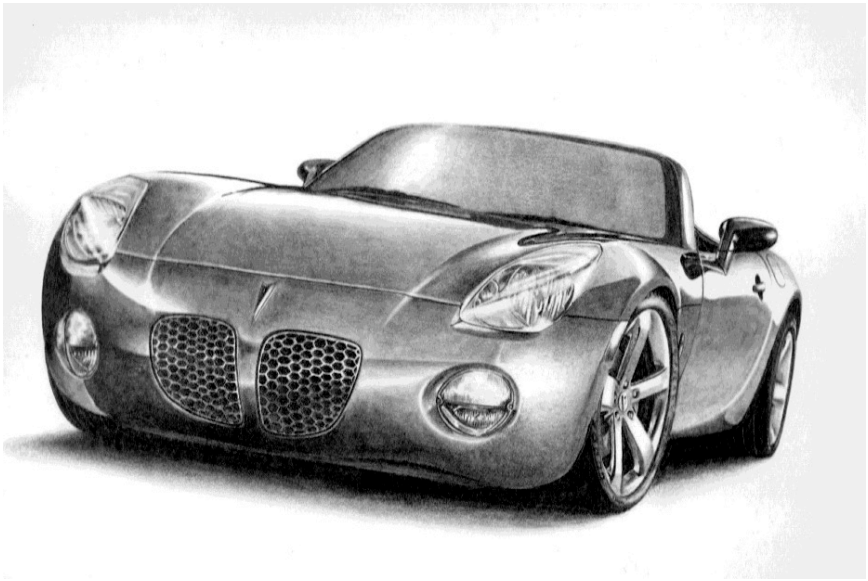
SOISTICe: Software Synthesis with Timing Contracts for Cyber-Physical Systems (2016 – 2020)



