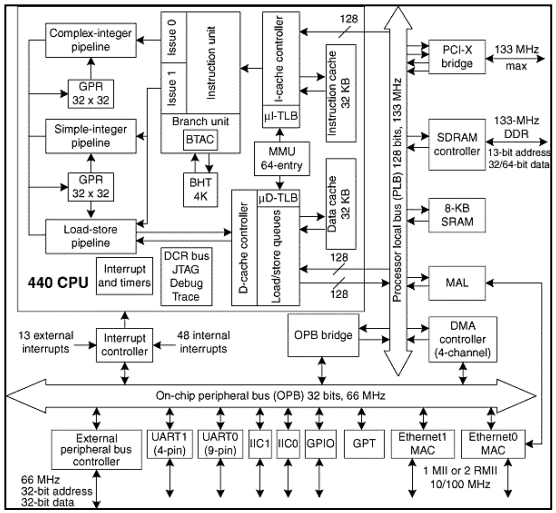
- Embedded: μP + software
- DSP



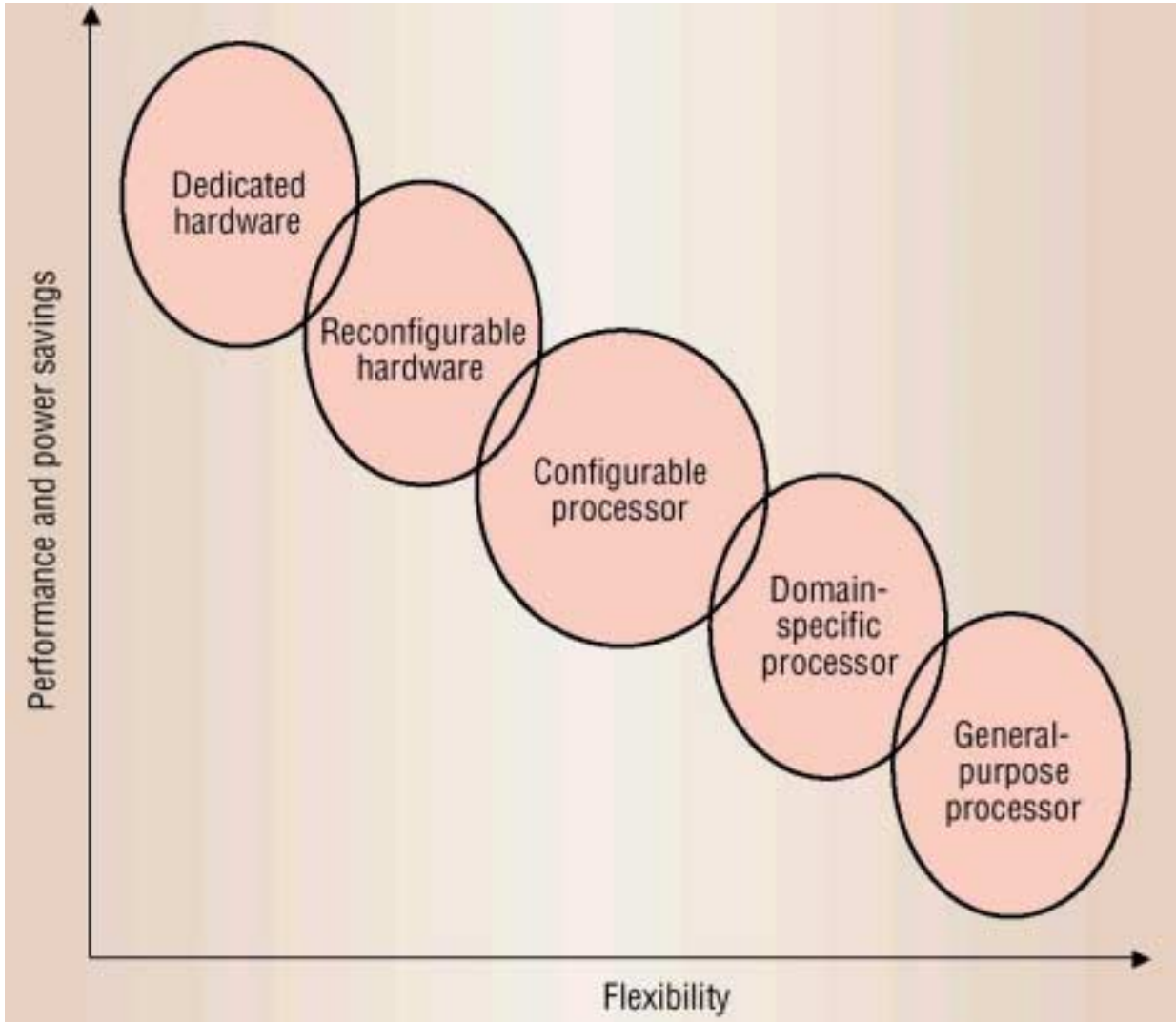
MPC555

- FPGA

- ASIC / SoC

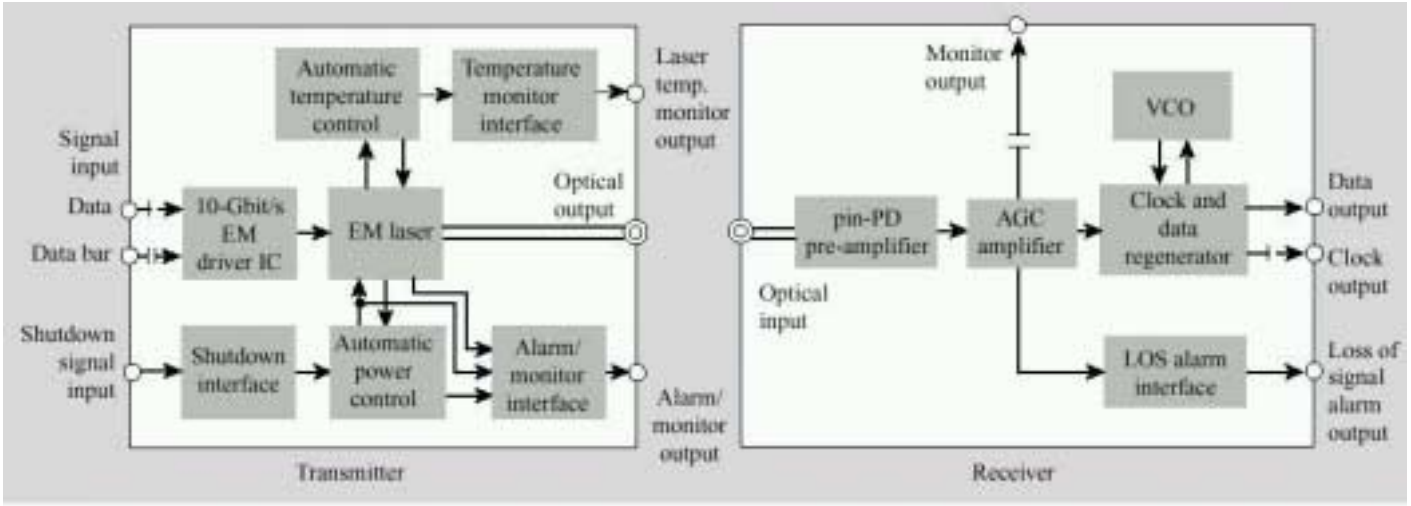


Embedded processor range



System platform, cont'd

- Analog/mixed electric circuits
  - power controllers
  - RF circuits
- Analog/mixed other
  - Gbs optical networks



Functional Block Diagram of 10-Gbit/s Optical Transmitter/Receiver.

