Software Engineering Institute | Carnegie Mellon

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

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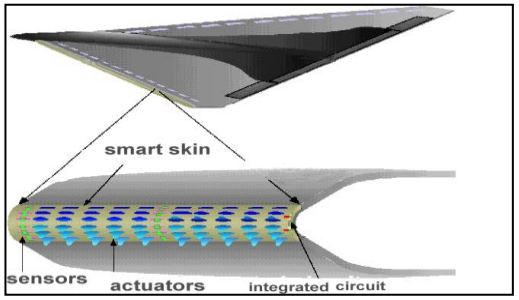
Software Engineering Institute, CMU

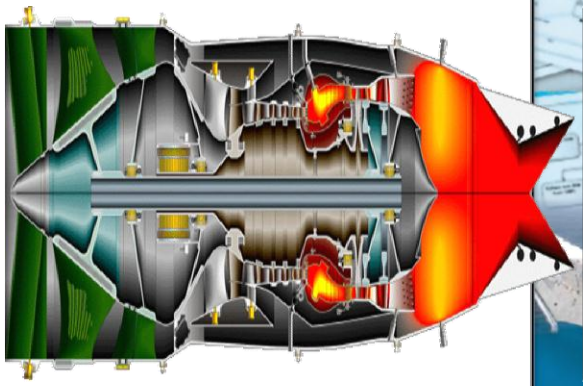
What this Talk is About

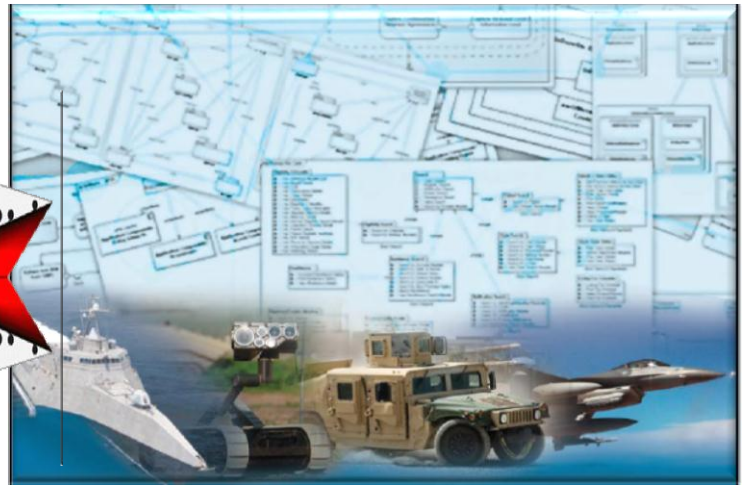
- The impact of **globalization** & **commoditization** of information technology (IT) on **software R&D**
- **Globalization**
  - "I speak Spanish to my God, Italian to women, French to men, German to my horse, & Japanese to my boss"
    - Paraphrasing King Charles the 5th of Spain

- **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

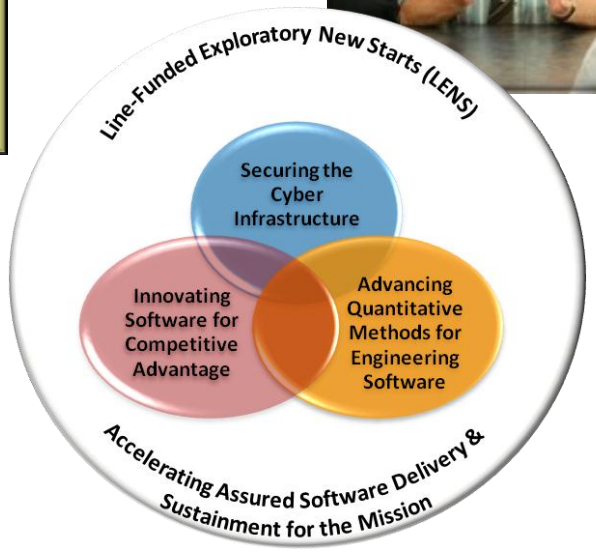
CTO

CTO

CTO

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

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Consequences of IT Commoditization

The Road Ahead

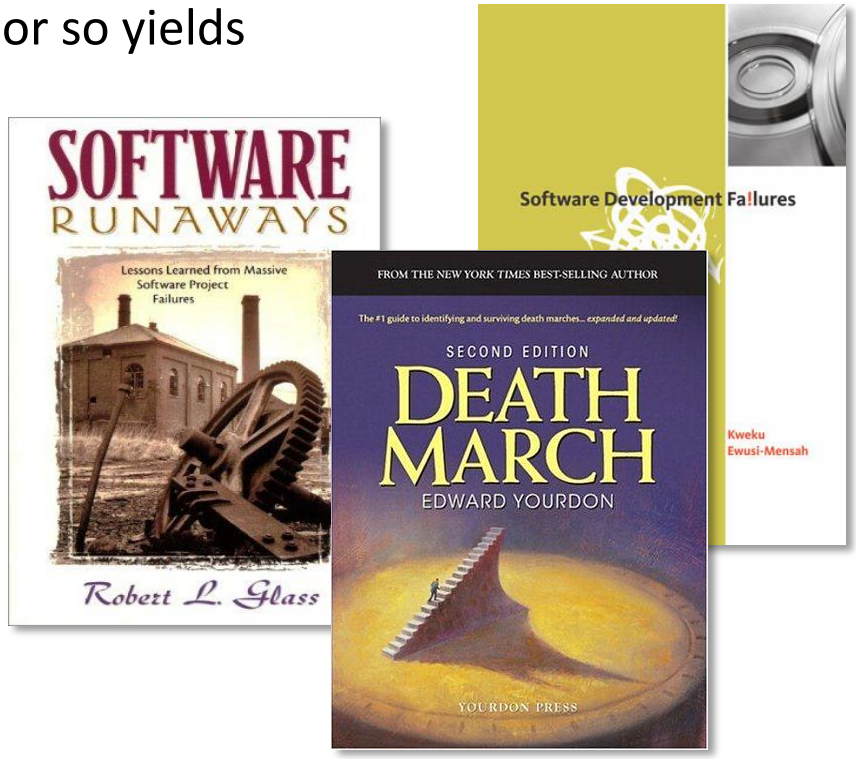
CPU & network performance has increased by orders of magnitude in past decades

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



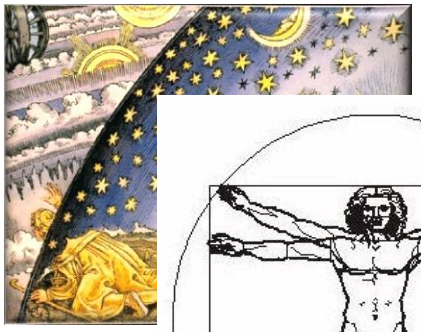
Standard/COTS Hardware & Networks

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

Human Nature



Accidental Complexities

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

Inherent Complexities

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

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

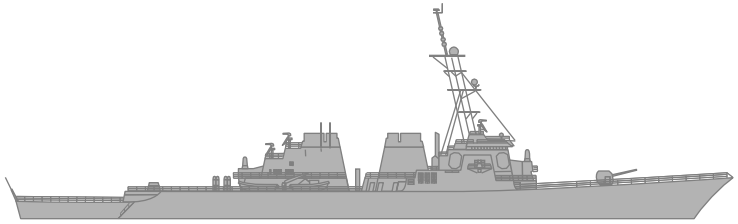
www.cs.wustl.edu/~schmidt/reuse-lessons.html

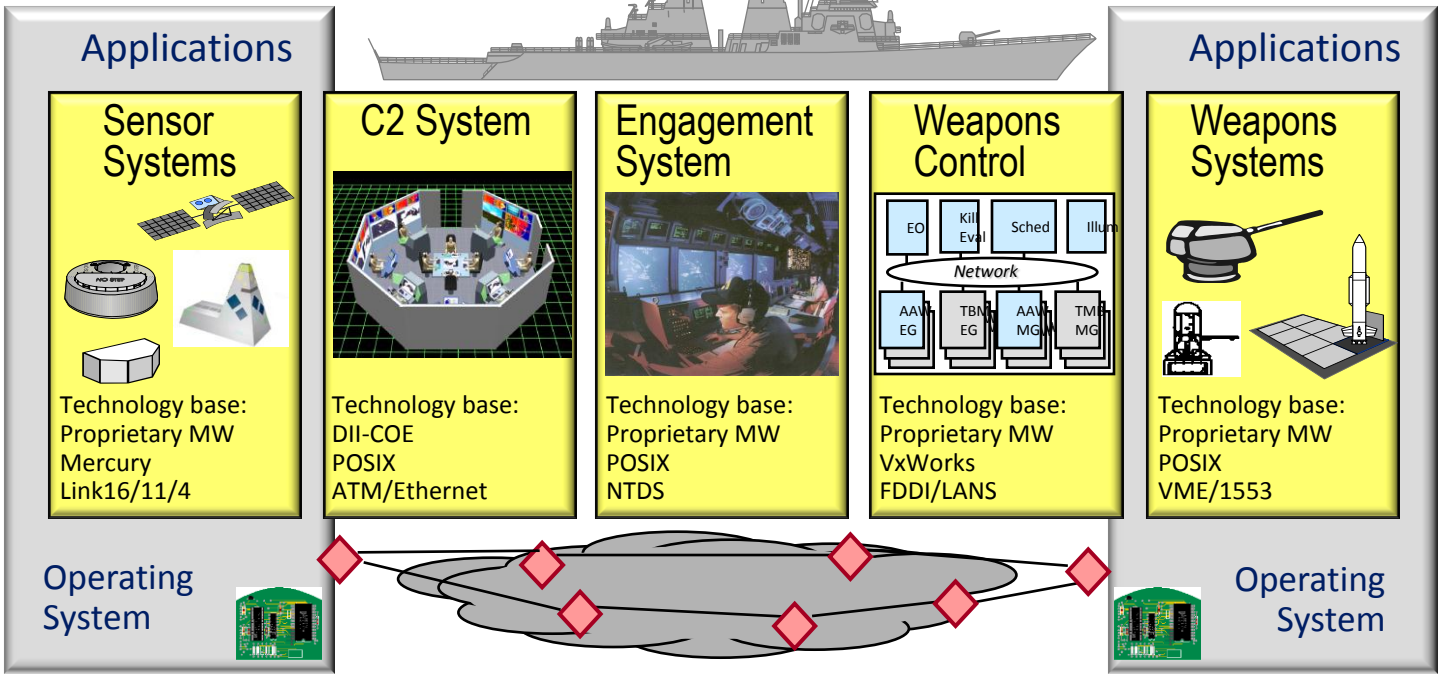
Evolution of DoD Software Development

Legacy DoD systems have historically been:

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

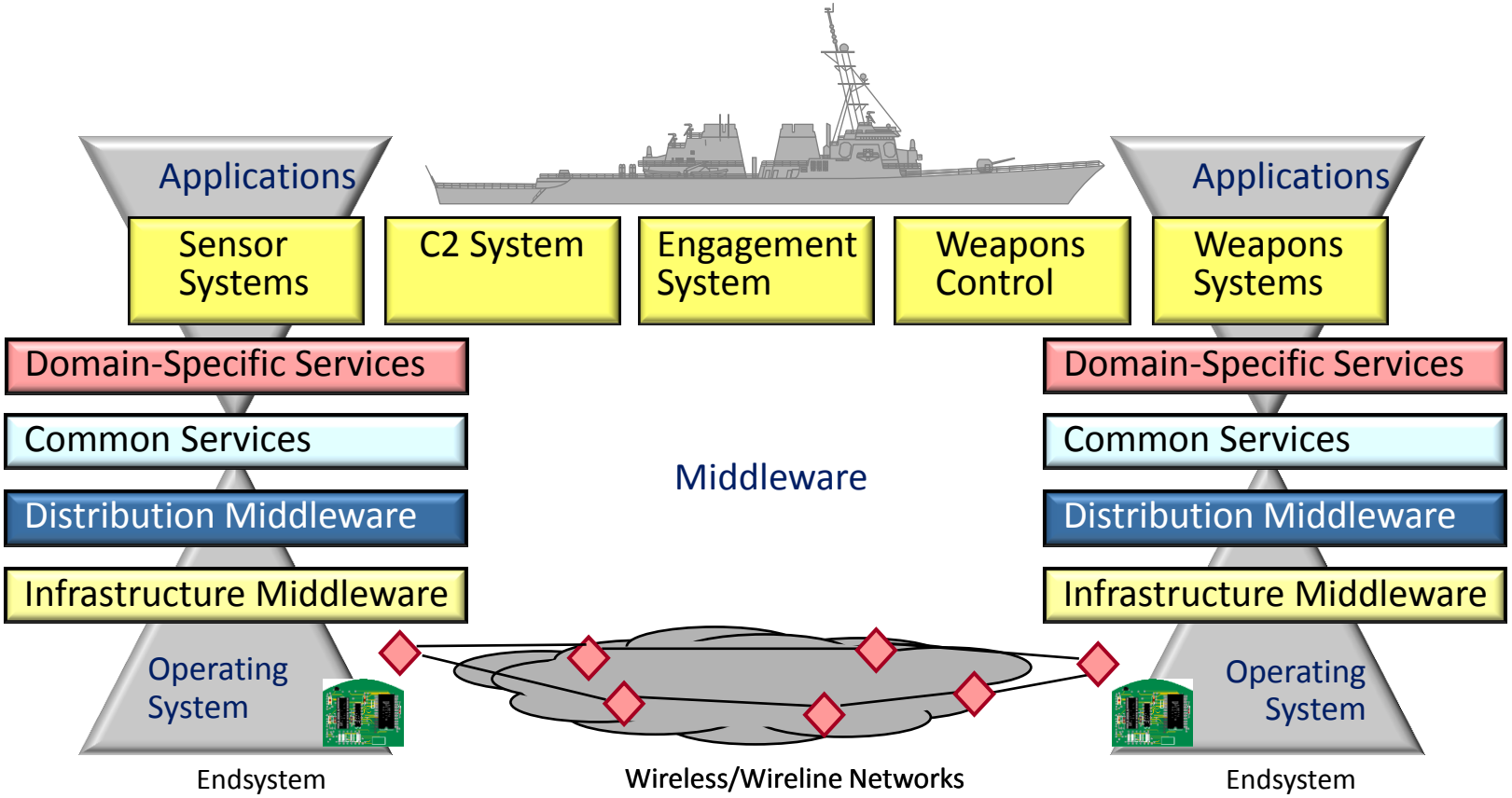
Consequence: Small HW/SW changes have big impact on system QoS & maintenance



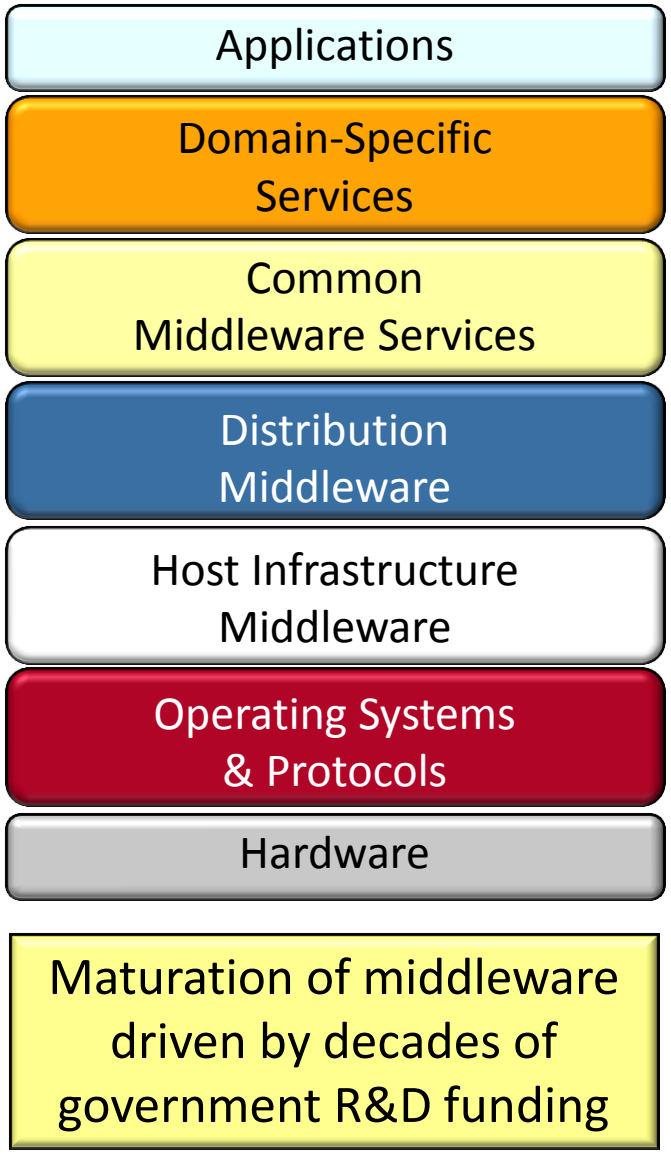


Evolution of DoD Software Development

- *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

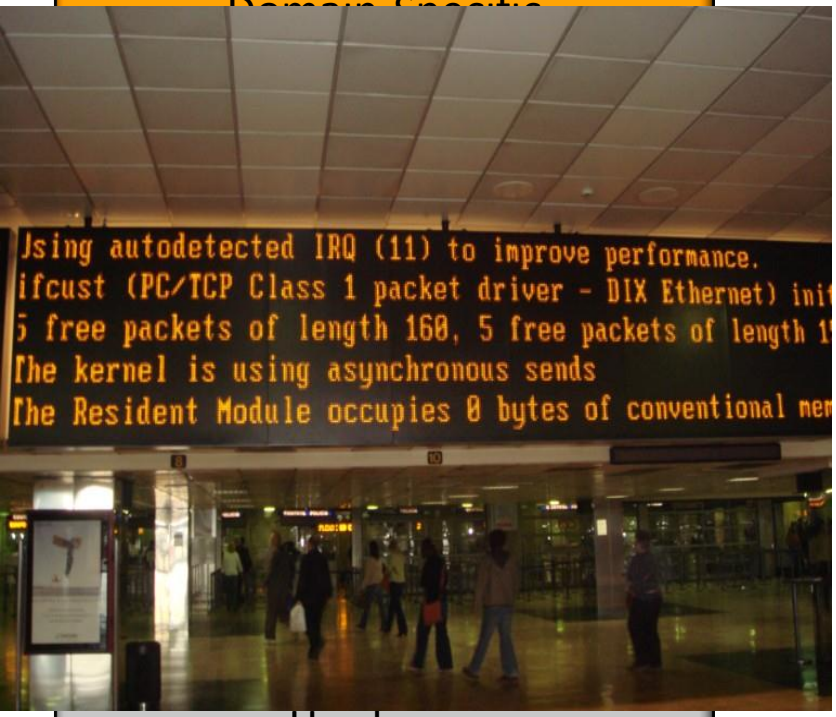
- Tedious, error-prone, & costly over lifecycles