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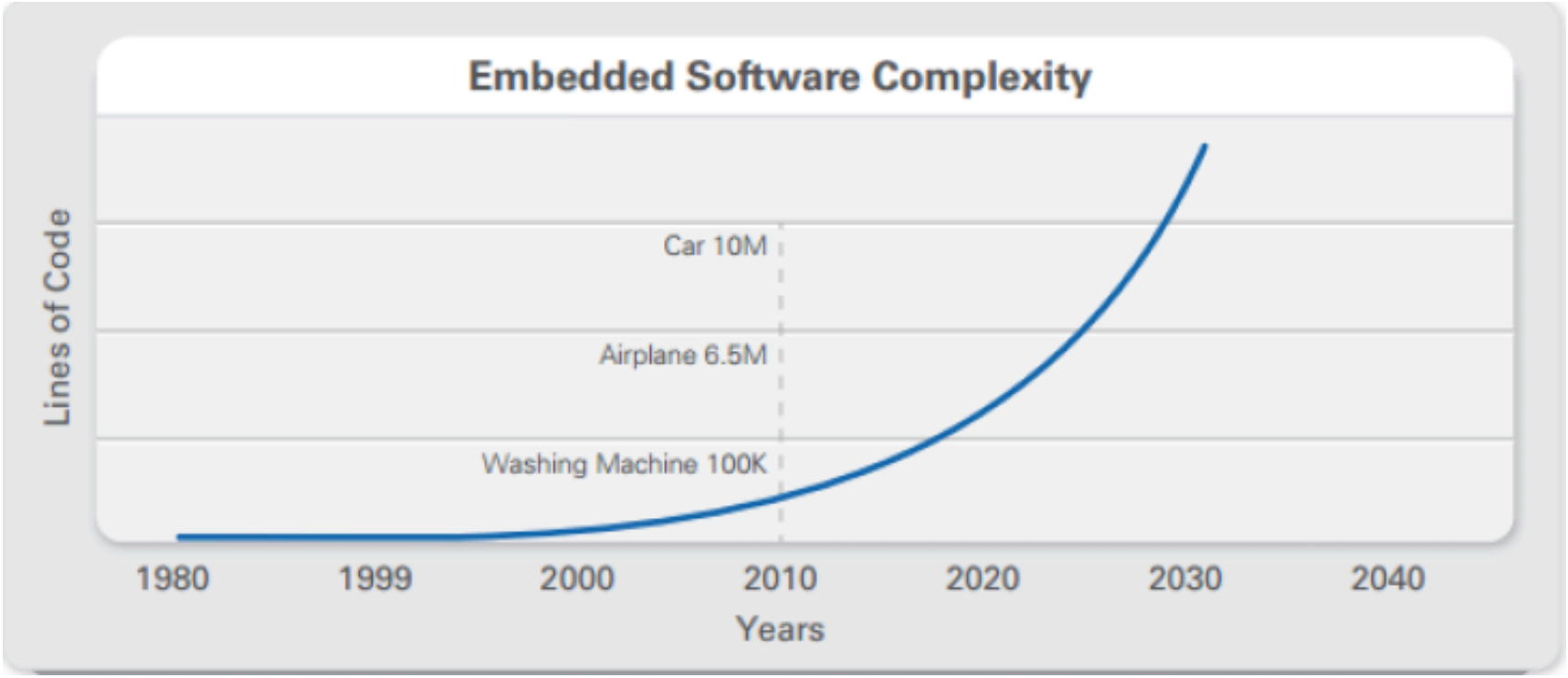
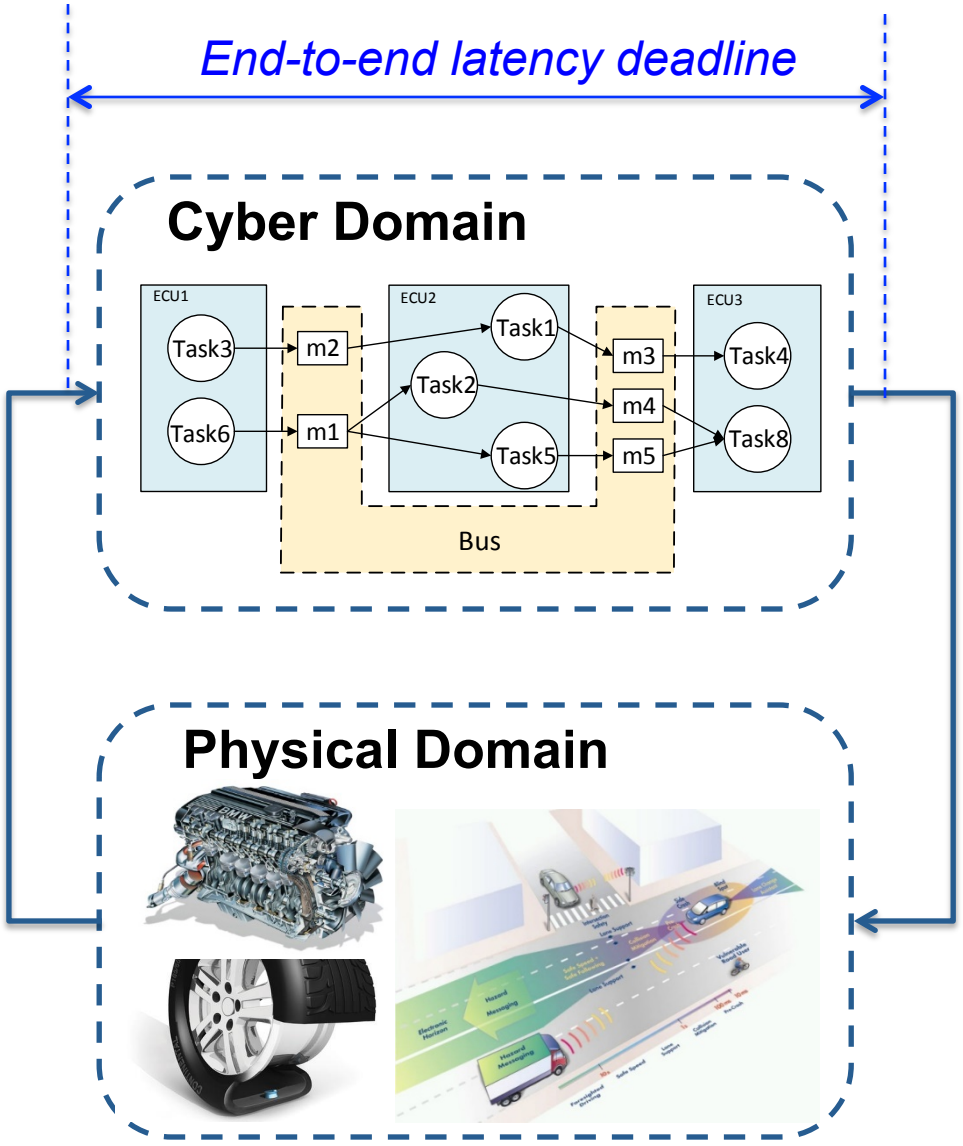
October, 2016

Challenges: Software Complexity Increase



(Source: National Instruments)

