Why Is R&D in the Cyber and Software Engineering Environment Different?

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Why Is Cyberspace Critical to All of Us?

- Why is cyberspace critical to all of us?
- What are the dynamics of cyberspace?
- What is the role that software engineering/cyber engineering plays in cyberspace?
- How is this field of science unique and what impact does that have on how we approach R&D in this arena?
- What major R&D work has been accomplished in the cyber assurance arena over the past ten years?
- How should that work impact an updated and comprehensive R&D vision?
- Where should we be focusing our efforts – where are some of the critical R&D gaps?
- What is the perfect trifecta?

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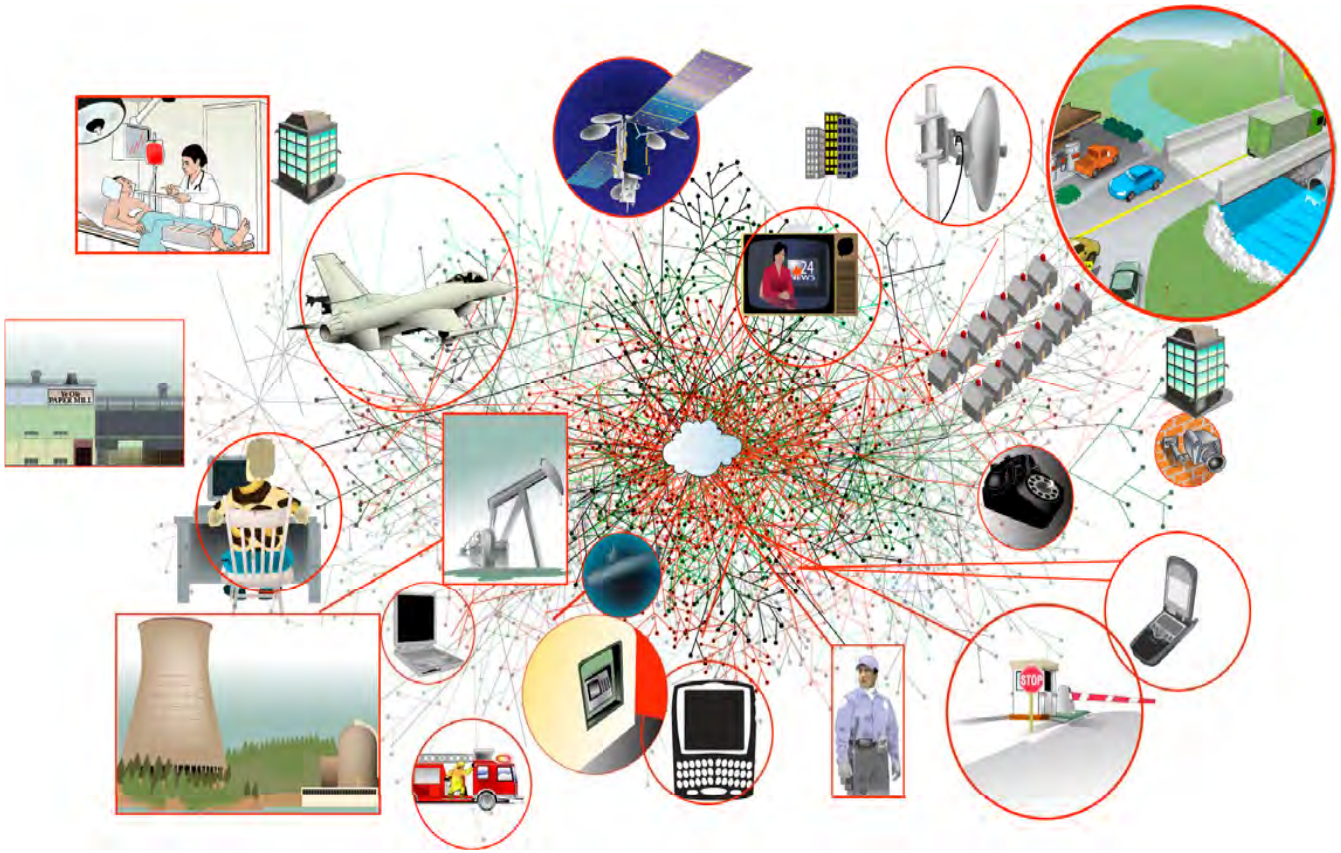
What Is the Cyber Environment?

Includes all

- System of Systems
- Architecture
- Services
- Netted Hardware/ Platforms
- People who digitally connect to cyberspace



Cyberspace is where our daily work and our priority missions are conducted

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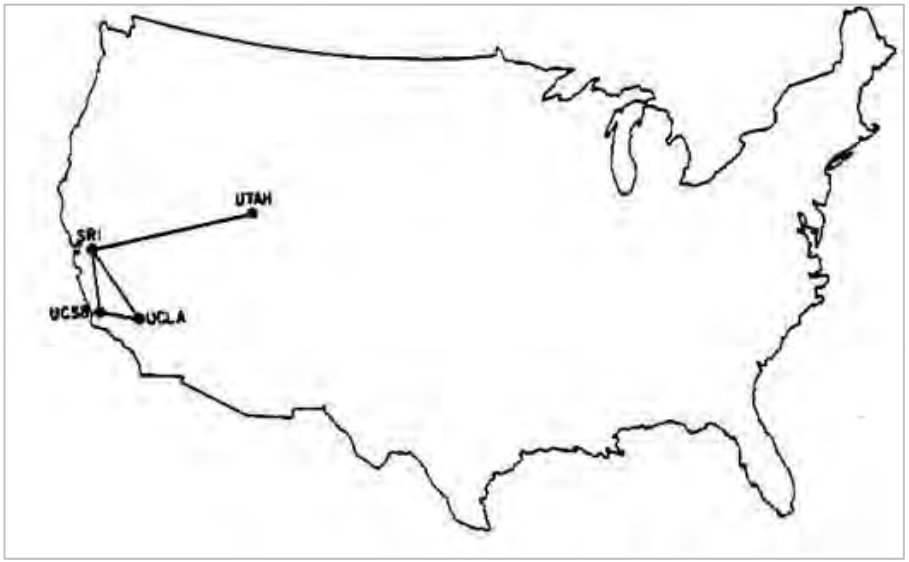
Growth of the Internet