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

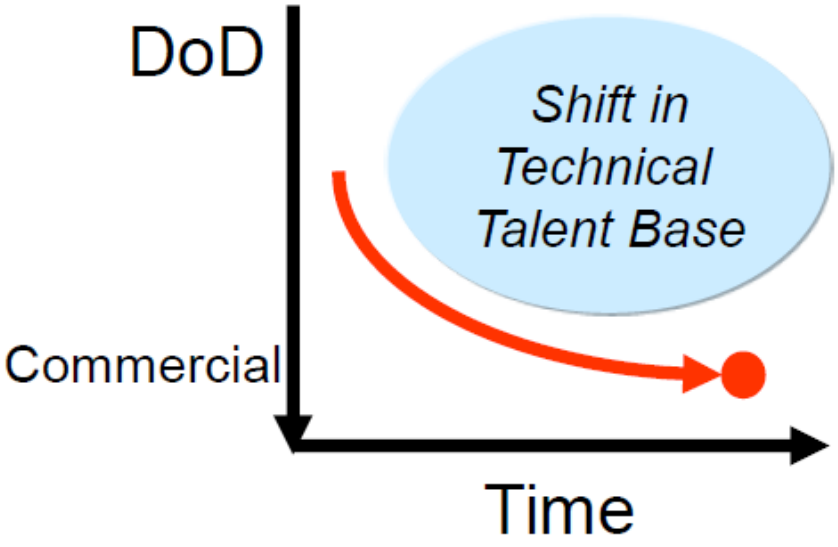


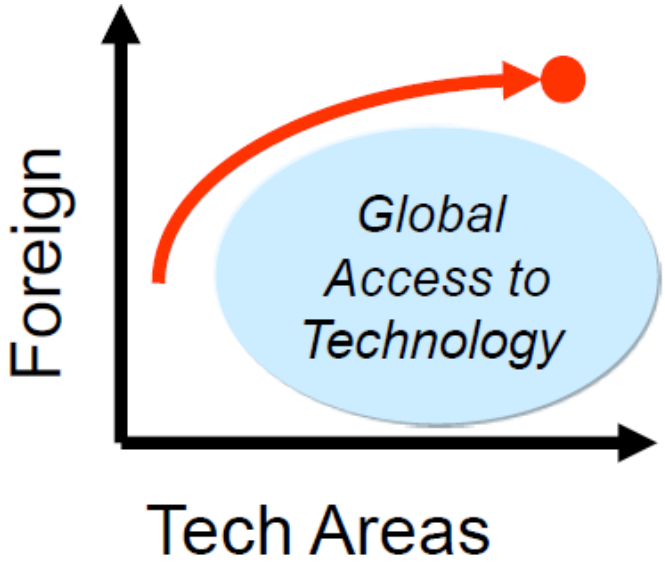
- More emphasis on integration rather than programming
- Increased technology convergence & standardization
- Mass market economies of scale for technology & personnel
- More disruptive technologies & global competition
- Lower priced—but often lower quality—hardware & software components
- The decline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

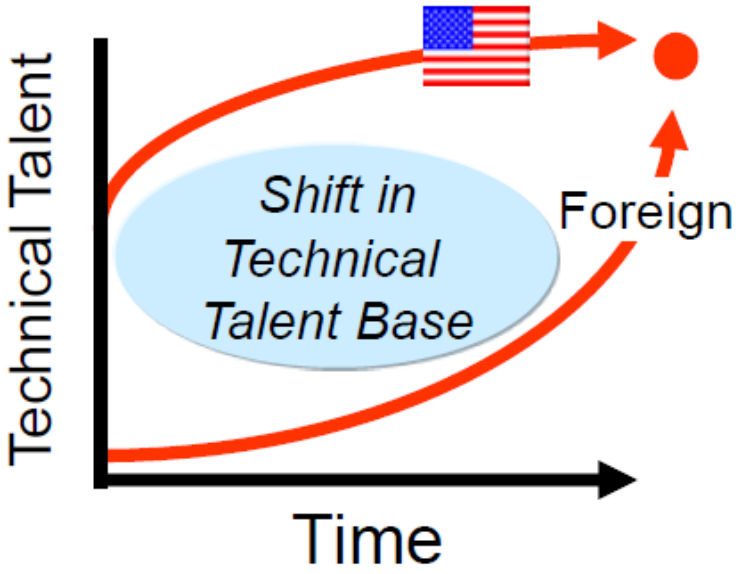
Not all trends bode well for traditional business & technology leaders

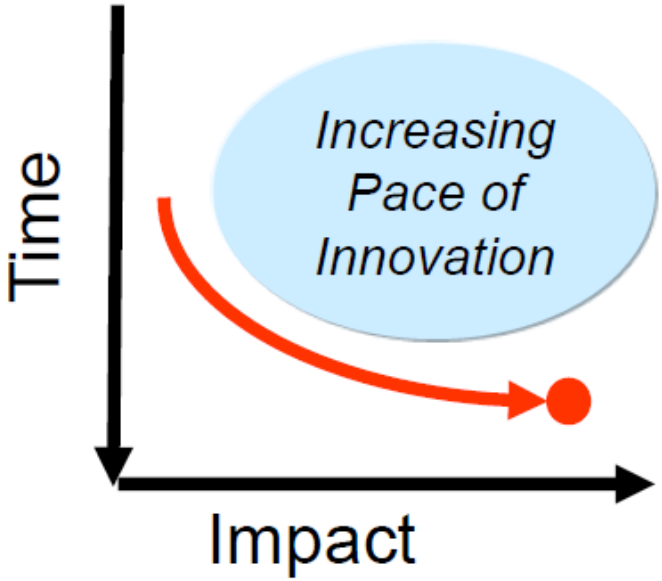
Ultimately, success requires mastery of non-commoditized domains, e.g., distributed real-time & embedded systems

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

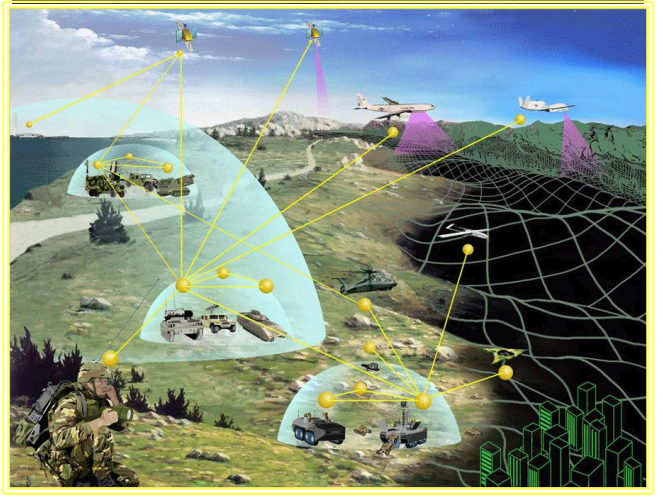
F/A-22

SBIRS High

Joint Tactical Radio Systems (JTRS)

DDG 1000

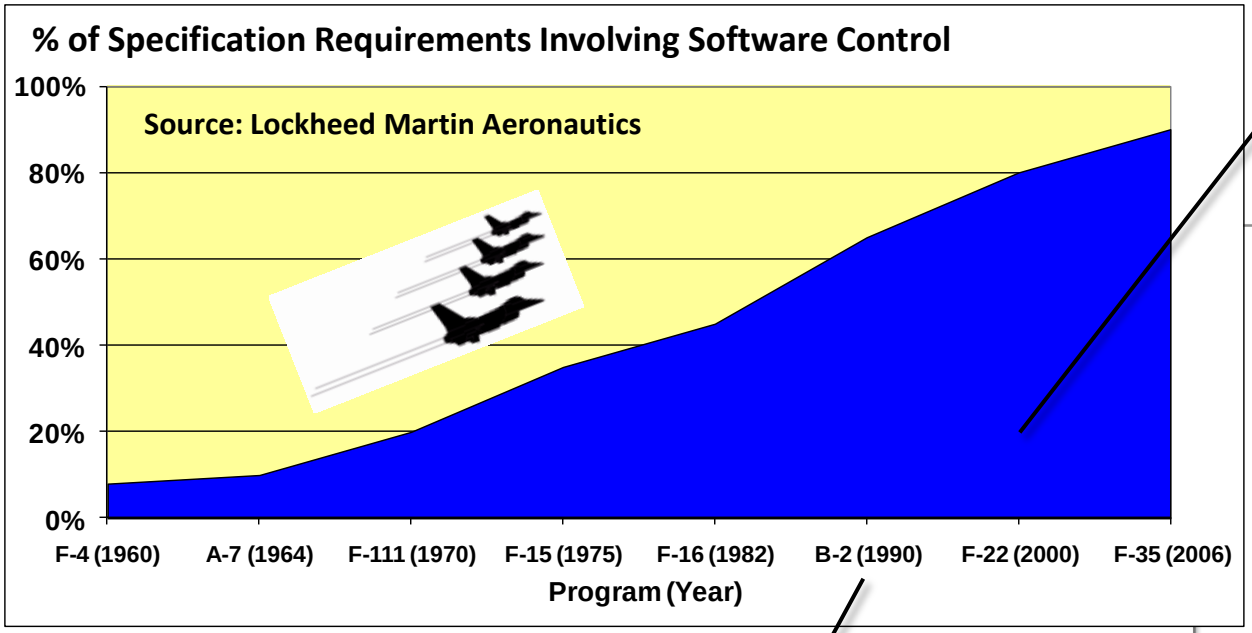
Future Combat System (FCS)



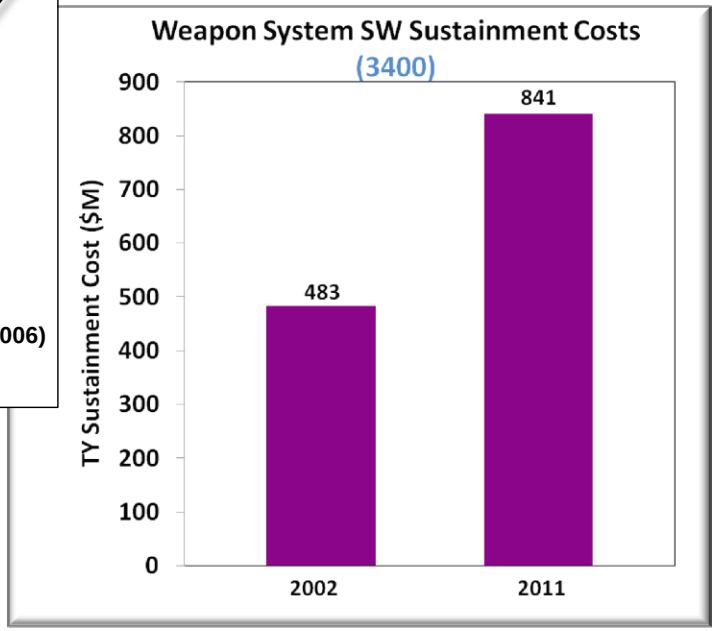
"If software isn't a major part of the cost of weapons systems, then it's a very significant part of the cost … You can build a frigate which costs $500 million to buy, but the largest part of the expense would not be the hull or the weapons, it would be the hardware and software."

