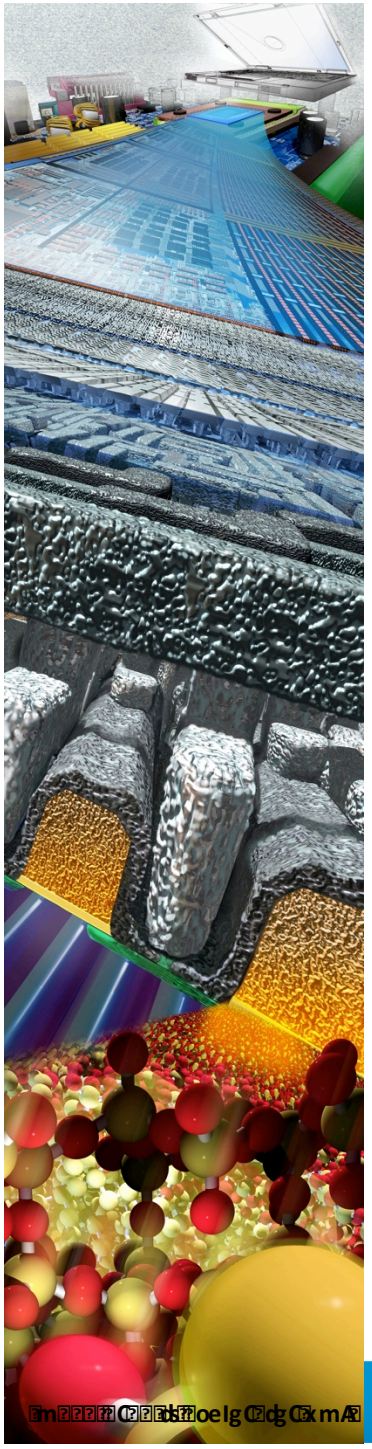

Innovating for Society: The Growing Imperative for Dependability Research and Practice

Farnam Jahanian
National Science Foundation
University of Michigan

IFIP Working Group 10.4
January 27, 2012

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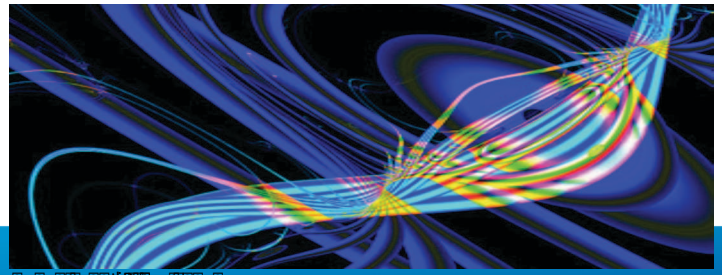

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Potential for Computing

- Computing and communication discipline has the potential to form a pervasive intellectual fabric that connects a wide range of disciplines – recognizing that:
  - Scientific discovery and technological innovations will be **at the core of our response to challenges facing humanity** – from climate change and sustainability, to health care and national security.
  - Many of tomorrow's breakthroughs will occur at **the intersections of diverse disciplines.**

Courtesy of National Institute for Computational Sciences and the University of Tennessee, photo taken by Jason Richards at Oak Ridge National Laboratory

Credit: Kirsty Pargeter

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Infrastructure and Sustainability

Envision a day when…

- Static infrastructures such as buildings and factories are transformed into smart spaces that adapt to consumption, growth, and changing environmental needs through the use of networked instrumentation and software control.

Kindly donated by Stewart Johnston

Credit: MO Dept. of Transportation

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Emergency Response

Envision a day when…

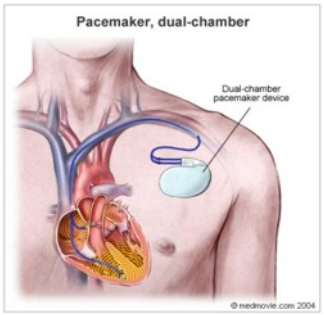
- During the time of a natural disaster or a national emergency, ***unmanned*** search, rescue, and recovery is a reality through the use of autonomous, highly coordinated, and remotely operated robots in shared physical spaces – the promise of distributed, low-power sensing combined with communications and control.