EM = Electr-opt Modulator

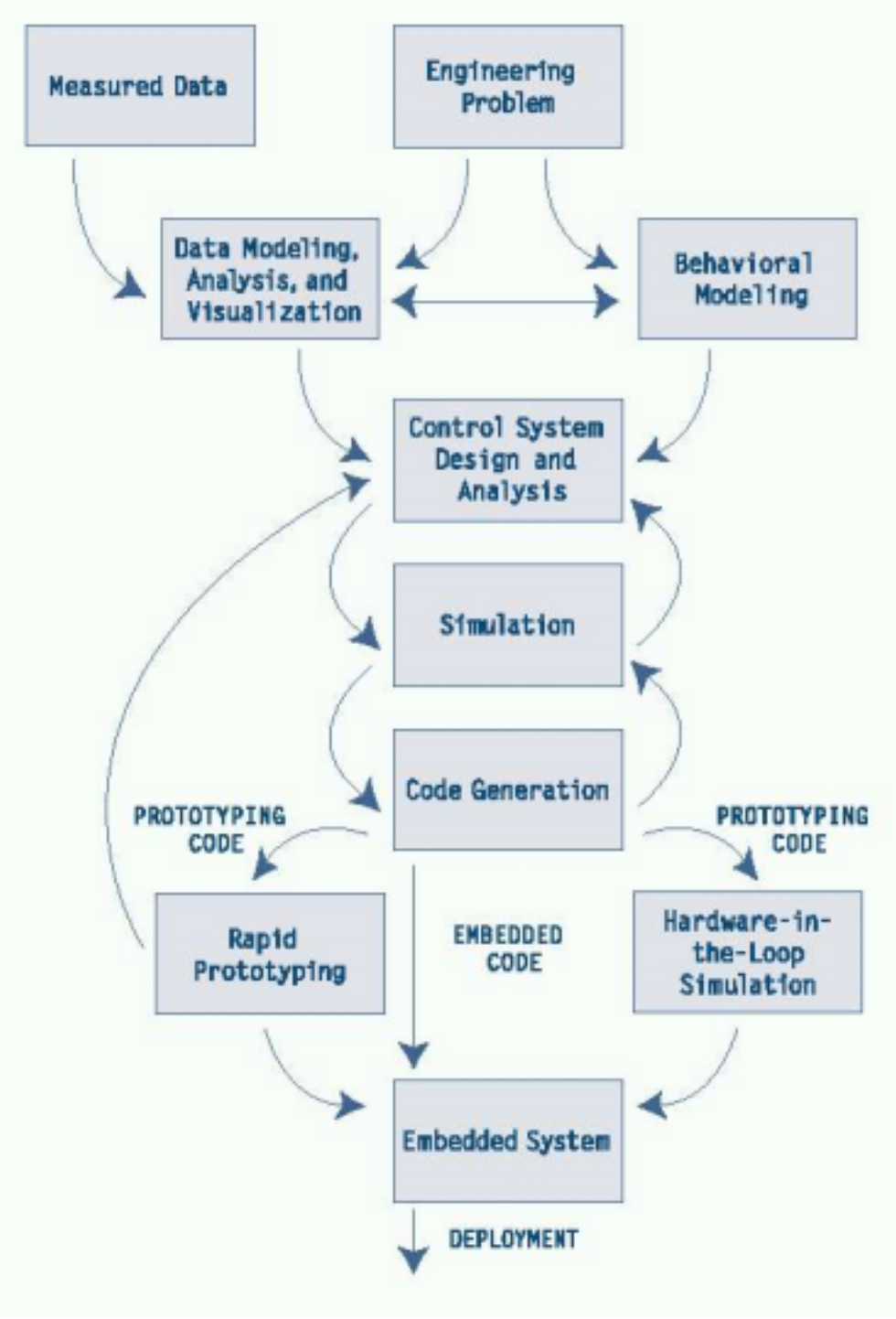
AGC = Auto Gain Control

Controls development cycle

- Analysis and modeling
  - physical model, or empirical, or data driven
  - use a simplified design model
  - system trade study - defines system design
- Heavy use of CAD tools
- Simulation