"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

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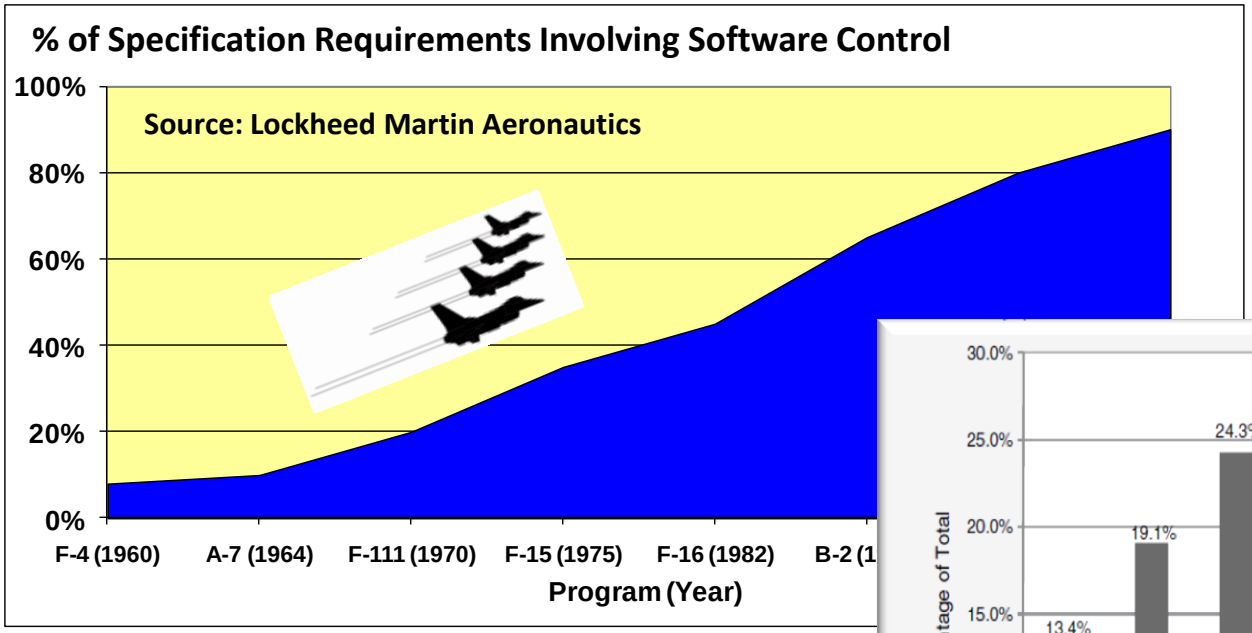


A 45% reduction in constant dollars over past decade for software research (SDP & HCSS)

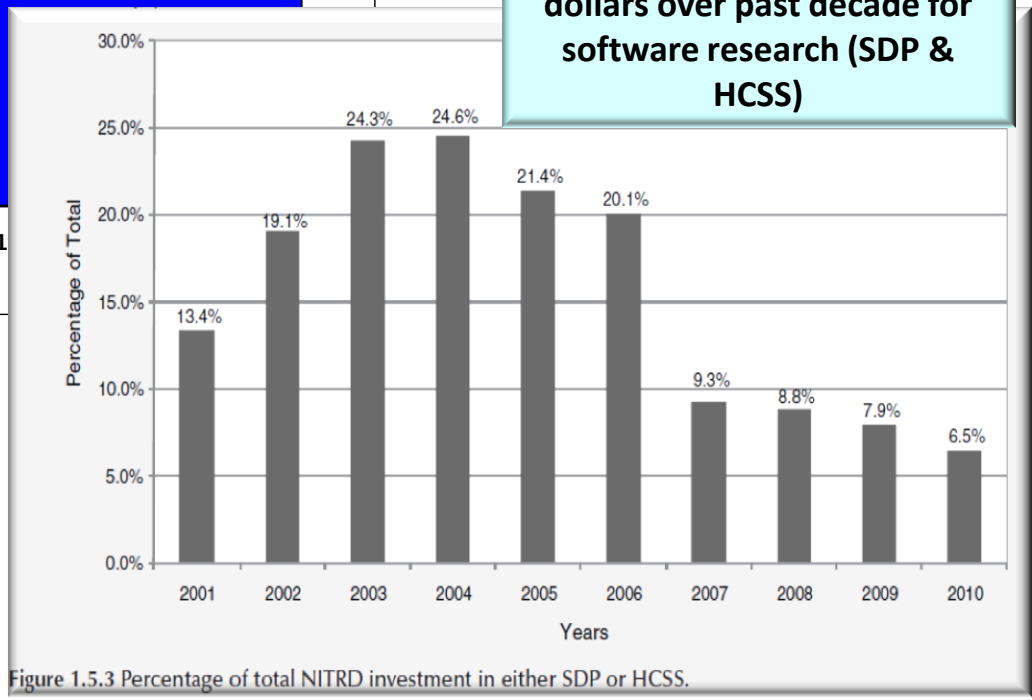


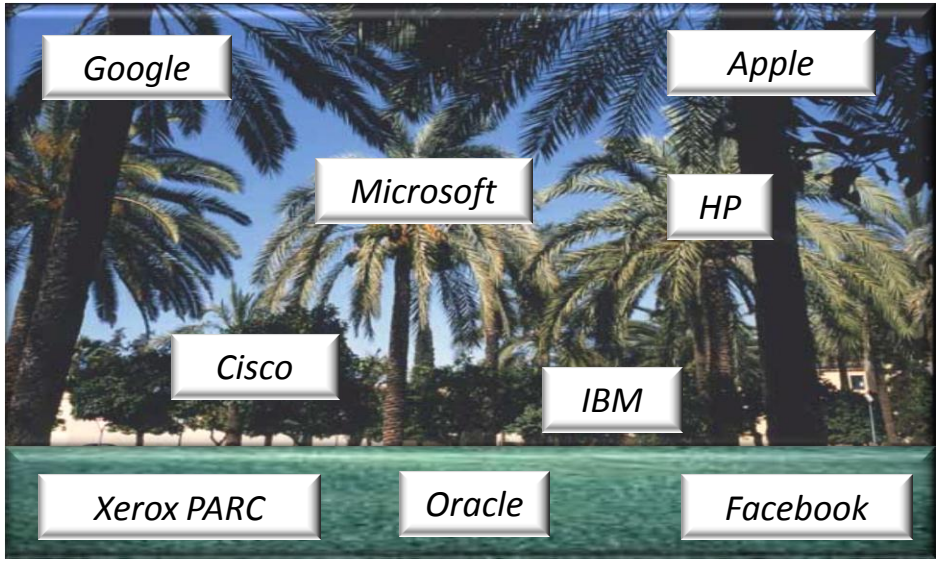
Figure 1.5.3 Percentage of total NITRD investment in either SDP or HCSS.

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

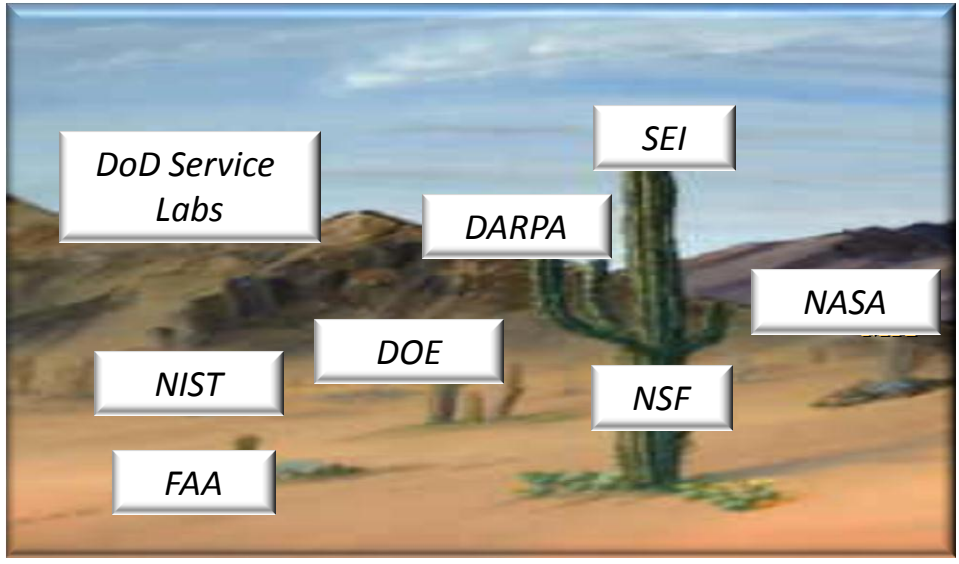
From NRC Report *Critical Code: Software Producibility for Defense* (2010), sponsored by Office of the Secretary of Defense (OSD)
www.nap.edu/openbook.php?record_id=12979&page=R1

DoD Software Science & Technology Status

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

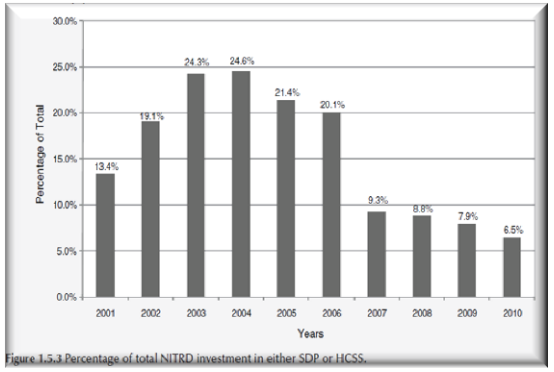


Reality
IT R&D investment is needed to seed & transform the IT desert for the DoD



