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Cyber Physical Systems – Opportunities for Innovation Aerospace Industry Perspective

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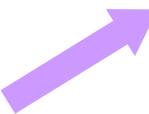
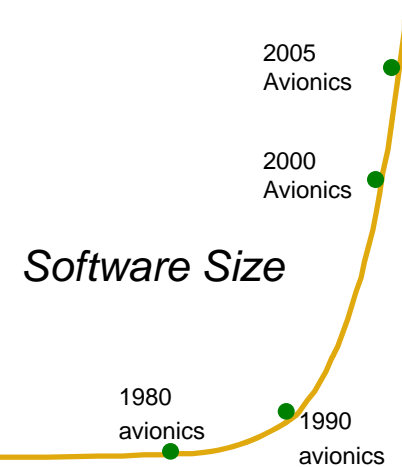
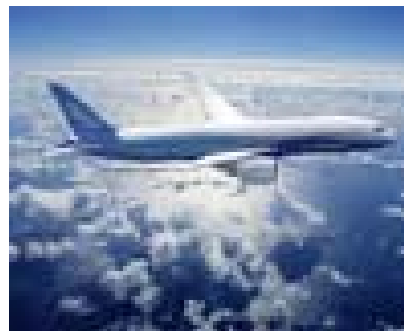
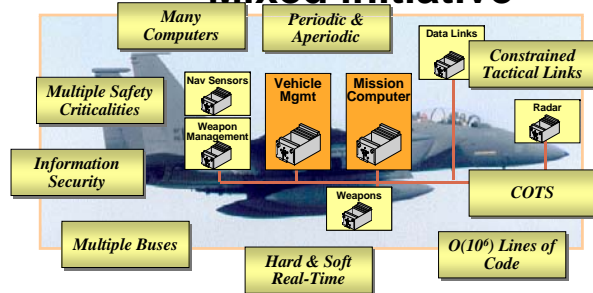
Boeing is a Key CPS Stakeholder

- **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
 - High reliability
- **Aircraft platforms**
 - **Commercial**
 - Stringent Certification and V&V processes and standards
 - Operating in future ATM
 - **Military**
 - Piloted and autonomous aircraft
 - Support all services
 - Varying levels of V&V requirements
 - Very long endurance



Today's Aerospace Systems are Increasingly CPS-Intensive

- **Systems for today and beyond**
 - **New capabilities**
 - **Agile behavior in highly dynamic operating environments**
 - **Operation in a SoS Network**
 - **Secure**
 - **Mixed initiative**

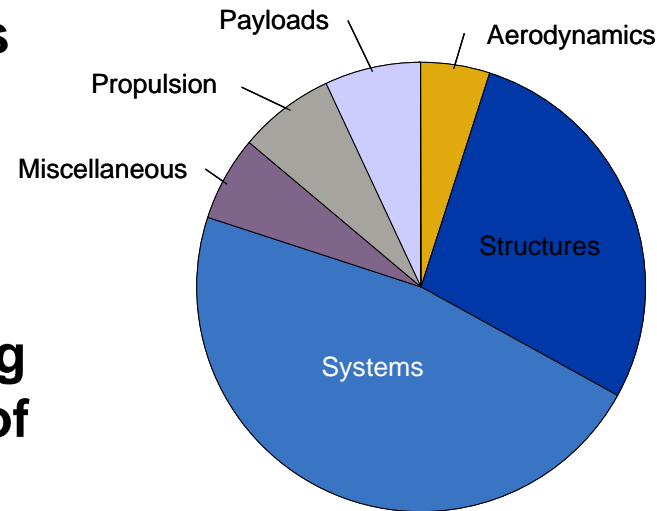


- **Avionics S/W challenges – 100M – >1B SLOC**
- **Software Intensive Systems**
- **Multiple levels of criticality**

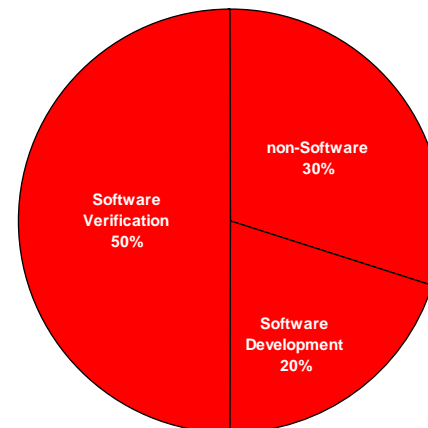


Importance of Software to Aerospace Systems

- **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**
- **Innovation challenge is to drastically reduce time to develop and certify with high confidence**