  - design validation using detailed performance model
- System development
  - control application, software platform, hardware platform
- Validation and verification
  - against initial specs
- Certification/commissioning

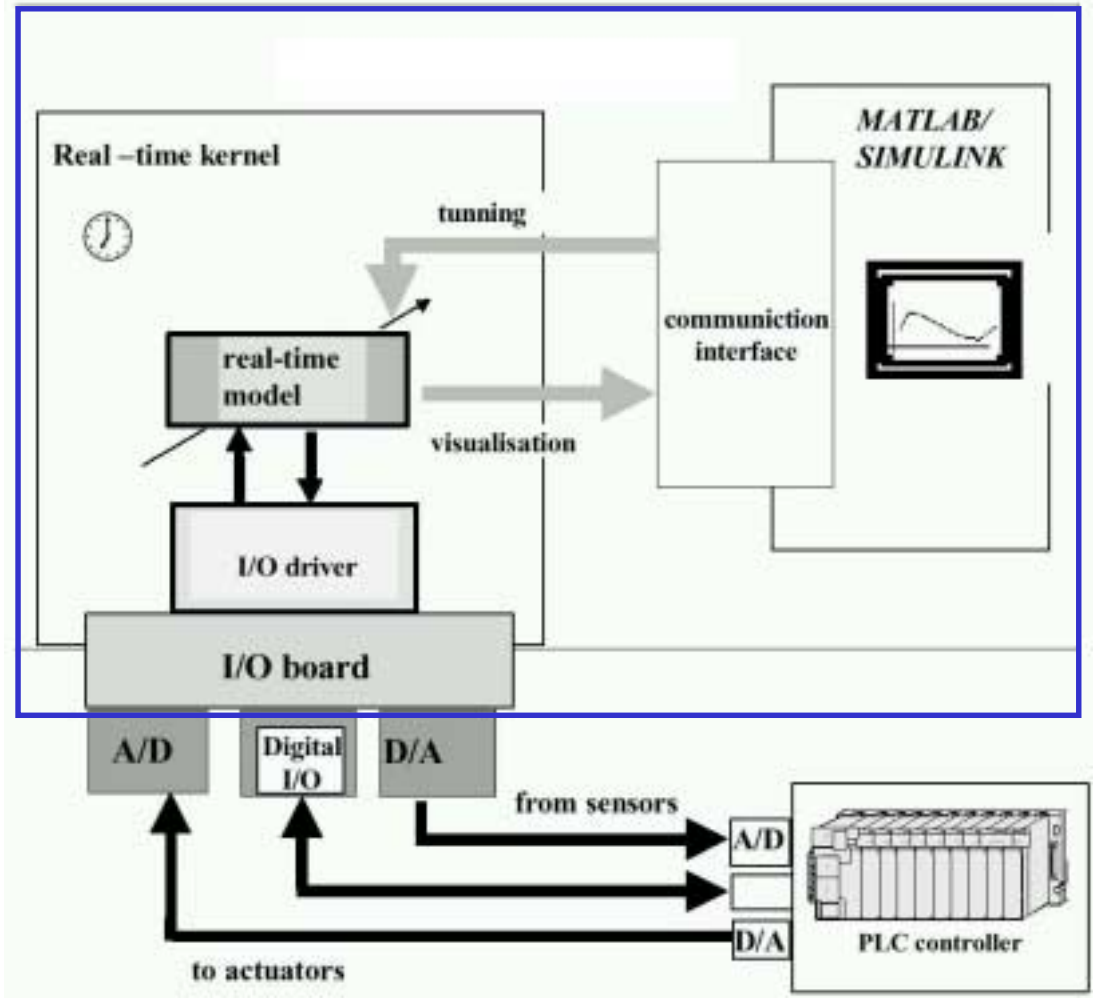
Control application software development cycle

