



Phantom

# Cyber Physical Systems – An Aerospace Industry Perspective

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# Who we are:

# Phantom Works Charter - Technology Transition to Multiple Customers

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Engineering & Information Technology



787-18 Wing Panel – Flex Track



F-15K Flex Track

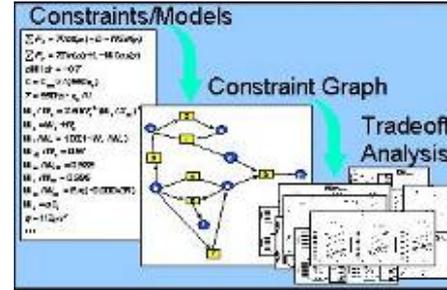


P-8A



Airborne Laser

## Design Sheet Applications



Joint Tactical Radio System



V-22

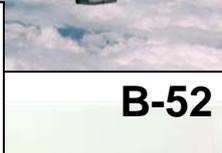


E-3



C-17

Network Centric Operations Demonstrations



B-52



Ground Vibration Testing Advancements BCA & IDS platforms

# Boeing is a Key CPS Stakeholder

- **The Boeing Company is working a rich set of application areas that are benefiting from CPS research**
  - Air (military and commercial)
  - Space (high-reliability applications)
  - Land
- **Applications involve multiple networked CPS systems**
  - Safety-critical aspects
  - Security
  - Need for predictability in face of dynamic environments
- **Aircraft platforms**
  - Commercial
    - Stringent Certification and V&V processes and standards
  - Military
    - Piloted and autonomous aircraft
    - Support all services
    - Varying levels of V&V requirements



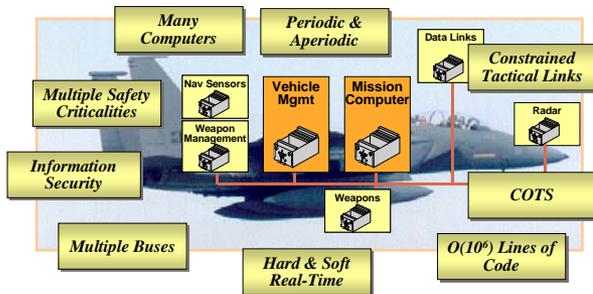
# Testimony before House Committee on Science and Technology – 31 July 2008



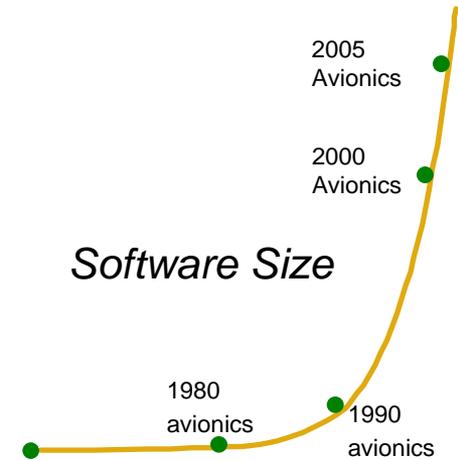
- **CPS are of great importance to Boeing, the Aerospace Industry**
- **“The challenges today are far greater than those faced in even the recent past and continue to grow as individual systems evolve, operate with greater autonomy and intelligence, and operate as part of a networked system of systems,”**
- **“Requirements for cyber-physical systems and software are far more stringent than those for typical office automation applications. Our systems must support real-time behavior. We require ultra-high reliability and many of our systems are safety critical and require certification.”**

# Today's Aerospace Systems are Increasingly CPS-Intensive

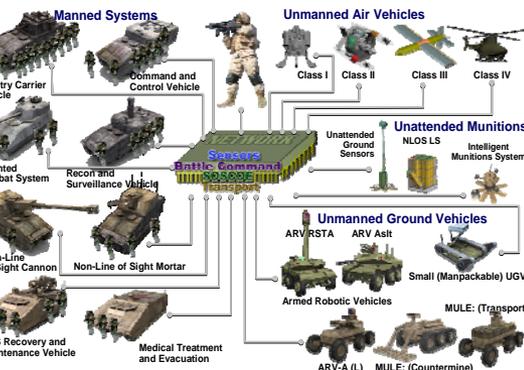
- **Aerospace systems for today and beyond**
  - **New capabilities**
  - **Agile behavior in highly dynamic operating environments**
  - **Operation in a SoS Network**



