Is Science in System Integration?

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• CPS consolidates as a valid scientific direction by 2010. Universities led the charge with strong involvement of computer and systems scientists and with strong industry support.

• In 2010 NSF starts the CPS program in the Computer and Information Science and Engineering (CISE) directorate, establishes the CPS Virtual Organization (CPS-VO.org) at Vanderbilt, starts Annual CPS PI Meetings. First ICCPS is in 2010 Stockholm.

• Between 2012-2015 industrial consortiums are created (Industrial Internet Consortium (2014), OpenFog Consortium (2015), IoT, Industry 4.0 (Germany) and the “new Gold Rush” kicks off.
• **System integration**: implemented components are connected and system-level properties are verified/tested
  
  – High risk – many fundamental problems surface during system integration
  
  – Ad-hoc – ‘making it work somehow’ attitude
  
  – *Fundamental problem* – *limited composability and compositionality in heterogeneous systems lead to lack of constructivity in system design*
• Goal: extend the limits of “correct-by-construction” design:

  – in *broad sense*: model-based design process that leads to manufacturable CPS products with desired properties

  – in *narrow sense*: use architectures (design invariants) that guarantee certain properties
Sol Project Goals

1. Investigate composition and compositionality of heterogeneous systems to achieve constructivity and predictability in CPS integration.

2. Construct tool chains for CPS design based on semantically rigorous methods to define and compose of heterogeneous modeling languages.

3. Experimental validation of the ideas in automotive and other applications.

4. Education methods and reusable material.
Controller dynamics is developed without considering implementation uncertainties (e.g. word length, clock accuracy) optimizing performance.

Software architecture models are developed without explicitly considering systems platform characteristics, even though key behavioral properties depend on it.

Assumption: Effects of digital implementation can be neglected

System-level architecture defines implementation platform configuration. Scheduling, network uncertainties introduce time varying delays that may require re-verification of key properties on all levels.

Assumption: Effects of platform properties can be neglected
Key Results

• **Foundations:** Developed theory and has shown experimentally the compositionality of distributed safety controllers on vehicles with guaranteed stability and has **employed passivity to decouple control design from implementation uncertainties.**

• **Tools and tool architectures:** Has demonstrated the practicality and semantic soundness of horizontal integration platforms in a complex CPS tool chain

• **Education:** Introduced integrated CPS design tools in courses, undergraduate design studio and internship programs including high-school students