Challenges: Timing in CPS Software Design

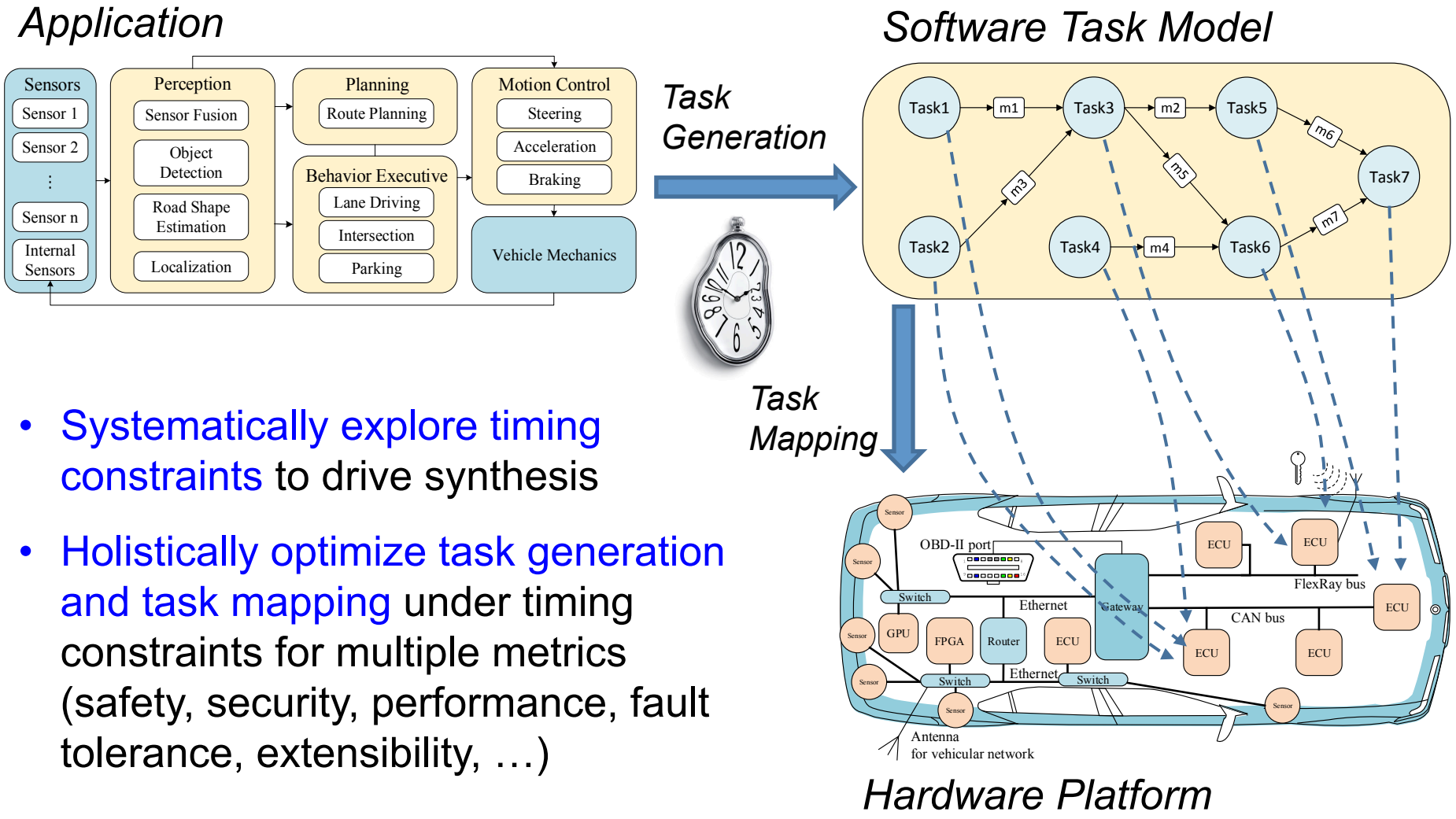


Timing constraints have to be satisfied for correct behavior.

Timing constraints have to be set properly.

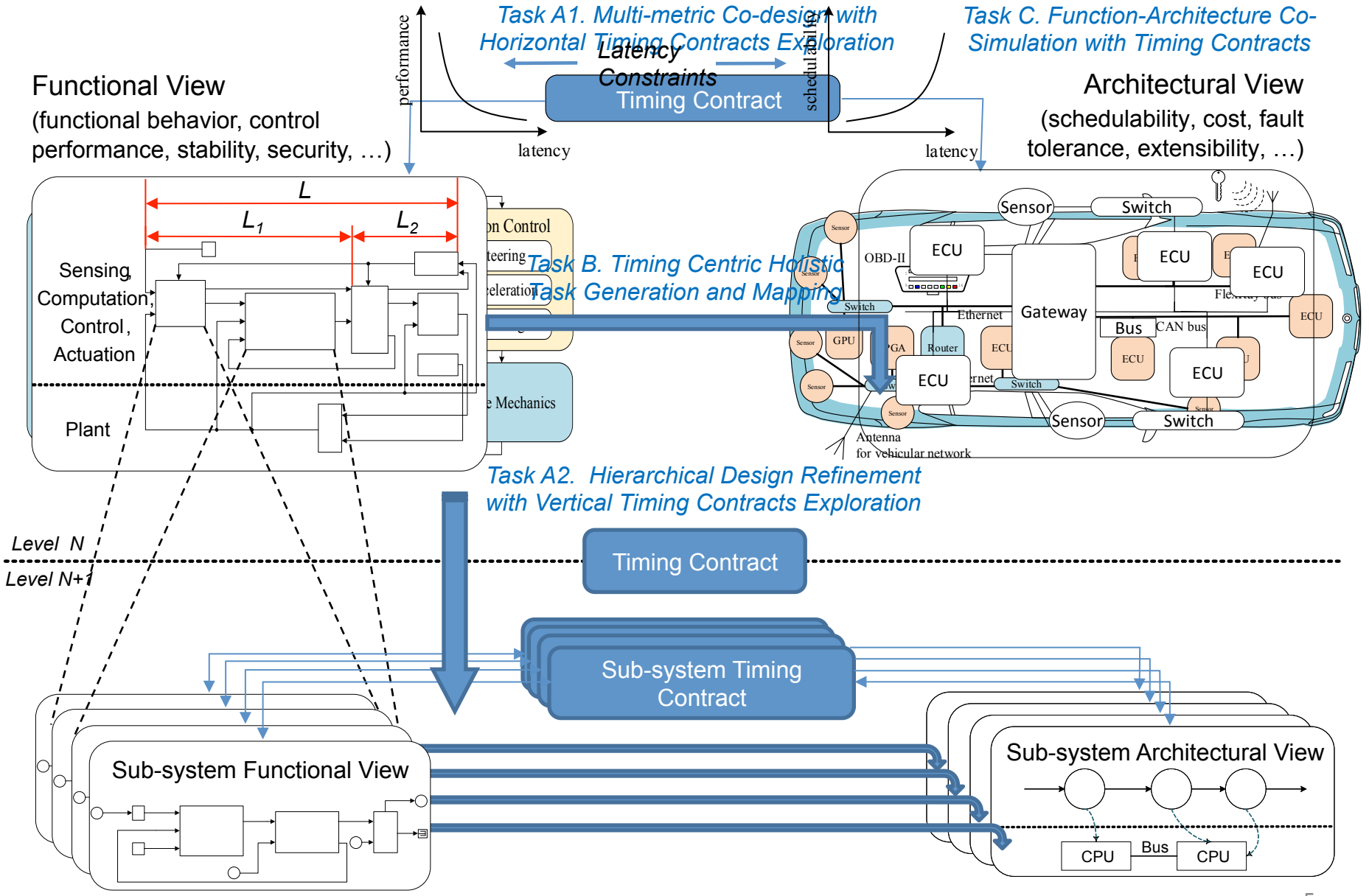
- Diverse timing requirements from different design metrics
- Complex timing analysis under increasing scale, hierarchy and concurrency
- Uncertain timing behavior from dynamic environment, input, and platform conditions