Typical Recent Commercial Aircraft Cost Distribution



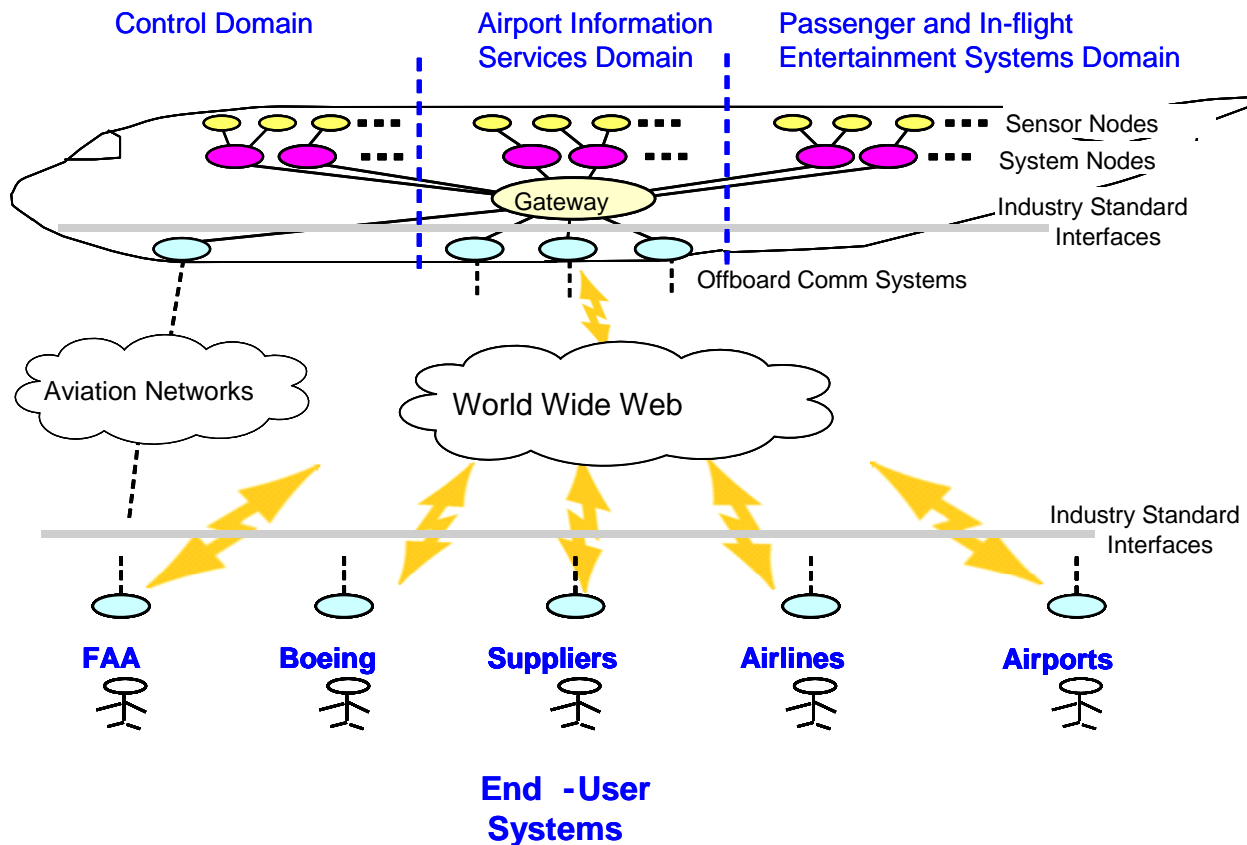
Commercial Aerospace Environment of Tomorrow

- **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 customer expectations
- Emerging challenges to operate in global Net Enabled Environment from factory to gate
 - Reduce cost
 - Improve efficiency
 - Improve customer experience
 - Still in its infancy for Commercial airplanes



