



Conducting Leading-Edge Software R&D in a Globalized, Commoditized World

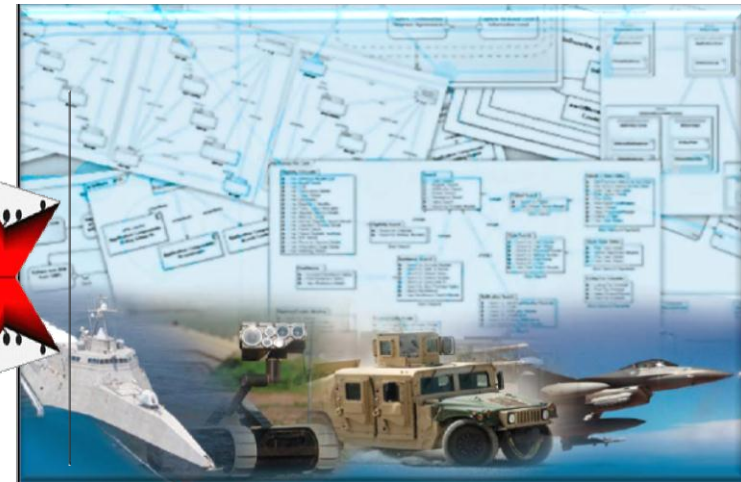
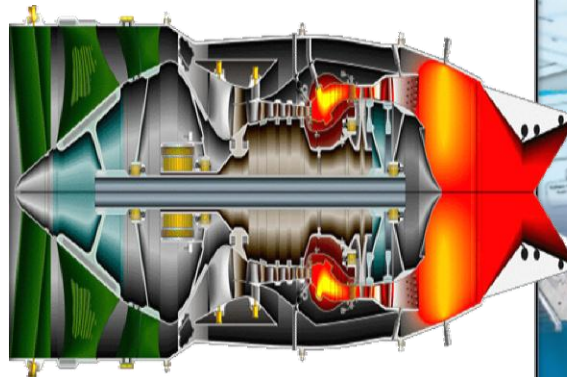
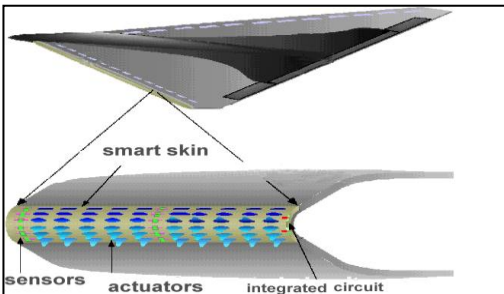
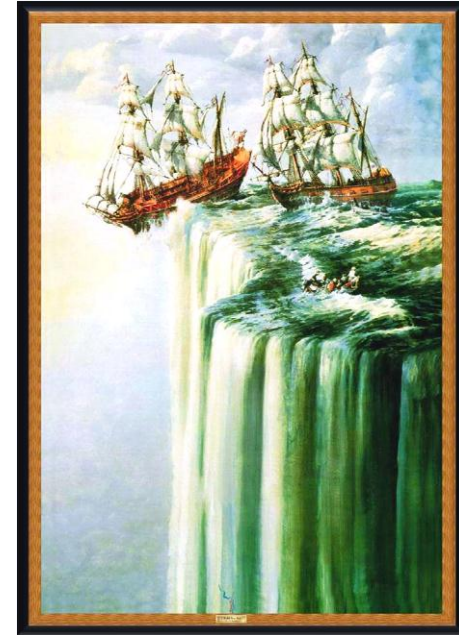
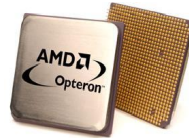
Dr. Douglas C. Schmidt

Deputy Director, Research, and Chief
Technology Officer

Software Engineering Institute, CMU

What this Talk is About

- The impact of **globalization** & **commoditization** of information technology (IT) on **software R&D**
- **Globalization**
 - “I speak Spanish to my God, Italian to women, French to men, German to my horse, & **Japanese to my boss**”
– Paraphrasing King Charles the 5th of Spain
- **Commoditization of IT**
 - “Everything gets cheaper forever”
– John Chambers, CEO Cisco Systems
- **Software R&D**
 - Innovating software for competitive advantage





Conducting Leading-Edge Software R&D in a
Globalized, Commoditized World

My Background

My Background

Education

BA & MA,
Sociology



MS & PhD,
Computer
Science



Academics

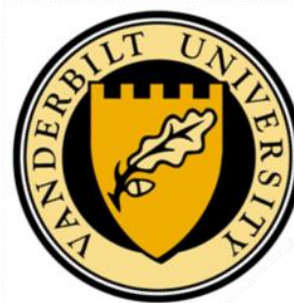
Asst.
Prof



Assoc.
Prof



Full
Prof



Government/Industry

Program Manager
& Deputy Director



Co-Chair,
Software Design
& Productivity



USAF Science
Advisory Board



CTO



CTO



CTO



Software Engineering Institute

What I Do at the SEI

Provide technical management across SEI lines of business to ensure that SEI program R&D plans are aligned with overall SEI R&D strategy plans

Chief Technology Officer role

- Lead the formulation of the SEI's technology strategy
- Amplify external relationships with academia & industry
- Align the expertise of the SEI technical staff to identify & respond to the needs of sponsors, customers, & partners
- Help the SEI shape future innovations in complex software-reliant systems

Deputy Director, Research role

- (Meta) Manage the line funded programs, including the Internal R&D program
- Manage the technical interface to the DoD & other US government agencies



SEI's research program is essential to ensure a long/healthy future as an R&D FFRDC



Conducting Leading-Edge Software R&D in a
Globalized, Commoditized World

Consequences of IT Commoditization

The Road Ahead

CPU & network performance has increased by orders of magnitude in past decades



10 Megahertz to
~3 Gigahertz

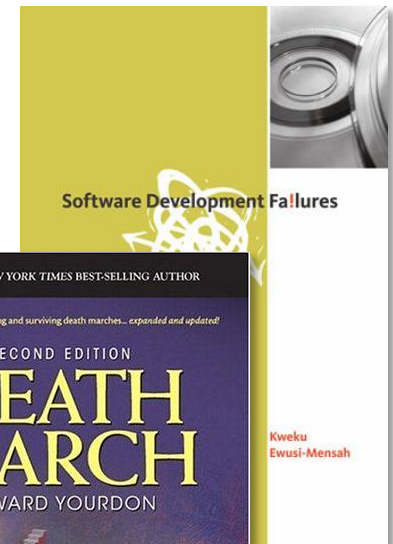
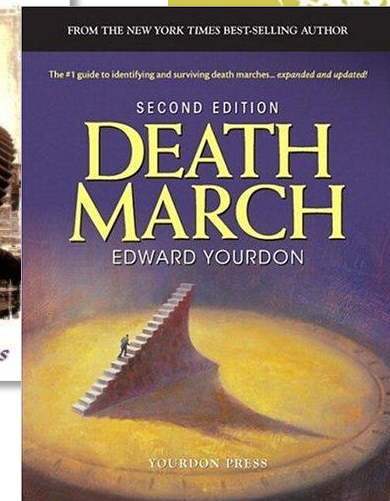
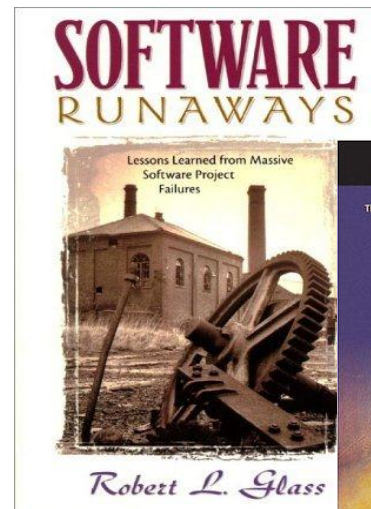


1,200 bits/sec to
10+ Gigabits/sec

Extrapolating these trends another decade or so yields

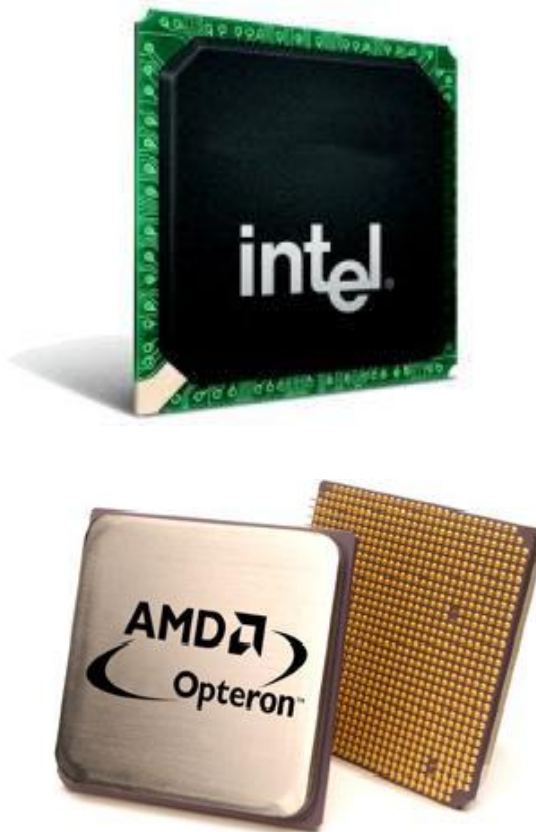
- ~4-5 Gigahertz CPUs with 10s-100s of cores
- ~100 Gigabits/sec LANs
- ~100 Megabits/sec wireless
- ~10 Terabits/sec Internet backbone

Unfortunately, software quality & productivity hasn't improved as rapidly or predictably as hardware – especially for mission-critical distributed real-time & embedded systems



Why Hardware Improves So Consistently

Advances in hardware & networks stem largely from R&D on *standardized & reusable* APIs & protocols



x86 chipsets



TCP/IP

Why Software Fails to Improve as Consistently



*Proprietary &
Stovepiped
Application &
Infrastructure
Software*



*Standard/COTS
Hardware &
Networks*

Commodity software quality has historically lagged behind commodity hardware, especially for mission-critical distributed real-time & embedded systems

What's So Hard About Software?

Technical Complexities



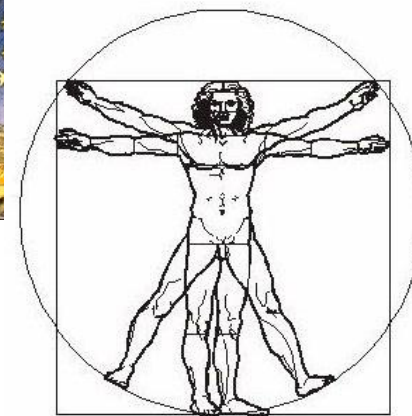
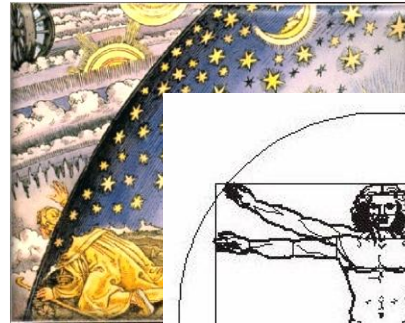
Accidental Complexities

- Low-level APIs & debugging tools
- Interoperability & portability

Inherent Complexities

- Quality of service (QoS)
- Scheduling & synchronization
- Intermittent connectivity
- Information assurance
- ...

