**Objectives**

- Consistent representation of a system with multiple models
- Verification using heterogeneous models
- Tools to support CPS modeling and verification

**Architectural Approach**

We use architectural models (components and connectors) to represent common structural and semantic features to guarantee consistency.

Heterogeneous models allow experts to address different aspects of the system design. Although convenient for the experts, creates two challenges: consistency and verification.

The challenges may occur because of:
- Timing: periods, events, determinism
- Movement: geometry, dimensionality
- Sensing and actuation: delays, precision
- ...

**Research Directions**

- Consistency
- Verification

**Tools**

- AcmeStudio – architectural design environment for representation and analysis of architectural views.
- AcmeMaps – specification of relations between views.
- KeYmaera – hybrid program language and proof system for verification in differential dynamic logic
- Sphinx – a Graphical and Textual Modeling Tool for Hybrid Programs.

**Case Studies**

**Quadrotor**

Goal: ensure consistency of heterogeneous models for a STARMAC quadrotor.

Results:
- Developed architectural modeling for structural consistency.
- Detected several inconsistencies in design.

**CICAS-SSA**

Goal: verify a stop sign assist algorithm.

Results:
- Formalized heterogeneous model semantics using behavior relations.
- Developed a compositional approach to heterogeneous abstraction.

**Robot Collision Avoidance**

Goal: verify a family of robot controllers for collision safety with obstacles.

Results:
- Proved safety for moving obstacles in presence of location and actuator uncertainty.
- Work in progress.