- Matlab+toolboxes
- Simulink
- Stateflow
- Real-time Workshop

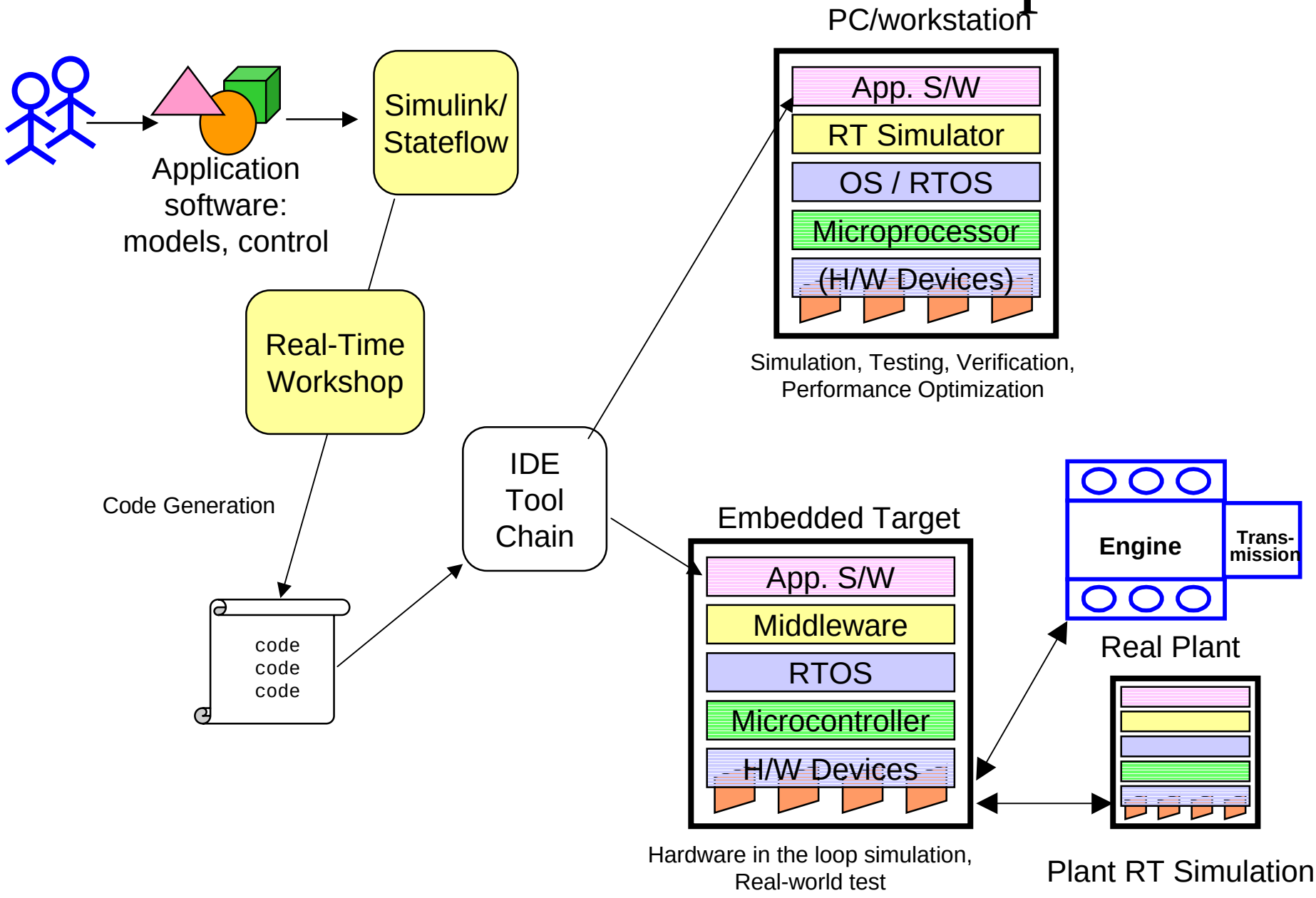


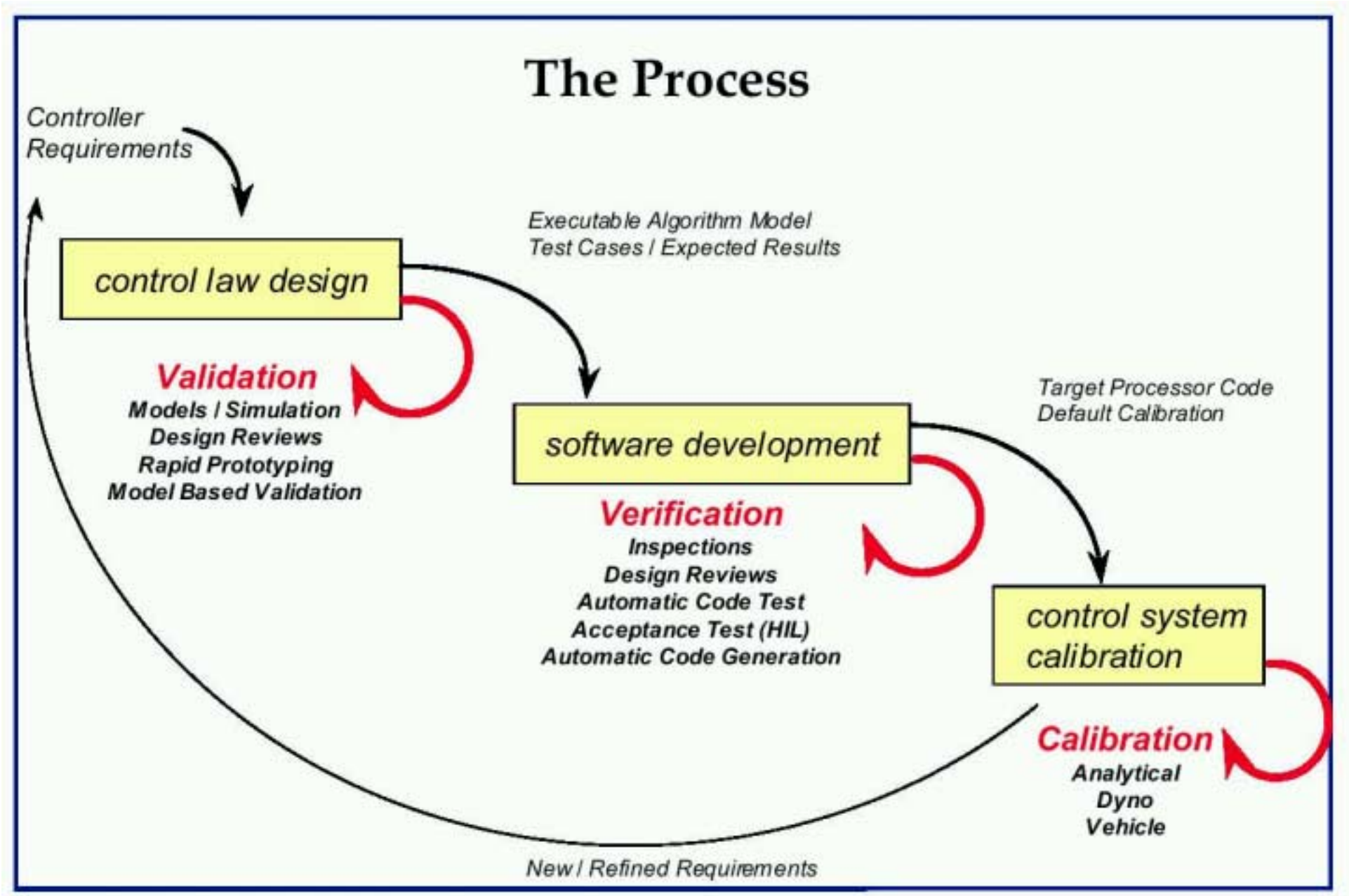
Hardware-in-the-loop simulation

- Aerospace
- Process control
- Automotive

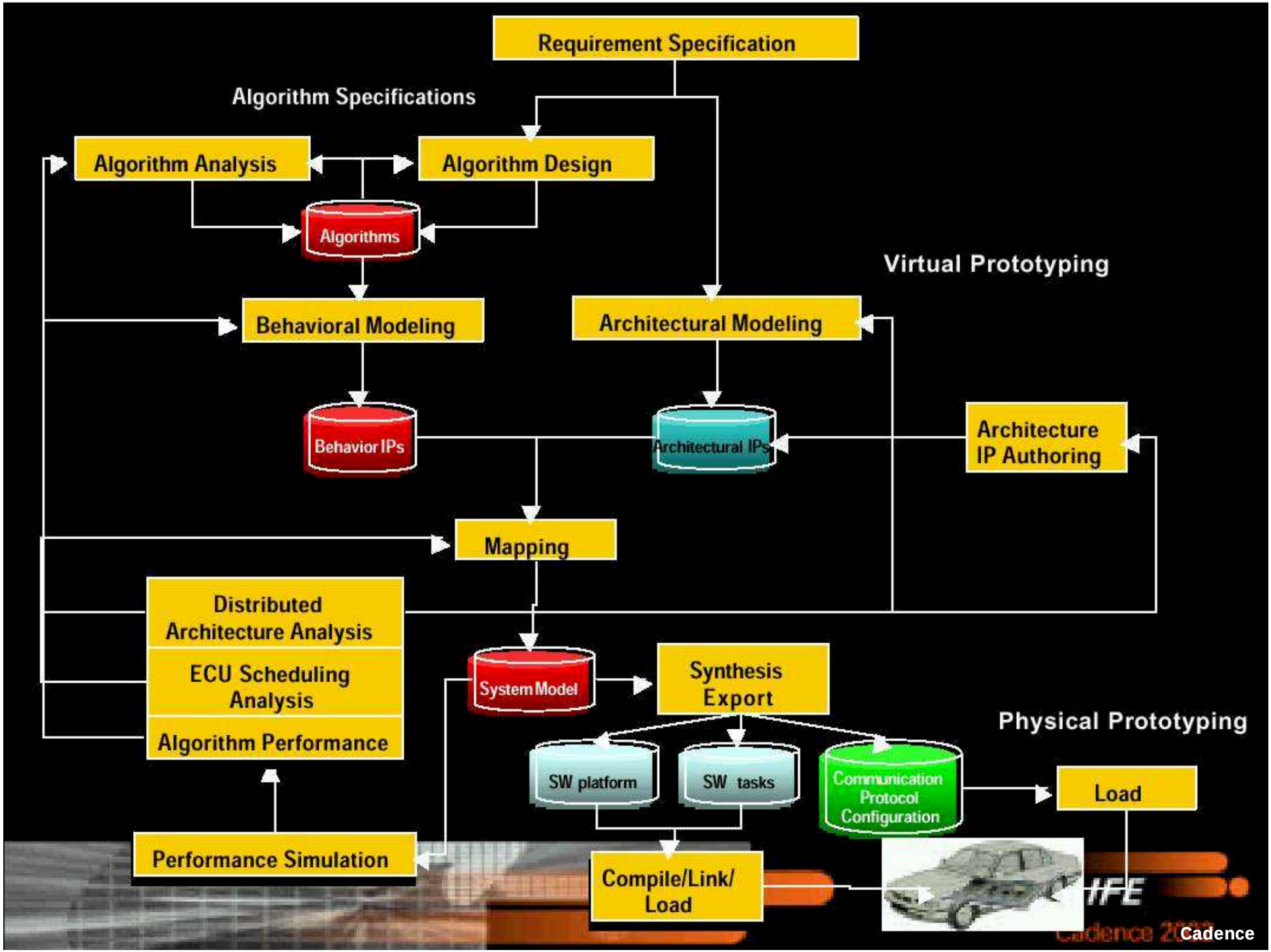