Human Nature



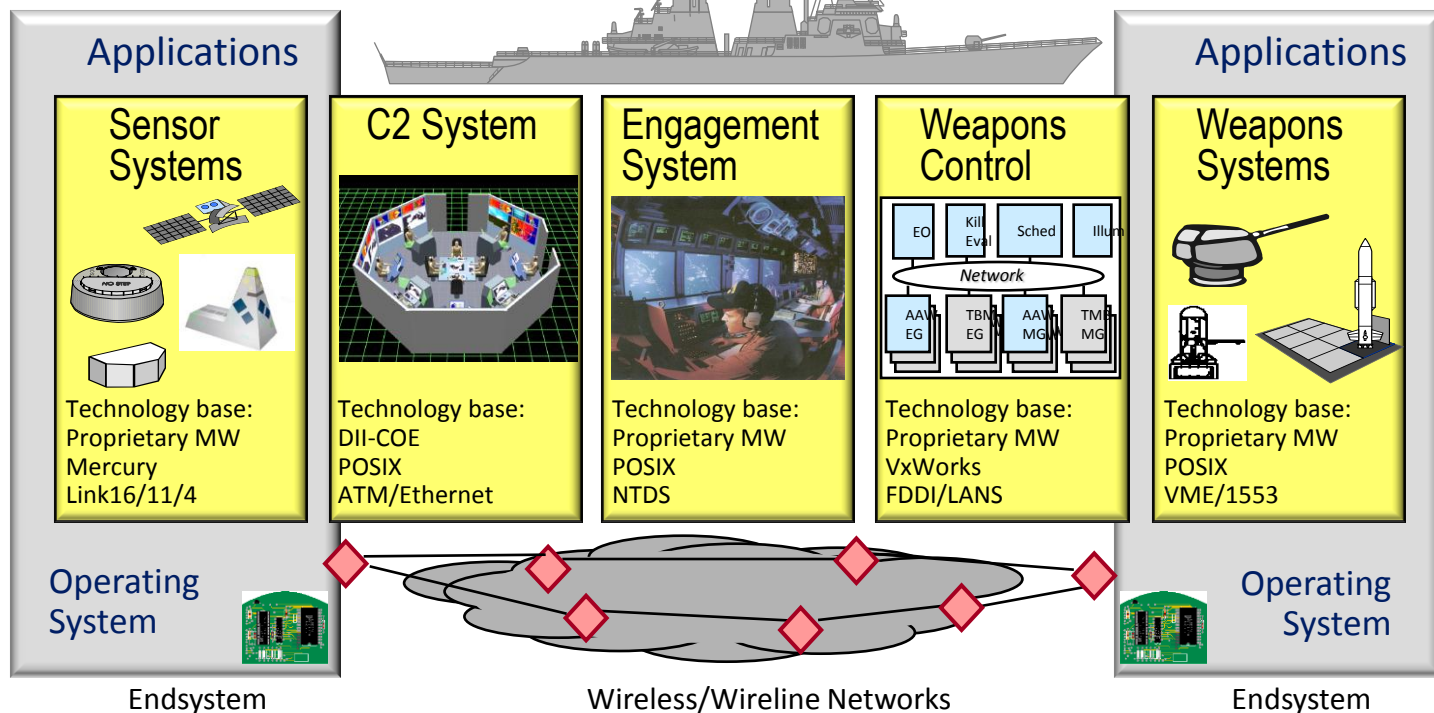
- Organizational & managerial impediments
- Economic impediments
- Policy impediments
- Political impediments
- Psychological impediments
- ...

Evolution of DoD Software Development

Legacy DoD systems have historically been:

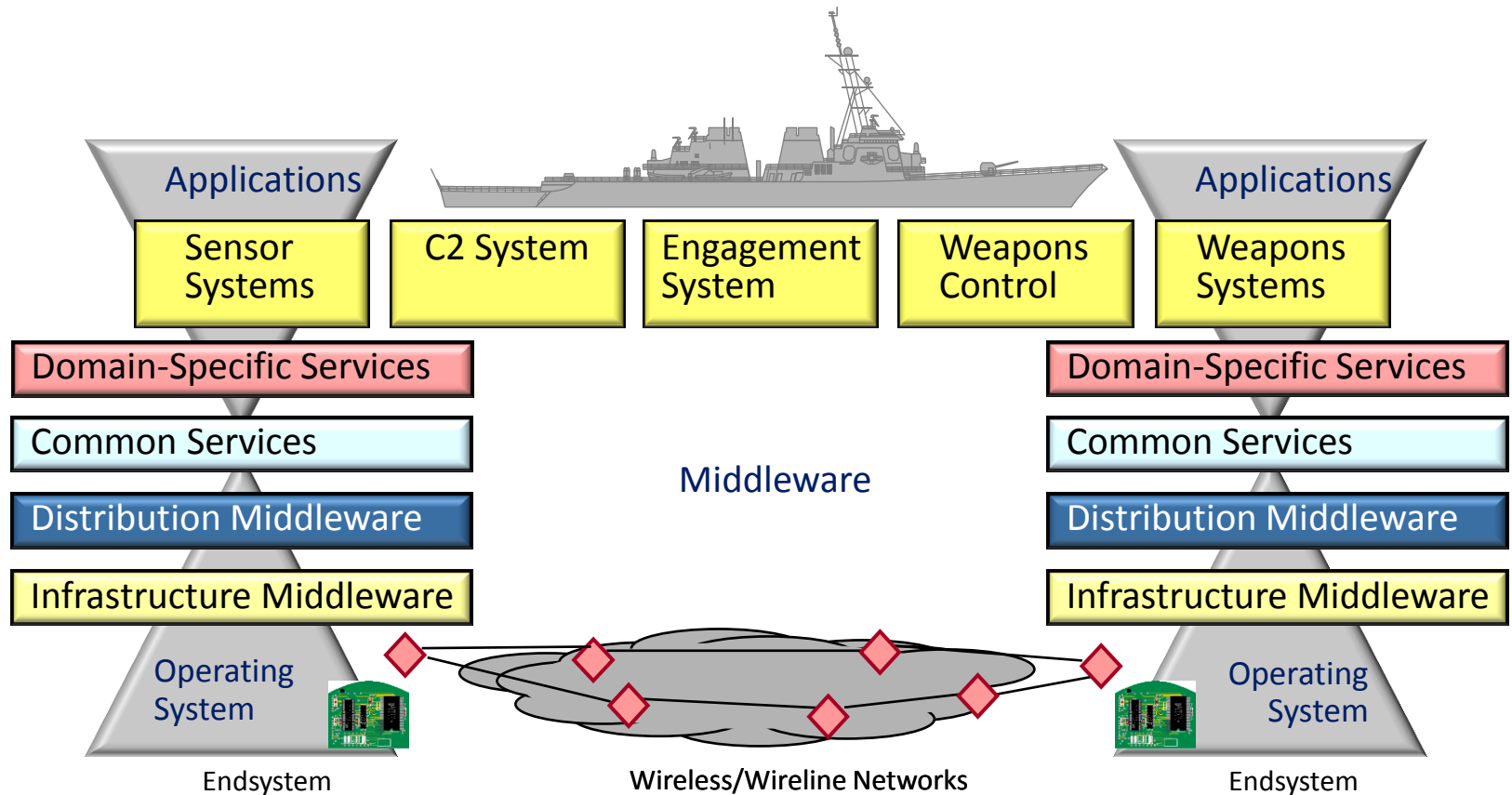
- Stovepiped
- Proprietary
- Brittle & non-adaptive
- Expensive
- Vulnerable

Consequence: Small HW/SW changes have big impact on system QoS & maintenance

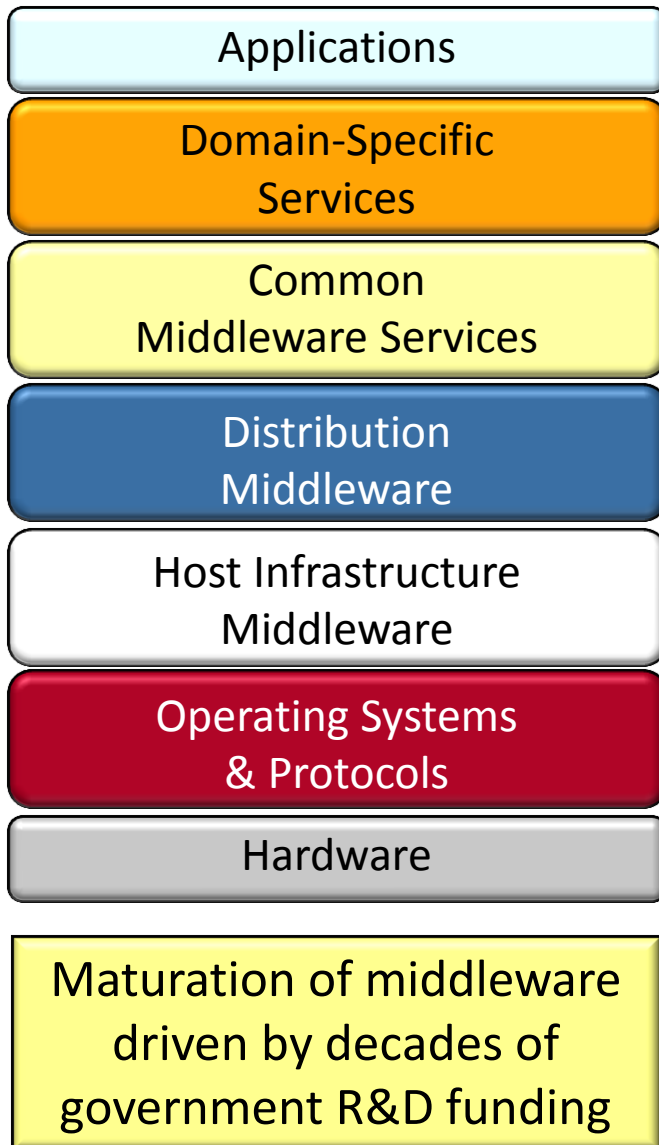


Evolution of DoD Software Development

- *Middleware* has effectively factored out many reusable services from traditional application responsibility
- Essential for product-line architectures, common operating environments, open architectures, etc.