Global Aircraft Integrated Network (GAIN) Environment

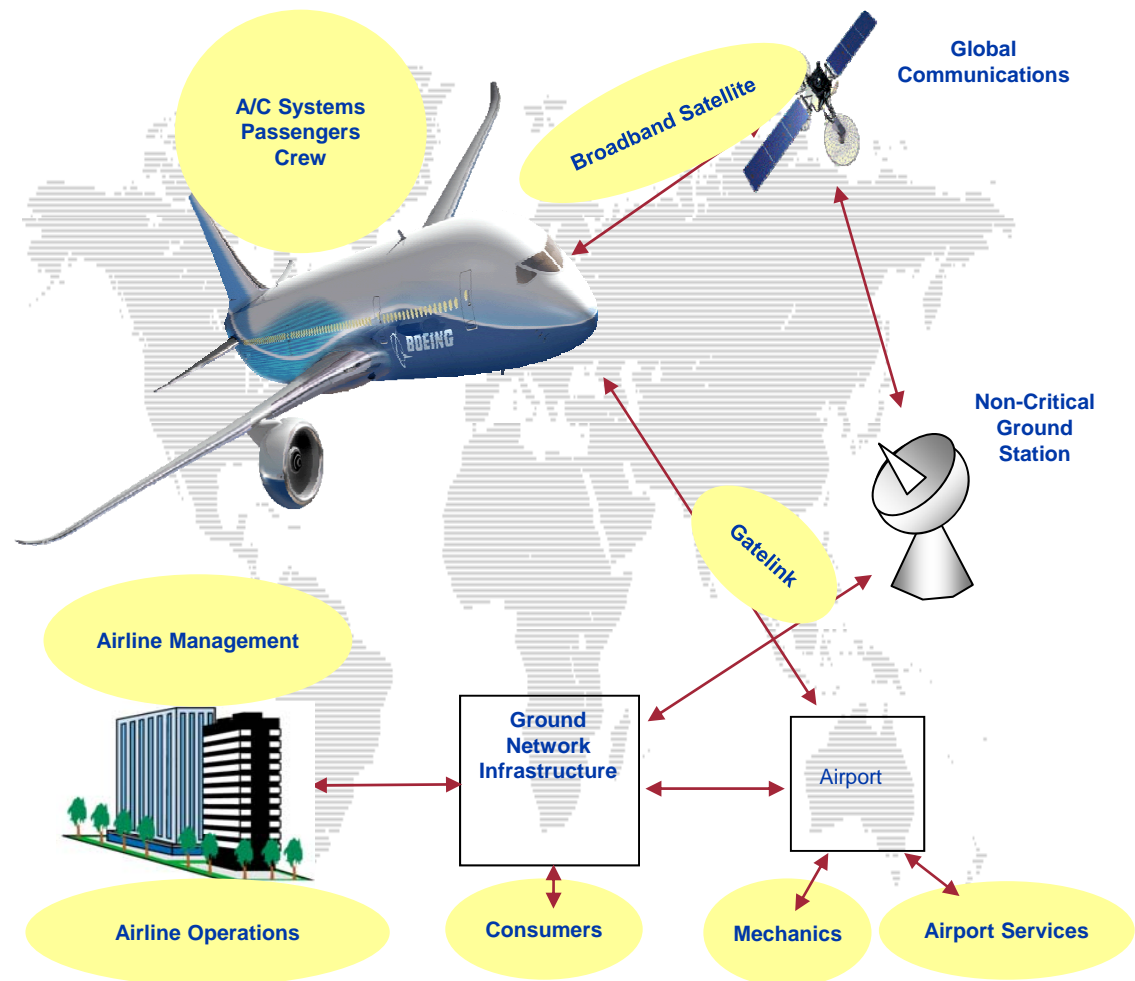
Innovation challenges for CPS proliferate the GAIN domain



Commercial Aviation Challenges & Opportunities

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)