350,000,000 – number of Facebook accounts created between Jan 2004 - Nov 2009

40,000,000 to 180,000,000 – increase in domain name registrations between Dec 2000 and Sep 2009

1 to 250,000,000 – growth of websites from Dec 1990 to Jul 2009

4 to 700,000,000 – growth of Internet hosts between Dec 1969 and Sep 2009



Map of the ARPANET, 1969

sources: statistics – R.H. Zakon, "Hobbes' Internet Timeline 10." www.zakon.org/robert/internet/timeline/.
ARPANET Map – http://som.csudh.edu/cis/lpress/history/arpamaps/

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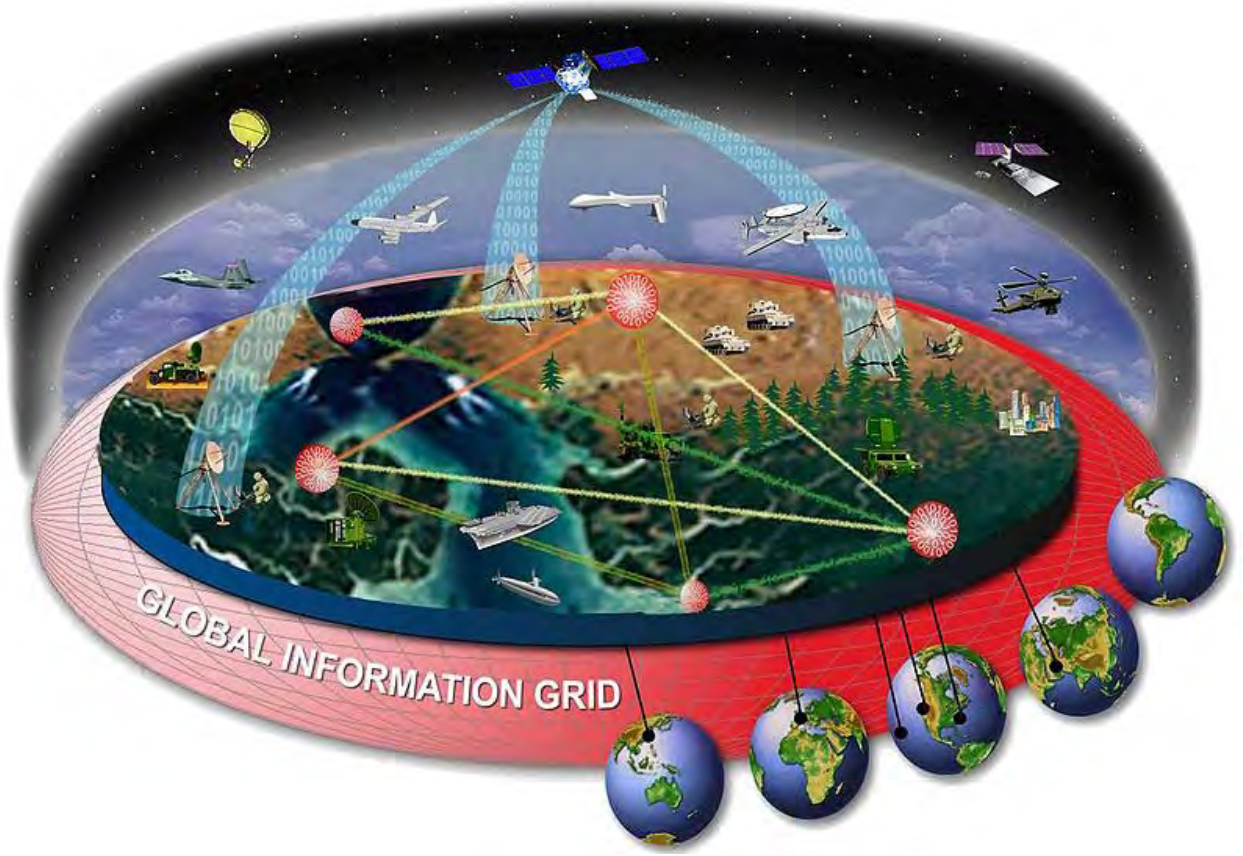
The Global Information Grid (GIG)

The GIG connects:

- roughly 3 million computers
- 100,000 LANs
- 100 long-distance networks
- a multitude of wireless networks and devices



source: DoD Directive 8000.01. Management of the Department of Defense Information Enterprise. Feb 10, 2009.

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Federal IT Market Growth

In the next five years, IT contractors will see the federal market for their services increase by a compound annual growth rate of 5.4 percent to a total of $111.9 billion by 2015.