Software Size

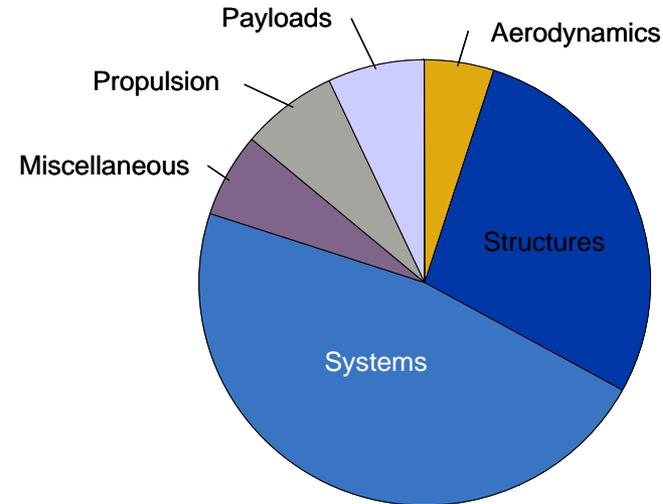


- **Avionics S/W challenges – 100M – >1B SLOC**
- **Software Intensive Systems**
- **Multiple levels of criticality**

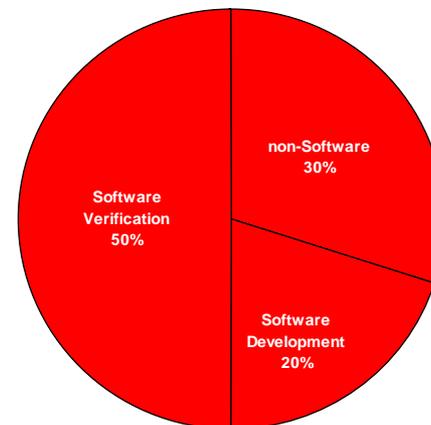


# Importance of Software to Aerospace Systems

- **Aerospace systems cost trend is shifting away from traditional structures, aero and propulsion to software and systems**
- **Software verification is becoming one of the leading components of system cost – supporting FAA flight certification**
- **Verification will become even larger challenge as systems become more highly integrated**



**Typical Recent Commercial Aircraft Cost Distribution**



# Commercial Aerospace Environment of Tomorrow

- **Worldwide commercial aircraft environment**
  - A complex network of systems, processes, & people
  - Evolved independently over decades
- **This industry is now undergoing a major paradigm shift**
  - Explosion of Information Technology (IT)
  - Increasing costs and passenger demands
- **This needs to be a Network Enabled Environment**
  - To improve efficiency & reduce cost
  - Still in its infancy for Commercial airplanes