Credit: Edwin Olsen, University of Michigan

Smart Health

Envision a day when…

- We can improve quality of life through personalized healthcare and assistive technologies, enabled in part by robust, usable, and trustworthy wearable mobile devices integrated with instrumented environments.
- We can create a healthcare system that helps people prevent and manage chronic and acute diseases in their own every day context; robots extend independent living for seniors; and devices worn or embedded in the home can report adverse health events.



Courtesy of the Center for Integration of Medicine and Innovative Technology (CIMIT)

Transportation: Safety and Energy

Envision a day when…

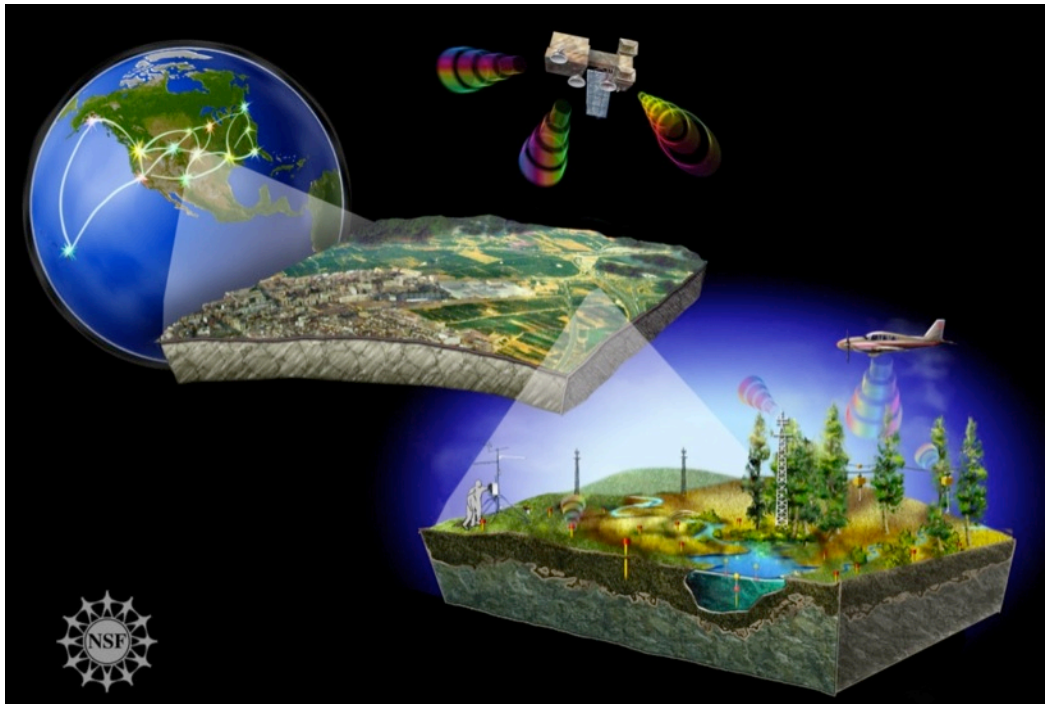
- Your car will be able to drive you safely and securely to your destination, where traffic fatalities are uncommon rather than daily events.
- Your home and car both consume energy from – and provide energy to – the electricity grid, and where advanced controls can provide substantial energy savings that can decouple the economic benefits of transportation from regional and global environmental impacts.

Credit: PaulStamatiou.com

Environment and Sustainability

Envision a day when…

- By developing rich ecological and environmental monitoring systems, we can create accurate models that support forecasting and management of increasingly stressed watersheds and ecosystems.