…spending with contractors will outpace overall IT growth

-- Ben Bain
Federal Computer Week
April 8, 2010

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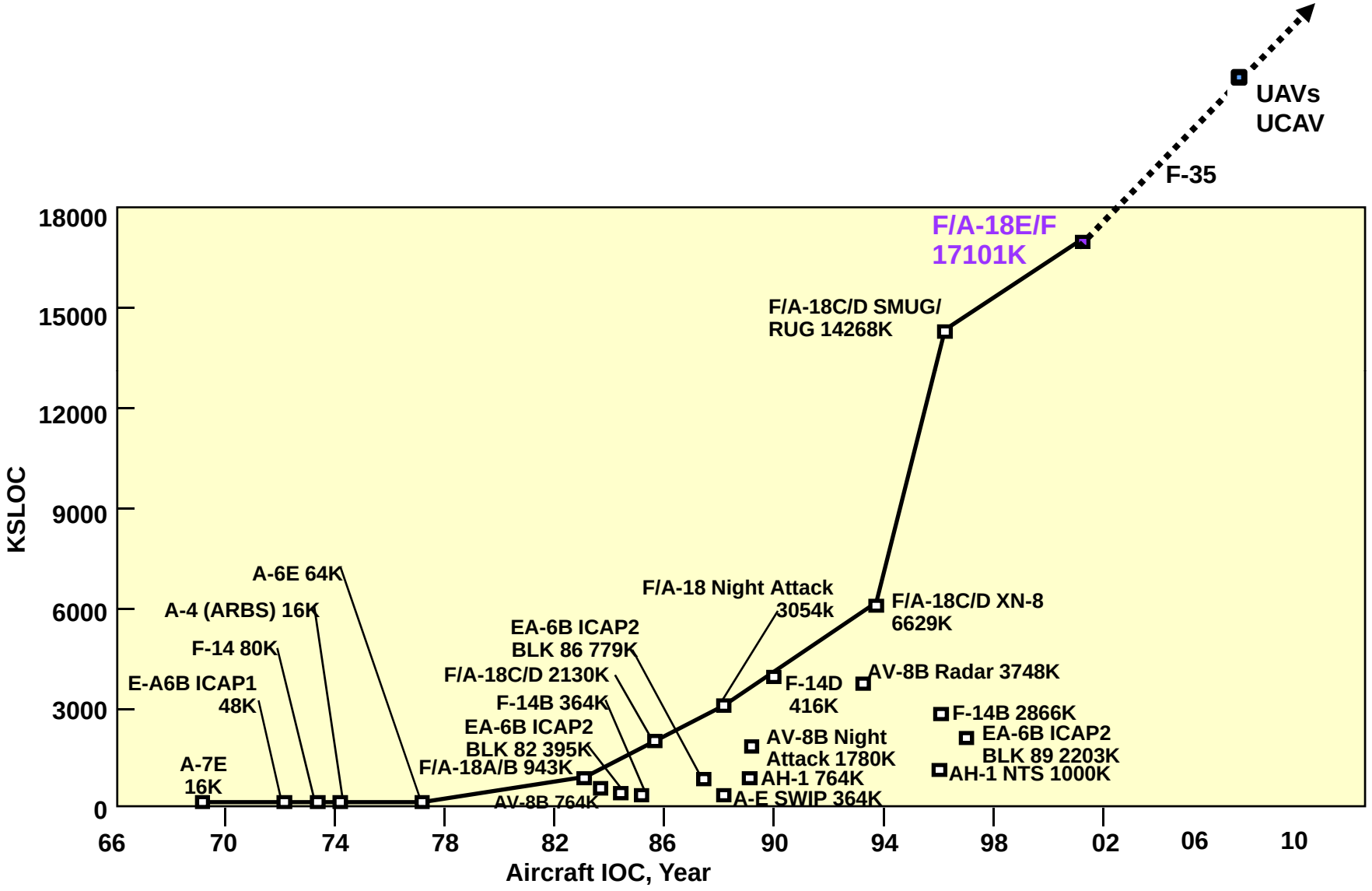
Increasing Software Lines of Code & Complexity



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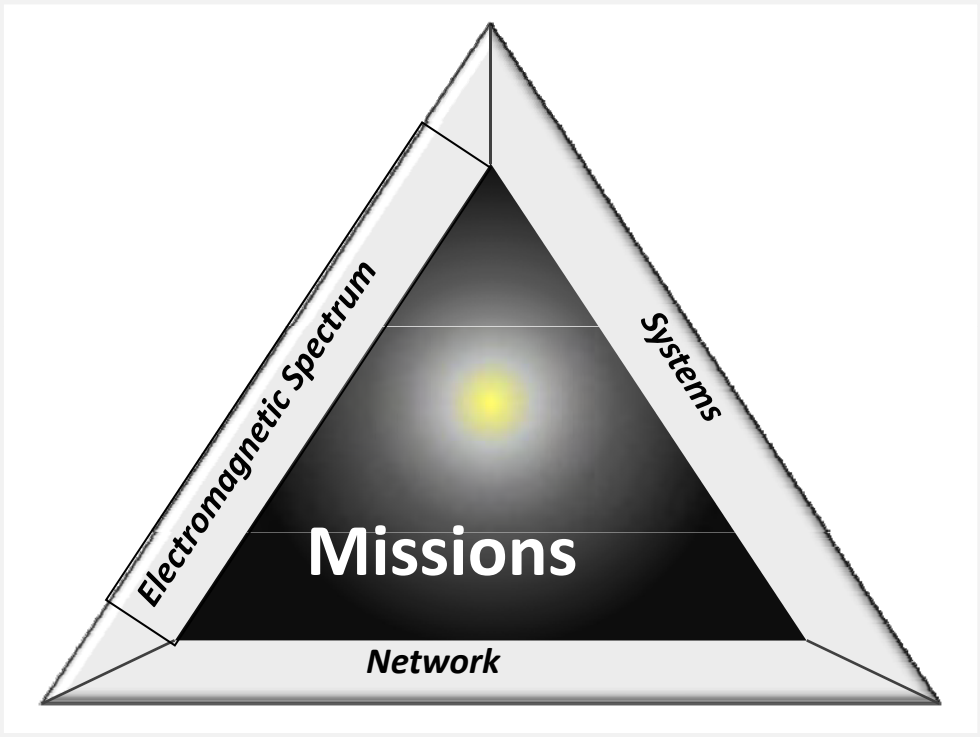
What Is Today's Cyber Environment?