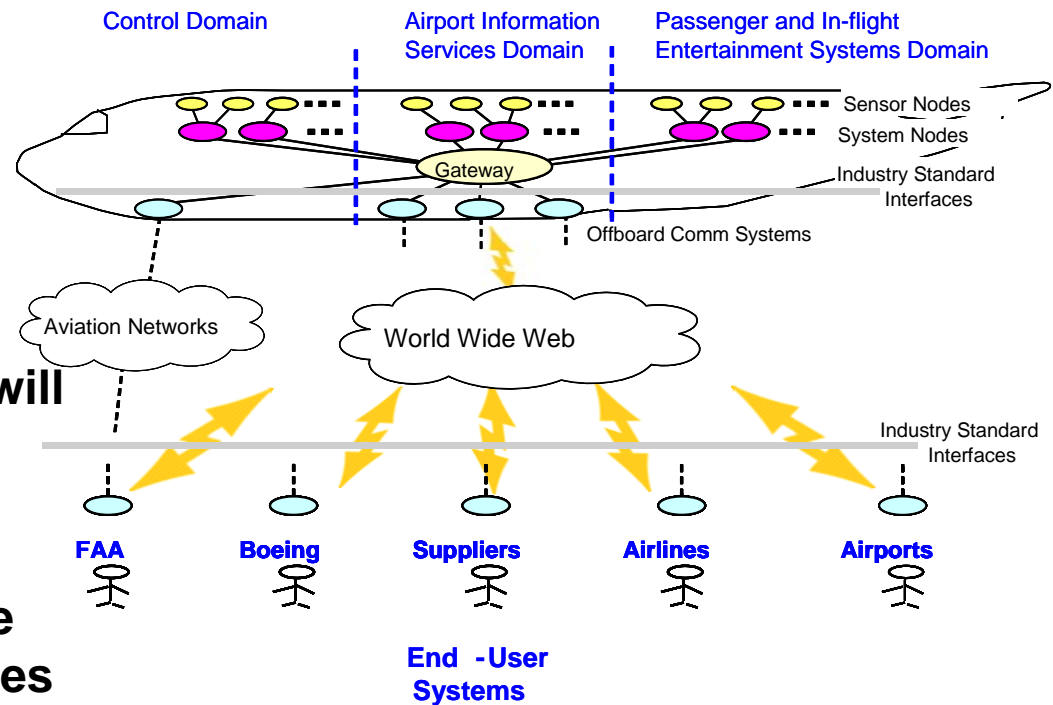


Security Considerations for Future Commercial Aircraft Environment

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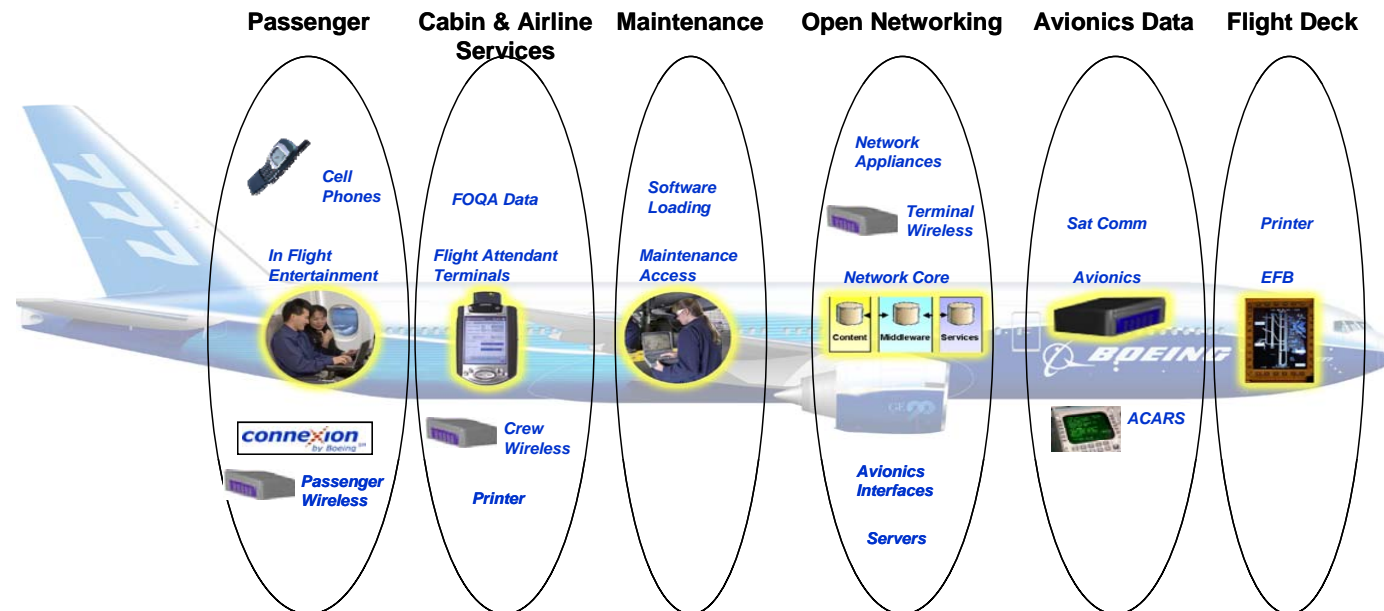
- **Security is a critical component of aviation industry**
- **When integrated, the network will span various levels of security requirements**
- **In the past some of these were physically separated to ensure robust security**
- **In an integrated environment we will have to depend on logical separations,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