Example: The Evolution of Middleware



Historically, mission-critical apps were built directly atop hardware & OS

- Tedious, error-prone, & costly over lifecycles

There are layers of middleware, just like there are layers of networking protocols

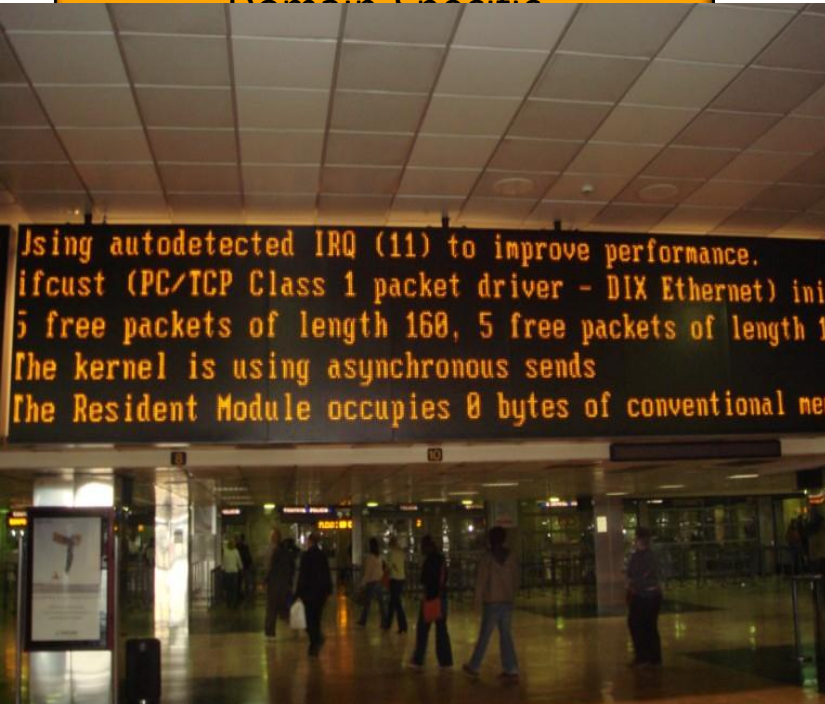
Standards-based COTS middleware helps support key mission goals:

- Control end-to-end resources & QoS
- Leverage hardware & software technology advances
- Evolve to new environments & requirements
- Provide a wide array of reusable, off-the-shelf developer-oriented services

Consequences of Software Commoditization

Applications

Domain Specific



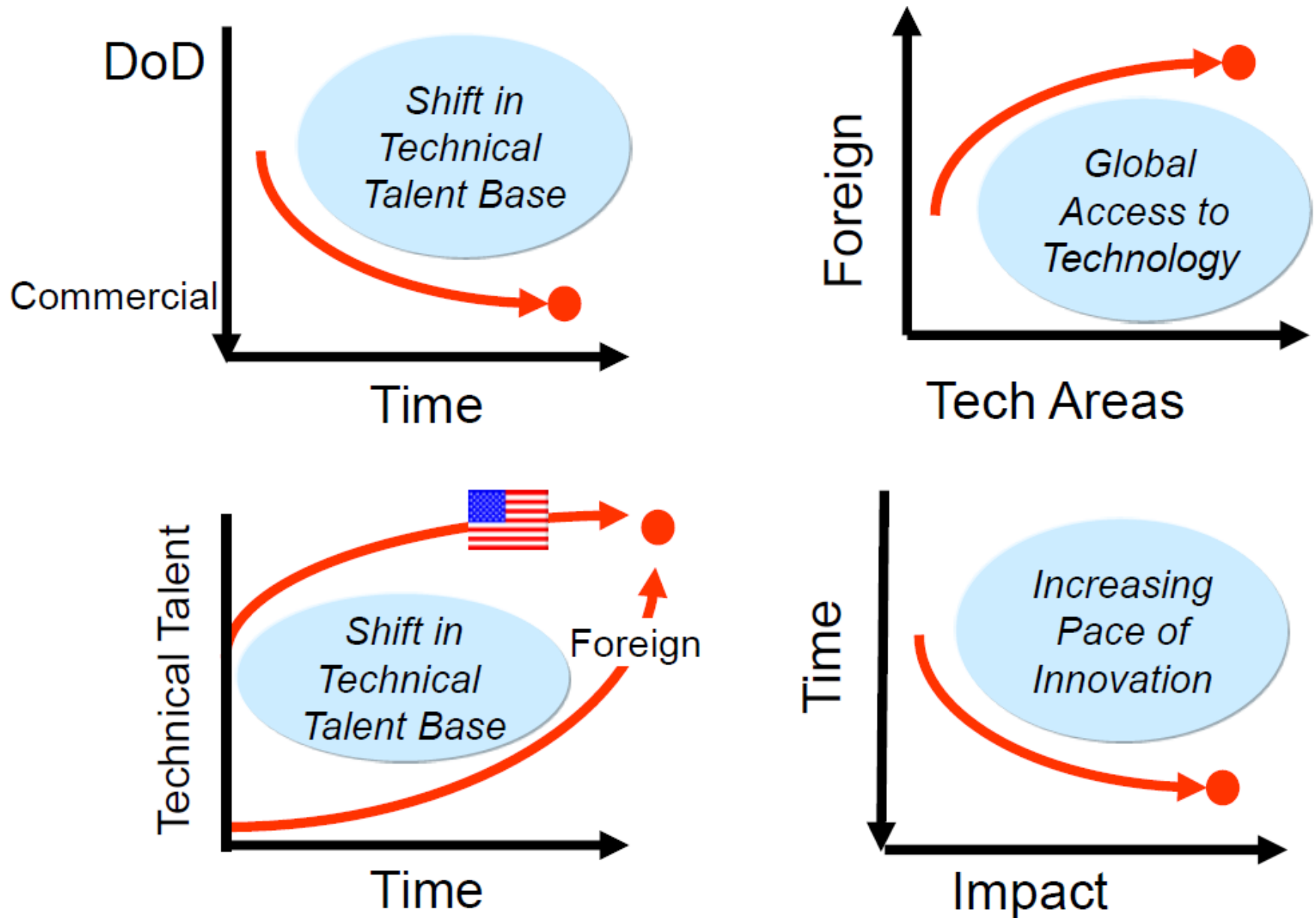
Hardware

Not all trends bode well
for traditional business &
technology leaders

- More emphasis on integration rather than programming
- Increased technology convergence & standardization
- Mass market economies of scale for technology & personnel
- More disruptive technologies & global competition
- Lower priced—but often lower quality—hardware & software components
- The decline of internally funded R&D (eating our seed corn)
- Potential complexity cap in next-generation systems-of-systems & ultra-large-scale systems

Ultimately, success requires mastery of
non-commoditized domains, e.g.,
distributed real-time & embedded systems

Reality Check: Software Expertise in the Flat World





Conducting Leading-Edge Software R&D in a
Globalized, Commoditized World

SEI's R&D Strategy

DoD's Software Challenge

"New GAO report highlights \$6.9 billion in over-budget IT projects at the Department of Defense" – ZDNet, 9/30/2010

F/A-22



SBIRS
High



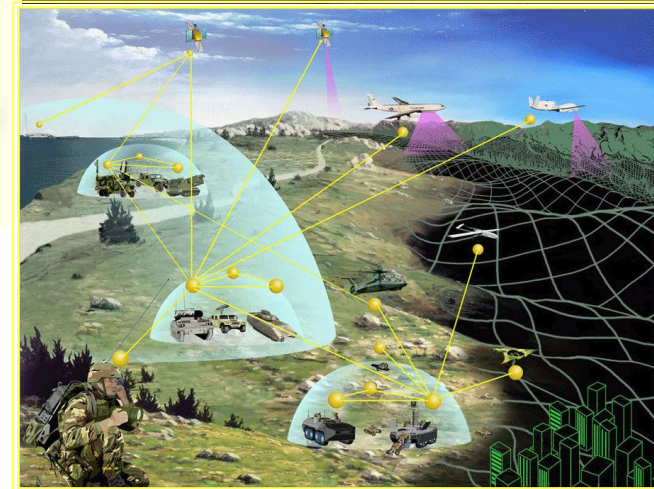
Joint Tactical Radio Systems
(JTRS)



DDG
1000



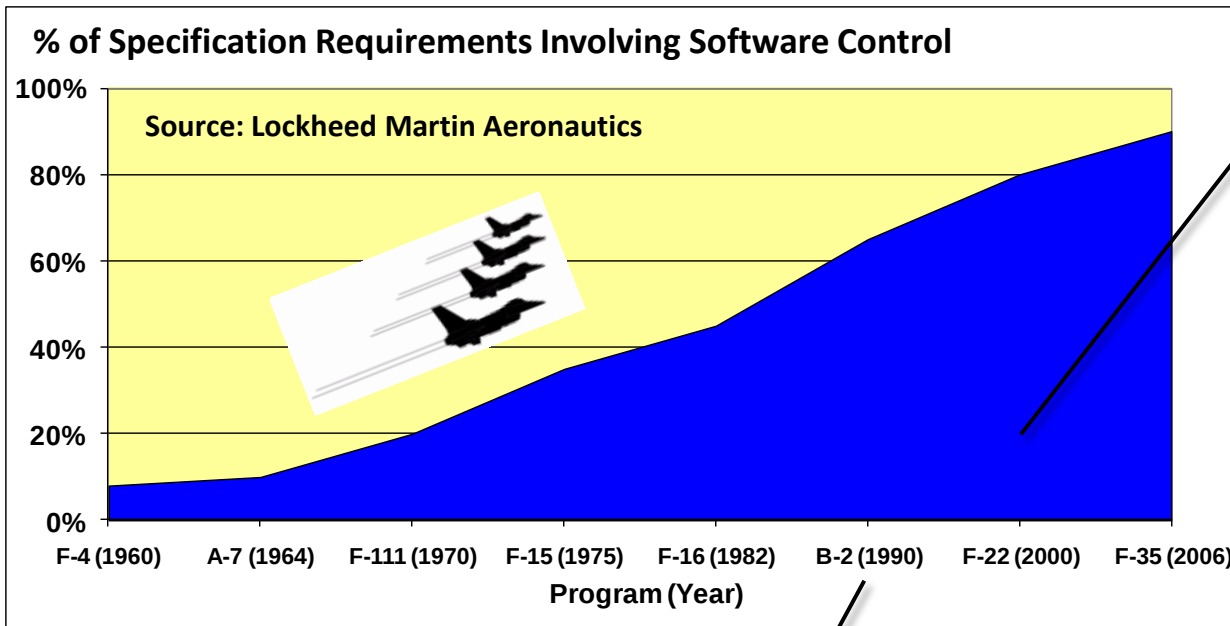
Future Combat
System (FCS)



"If software isn't a major part of the cost of weapons systems, then it's a very significant part of the cost ... You can build a frigate which costs \$500 million to buy, but the largest part of the expense would not be the hull or the weapons, it would be the hardware and software."

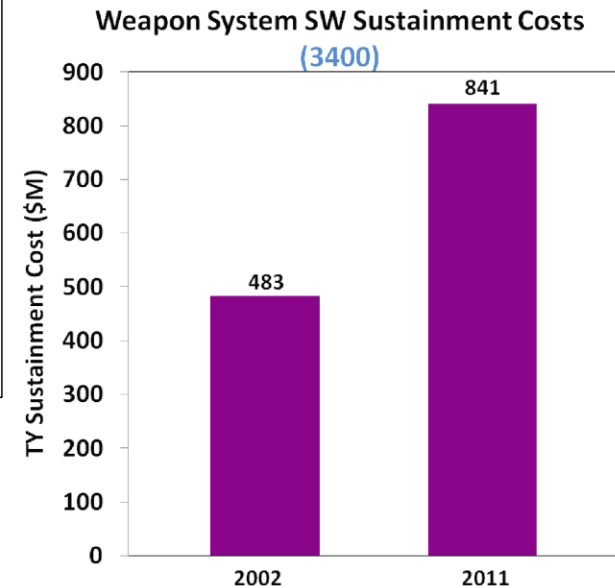
"The Software Challenge: Balancing Costs and Security Risks," January 16, 2009, Wharton Aerospace and Defense Report