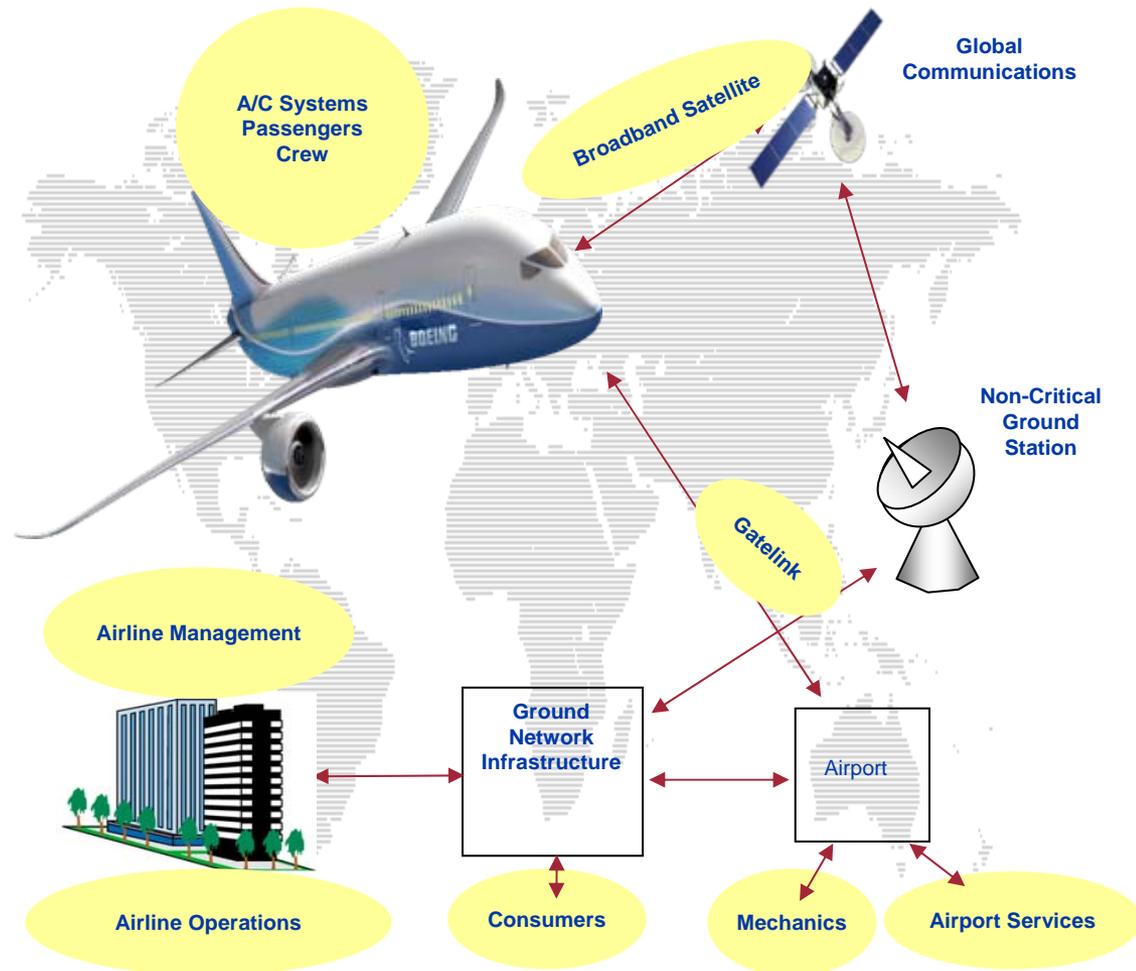
# Commercial Aviation Challenges & Opportunities

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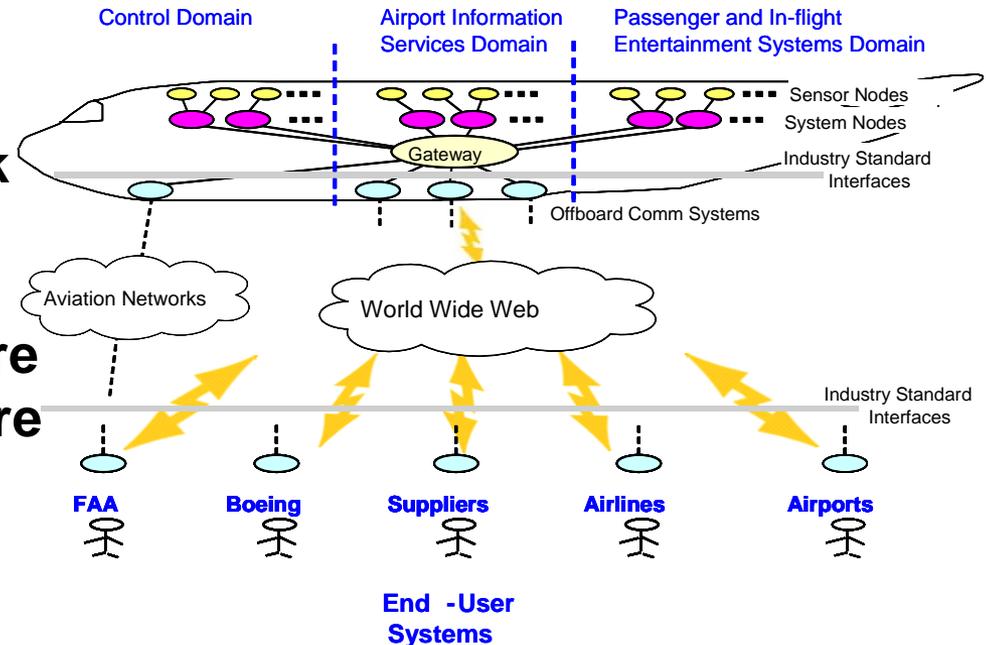
## Integrated Network infrastructure can be divided into 5 groups:

1. Onboard Connectivity
2. Off board Connectivity
3. Network Interoperability Technologies
4. Information Architecture
5. Information Management (Post processing)



# Security Considerations for Future Commercial Aircraft Environment

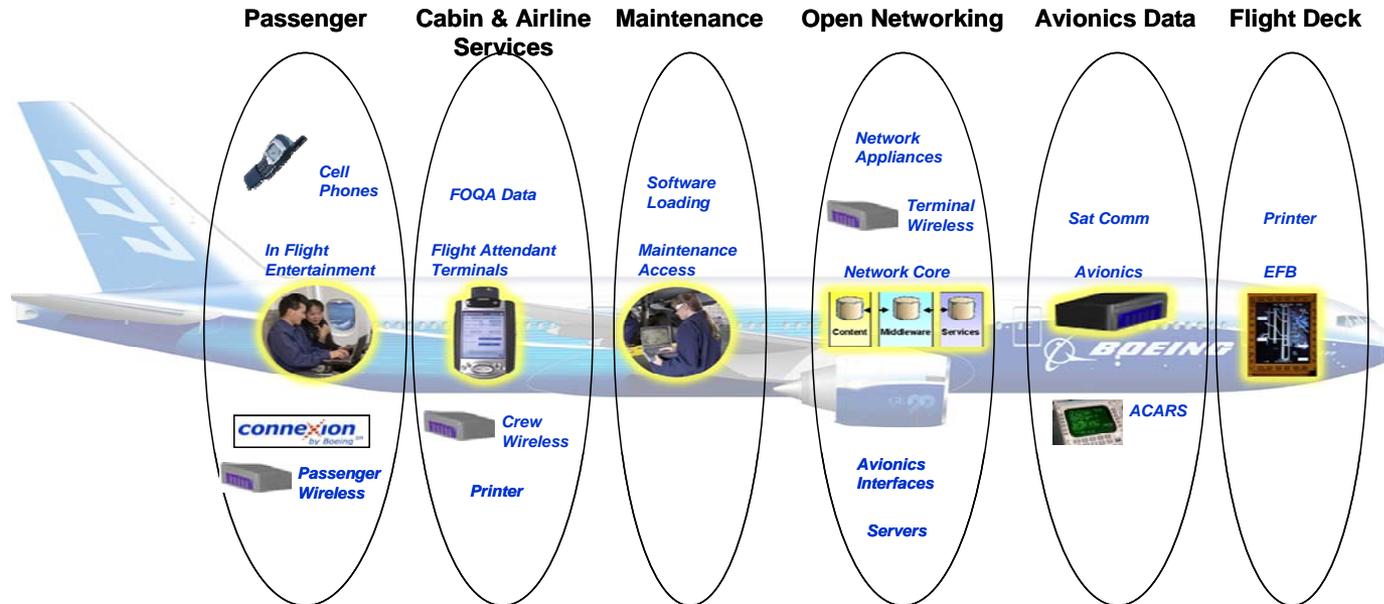
- **Security is a critical component of aviation industry**
- **When integrated, the network will span various levels of security requirements**
- **In the past some of these were physically separated to ensure robust security**
- **In an integrated environment we will have to depend on logical separations, without any security compromise**
- **Requires breakthrough security technologies that can be deployed worldwide**