Cyber environment[1] refers to the entire set of conditions when interacting with computing and networking resources.

The cyber environment encompasses users, networks, devices, systems, software, hardware, data in storage or transit, applications, services, and processes that can be connected directly or indirectly to networks.



National Military Strategy for Cyberspace Operations

[1] SEI definition with input from International Telecommunications Union: http://www.itu.int/ITU-T/studygroups/com17/sg17-q4.html

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Continuous Migration of DoD/IC/Civil Missions & Functions to Cyberspace

1995 - 2002

Administration

Basic Comms & Logistics

Non-Time Critical Ops Coordination

Person-to-Person Communications

Tasker Management

2002 - Today

All Operational Planning and Execution

Majority C4 and Intelligence

Majority Training & Exercises

All Personnel Management

All Medical Management

All Financial Management

What non-physical work today isn't conducted in cyberspace?

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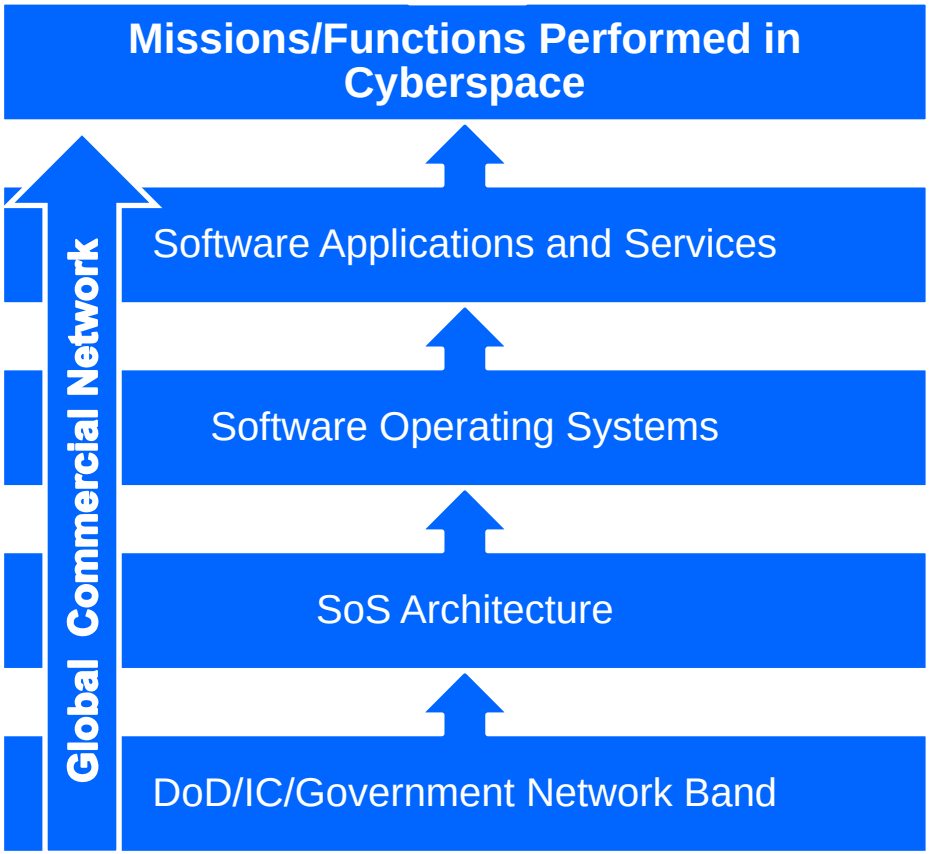
Where Do the Disciplines of Software and Cyber Engineering Fit?

What is Cyber Engineering?

Could it be the discipline of software engineering body of knowledge and practices applied in a netted environment?