CPS Needs in Wireless Sensor Technologies

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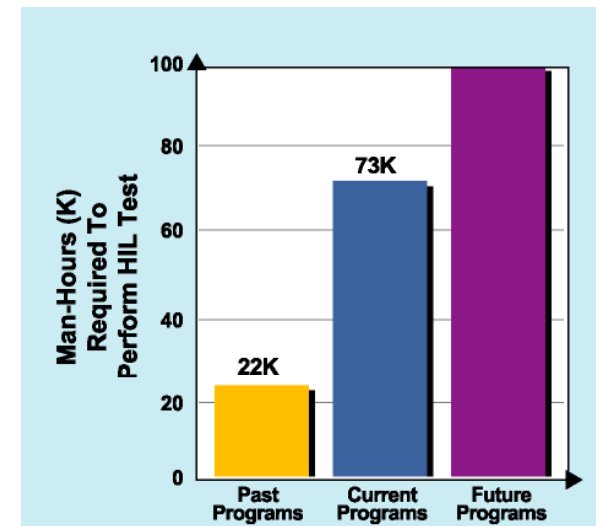
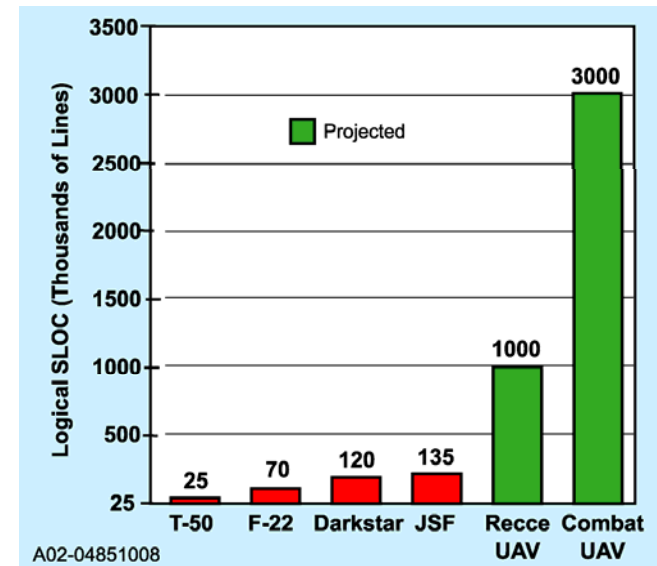


- **Current sensors impose extensive wiring and power requirements that limit their use**
- **Innovation challenge is to dramatically reduce the amount of wired sensing, actuation, and communication -**
 - **Extremely low energy or energy harvested sensors**
 - **Highly efficient sensor communication**
 - **Have high availability**
 - **Highly secure**