# CPS Needs in Wireless Sensor Technologies

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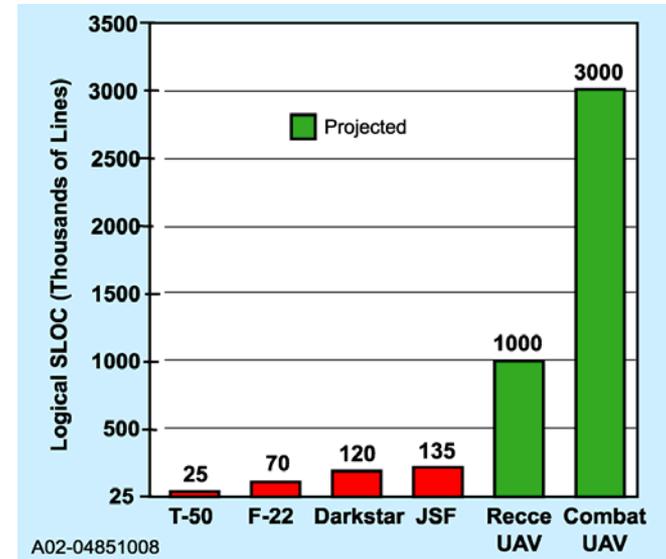
- **Current sensors impose extensive wiring and power requirements that limit their use**
- **Breakthrough technologies in wireless sensing and actuation required**
  - Extremely low energy or energy harvested sensors
  - Highly efficient sensor communication
  - Have high availability
  - Highly secure
  - Spectrum compliant, globally

# Trends in Military Aerospace Systems

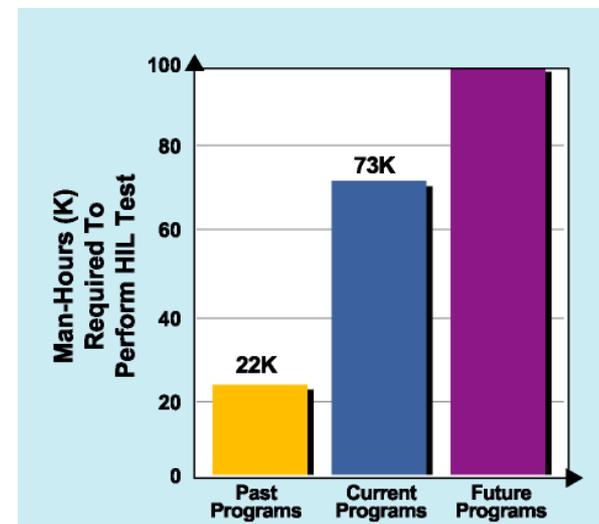
- **Future military systems will incorporate greater intelligence and autonomy resulting in highly complex systems**
- **Future autonomous systems will no longer be limited to operating in restricted airspace**
- **CPS technology advances in characterizing system behavior needed to reflect both system complexity and need to meet similar safety critical levels systems.**



In Aug. 2003, Global Hawk became first UAV – although not autonomous - to receive authorization from FAA to fly in National Airspace