Goal: Explore Timing Constraints, Synthesize Software Architecture

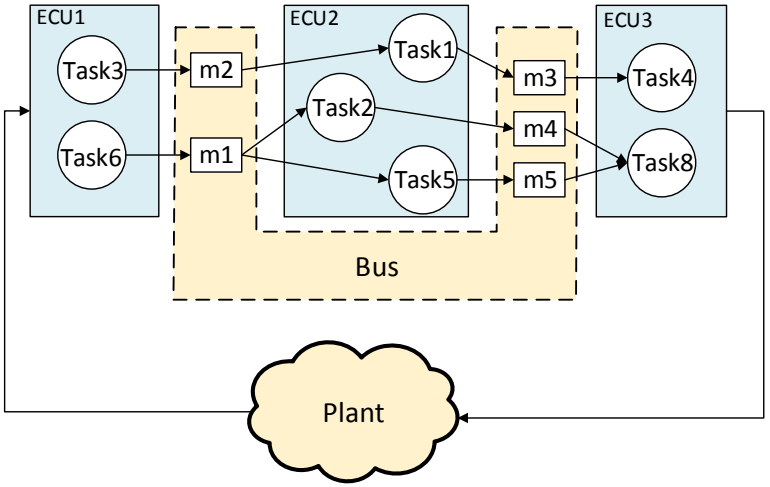


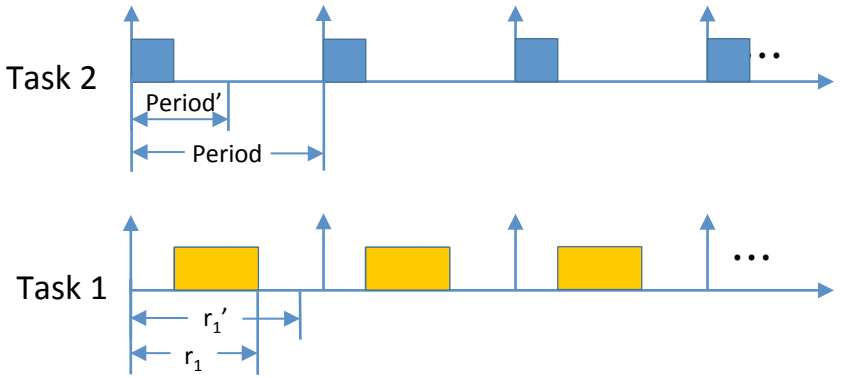
- Systematically explore timing constraints to drive synthesis
- Holistically optimize task generation and task mapping under timing constraints for multiple metrics (safety, security, performance, fault tolerance, extensibility, …)