Software Engineering is Foundational to and Inextricably Linked to the Cyber Environment

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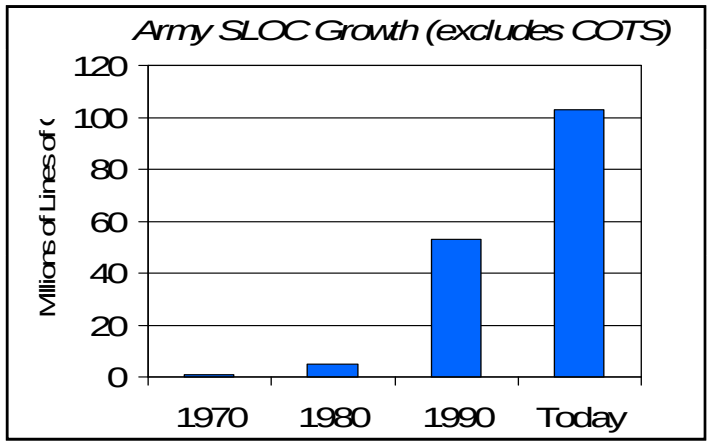
The Impact of Software Engineering Today

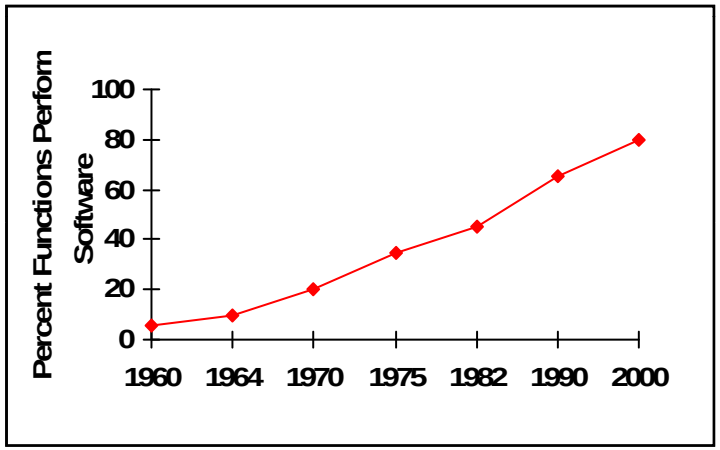
Software is both foundational and pervasive

- IT Systems
- C4ISR
- Weapons

Software is mission critical

- 20-80% of weapons/platforms/systems is software dependent [4]
- software failure can be catastrophic





[4] derived from GAO Report IMTEC-92-62BR

Software is the heart and mind of your system

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Challenges We Are Facing in Cyberspace

- Increasing dependence on large-scale, highly distributed systems, SOA, cloud computing, multi-core…
- Constantly evolving nature of the threat
- Ever-increasing number and potential impact of cyber attacks
- Software and system engineering and network monitoring tools are not keeping pace with changes in attack methods and technologies
- Increasing need for an advanced scientific body of knowledge and a mature engineering discipline underlying cyber assurance

All of the above must be addressed by cutting edge R&D focused on game changing technological advances that are based upon foundational scientific study

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Cyber R&D Dynamics

- What is today's cyber environment? …much more than the network
- What do we do in the cyber environment? …almost everything
- Will the cyber environment be there when we need it for financial transactions, for critical infrastructure, for National Defense, for telecommunications?
- Where does the U.S. government fit in the cyber arena? …it is dependent upon it, but does not own it (it is mostly owned, operated and serviced by International Industry)
- Is today's cyber environment inherently fragile and unreliable?

How can industry and government fully leverage a comprehensive and responsive R&D approach to establish a resilient network for the near term and an assured network alternative for the future – in support of all essential missions and functions?

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Institute for Information Infrastructure Protection 2009 Report Recommendations

1. **A coordinated and collaborative approach is needed.**
   Cyber security research and development efforts in the U.S. must be better coordinated; only through information sharing and collaboration can effective solutions emerge.
2. **Metrics for security are a broad enabler and must be developed.**
   Metrics are enablers, essential to helping companies, governments, and suppliers make better security decisions; they also strengthen the legal and policy framework.
3. **An effective legal and policy framework for security must be created.**
   A national strategy for cyber security requires a sound domestic legal and policy framework as well as an international doctrine.
4. **The human dimension of security must be addressed.**
   Technologists and policymakers must consider the human element carefully when developing security solutions.

source: “National Cyber Security Research and Development Challenges” www.thei3p.org/docs/publications/i3pnationalcybersecurity.pdf

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Current DoD S&T Investments in Cyber Security and Information Assurance

OSD-Led Task Force Recommendations

- Address key points of the cyberspace S&T study from within S&T resources starting in FY10
- Examine and refine cyber protection needs in QDR 10
- Develop measures to assess how much cyber protection is enough for DoD
- Expand the role of the IA S&T Steering Council to include oversight of all defensive cyber S&T programs
- Reprioritize DoD S&T funding to increase Cyber Conflict S&T in coordination with Defense S&T Advisory Group
- Enhance cooperation between offensive and defensive communities to enable improved cyber defense

source: DoD S&T Investment in Cyberspace Security and Information Assurance Report from December 2009

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Before Discussing an Optimal R&D Agenda

Think about it…

- How does R&D differ in this unique arena?
- Why is it an imperative that we embark on a comprehensive R&D approach today?
- How does an effective partnership with academia, industry, and government enable us to take the science to the next level?

