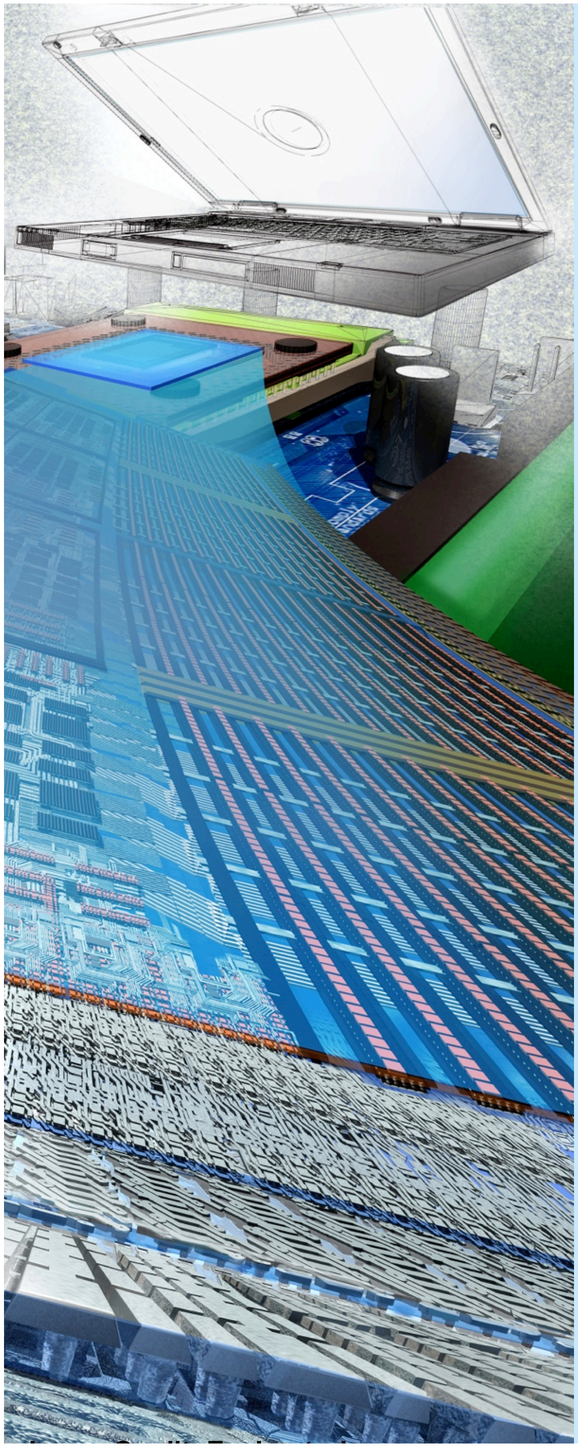

CPS Reference Architectures

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Why are we here?

- The Cyber-physical Systems community was established through the recognition that there are ***common research and design principles*** across different domains of CPS as we know it today
- A reference architecture can enable sharing of best design practices, design modularity (and compatibility), provide a common vocabulary of fundamental CPS concepts across domains, and ***help accelerate research by enabling focus on the challenges not the scaffolding***
- A community-generated reference architecture firmly anchors CPS identity, design principles, and establishes the community consensus on CPS research going forward.

CPS Architectures Discussion Items

- Do they exist today?
  - Yes, some exist. Were quite useful in the past. Middleware based to provide hardware and OS independence.
  - Standards from pre-competitive groups
- Should there be standard architectures?
  - Perhaps, but many obstacles to adoption
  - Domain specificity
  - Start anew each time?
- What are future architecture design drivers
  - What should the critical features be?
  - What are the research challenges?
  - How do they advance CPS science and engineering?
  - Who and how will the architecture (s) be used

Some Desirable Features of CPS Architectures

- Hardware and OS Portability
- Product line
- Real-time
- Support for control at multiple levels
- Support fault tolerant
- Network abstraction
- Time coordination
- Support for periodic and aperiodic
- Time triggered or event based
- Low overhead latency
- Predictability
- Security

Objectives

- Identify drivers that may shape future architecture needs including control and networking for the Industrial Internet
- Review reference architectures arising from several CPS domains (Aerospace, Automotive, Building, Medical)
  - How have they been used
  - What have been results
- Identify common threads and future research challenges