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



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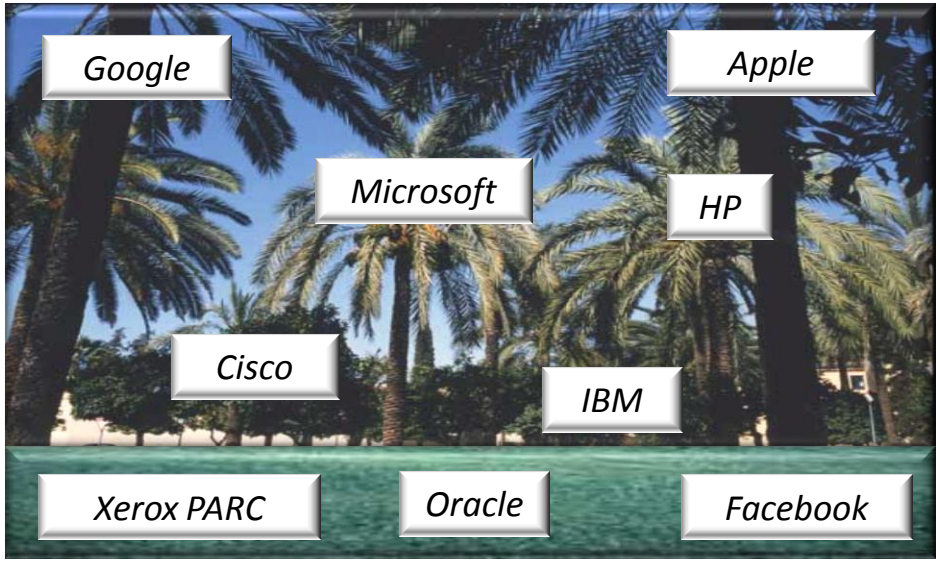

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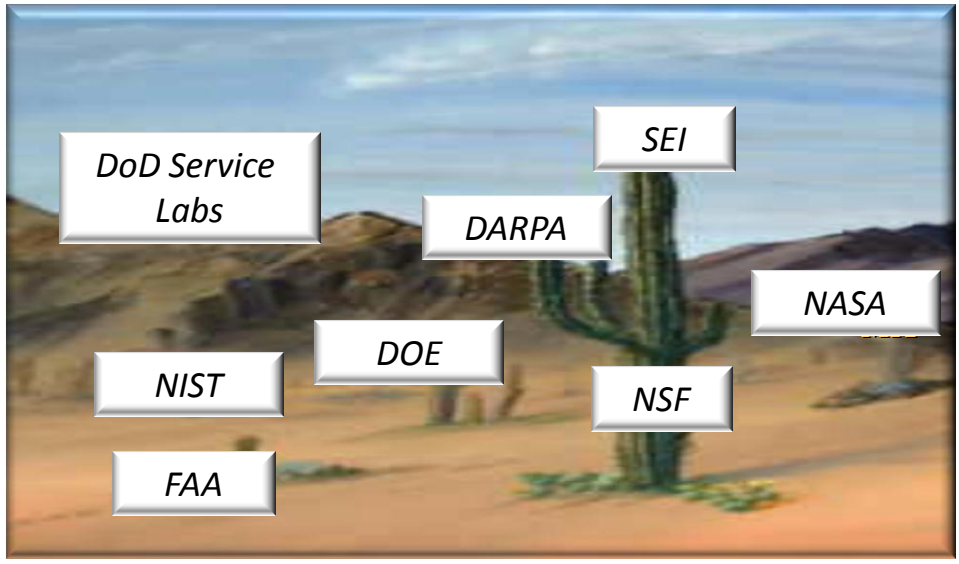


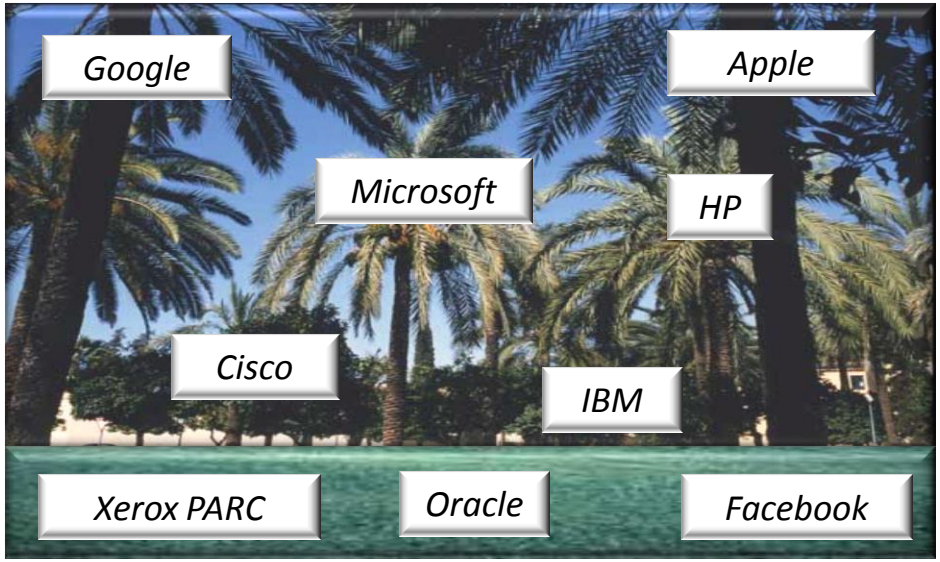
Why Commercial Industry Alone Won't Solve the DoD Software Problem

- 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



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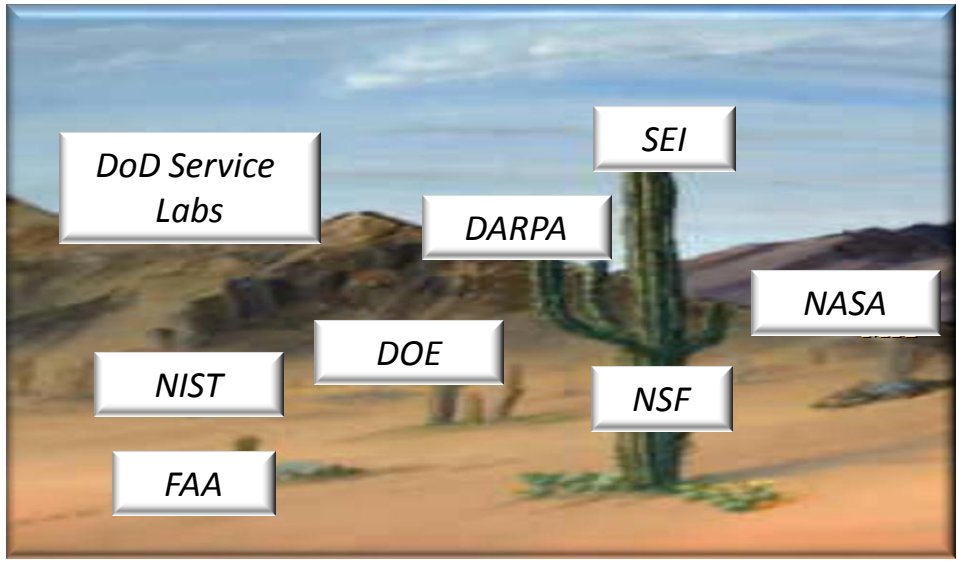


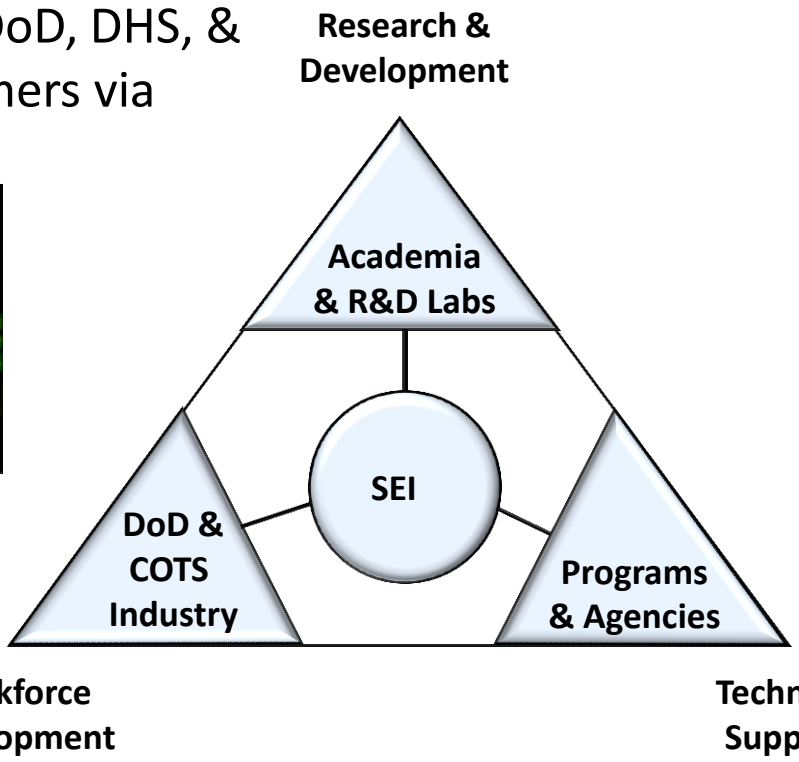
Why Defense Industry Alone Won't Solve the DoD Software Problem