Approach: SOISTICe Framework

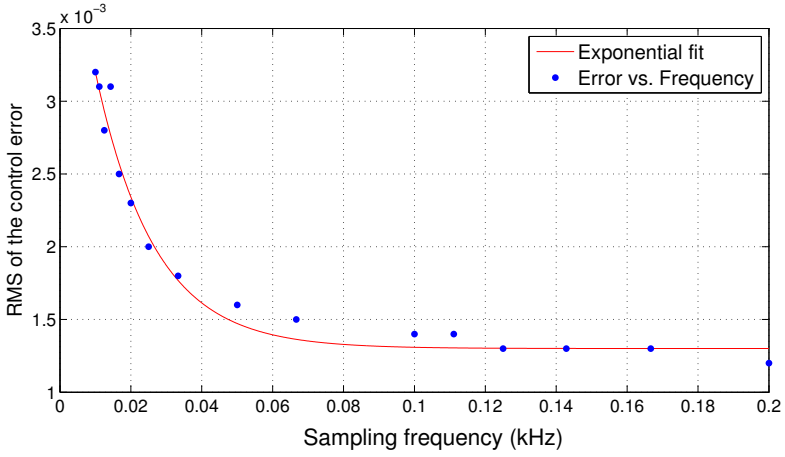


Co-design of Control Performance and Schedulability through Period Optimization





Sampling Period vs. Schedulability

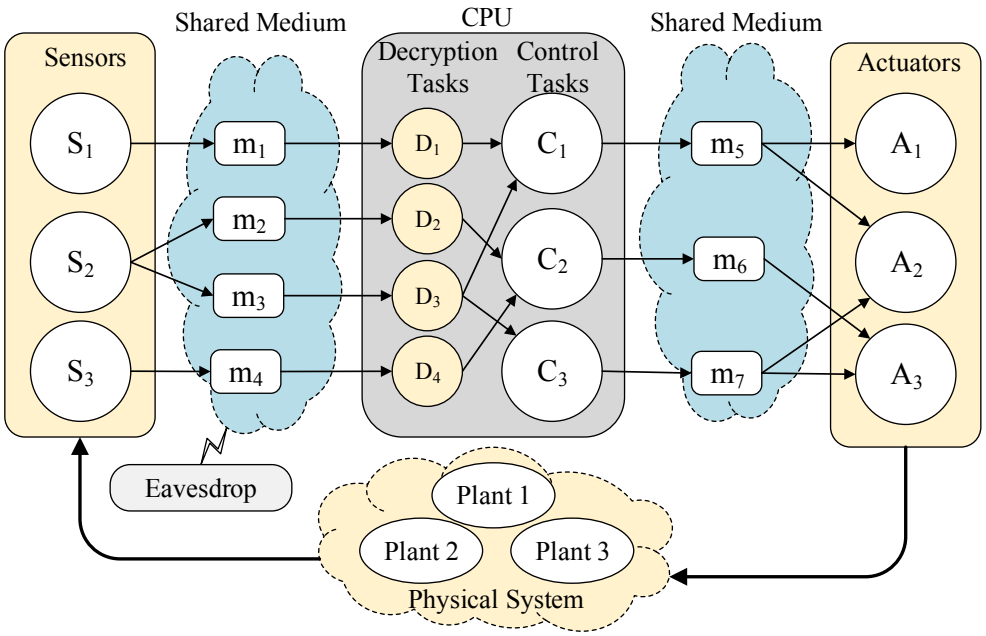


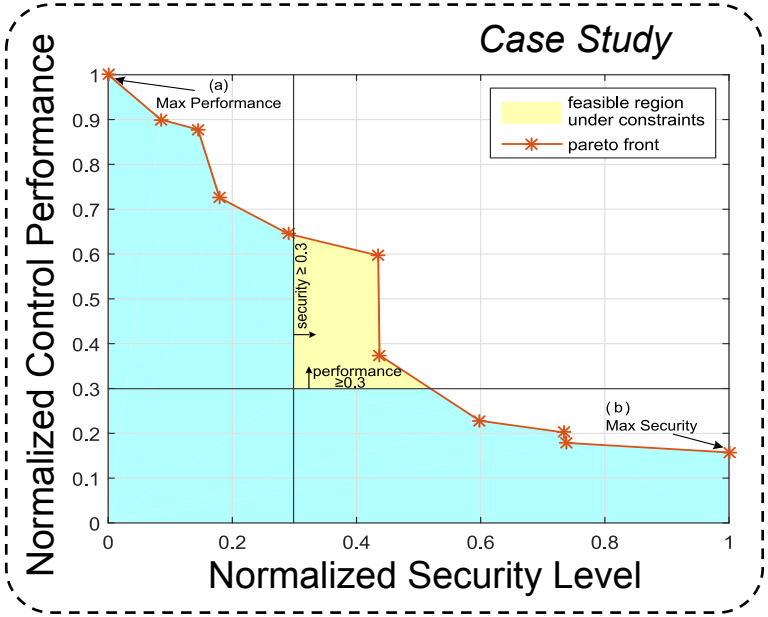
Sampling Period vs. Performance

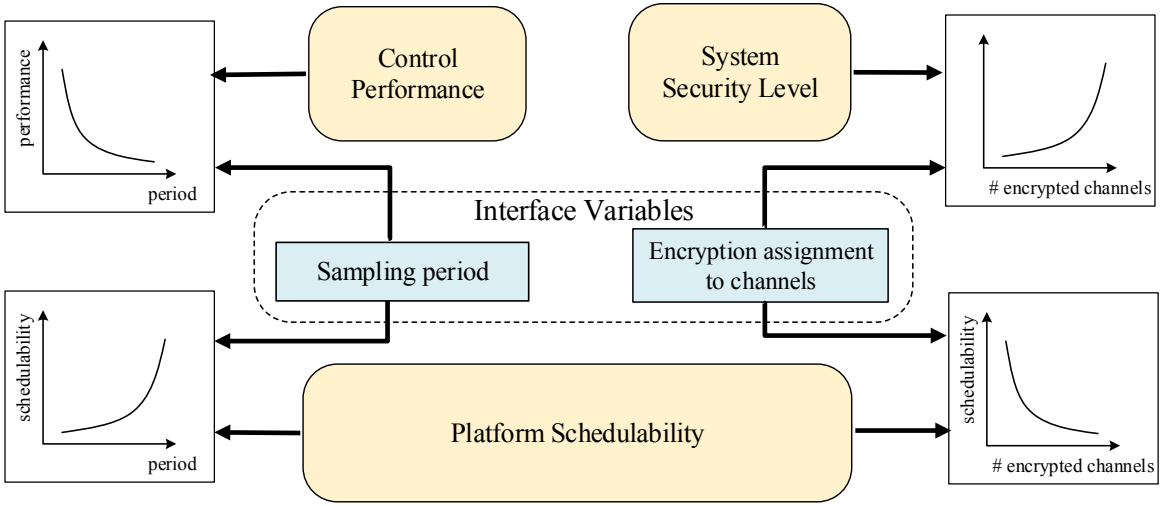
- Developed an efficient geometric programming (GP) based algorithm to explore the sampling periods
- Significantly improves control performance while guaranteeing system schedulability