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Generations of Game Changing Technologies

Decade of the 1950's

Lasers

Programmable Systems

WWII Ballistic Computing/ ENIAC

Transistor

Atomic Clock

DNA

Today for 2020 and beyond…

Nanotechnology

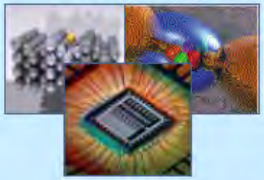
Institute for Soldier Nanotechnologies (ISN)

Micro-robotics

Immersive Environments

Institute for Creative Technologies (ICT)

High Performance Computing



The Network

Flexible Displays

Biotechnology

Institute for Collaborative Biotechnologies (ICB)

source:: **Dr. Thomas H. Killion, *Enabling Future Technology Ultra-Large-Scale Systems in the Army***
www.sei.cmu.edu/library/assets/killion.pdf

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Cyber Compared with Other Sciences

	PHYSICAL SCIENCE	BIOSCIENCE	COMPUTER/SOFTWARE/CYBER SCIENCE
Origins/History	Begun in antiquity	Begun in antiquity	Mid-20th Century
Enduring Laws	Laws are foundational to furthering exploration in the science	Laws are foundational to furthering exploration in the science	Only mathematical laws have proven foundational to computation
Framework of Scientific Study	Four main areas: astronomy, physics, chemistry, and earth sciences	Science of dealing with health maintenance and disease prevention/treatment	• Several areas of study: computer science, software/ systems engineering, IT, HCI, social dynamics, AI • All nodes attached to/relying on netted system
R&D and Launch Cycle	10-20 years	10-20 years	Significantly **compressed**; solution time to market needs to happen very quickly

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Software/Cyber Science: R&D Key Premises

- Few foundational laws; no enduring laws
- Mid-20th century invention—still in its infancy
- No systematic, globally accepted method for scientific discovery
- An environment of scientific study that is totally technological
- An environment that is not owned or controlled by government or industry
- R&D timelines are measured in seconds, minutes, days—not years

So much left to discover, research, analyze, codify, develop and test

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CMU/Cylab/SEI-CERT Cyber R&D Review: Vision to Establish Preeminence in Cyber R&D

- Enable cyber research to keep pace
- Envision future needs: emerging trends, changes in technology, threat capabilities, and appropriate responses
- Maintain a contextual reference for what key cyber R&D is being done where unique contributions could be made
- Fully connect to and leverage current cyber R&D Body of Knowledge across all organizations and individuals focused on similar challenges or gaps
- Recommend usable and potentially high impact investments

…while establishing a foundational cyber science

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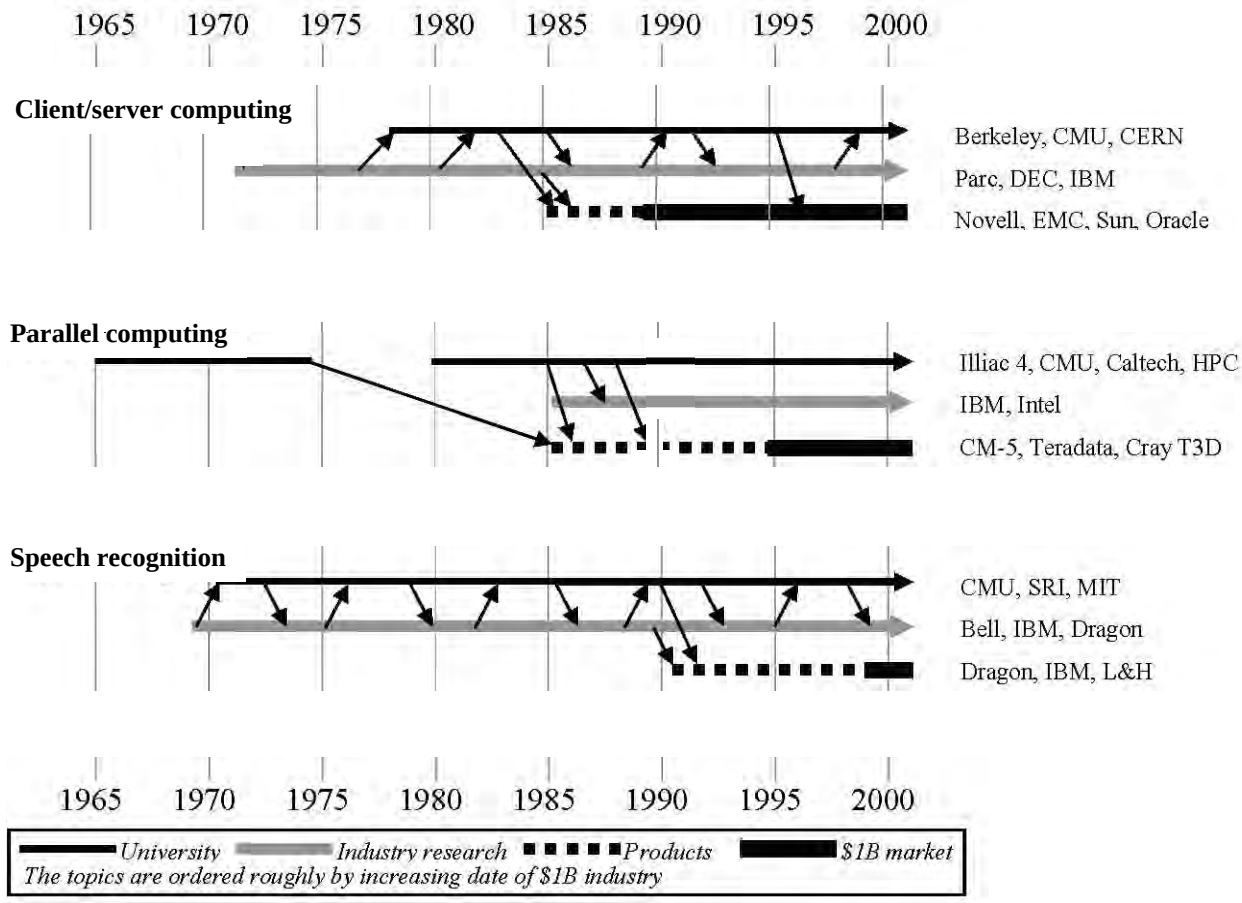
Illustrative High-Impact Research Partnerships: Three Examples of Recent $ 1B+ Markets Created



source: B. Lampson (www.cra.org/govaffairs/images/Tire-Tracks-Color_lg.jpg)