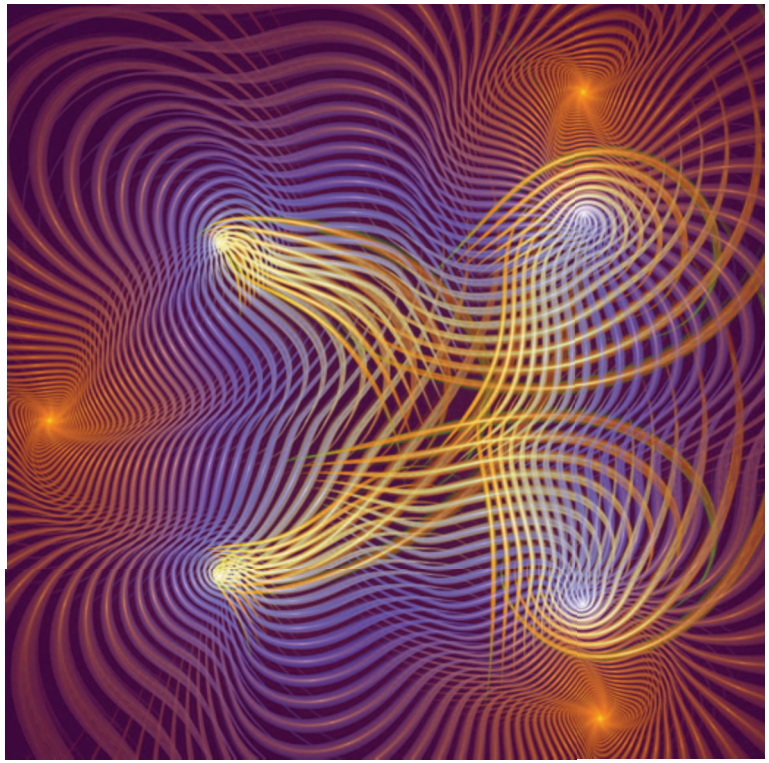


Conception of the National Ecological Observatory Network (NEON). Credit: Nicolle Rager Fuller, National Science Foundation

The Promise

Advances in computing and information technology hold the potential to reshape our world with more responsive, precise, and efficient systems that:

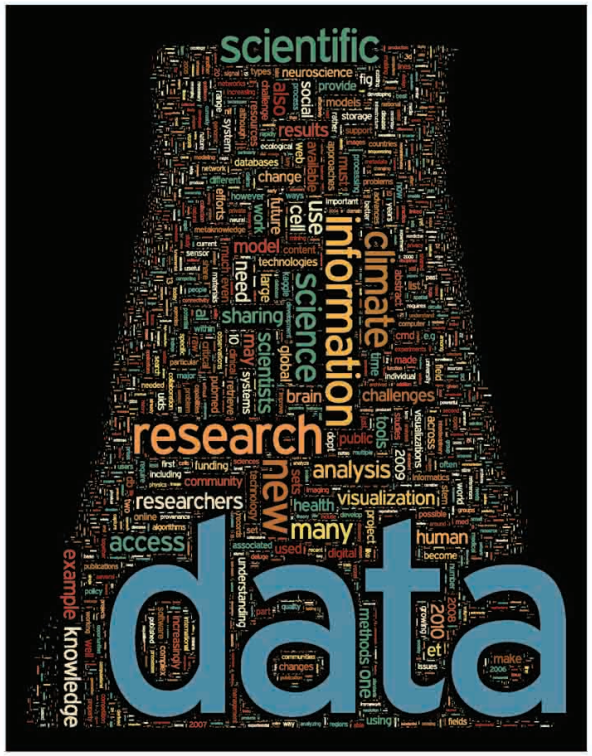
- augment human capabilities
- Provide context for decision making
- contribute to a sustainable future
- transform the way we live
- enhance societal well-being