Embedded Software Development





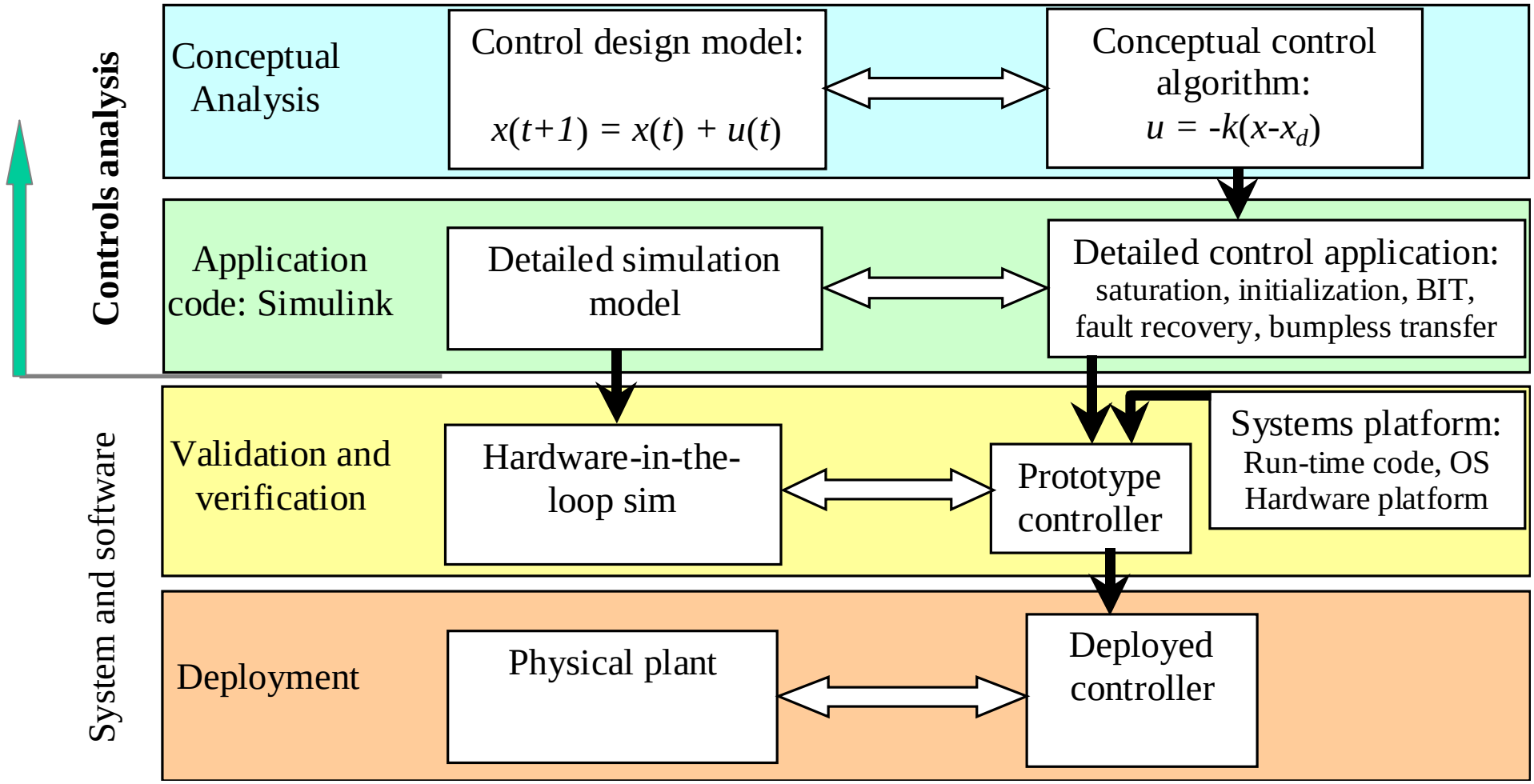
Ford Motor Company


Requirement Specification
Algorithm Specifications
Algorithm Analysis
Algorithm Design
Algorithms
Virtual Prototyping
Behavioral Modeling
Architectural Modeling
Behavior IPs
Architectural IPs
Architecture IP Authoring
Mapping
Distributed Architecture Analysis
ECU Scheduling Analysis
Algorithm Performance
System Model
Synthesis Export
Physical Prototyping
SW platform
SW tasks
Communication Protocol Configuration
Load
Performance Simulation
Compile/Link/ Load
Cadence