[P. Deng, et al., "An Efficient Control-driven Period Optimization Algorithm for Distributed Real-time Systems", IEEE Transactions on Computers (TC), 2016.]

Co-design of Security, Control Performance and Schedulability



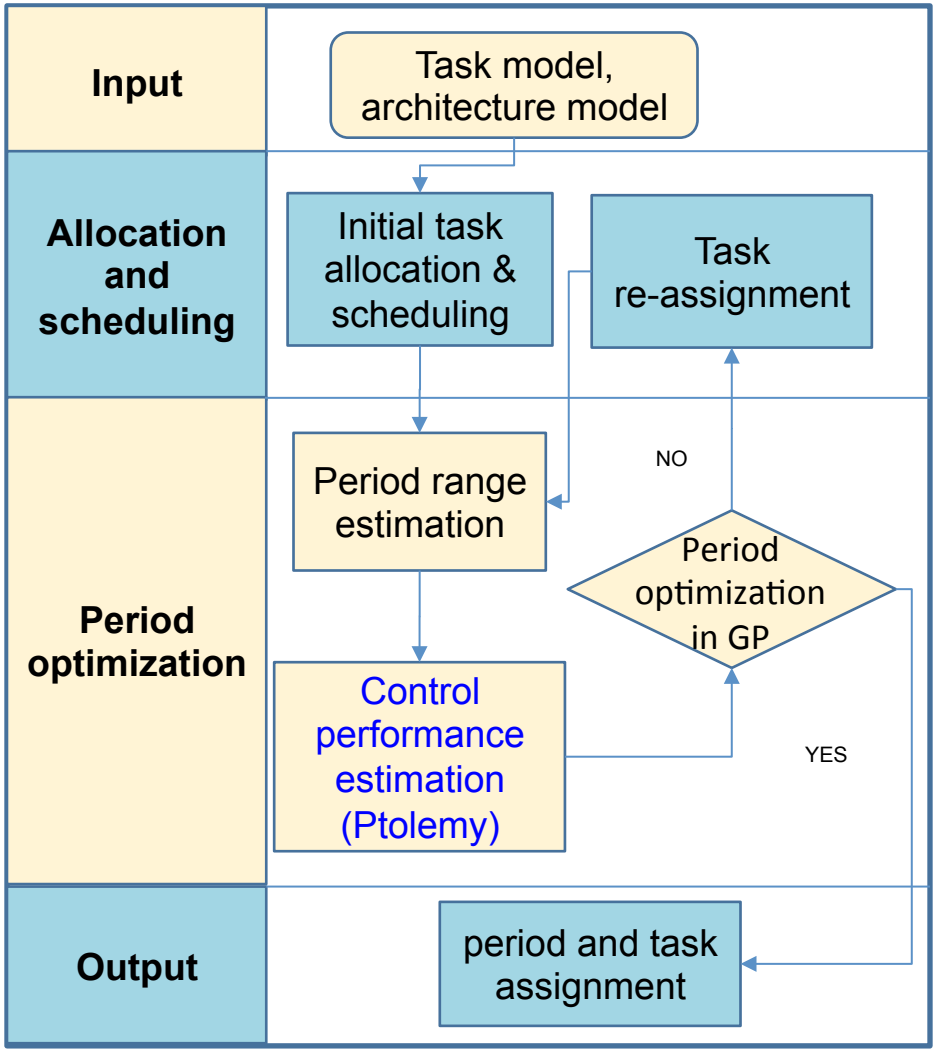




[B. Zheng, P. Deng, R. Anguluri, Q. Zhu and F. Pasqualetti, "Cross-Layer Codesign for Secure Cyber-Physical Systems", IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems (TCAD), 2016.]