Trends and Advances Shaping the Computing Discipline

Explosive Growth in Size, Complexity, and Data Rates

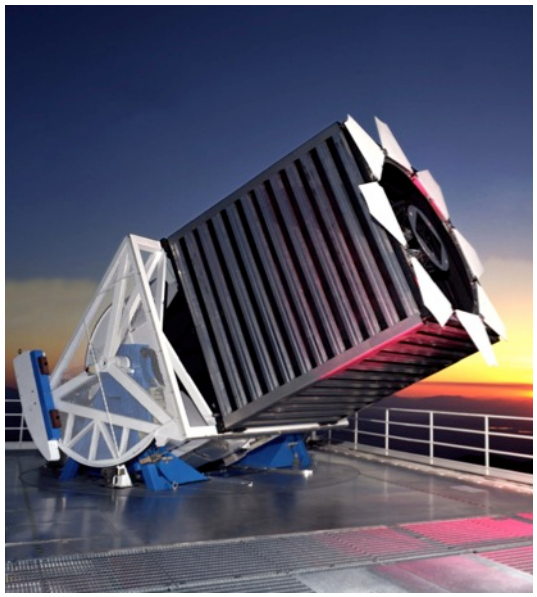
- **Enormous static or streaming data sets** are generated by modern experiments and observations
- **Automatic extraction of new knowledge** about the physical, biological and cyber world continues to accelerate
- **Infusion of computation** into science and engineering is revolutionizing research
- Multi-cores, concurrent and parallel algorithms, virtualization and advanced server architectures will enable **data mining and machine learning**, and **discovery and visualization of "Big Data"**



A word cloud generated from all of the content from the Dealing with Data special section. From *Science* (Feb 11, 2011) 331 (6018). Reprinted with permission from AAAS.

Conceptualizing "Big Data"

- Amount of data growing rapidly
- Sloan Digital Sky Survey in 2000, collected more data in its 1st few weeks than had been amassed in the entire history of astronomy
  - Within a decade, over 140 terabytes of information collected
  - The Large Synoptic Survey Telescope due in Chile in 2016 will amass that quantity of data every 5 days
- By 2015, the world will generate the equivalent of approximately 93 million Libraries of Congress
- Estimated 40 exabytes of unique new information generated worldwide in 2010
- Only 5% of the information created is "structured" in a standard format of words or numbers; the rest are from cameras, smart phones, etc.



Sloan Digital Sky Survey telescope. Credit: Fermilab Photo

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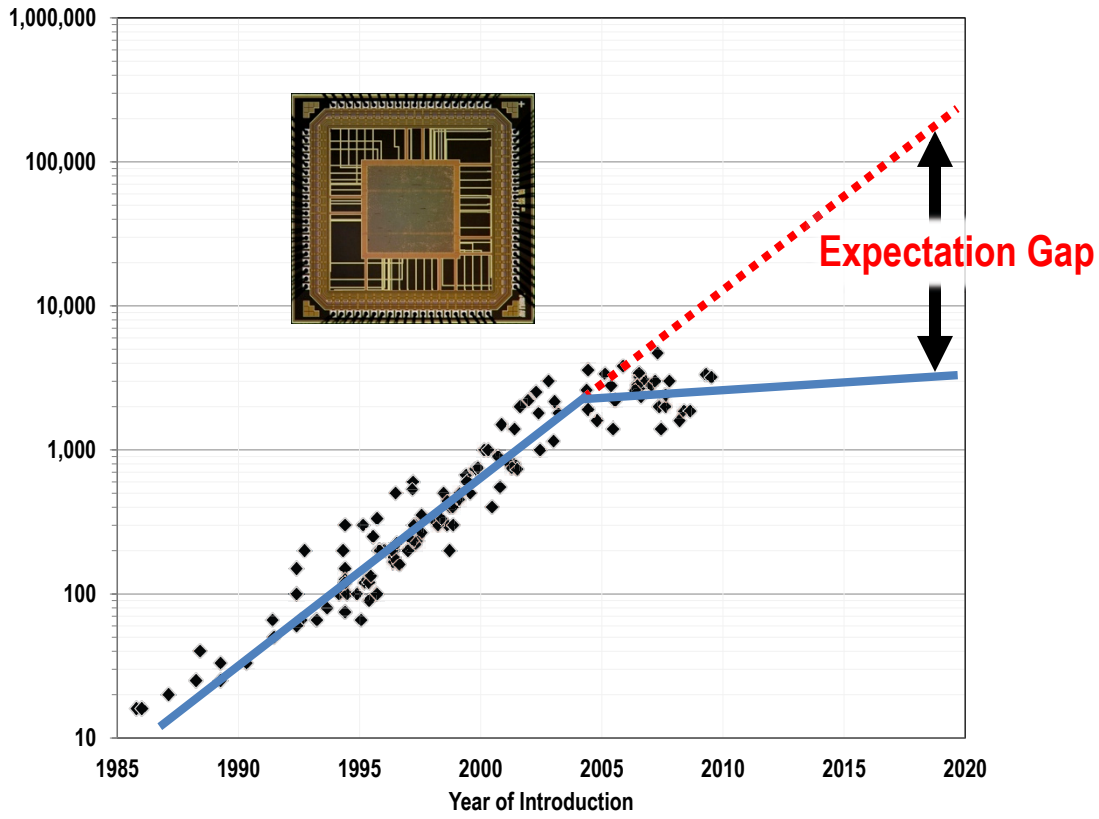
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NSF