Agenda

08:00– 08:45	Registration and Continental Breakfast	
09:00 - 09:30	Introductions and Objectives	Keith Marzullo (NSF), David Corman (NSF), Janos Sztipanovits (Vanderbilt)
09:30 – 10:00	General CPS Architecture Concepts	John Baras (University of Maryland)
10:00 – 10:30	CPS Reference Architecture Working Group - What and Why	Jim St. Pierre (NIST)
10:30 – 10:45	Break	
11:00 – 11:30	Industrial Internet and Implications for CPS Reference Architecture	Joe Salvo (GE Global Research)
11:30 – 12:00	Aerospace Domain Architectures	Sharp(Boeing)
12:00 – 13:00	Lunch	
13:00 – 13:30	Reference Architectures in UAV Swarm Control	Vijay Kumar (U Penn)
13:30 – 14:00	Automotive Domain Architectures	Tom Fuhrman(GM)
14:00 – 14:30	Medical CPS Architectures	Insup Lee (Upenn), John Hatcliff (Kansas State)
14:30 – 15:00	Industrial Automation Architectures	Srini Srinivasan (NIST)
15:00. – 15:15	Break	
15:15 – 15:45	OS Architectures for Building and Related CPS	David Culler (UCB)
15:45– 16:15	Networking Architectures for Industrial Internet	Paul Didier (Cisco)
16:15 - 16:30	Break	
16:30 – 17:30	Common Architectural Threads and Research Challenges (Moderated Discussion)	David Corman (NSF), Janos Sztipanovits (Vanderbilt)
17:30 – 18:00	Next Steps	

Desired workshop outcomes

- Start of building community consensus on scope of CPS reference architecture; where -to what extent- can the common characteristics be found?
- Identify fundamental challenges and research opportunities:
  – software/hardware modular compatibility/portability
  – manufacturing trustworthiness
  – design correctness/security
- Form basis for strategy going forward: working group, DCL, …

Some Personal Thoughts

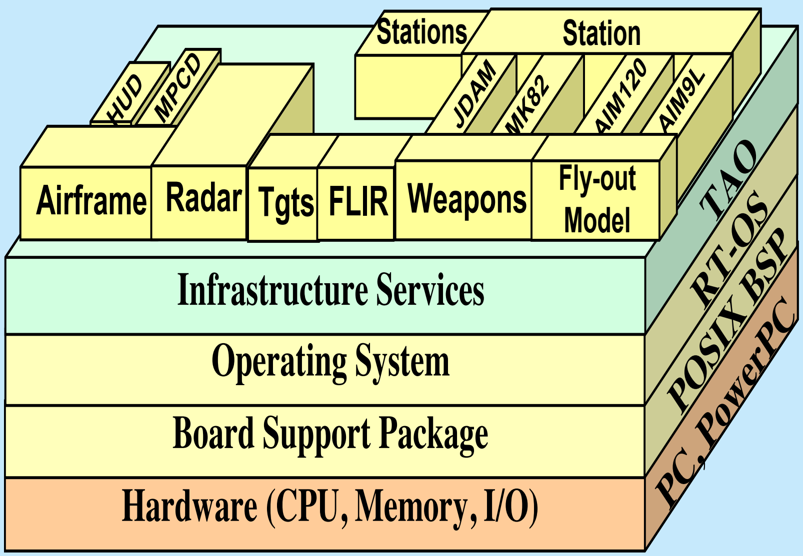
CPS Architectures

- Some original product-line architectures arose from Boeing Bold Stroke initiative in late 90’s
- Open Control Platform for Unmanned Air Vehicles from DARPA represented a next generation – 2004
  - Portability, Performance, Maintenance of architecture and components
- Component model library with product line architecture
  - Contains behavioral and physical models of application components and infrastructure components
  - Supports model based development and design
    - Enable rapid design, simulation, and verification of behaviors
  - Scalable and extensible

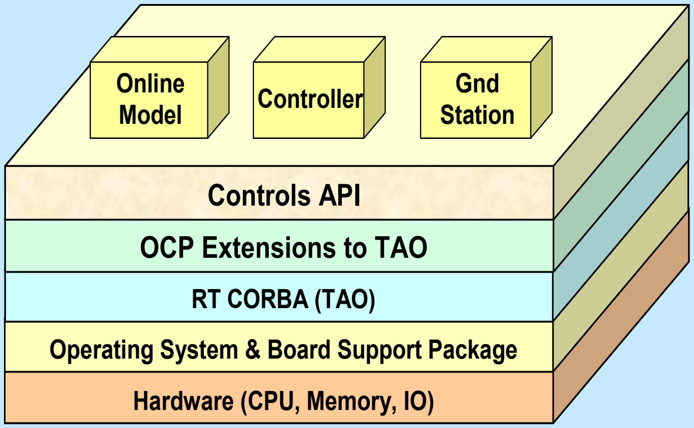
CPS Architectures – Desirable Path

- Component model library with product line architecture
  - Contains behavioral and physical models of application components and infrastructure components
  - Supports model based development and design
    - Enable rapid design, simulation, and verification of behaviors
  - Scalable and extensible

Some CPS Architectures Were Created By Industry to Support DARPA / DOD Programs



Bold Stroke Product Line Architecture
(F/A-18, F-15, T-45) – circa 1995



Open Control Platform for
Autonomous Systems – circa 2005

Features
- Middleware abstraction layer for hardware and OS independence

What are Gaps

- What are the compositional principles that enable creation of verified systems out of verified components
- Where do “common” application or infrastructure components come from
  - Can some be pre-competitive?
  - Can some originate from “industrial strength” testbeds
- Maturing tool environments – converting research tools into capabilities that are transitioned to practice