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CMU/Cylab/SEI-CERT Cyber R&D Review: Technological Goals and Objectives

- **Disruptive**
  - Make a significant advancement in a fundamental approach to securing our information systems
- **Sustainable**
  - Have a long-term effect
- **High Payoff**
  - Result in qualitative improvement in the mid-term that justifies the investment
- **Doable**
  - Attainable and executable goals

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CMU/Cylab/SEI-CERT Cyber R&D Review: Approach

- Look beyond current work
- Develop a broad view of all the areas that merit research
- Institute a framework that continually refreshes and refines research areas
- Engage active & complementary participation and collaboration from academia, industry, and government
- Continuously inform and renew research agenda priorities

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CMU/Cylab/SEI-CERT R&D Review: Past Ten Years

- Conducted CERT Speaker Series – distinguished speakers presented ideas on current challenges and needed research
- Reviewed and categorized research recommendations from 1999-2009
- Held in-depth structured interviews with luminaries in the field to capture their ideas and recommendations
- Hosted CERT Technical Symposium to bring a concentration of bright minds together to describe challenges and future directions
- Leveraged Industrial Consortium to develop current needs
- Partnered with Carnegie Mellon University thought leaders in cyber security to share perspectives

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CMU/Cylab/SEI-CERT R&D Review: Recommended Focus Areas

- Protect the Network Fabric
- End-to-End Trusted Systems
- Secured Software and Systems Development
- Resilient Systems Operations
- Effective Evaluation Tools and Techniques
- Offensive Operations
- Forensics

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TWR Recommended R&D Priorities- 1

Establishment of an inclusive science of cyber engineering

- Define the new discipline, built upon Computer Science, Software Engineering, System Engineering and Mathematics
- Determine what foundational knowledge and core competencies are needed
- Develop the commensurate curriculum at the undergraduate and graduate levels
- Establish the profession across the workforce landscape

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TWR Recommended R&D Priorities- 2

Develop an assured cyber ecosystem scale – mission and domain specific (eg. Levels: 1-Minimal, 2-Moderate, 3-Maximum)

Establishment of an optimal resilient architecture continuum to achieve the desired/needed level of assurance (for software & cyber physical systems)

- Software coding standards at the language and coding practice level
- Software architecture design, w/ performance measures
- Model for composing secure systems from resilient & non-resilient components
- Development of assured architectural interoperable approaches
- Effective architectural mapping, diagnostics, and identification of risks with the ability to isolate and contain probable threats or aberrant behavior

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TWR Recommended R&D Priorities- 3

Create an enduring culture of performance & mission assurance

- Promote open discussion, debate, education and outreach
- Develop an economic model/ business case for building and designing w/ assurance in the forefront
- Determine high payoff and end-to-end approaches, models, technologies, with supporting metrics
- Establish a clearinghouse for high impact R&D prototyping, testing and transition technologies
- Draft technically informed and aware statute, policies and standards

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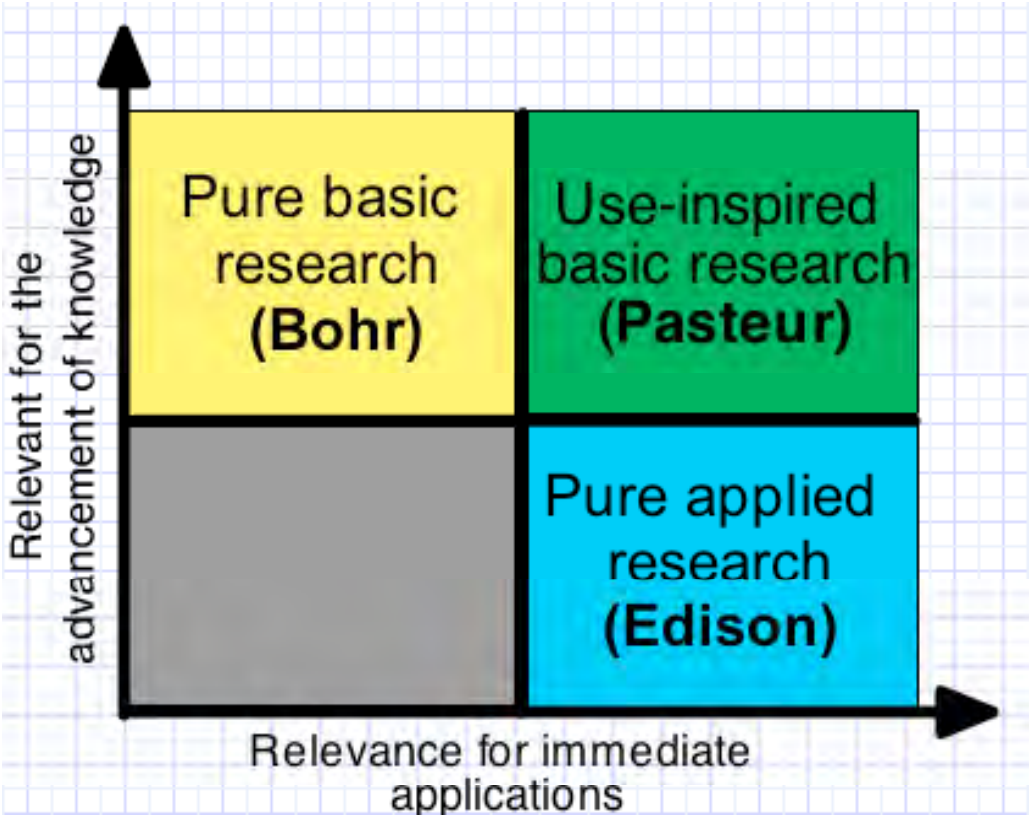
The Intersection of Basic and Applied Science