Computing Research Agenda Centered on Parallelism and Concurrency

- **Computational models** to enable new ways of "thinking parallel"
- **Programming languages** to enable effective expression of parallelism and concurrency at every scale
- **Algorithms** to better exploit parallelism and concurrency
- **Software systems** capable of handling both small and extreme-scale data systems and data analytics
- **Software Architectures** to enable resilient computation at scale
- **Parallel architectures** to achieve energy- and power-efficiency, resilient and secure systems, possibly customized for applications
- **Techniques to map legacy apps onto parallel architectures**
- **Rethinking the canonical computing "stack"** – applications, programming language, compiler, run-time systems, OS, architecture
- **Computing education** to include teaching of parallelism and concurrency


Situation Awareness : Humans as sensors feed multi-modal data streams
Percepts (sensors)
Agent (Reasoning)
Actions (controllers)
Temperature
light, microphone
ECG
Blood pressure
SpO2 GSR
Accelerometer

A Sea of Sensors

- We swim in **a sea of sensors and are drowning in data**:
  - Our smart phones, cars, increasingly instrumented homes and offices, health monitors, environmental monitors, …
  - New vision and speech recognition techniques for capturing data
  - Ability to analyze data in "real-time and retrospectively," create context for decisions, and offer meaningful actionable feedback
  - Data fusion and inference techniques over diverse potentially noisy data combined with contextual and location-aware data

- We need networked systems that not only scale up, but also **scale down** and **scale out**:
  - Smart, miniaturized, low-power, adaptive and self-calibrating instrumentation
  - Embedding sensors everywhere and connecting everything via networks leading to wide-scale sensors and control

Cloud Computing

"Computation may someday be organized as a public utility."
[John McCarthy, 1960]

Credit: Image courtesy Montage, IPAC, Caltech, SDSC

- Major public cloud service providers like Amazon are now able to provide vast computing resources to organizations … the interest in such services is staggering.
- Each day Amazon adds enough computing resources to power one whole Amazon.com circa 2000.
- Gartner Inc. believes the cloud computing marketplace will grow substantially: revenues of $68.3 billion in 2010, reaching $148.8 billion by 2014
- Compelling New Business Models: Mindset shift from asset ownership to a utility-based model and economies of scale gained through multi-tenancy