DoD Software is Growing in Size & Complexity



Multi-year delays associated with software & system stability

Software & testing delays push costs above Congressional ceiling

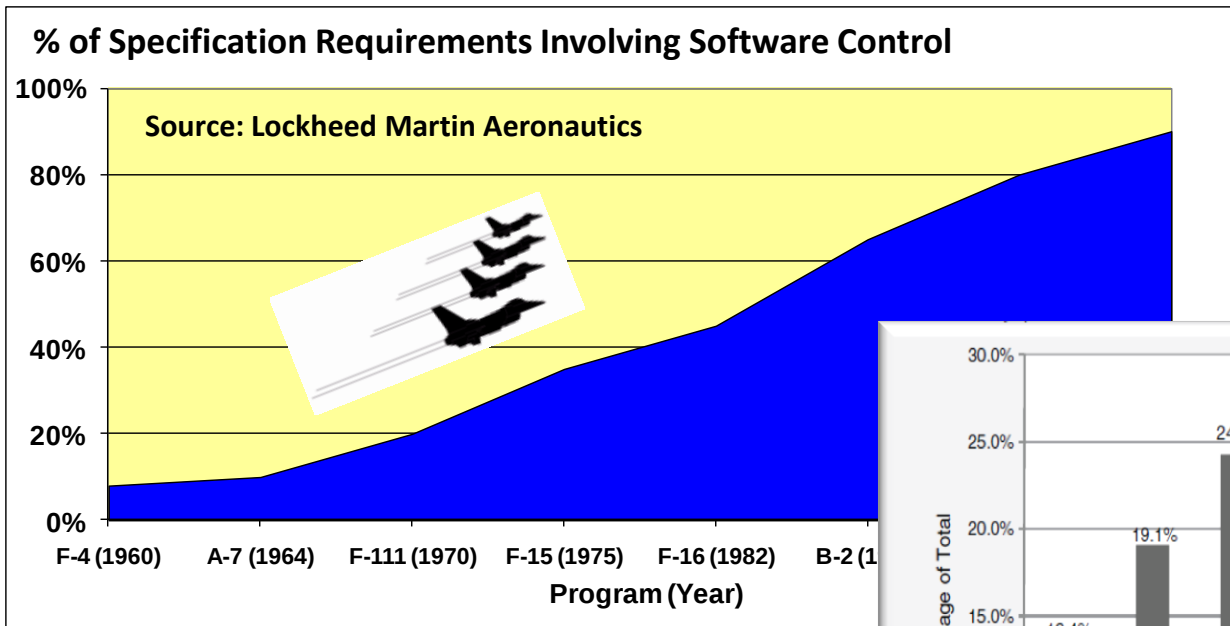


Source: FY11 Air Force SAB study on "Sustaining Aging Aircraft"

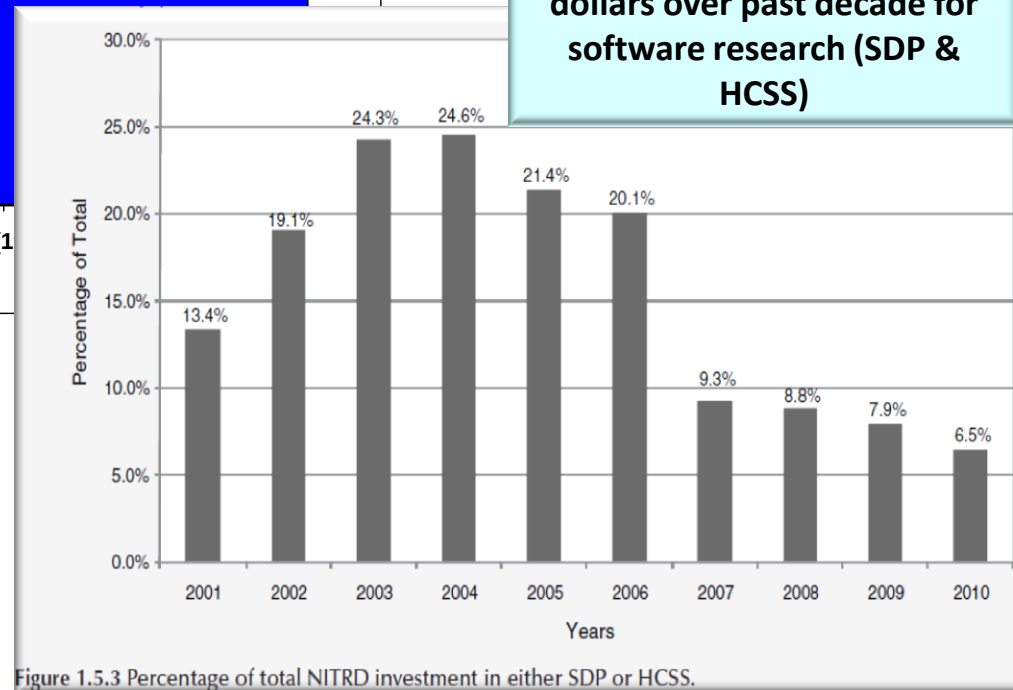
"[Software] continues to grow in importance in our weapons systems & remains a significant contributor to program cost, schedule, & performance shortfalls."

— Honorable Pete Aldridge, former USD, ATL

DoD Software is Growing in Size & Complexity



A 45% reduction in constant dollars over past decade for software research (SDP & HCSS)



DoD systems are increasingly dependent upon software, but it's also increasingly hard to motivate investments in long-term software research

From NRC Report *Critical Code: Software Producibility for Defense* (2010), sponsored by Office of the Secretary of Defense (OSD)
www.nap.edu/openbook.php?record_id=12979&page=R1

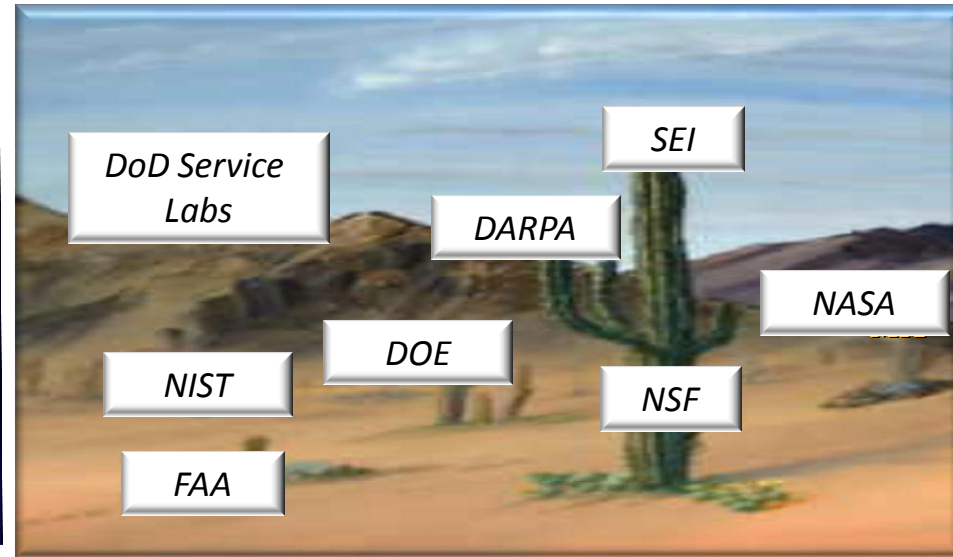
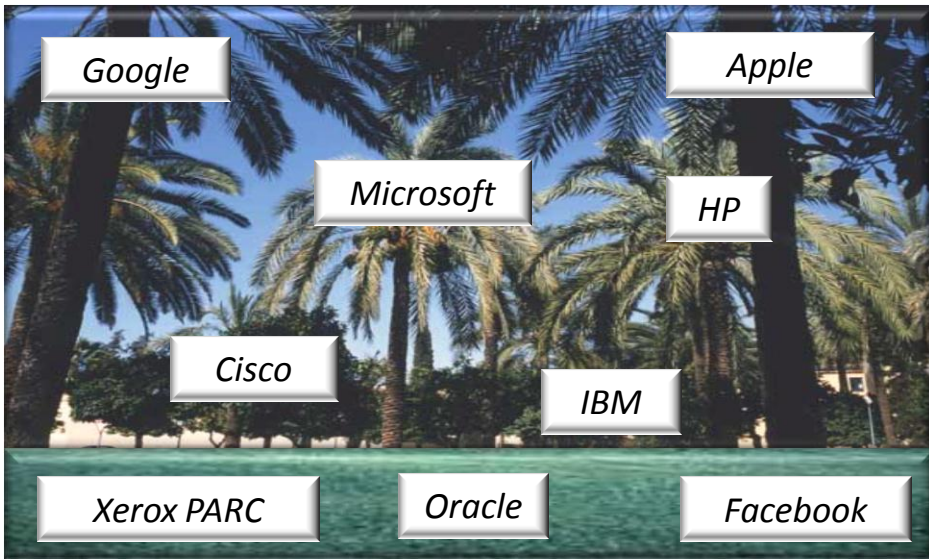
DoD Software Science & Technology Status

Misconception

The IT industry is a well-populated oasis for DoD programs

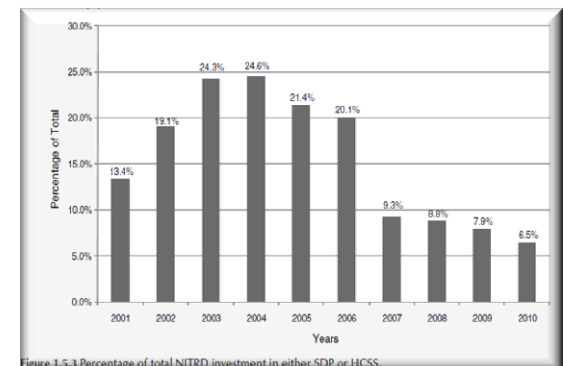
Reality

IT R&D investment is needed to seed & transform the IT desert for the DoD



Limitations with software contribute significantly to gap between (1) the IT the DoD *needs* vs. (2) the IT the DoD can *afford* given

- Current level of technology maturity
- Decade-long tailing off of DoD software R&D investments (especially “6.2” investments)
- Atrophy of government expertise-base



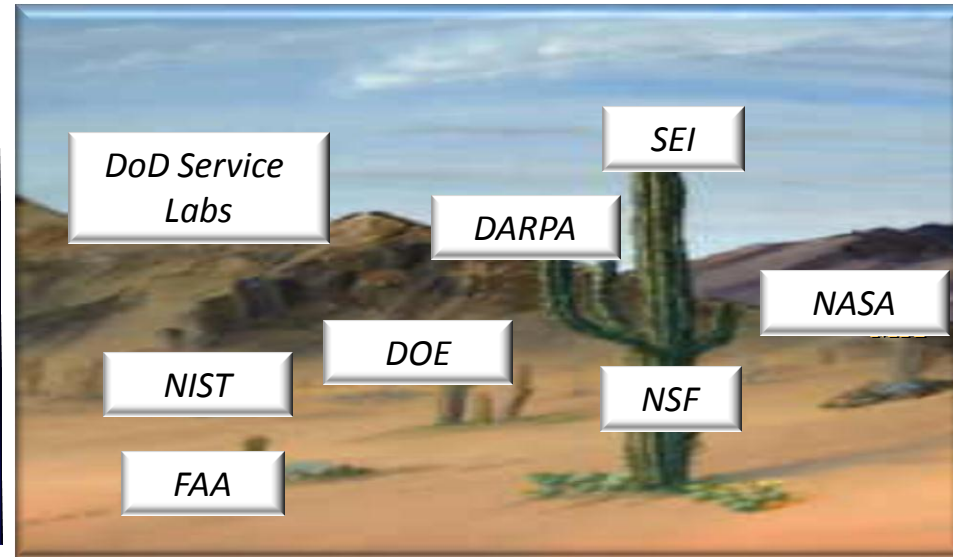
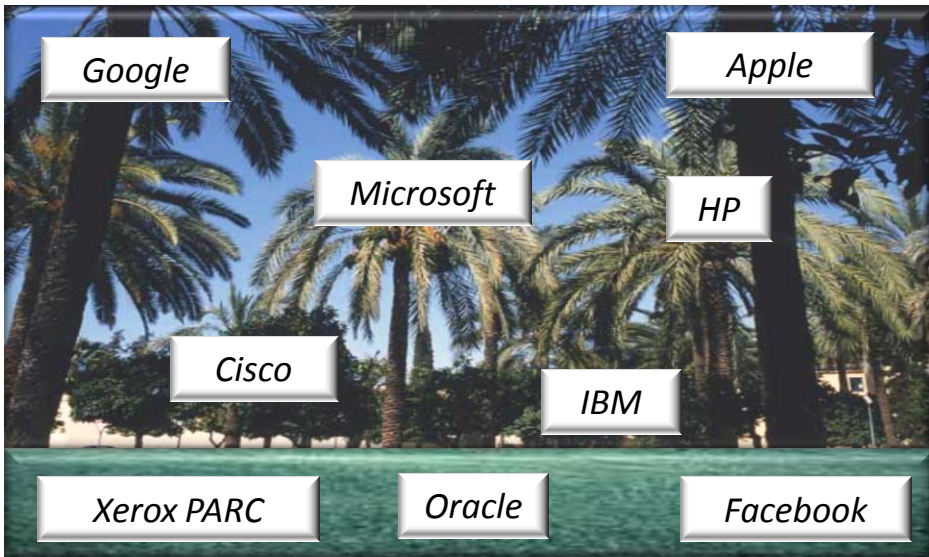
DoD Software Science & Technology Status