"We need the minds of the basic scientist and the application engineer, those in universities, and those in industry.

And we need them working together in the cauldron created by the urgency and technical demands of defense."

– Dr. Regina E. Dugan
Director, DARPA



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Optimal Cyber R&D Collaboration Requirements . . .

From Universities

- Creative and out-of-the-box 6-1 research
- Stability of innovative operations: 25 – 33% of all research funding
- “Nimble” R&D: 67 – 75% of all funding is competitive

From Industry

- Time-sensitive, marketable research
- Consistently focused: mid-range (3 – 5 years) focus
- Commitment to broad marketing of technology

From Government

- Longer term, high-end, transitionable research gaps/challenges
- Demonstrable successes, social vision
- Continuously leverage academia and industry top R&D

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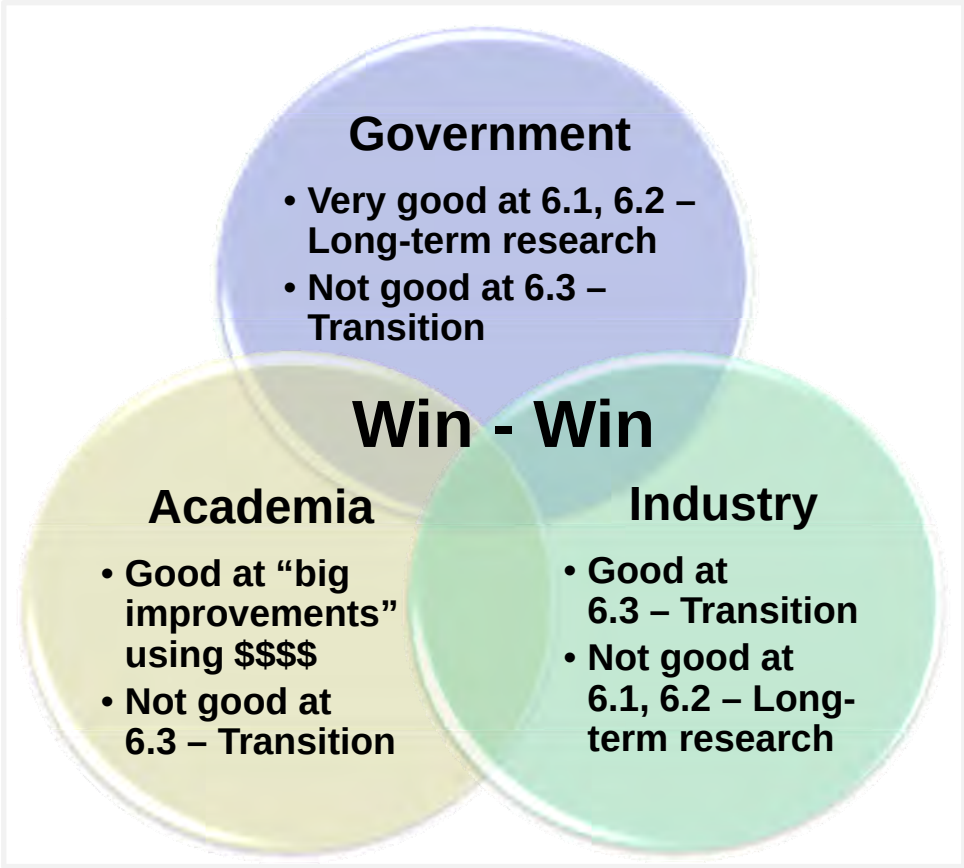
Cyber R&D Imperative: Institute a New Collaborative Approach

Across Academia, Industry, and Government

The Cyber R&D Trifecta:

- Unique contributions from each
- Effective government R&D must engage industry and academia
- Focus on and discuss who does what and leverage each other



Successful Cyber R&D Requires All Three Communities

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Why Is Cyberspace Critical to All of Us?

- ***Our society, our country and the world relies upon it.***
- What are the dynamics of cyberspace? Global, ever-changing, all encompassing.
- What is the role that software engineering/cyber engineering plays in cyberspace? Foundational disciplines & BoK – the mind & the engine.
- How is this field of science unique and what impact does that have on how we approach R&D in this arena? Driven by the pace of technology – an operational, time sensitive dynamic not seen in other sciences.
- What major R&D work has been accomplished in the cyber assurance arena over the past ten years? Mainly focused on near term solutions.
- How should that work impact our R&D vision? Need to focus on key gaps that map to our unique skill-sets and capabilities.
- Where should we be focusing our efforts – the critical R&D gaps? Many opportunities – need to prioritize according to customer requirements and assurance imperatives.
- **What is the perfect trifecta? It is a seamless and complementary partnership among industry, academia, and government.**

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