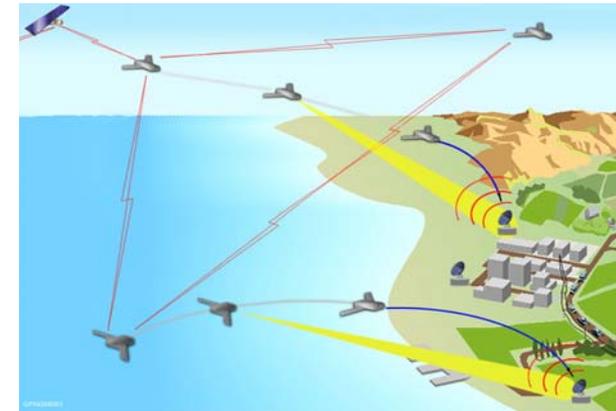
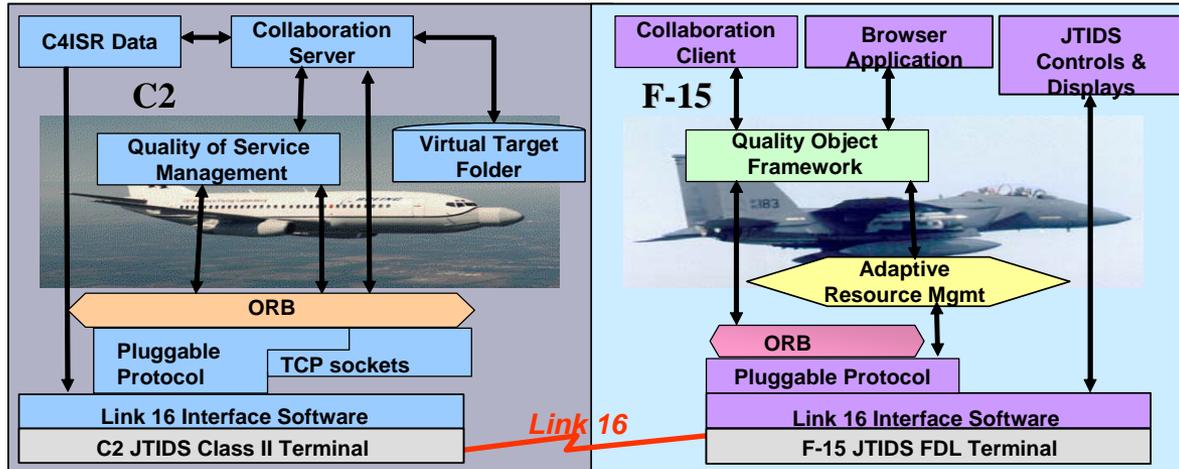


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# Dynamic System Behavior is Critical to Future Systems

Previously cleared for public release – NSF Nov 2006

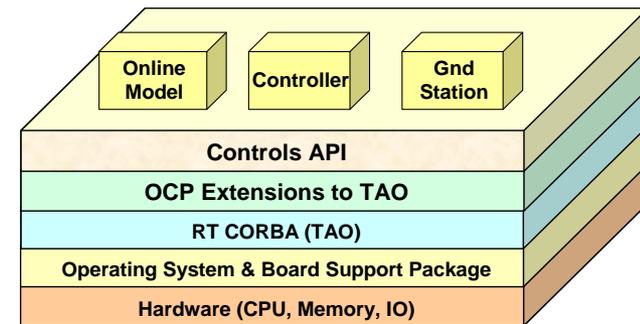
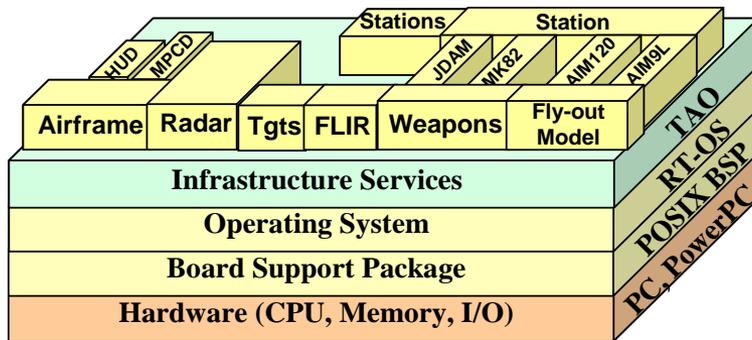
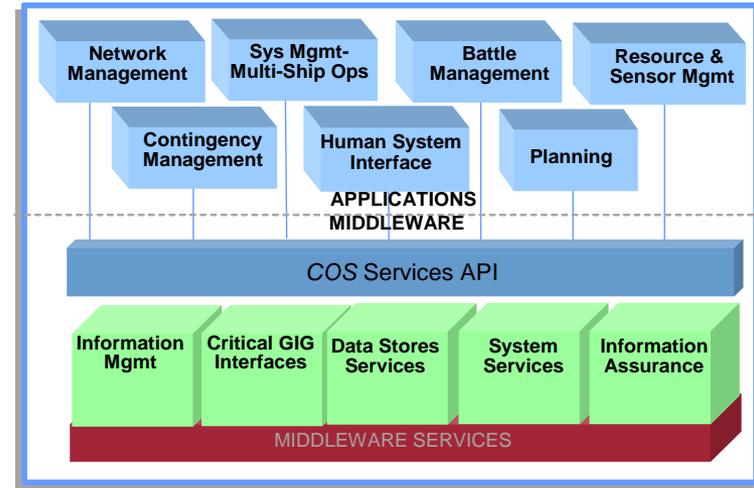
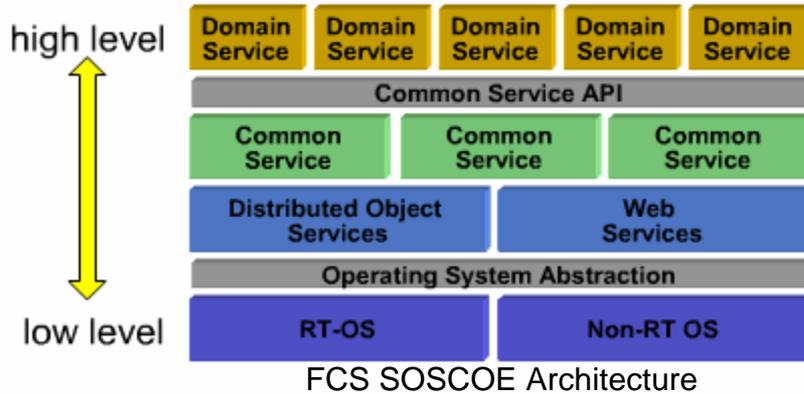