- 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



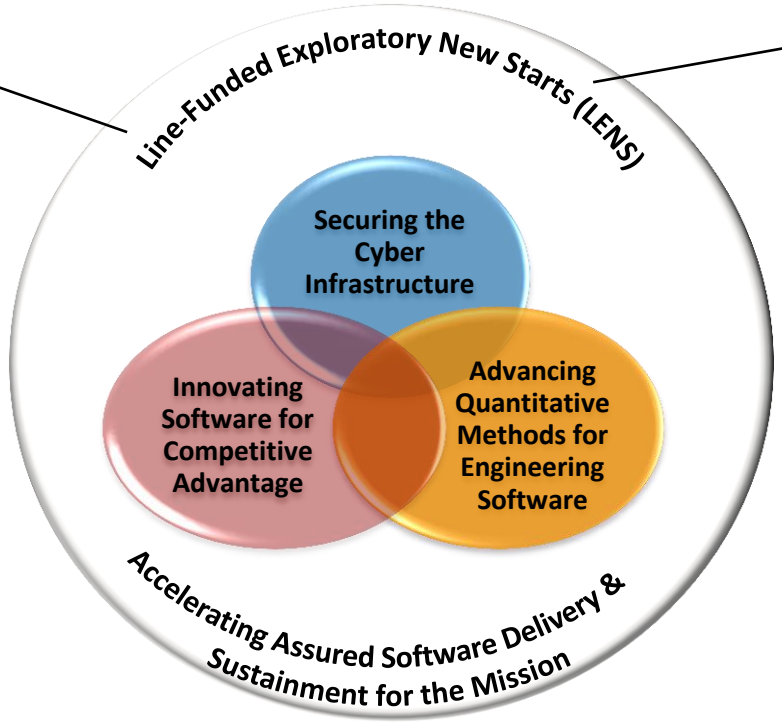
Summary of SEI's Strategic R&D Plan

What We Are Doing

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

What Difference It Makes

Prepare for an uncertain future

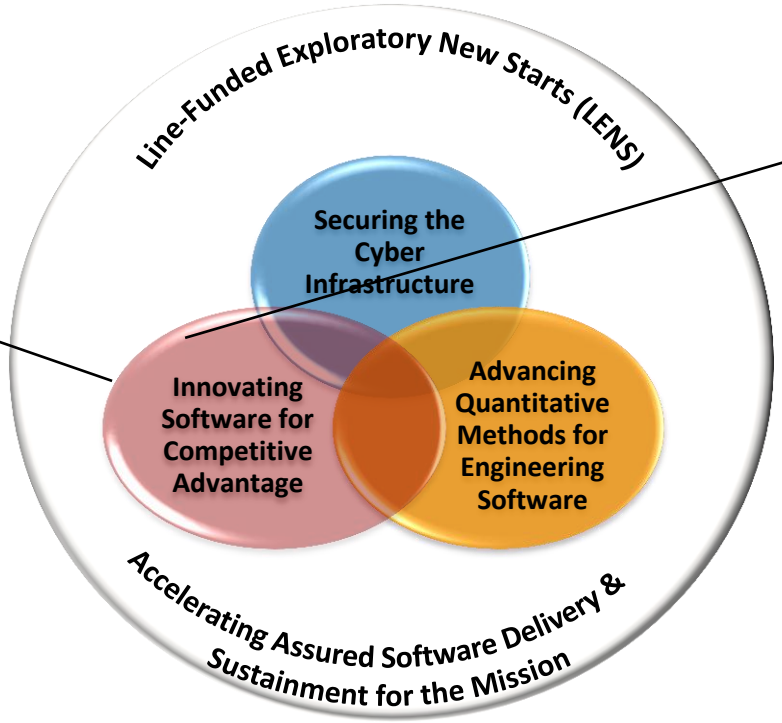


Summary of SEI's Strategic R&D Plan

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

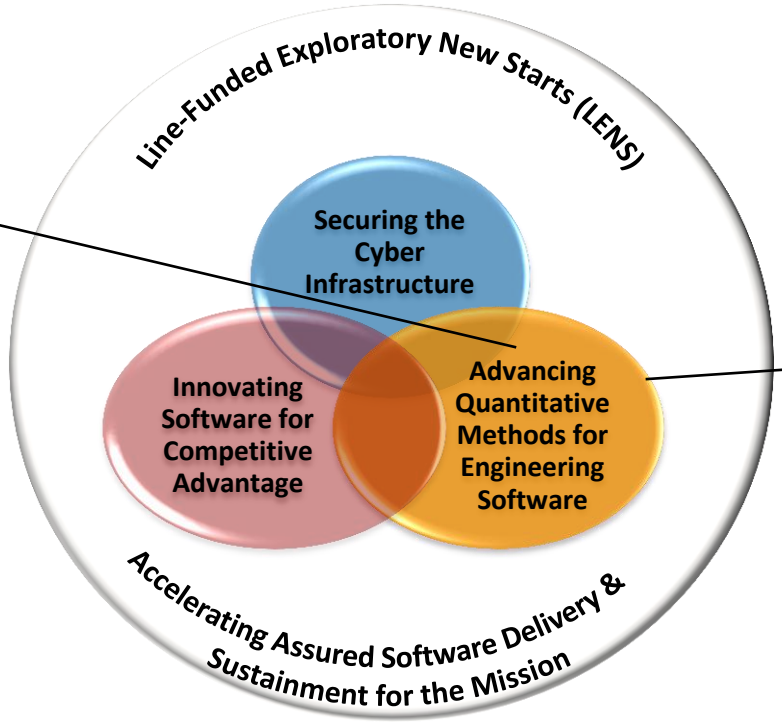
EXPLORE | CREATE | APPLY | AMPLIFY | SUSTAIN

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

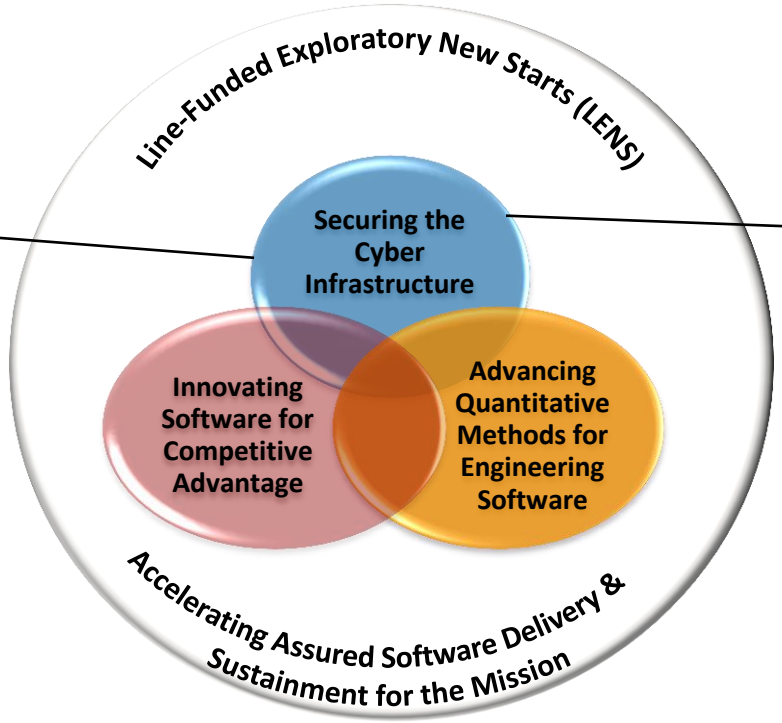
EXPLORE | CREATE | APPLY | AMPLIFY | SUSTAIN

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

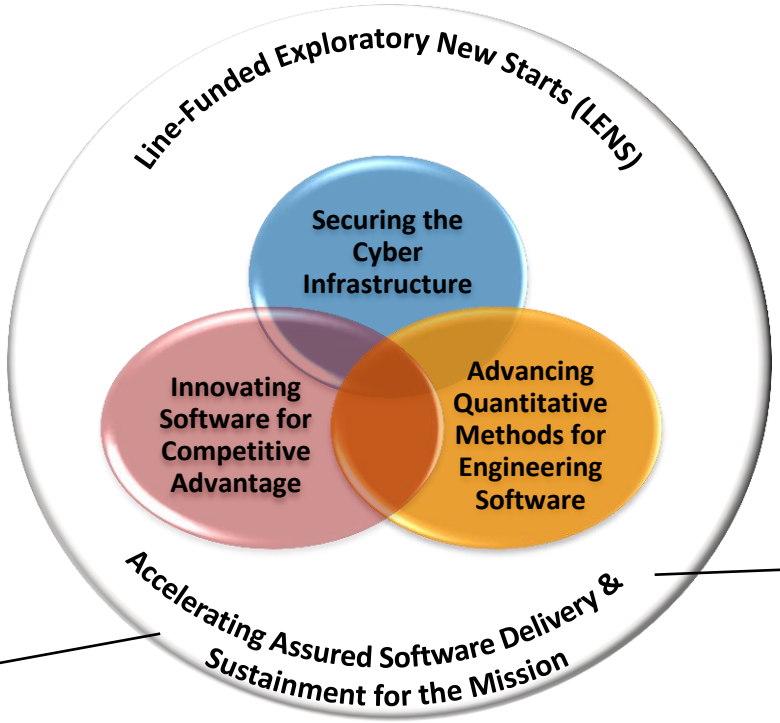
Summary of SEI's Strategic R&D Plan

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

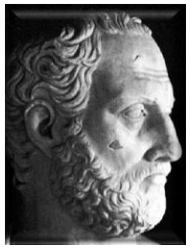


Expedite delivery of technical capabilities to win the current fight

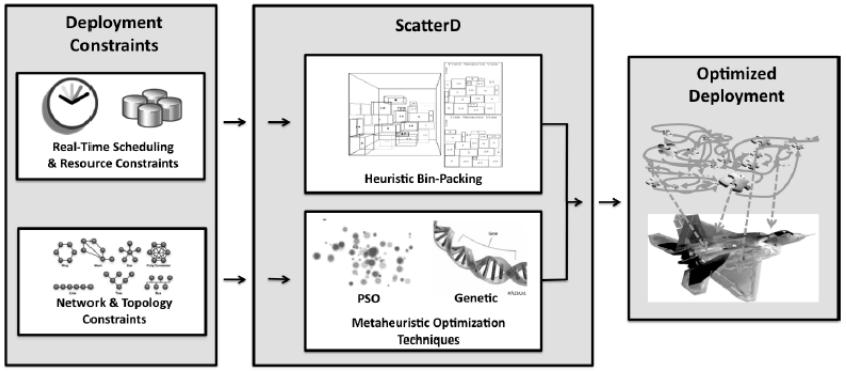
EXPLORE | CREATE | APPLY | AMPLIFY | SUSTAIN

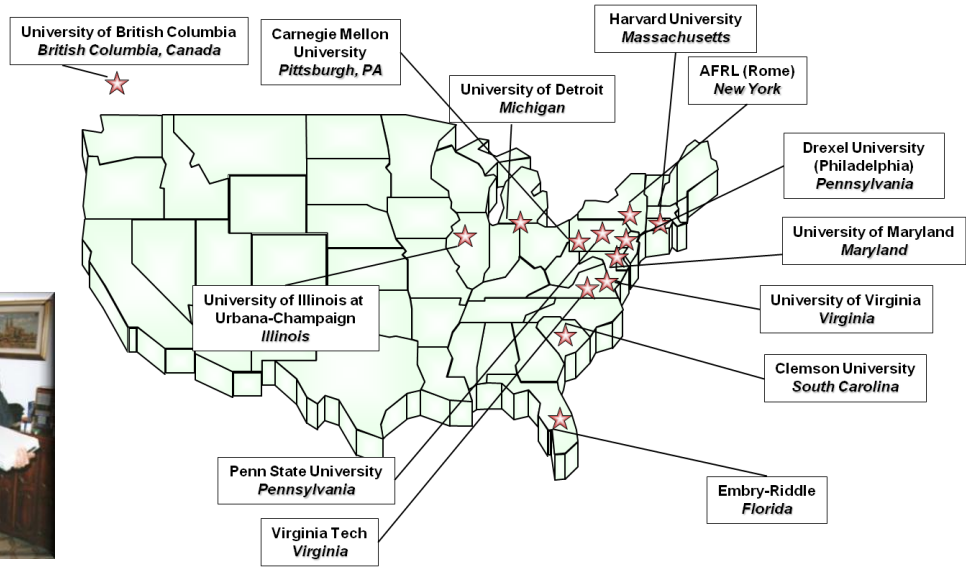
What I've learned Leading/Managing R&D Groups