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 as commercial systems.**

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



Innovation in Multiple CPS Technologies Required in Aerospace Domain

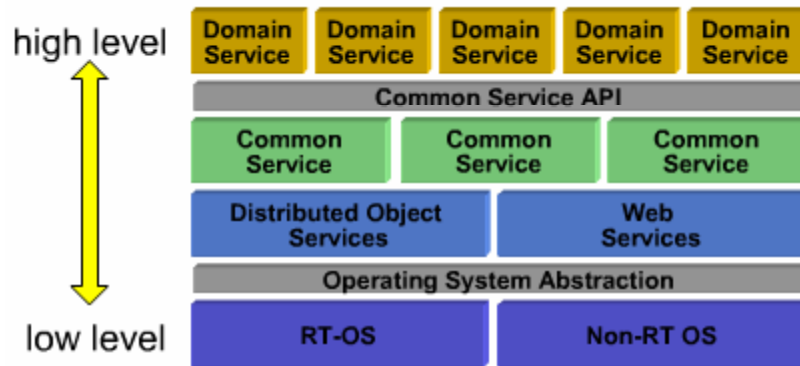
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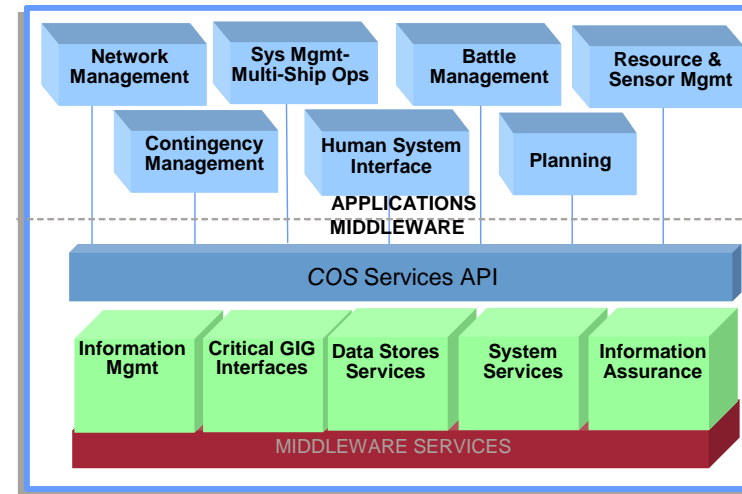
- **Advances in technologies such as model-based development tools, methods, and validation environments to build systems rapidly and affordably**
- **Product focused technologies including software reuse, architectures, real-time theory, languages, and product line architectures to achieve system affordability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

Problem: Technologies need maturation before they can be put into practice in constructing real systems

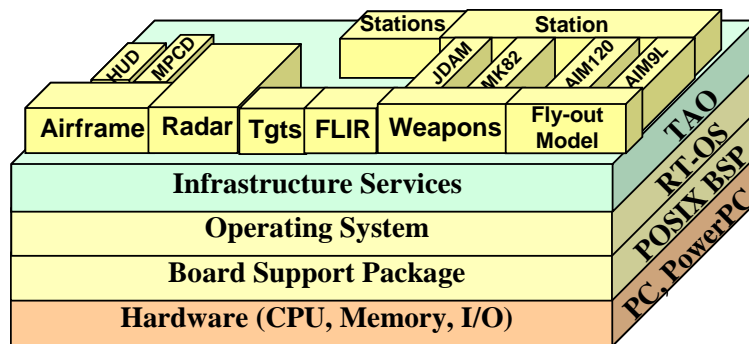
Product Line Architectures are Part of the Solution



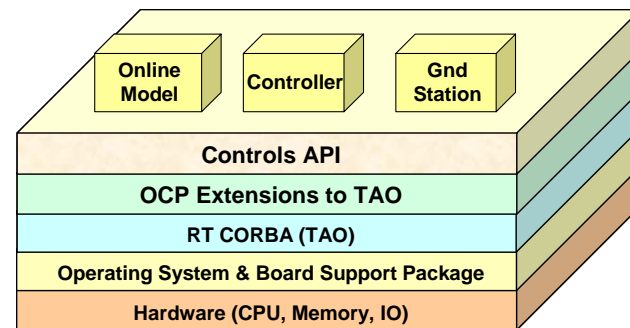
SOSCOE Architecture (2007)



J-UCAS Common Operating System (2005)



Bold Stroke Product Line Architecture (2001)



Open Control Platform for Autonomous Systems (2003)

Innovation Challenges for the Aerospace Industry

- **Future systems will be technology rich, secure and reliable**
- **Extraordinary economic times create tension between technology innovation and research expenditures**
 - Innovation to reduce cost and time to market
 - R&D expenditures decreasing
 - Develop systems within budget or else
- **Innovations need to demonstrate short term industry payoff as well as a well developed longer term strategy showing significant benefits**
- **Need to leverage Industry / Government / Academic collaboration**
 - Industry has to see significant value in technology at an early stage
 - Industry is called on frequently to “endorse” academic projects but there needs to be much more follow-through on all sides
 - Academic research needs to receive greater industrial visibility to support informed discussions on suitability for early transition

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**