Integration of Simulation and Analytical Algorithms

GP-based Analytical Algorithm



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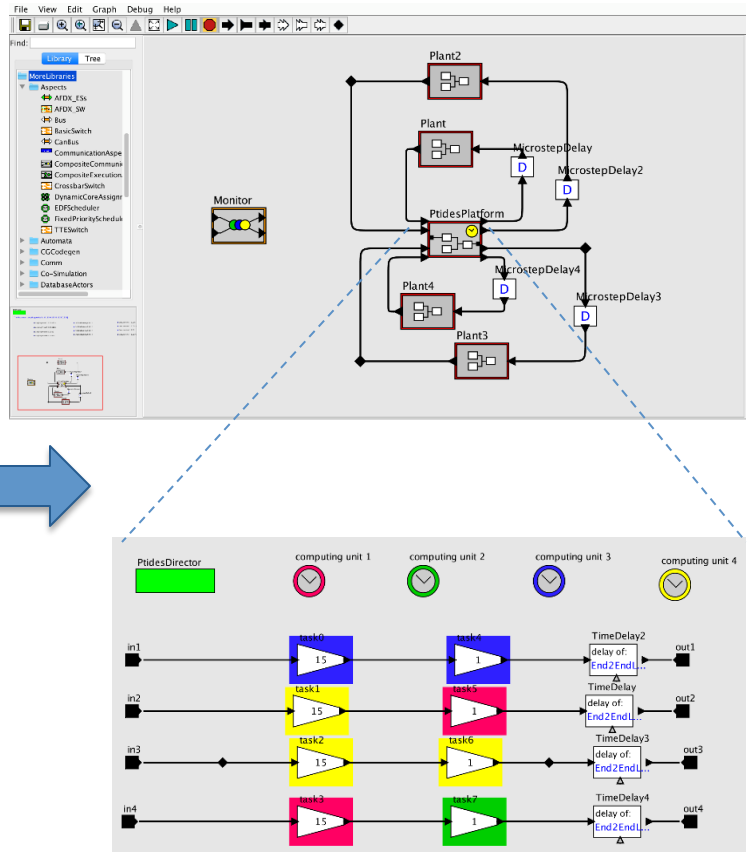
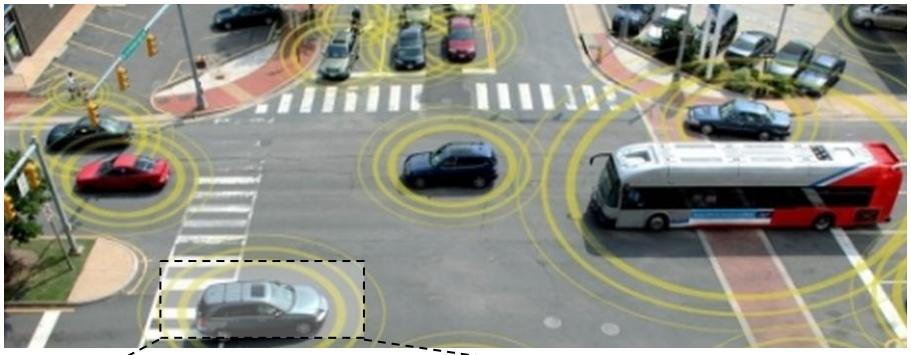
- Accurate functional simulation
- Validation of optimization results



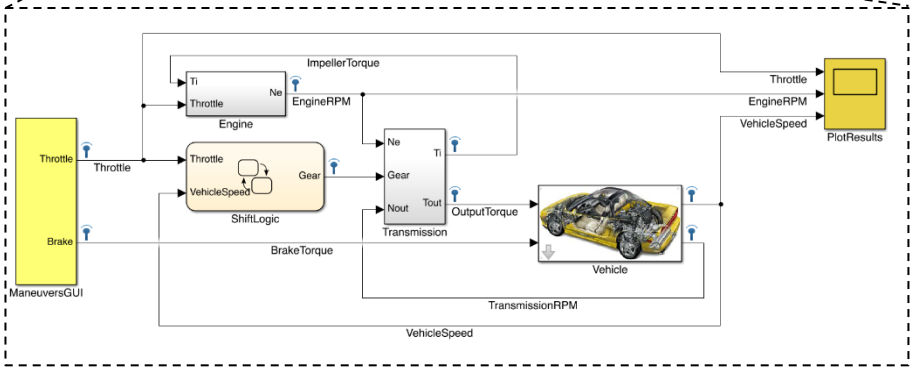
Application: CONVINCE: Cross-Layer Modeling, Exploration and Validation for Connected Autonomous Vehicles



V2X and Self-Driving Applications

Application-level verification, validation and certification
- Functional verification and validation with timing consideration
- V2X for autonomous driving
- Vehicle network modeling

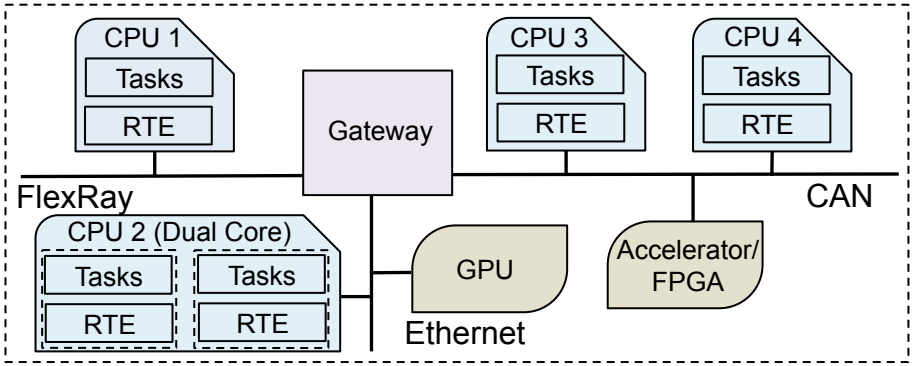
Constraints on V2X timing, safety, security, ...