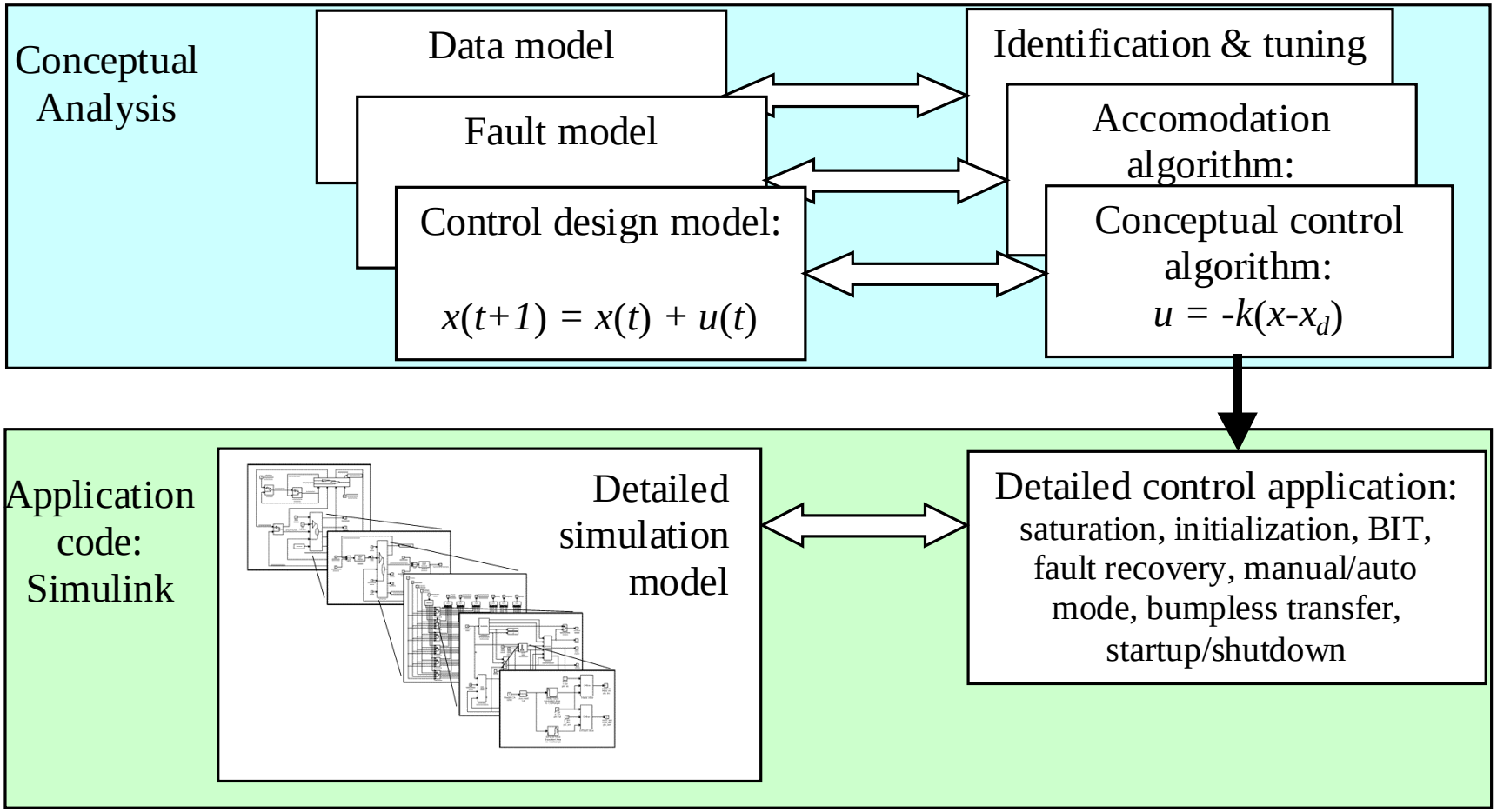
Control Technology

- Science
  - abstraction
  - concepts
  - simplified models
- Engineering
  - building new things
  - constrained resources: time, money,
- Technology
  - repeatable processes
  - control platform technology
  - control engineering technology

Controls development cycle



Controls analysis



Algorithms/Analysis

Much more than real-time control feedback computations

- modeling
- identification
- tuning
- optimization
- feedforward
- feedback
- estimation and navigation
- user interface
- diagnostics and system self-test
- system level logic, mode change

Practical Issues of Control Design

- Technical requirements
- Economics: value added, # of replications
  - automotive, telecom, disk drives - millions of copies produced
  - space, aviation - unique to dozens to several hundreds
  - process control - each process is unique, hundreds of the same type
- Developer interests
- Integration with existing system features
- Skill set in engineering development and support
- Field service/support requirements
- Marketing/competition, creation of unique IP
- Regulation/certification: FAA/FDA

Major control applications

Specialized control groups, formal development processes

- Aviation
  - avionics: Guidance, Navigation, & Control
  - propulsion - engines
  - vehicle power and environmental control
- Automotive
  - powertrain
  - suspension, traction, braking, steering
- Disk drives
- Industrial automation and process control
  - process industries: refineries, pulp and paper, chemical
  - semiconductor manufacturing processes
  - home and buildings

Commercial applications

Advanced design - commercial

- Embedded mechanical
  - mechatronics/drive control
- Robotics
  - lab automation
  - manufacturing plant robots (e.g., automotive)
  - semiconductors
- Power
  - generation and transmission
- Transportation
  - locomotives, elevators
  - marine
- Nuclear engineering

High-performance applications

Advanced design

- Defense and space
  - aero, ground, space vehicles - piloted and unmanned
  - missiles/munitions
  - comm and radar: ground, aero, space
  - campaign control: C4ISR
  - directed energy
- Science instruments
  - astronomy
  - accelerators
  - fusion: TOKAMAKs, LLNL ignition

Embedded applications

No specialized control groups

- Embedded controllers
  - consumer
  - test and measurement
  - power/current
  - thermal control
- Telecom
  - PLLs, equalizers
  - antennas, wireless, las comm
  - flow/congestion control
  - optical networks - analog, physics

Emerging control applications

A few selected cases

- Biomedical
  - life support: pacemakers anesthesia
  - diagnostics: MRI scanners, etc
  - ophthalmology
  - bio-informatics equipment
  - robotics surgery
- Computing
  - task/load balancing
- Finance and economics
  - trading