- **New applications require dynamic behaviors**
  - Mixture of hard and soft real-time tasks
  - Active resource management and dynamic scheduling
  - Mode changes with component configuration changes
  - Dynamic changes to system membership (e.g. swarms)
  - Capability to handle vast numbers of elements (1000's)
- **Current component/system models favor static systems**
  - CCM
  - Bold Stroke / OCP
- **Must meet Embedded/Real-Time constraints in a dynamic setting**
  - Need to handle during system execution things that were typically dealt with “out of band” at startup

# Multi-disciplined CPS Research Agenda Is Required

- **Advances in technologies such as model-based development tools, methods, and validation environments to build systems rapidly and affordably**
- **Product focused technologies including software reuse, architectures, real-time theory, languages, and product line architectures to achieve system affordability by recouping investment across multiple system developments.**

# Product Line Architectures are Part of the Solution



# Verification, Validation and Certification Challenges

- **V&V and Certification is expensive, and getting more expensive, for fielded systems**
- **Future advanced manned and un-manned systems may not fit naturally under current V&V and Certification regimes**
- **Need approaches for efficient V&V and Certification for emerging technologies for them to be deployable**
  - **Multi-entity Systems**
  - **Human interaction with Autonomy.**
  - **Fused Sensor Systems**
  - **Adaptive Systems that change with environmental stimulus**
  - **Mixed Criticality - Functions dependent on information of varying confidence**



# Government-Sponsored CPS Research Contributes to the Solution

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- **NSF CPS Research Initiative**
- **AFRL Flight Critical Systems & Software Initiative**
- **OSD Software Intensive Systems**

# The Way Ahead

- **Corporate research dollars for CPS are limited**
  - **Focus on short and mid-term investments in technology to make our products more attractive in a highly competitive market place and enhance our shareholder value.**
- **CPS investments cross multiple technology domains and require industry-level critical mass to achieve the needed results**
- **National strategy in which long-term CPS technology needs are achieved by combined Government and Corporate investment is required**
- **Need to more effectively engage Industry in transitioning CPS research into real systems**