Misconception

The IT industry is a well-populated oasis for DoD programs

Reality

IT R&D investment is needed to seed & transform the IT desert for the DoD



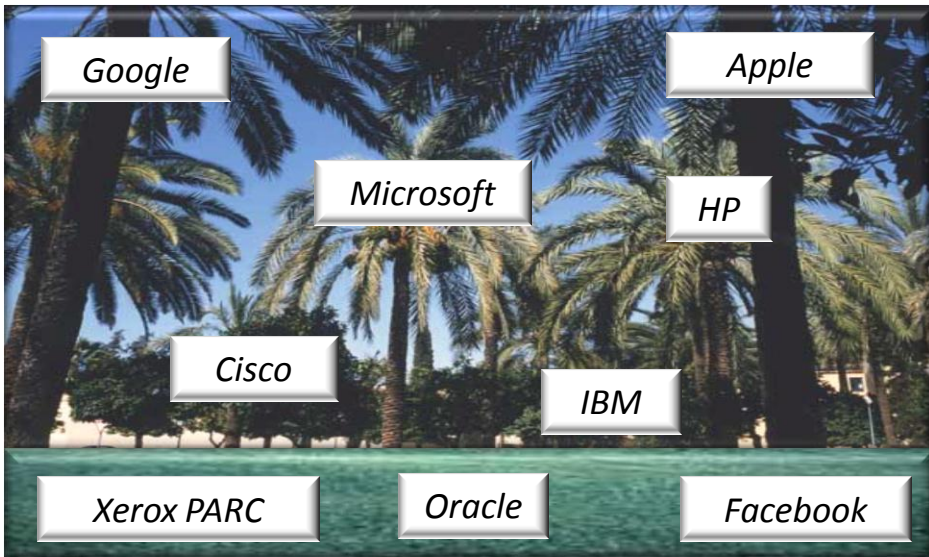
Why Commercial Industry Alone Won't Solve the DoD Software Problem

- Commercial R&D often inappropriate for DoD problems
 - It's targeted for specific products, not long-term tech improvement
 - Focused on selling products – dependability is lower priority
 - Global resourcing/competition for R&D limits applicability to DoD

DoD Software Science & Technology Status

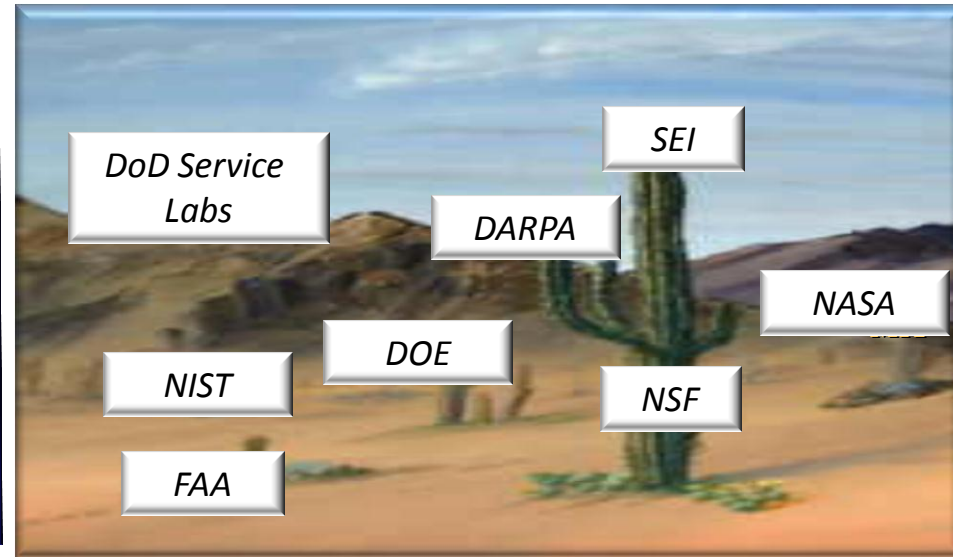
Misconception

The IT industry is a well-populated oasis for DoD programs



Reality

IT R&D investment is needed to seed & transform the IT desert for the DoD



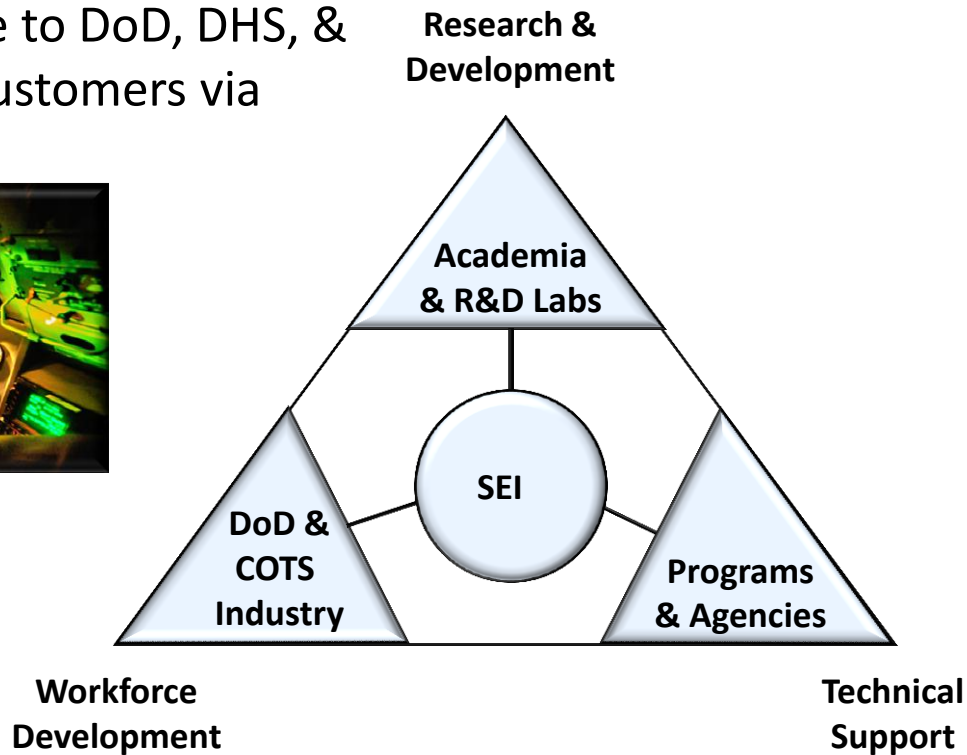
Why Defense Industry Alone Won't Solve the DoD Software Problem

- R&D targeted at company-specific projects
- Software enhances competitiveness but not a direct profit driver for many DoD activities
- Less interest in retaining software technologies as company IP

What the SEI Does & the Value We Provide

Mission: advancing the practice of software engineering through research & technology transition

- SEI provides value to DoD, DHS, & other sponsors/customers via



EXPLORE

CREATE

APPLY

AMPLIFY

SUSTAIN

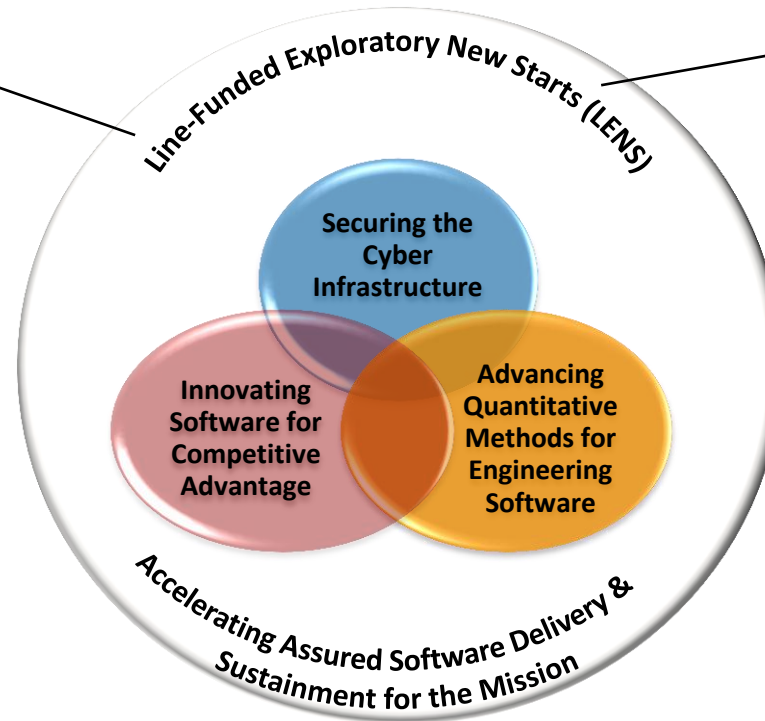
Summary of SEI's Strategic R&D Plan

What We Are Doing

"Prevent surprise" to DoD, Intelligence Communities, & SEI

What Difference It Makes

Prepare for an uncertain future



EXPLORE

CREATE

APPLY

AMPLIFY

SUSTAIN

Summary of SEI's Strategic R&D Plan

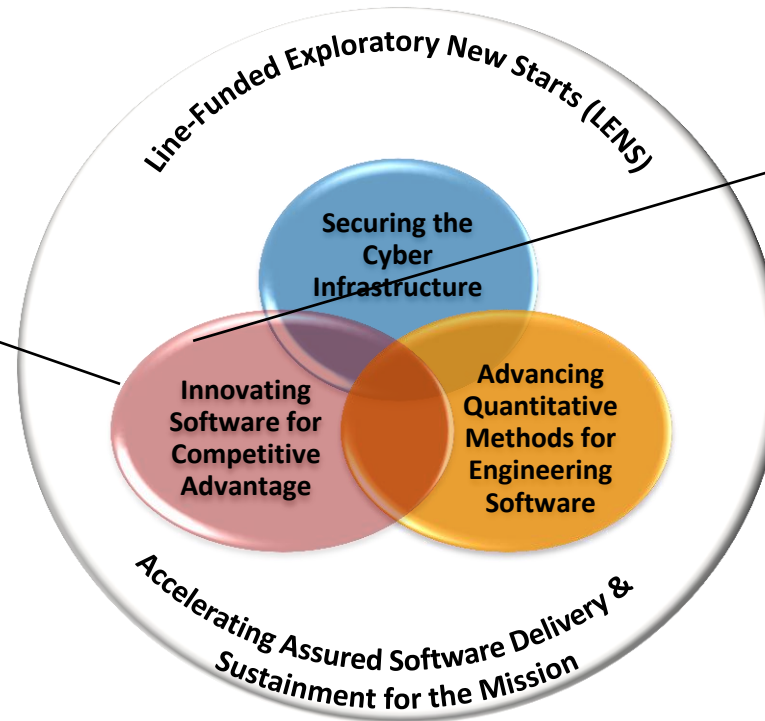
What We Are Doing

Produce innovations that revolutionize development of assured software-reliant systems