Autonomous Vehicle Software Architecture

Software architecture modeling and synthesis
- Holist task generation and mapping from functional model
- End-to-end timing analysis for application-level validation

Constraints on in-vehicle timing, resource, dependability, …



Autonomous Vehicle Hardware Architecture

Hardware architecture modeling and exploration
- Heterogeneous multicore architecture modeling (CPU, GPU, FPGA, Accelerators, …)
- Efficient architecture exploration

Industry Collaboration

Automotive software synthesis, case studies, simulator, …

Avionics software synthesis, case studies, …

Timing constraints formulation, simulation methodologies, …

Energy and manufacturing case studies, simulator, education, …

Interdisciplinary Education: CPS via Lego

- Lego Mindstorms: CPS platform for kids (and adults)
- LabVIEW: model-based design programing interface
- Developing Lego Mindstorms labs for K-12 students
- Local Lego Mindstroms contest

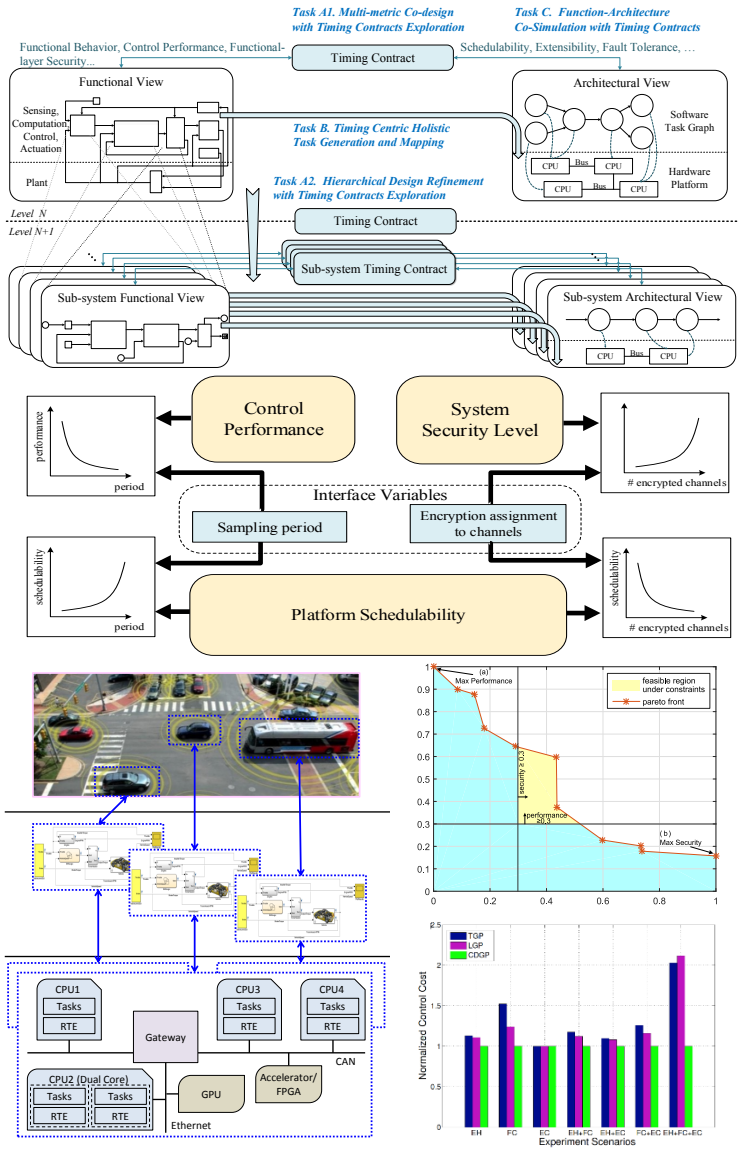
CAREER: SOISTICe: Software Synthesis with Timing Contracts for Cyber-Physical Systems

Challenges

- Synthesis of CPS software faces timing challenges:
  - Diversity of timing requirements
  - Complexity of timing analysis
  - Uncertainty of timing behavior
- Timing constraints should be set systematically throughout software synthesis.

Solutions

- Multi-metric co-design with horizontal timing contracts exploration
- Design refinement with vertical timing contracts exploration
- Timing-centric holistic task generation and mapping
- Function-architecture co-simulation with timing contracts



Scientific Impacts

- Software synthesis flow driven by methodologies for timing constraints exploration
- Produce correct and optimal software design w.r.t. multiple metrics

Broader Impacts

- Advances design automation for CPS
- Close industry collaborations
- Applications in automotive and transportation
- Interdisciplinary education for grad, undergrad, and K-12 students

CCF-1553757, Qi Zhu (UCR)

Thank you!

Pontiac Solstice