- 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

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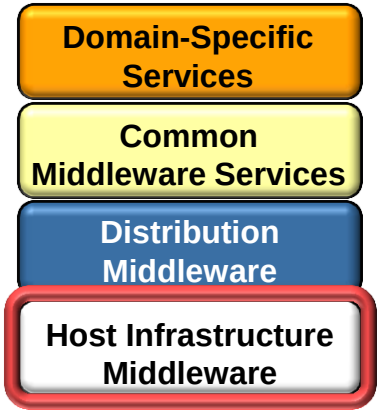
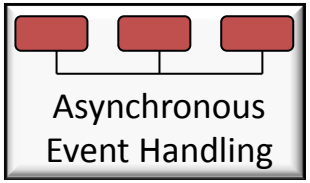
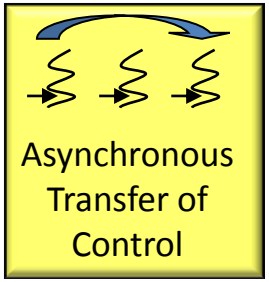
Backup

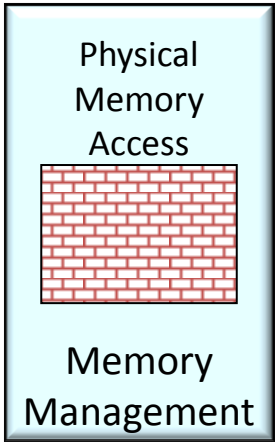
Host Infrastructure Middleware

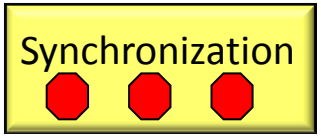


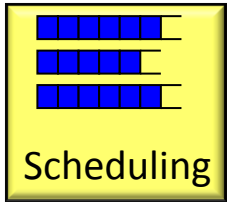
- Encapsulates & enhances native OS mechanisms to create reusable network programming components
- Examples
  - Java Virtual Machine (JVM), Common Language Runtime (CLR), ADAPTIVE Communication Environment (ACE)



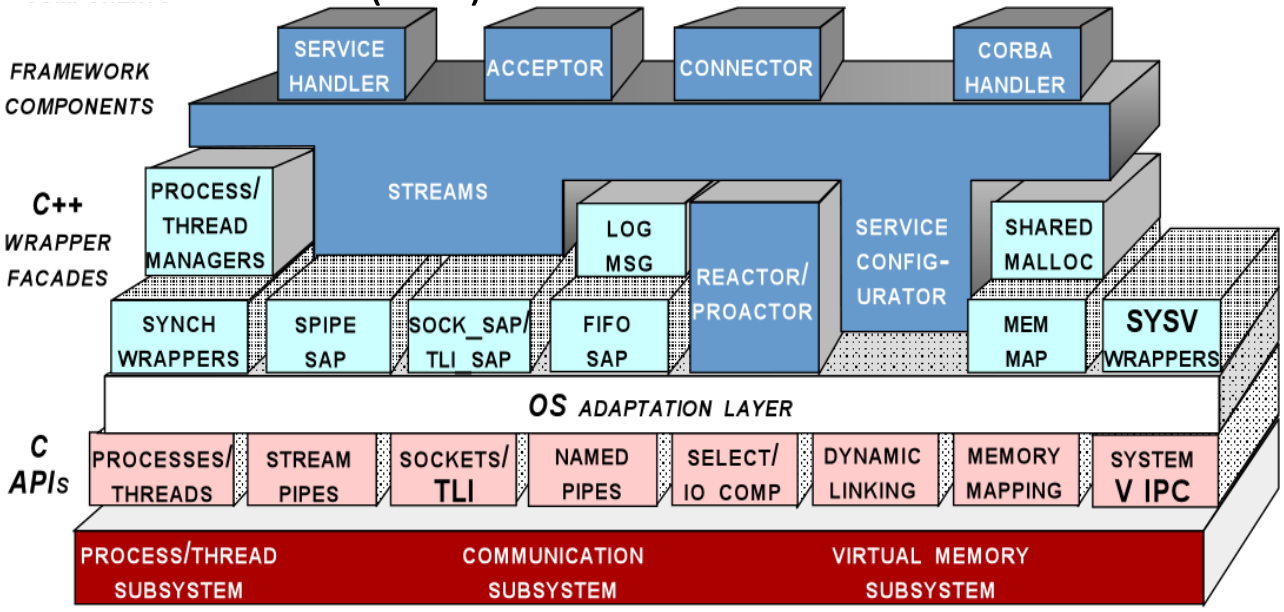








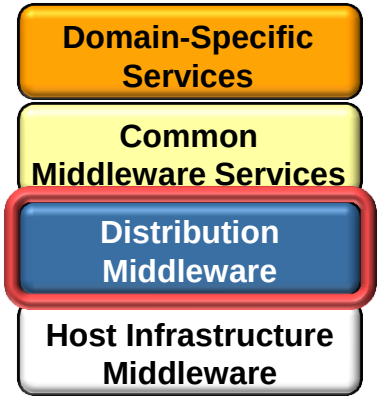
www.rtj.org



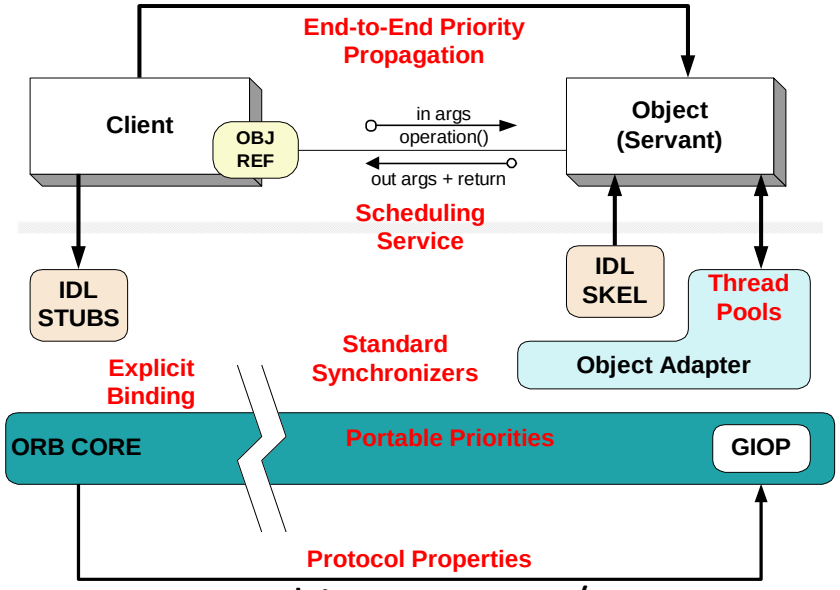
www.cs.wustl.edu/~schmidt/ACE.html

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

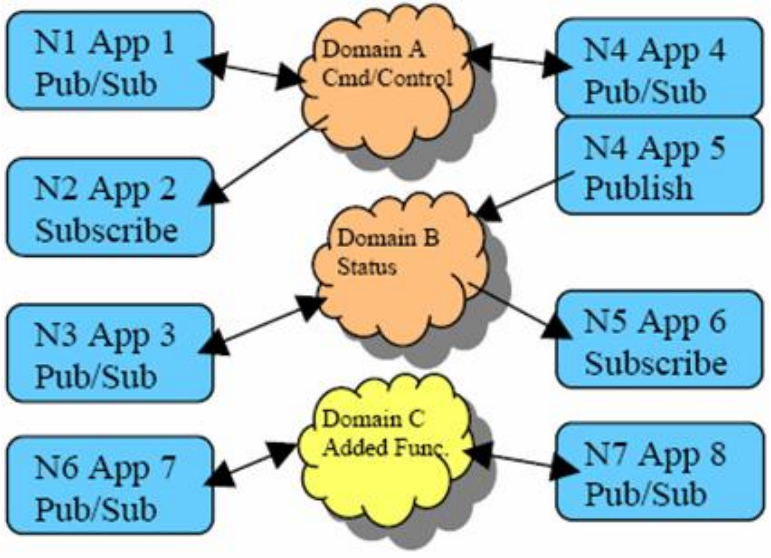
Distribution Middleware



- 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)