**Research, Technology,
& System Solutions
(RTSS)**

What Difference It Makes

Maintain US competitive edge software technologies vital to National security



EXPLORE

CREATE

APPLY

AMPLIFY

SUSTAIN

Summary of SEI's Strategic R&D Plan

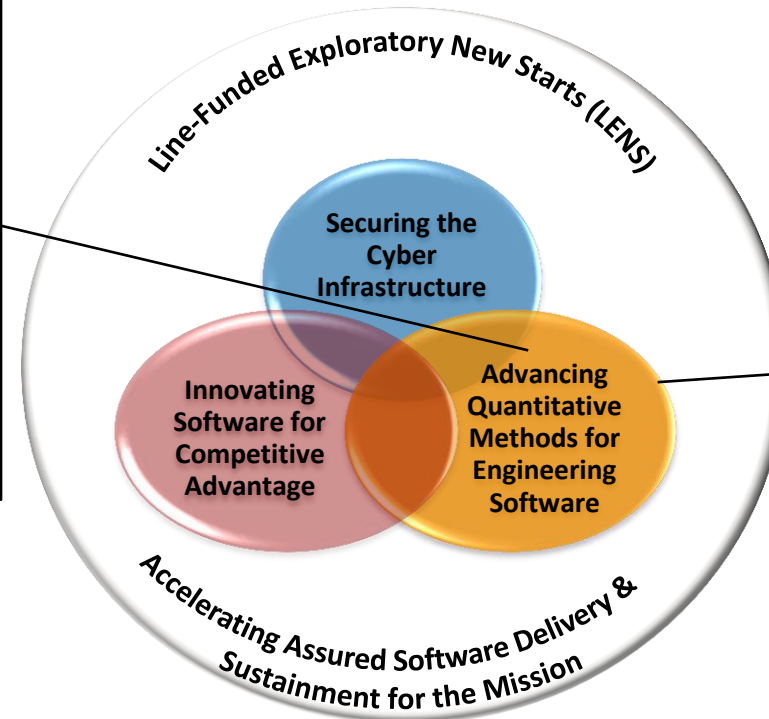
What We Are Doing

Improve the sustainment, affordability, & availability of software-reliant systems through quantitative models, measurement, & management methods

Software Engineering Measurement & Analysis (SEMA)

What Difference It Makes

Reduce the cost, acquisition time, & risk of our major defense acquisition programs



EXPLORE

CREATE

APPLY

AMPLIFY

SUSTAIN

Summary of SEI's Strategic R&D Plan

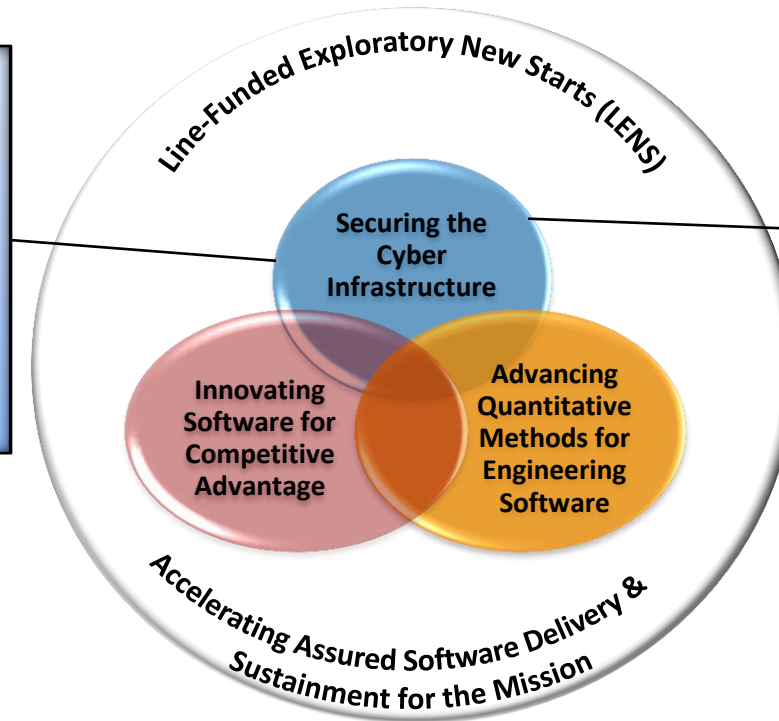
What We Are Doing

Enable informed trust & confidence in using information & communication technology to ensure a securely connected world

**Networked Systems
Survivability (NSS) &
CERT**

What Difference It Makes

Protect & sustain vital
US cyber assets &
services



EXPLORE

CREATE

APPLY

AMPLIFY

SUSTAIN

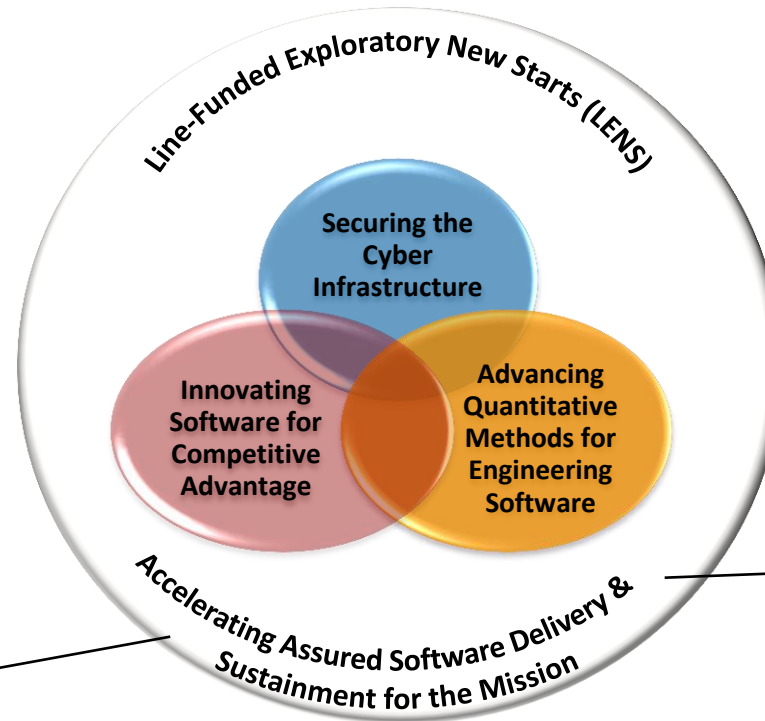
Summary of SEI's Strategic R&D Plan

What We Are Doing

What Difference It Makes

Acquisition Support Program (ASP)

Ensure predictable mission performance in the acquisition, operation, & sustainment of software-reliant systems



Expedite delivery of technical capabilities to win the current fight

EXPLORE

CREATE

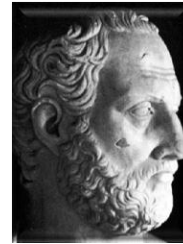
APPLY

AMPLIFY

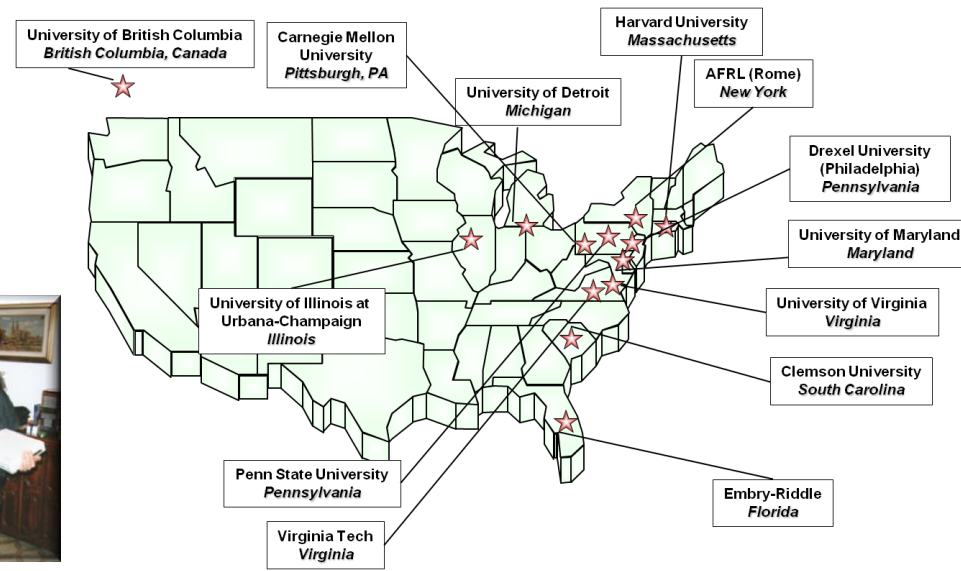
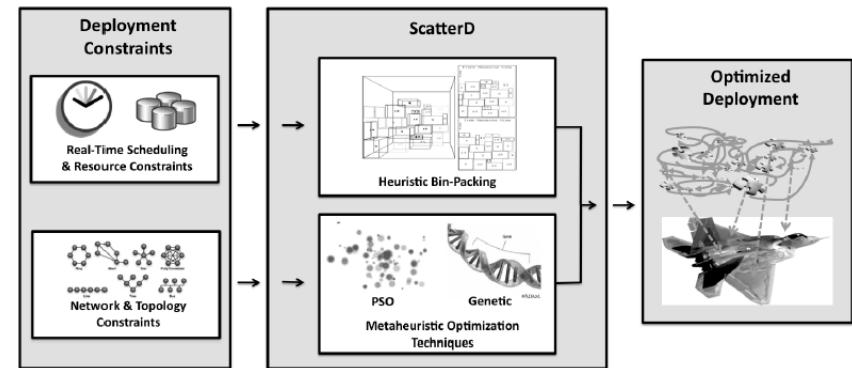
SUSTAIN

What I've learned Leading/Managing R&D Groups

- Dissemination of information is essential for visibility & continued success/impact
 - Publish where it matters to ensure the most success/impact
 - e.g., where the bulk of the sponsors, customers, & partners reside
- Software R&D impact most often comes from working on hard problems together with partners, customers, & consumers
 - Be relevant, modern, practical, & scalable
- Collaborations are essential to expand R&D reach & amplify R&D expertise
- “The more you give, the more you get”
 - Open-source can be an impact accelerator

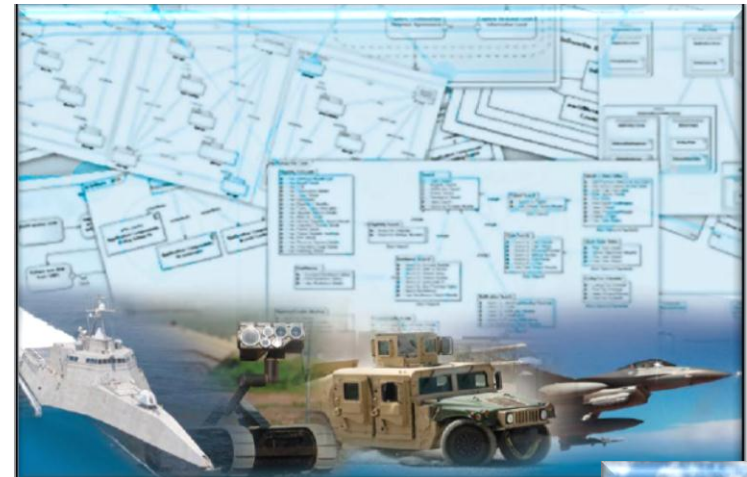


“A person who has the knowledge, but lacks the power to express it, is no better off than if he/she never had any ideas at all.” – Thucydides



Concluding Remarks

- In a highly commoditized, IT-driven economy, human resources are an increasingly strategic asset
 - Quality technical staff are rarely “plug compatible” or easily replaceable
- Premium value & competitive advantage accrues to individuals, organizations, & companies that
 - Continue to invest in software R&D &
 - Master principles, patterns, & protocols necessary to integrate COTS hardware & software to develop complex systems that can't be bought off-the-shelf yet
- To succeed requires close collaboration between academia, industry, & government



See blog.sei.cmu.edu for more discussions of SEI software R&D activities

Contact Information

Douglas C. Schmidt

Deputy Director, Research, & CTO

Telephone: +1 615-294-9573

Email: dschmidt@sei.cmu.edu

Web:

www.sei.cmu.edu

www.sei.cmu.edu/contact.cfm

U.S. mail:

Software Engineering Institute

Carnegie Mellon University

4500 Fifth Avenue

Pittsburgh, PA 15213-2612

USA

Customer Relations

Email: info@sei.cmu.edu

Telephone: +1 412-268-5800

SEI Phone: +1 412-268-5800

SEI Fax: +1 412-268-6257



- This material SHALL NOT be reproduced or used for any other purpose without requesting formal permission from the SEI at permission@sei.cmu.edu.
- THE MATERIAL IS PROVIDED ON AN “AS IS” BASIS, & CARNEGIE MELLON DISCLAIMS ANY & ALL WARRANTIES, IMPLIED OR OTHERWISE (INCLUDING, BUT NOT LIMITED TO, WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE, RESULTS OBTAINED FROM USE OF THE MATERIAL, MERCHANTABILITY, AND/OR NON-INFRINGEMENT).



Conducting Leading-Edge Software R&D in a
Globalized, Commoditized World

Backup

Host Infrastructure Middleware

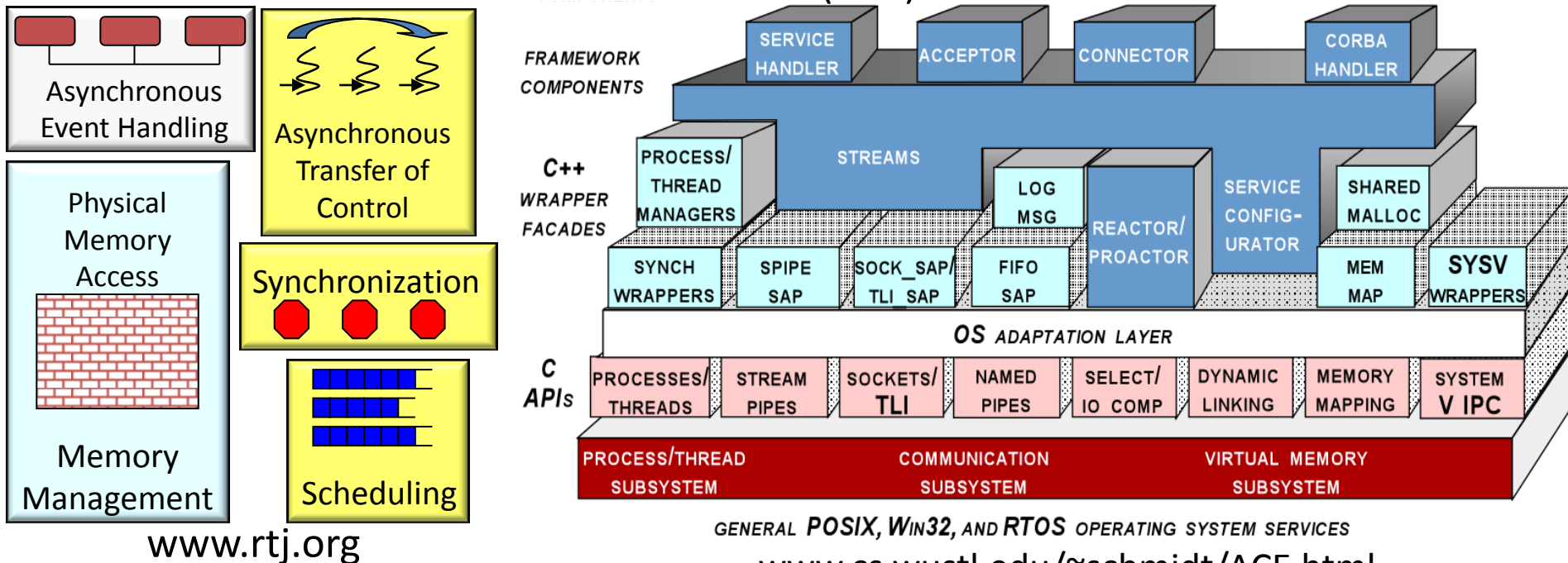
Domain-Specific Services

Common Middleware Services

Distribution Middleware

Host Infrastructure Middleware

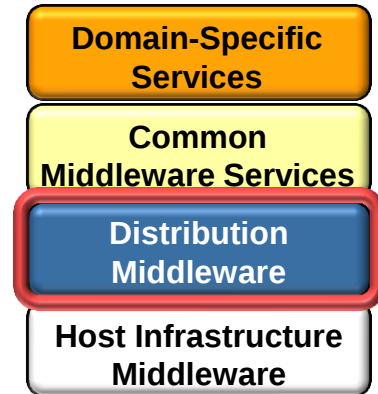
- Encapsulates & enhances native OS mechanisms to create reusable network programming components
- Examples
 - Java Virtual Machine (JVM), Common Language Runtime (CLR), ADAPTIVE Communication Environment (ACE)



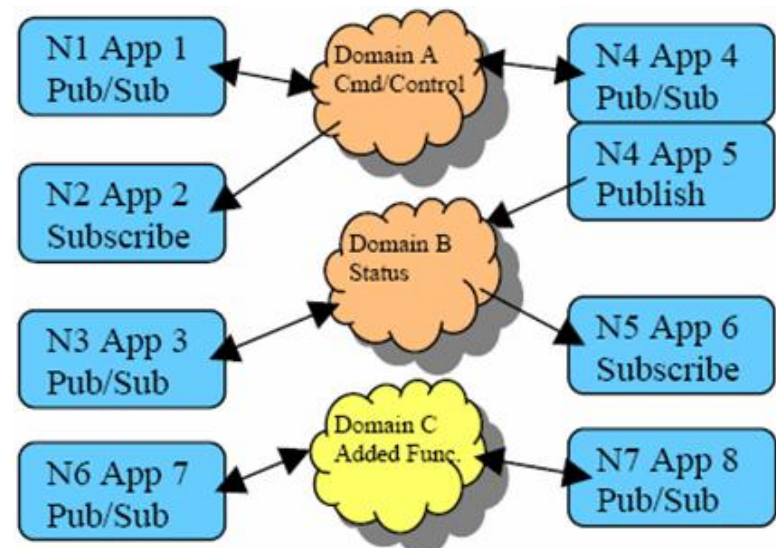
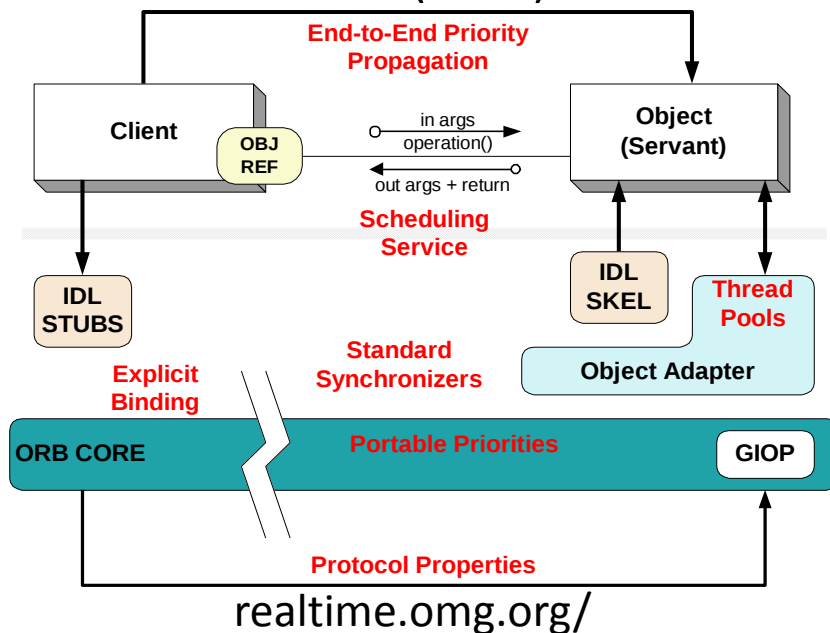
www.cs.wustl.edu/~schmidt/ACE.html

Host infrastructure middleware components abstract away many tedious & error-prone aspects of low-level OS APIs

Distribution Middleware



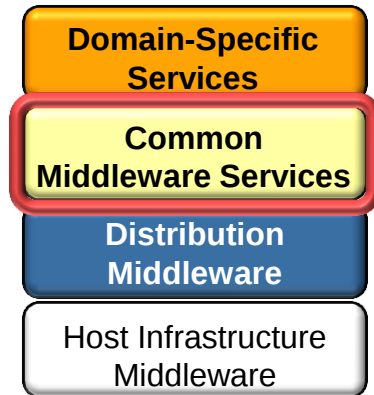
- Defines distributed programming models whose reusable APIs & components automate & extend native OS capabilities
- Examples
 - OMG Real-time CORBA & the Data Distribution Service (DDS), W3C Simple Object Application Protocol (SOAP) Remote Procedure Calls (RPCs)



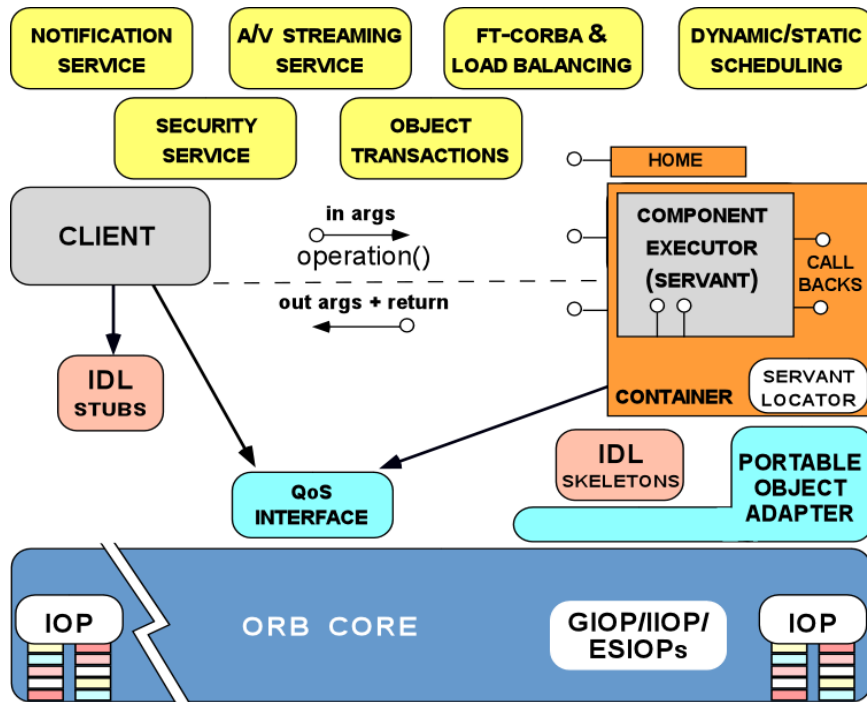
en.wikipedia.org/wiki/Data_Distribution_Service