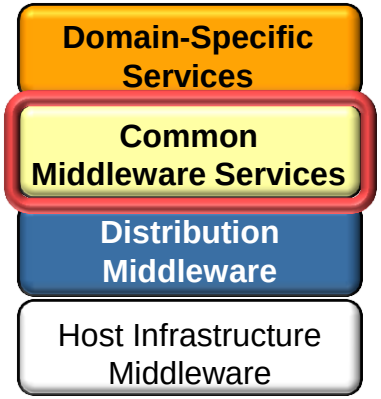
realtime.omg.org/



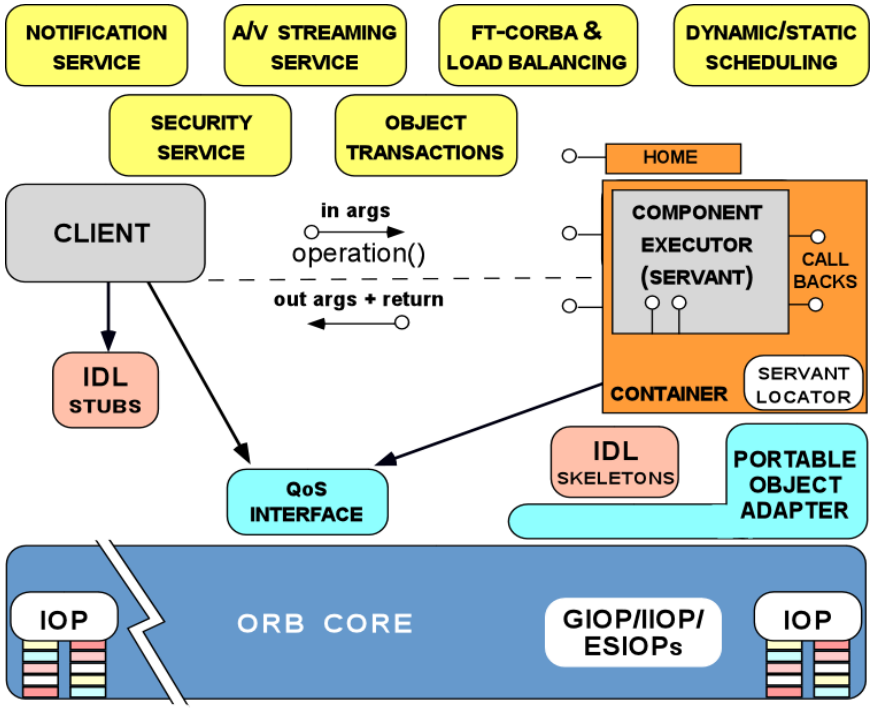
en.wikipedia.org/wiki/Data_Distribution_Service

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

Common Middleware Services

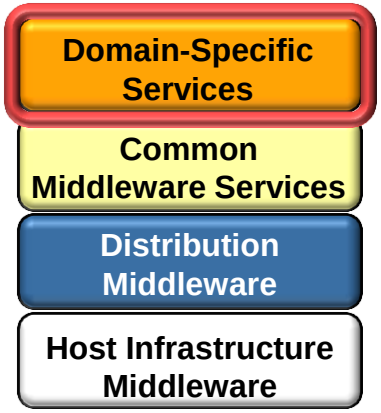


- Augments distribution middleware by defining domain-independent services that focus on programming "business logic"
- Examples
  - Sun's J2EE, Microsoft's .NET, W3C Web Services, CORBA Component Model & Object Services

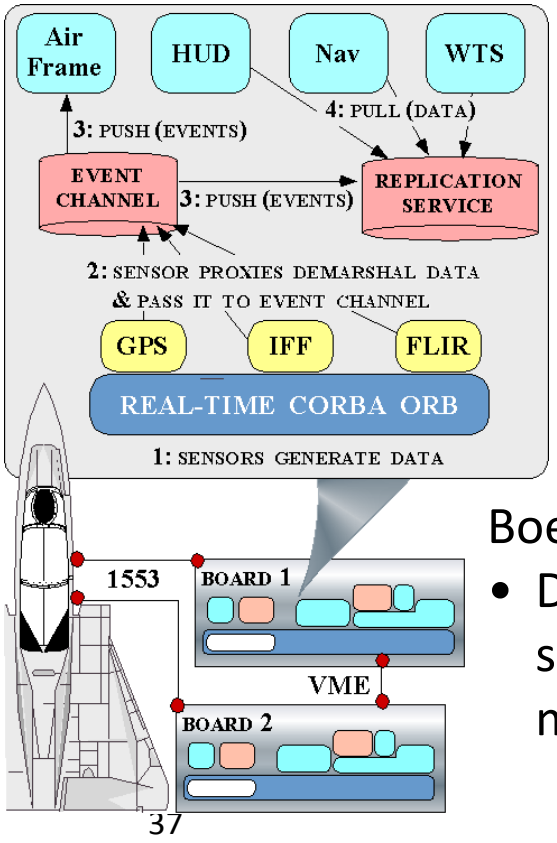


- Common middleware services support many recurring distributed system capabilities, e.g.,
  - Transactions & load balancing
  - Authentication & authorization
  - Database connection pooling & concurrency control
  - Active or passive replication
  - Dynamic resource management

Domain-Specific Middleware



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

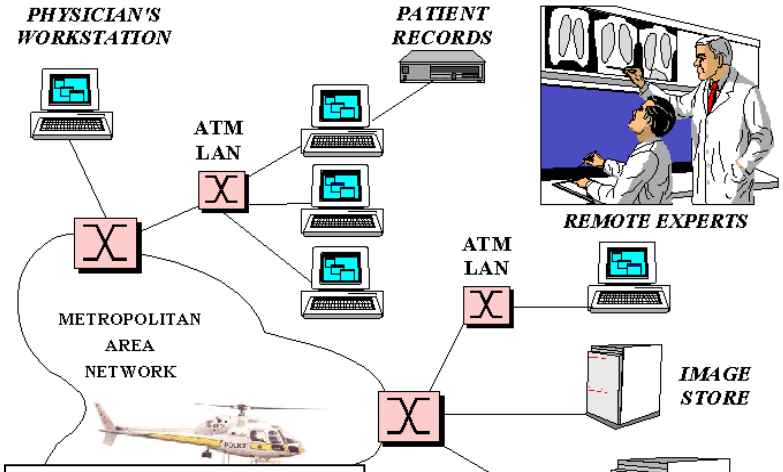


Siemens MED Syngo

- 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

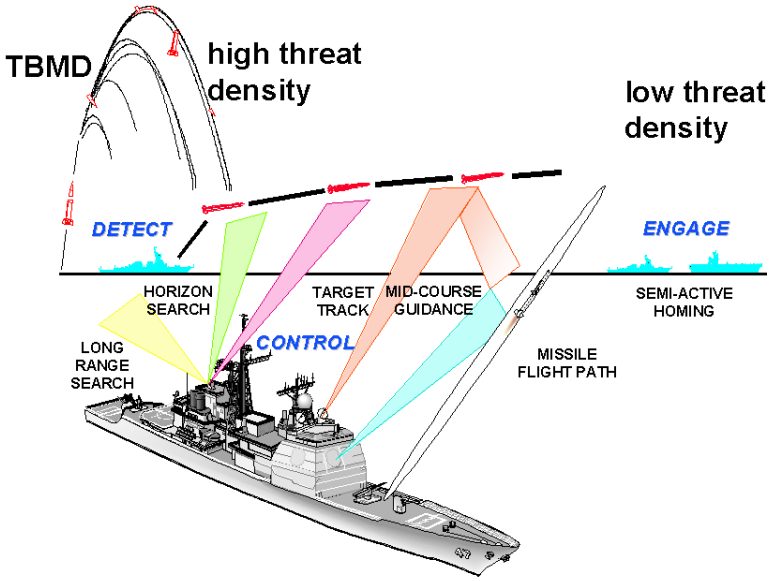


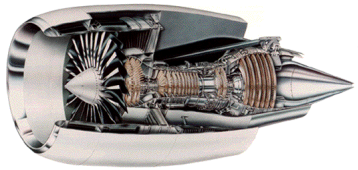
Modalities

e.g., MRI, CT, CR, Ultrasound, etc.

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”!!

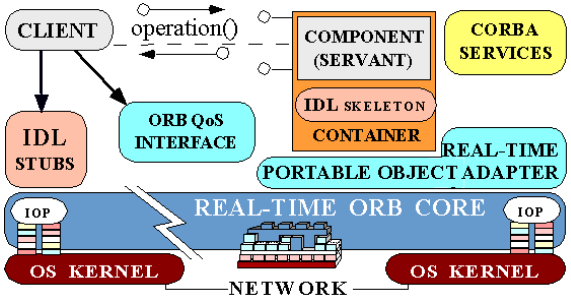




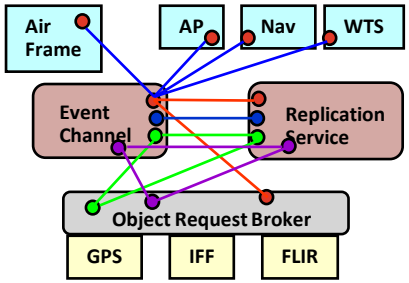
My Areas of Expertise: Patterns, Frameworks, & Tools for DRE System Middleware & Applications

www.dre.vanderbilt.edu/~schmidt

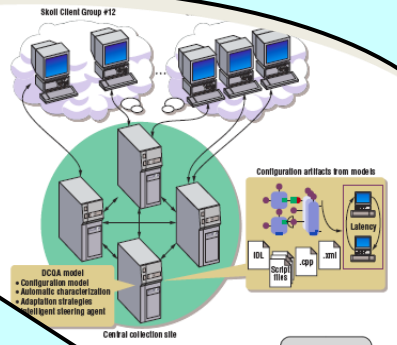
QoS-enabled component middleware & frameworks



Multi-faceted Software Development

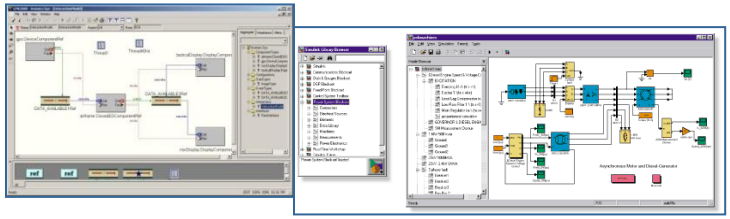


Distributed continuous quality assurance techniques



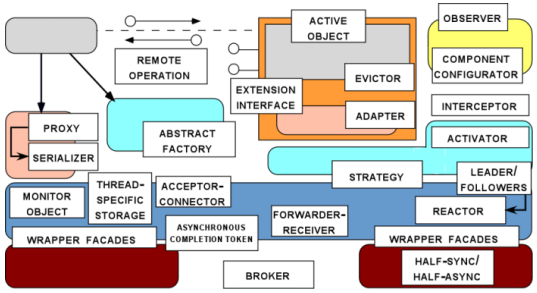
Cross-cutting Concerns

- Synchronization
- Persistence
- Memory Management
- Fault Tolerance



Model-based analysis, generation, & integration

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

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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

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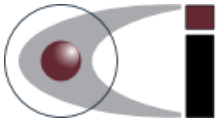
  - download.dre.vanderbilt.edu
- 1,000+ of commercial & military users
  - www.dre.vanderbilt.edu/users.html
- Spawned $100+ million industry over past decade



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