Distribution middleware avoids hard-coding client & server application dependencies on object location, language, OS, protocols, & hardware

Common Middleware Services

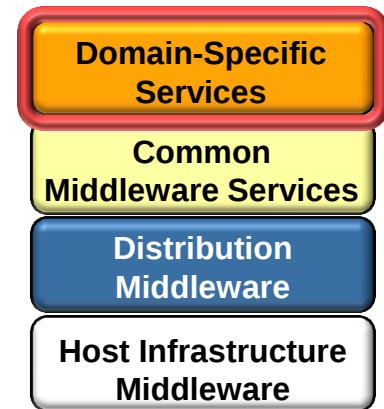


- Augments distribution middleware by defining domain-independent services that focus on programming “business logic”
- Examples
 - Sun’s J2EE, Microsoft’s .NET, W3C Web Services, CORBA Component Model & Object Services

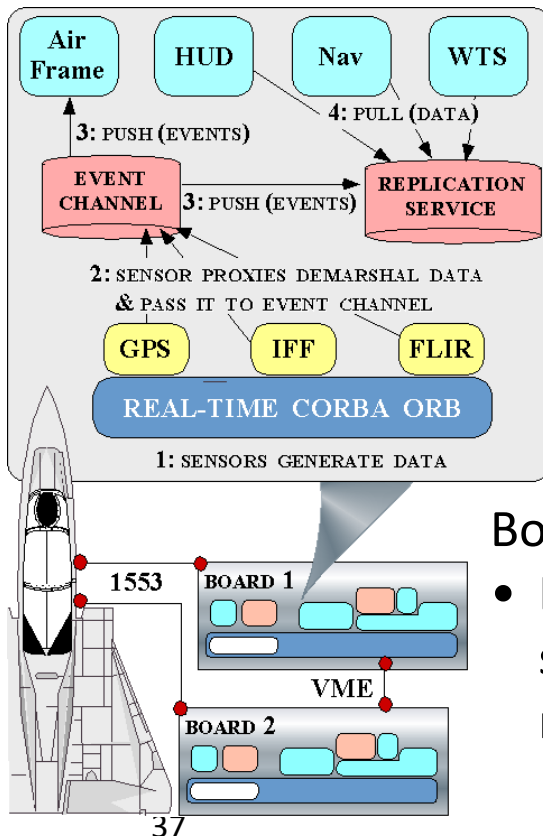


- Common middleware services support many recurring distributed system capabilities, e.g.,
 - Transactions & load balancing
 - Authentication & authorization
 - Database connection pooling & concurrency control
 - Active or passive replication
 - Dynamic resource management

Domain-Specific Middleware



- Services tailored to the requirements of particular domains, such as telecom, e-commerce, health care, process automation, avionics, etc.
- Examples

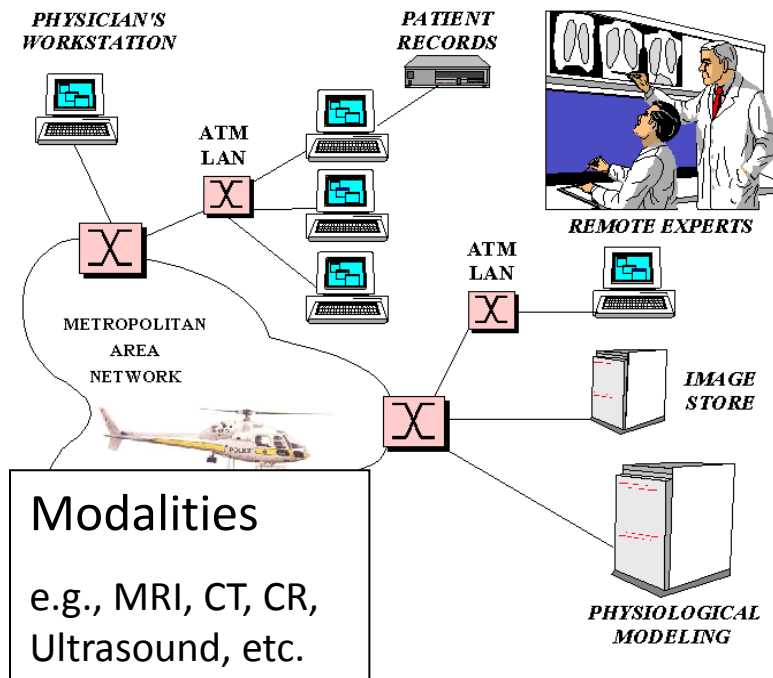


Siemens MED Syngo

- Domain-specific services for distributed electronic medical systems
- Used by all Siemens MED business units worldwide

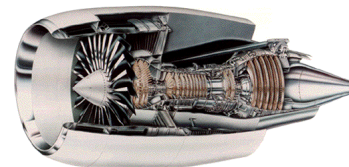
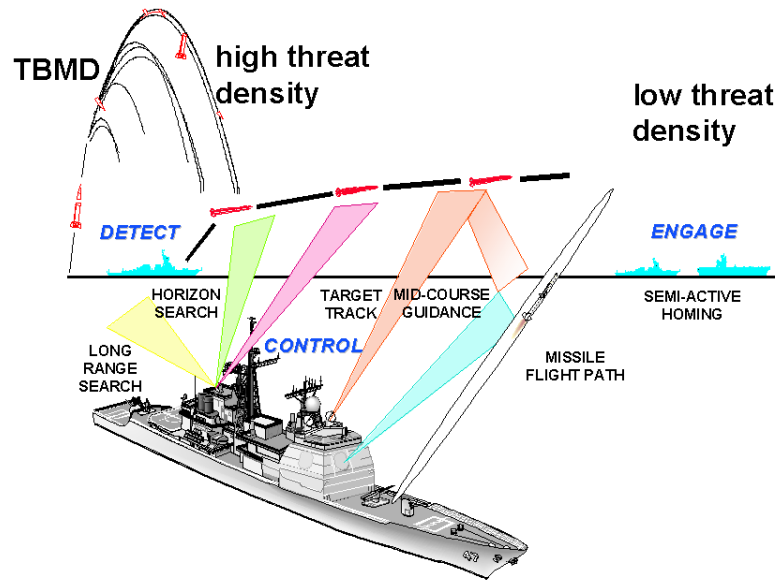
Boeing Bold Stroke

- Domain-specific services for avionics mission computers



My R&D Background: Software for Distributed Real-time & Embedded (DRE) systems

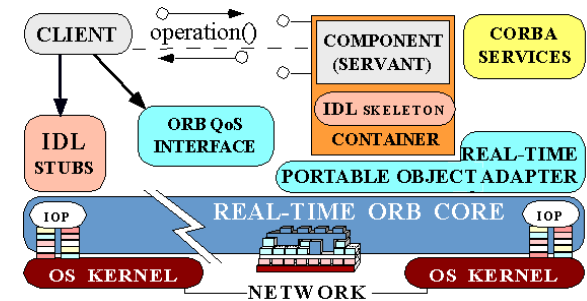
In DRE systems the “right answer” delivered too late becomes the “wrong answer”!!



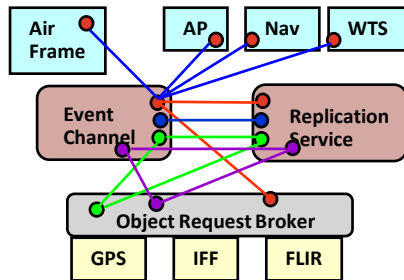
My Areas of Expertise: Patterns, Frameworks, & Tools for DRE System Middleware & Applications

www.dre.vanderbilt.edu/~schmidt

QoS-enabled
component
middleware &
frameworks

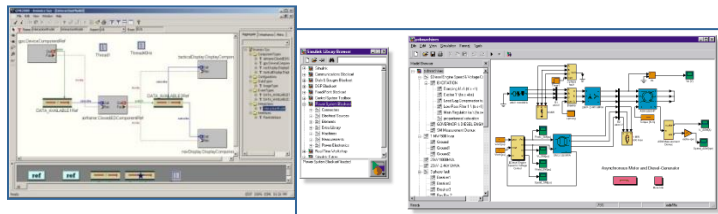


Multi-faceted Software
Development



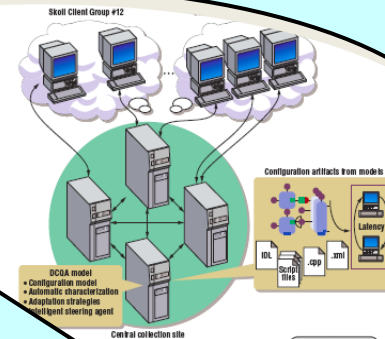
Cross-cutting Concerns

- Synchronization
- Memory Management
- Persistence
- Fault Tolerance

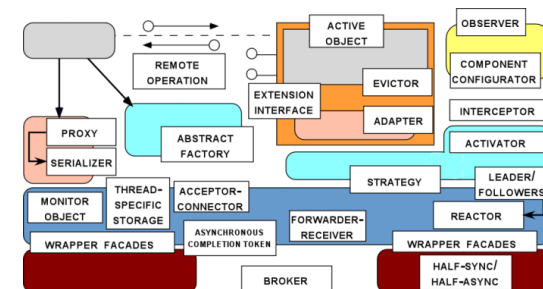


Model-based analysis, generation, & integration

Distributed
continuous
quality assurance
techniques



Patterns to
capture best
practices & design
experience



Some Measures of My R&D Impact

www.dre.vanderbilt.edu/~schmidt/CV.html

- 500+ papers & 10 books
 - “h index” = 62
- \$26+ M funding from 50+ sponsors
- 40+ Ph.D. & MS students graduated
- Created 3+ million lines of open-source software
 - download.dre.vanderbilt.edu
- 1,000+ of commercial & military users
 - www.dre.vanderbilt.edu/users.html



Alcatel-Lucent

SAMSUNG

ERICSSON

NOKIA

SIEMENS

CISCO SYSTEMS



Communications

BOEING

NORTHROP GRUMMAN

LOCKHEED MARTIN

THALES

Raytheon

GENERAL DYNAMICS

Military/Aerospace



GE Healthcare



SIEMENS
medical

Health Care



Morgan Stanley

citigroup

Bloomberg

JPMorgan

Financial Services

Some Measures of My R&D Impact

www.dre.vanderbilt.edu/~schmidt/CV.html

- 500+ papers & 10 books
 - “h index” = 62
- \$26+ M funding from 50+ sponsors
- 40+ Ph.D. & MS students graduated
- Created 3+ million lines of open-source software
 - download.dre.vanderbilt.edu
- 1,000+ of commercial & military users
 - www.dre.vanderbilt.edu/users.html
- Spawned \$100+ million industry over past decade



Remedy IT



www.dre.vanderbilt.edu/support.html