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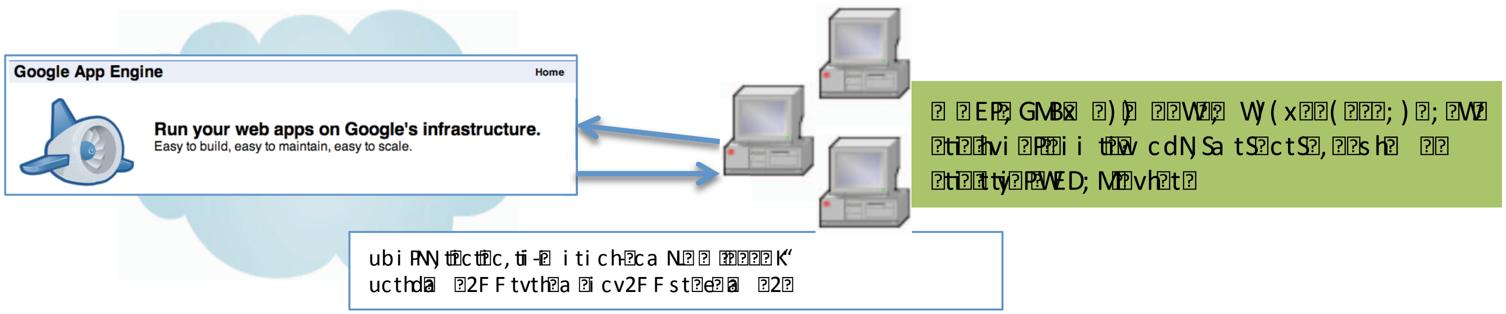

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TODAY @ PCWORLD

Gmail Outage Marks Sixth Downtime in Eight Months

By JR Raphael, PCWorld Feb 24, 2009 5:33 pm

Google

Server Error

T-Mobile: All Your Sidekick Data Has Been Lost Forever

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December 11, 2009 2:07 PM PST

Amazon EC2 cloud service hit by botnet, outage

by Lance Whitney

Font size · Print · E-mail · Share · 19 comments

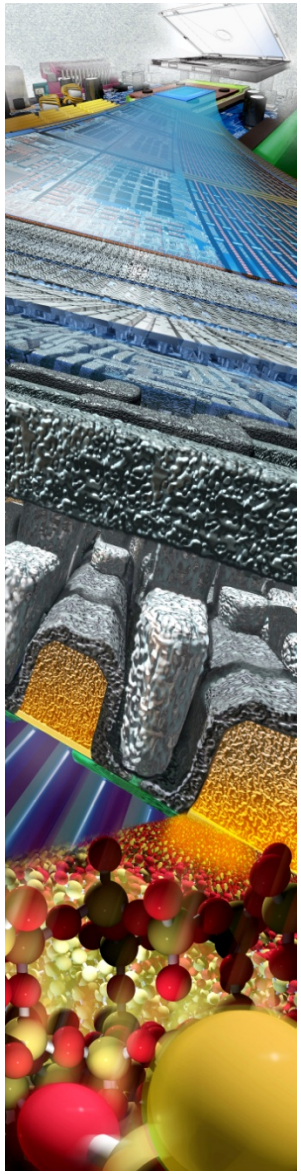
Tweet 0 · Share 4

The folks who run Amazon's EC2 cloud service must be happy the week is nearly over.

The cloud-based EC2 (Elastic Compute Cloud) was kept jumping this past week by two incidents: a compromised internal service that triggered a botnet, and a data center power failure in Virginia.

On Wednesday, **security researchers for CA** found that a variant of the infamous password-stealing **Zeus**

amazon web services



Zoom into a Computer Chip.
Credit: *Exploratorium*

So What's New?

Technology Enablers:

- Universal connectivity and ubiquity of high-speed broadband
- Virtualization technology breaks the lock between software and hardware
  - Multi-tenant systems enable sharing of resources and costs among a large pool of users leading to better utilization, increase in peak-load capacity,
- Multi-core architecture is also an enabler

Challenges and Opportunities

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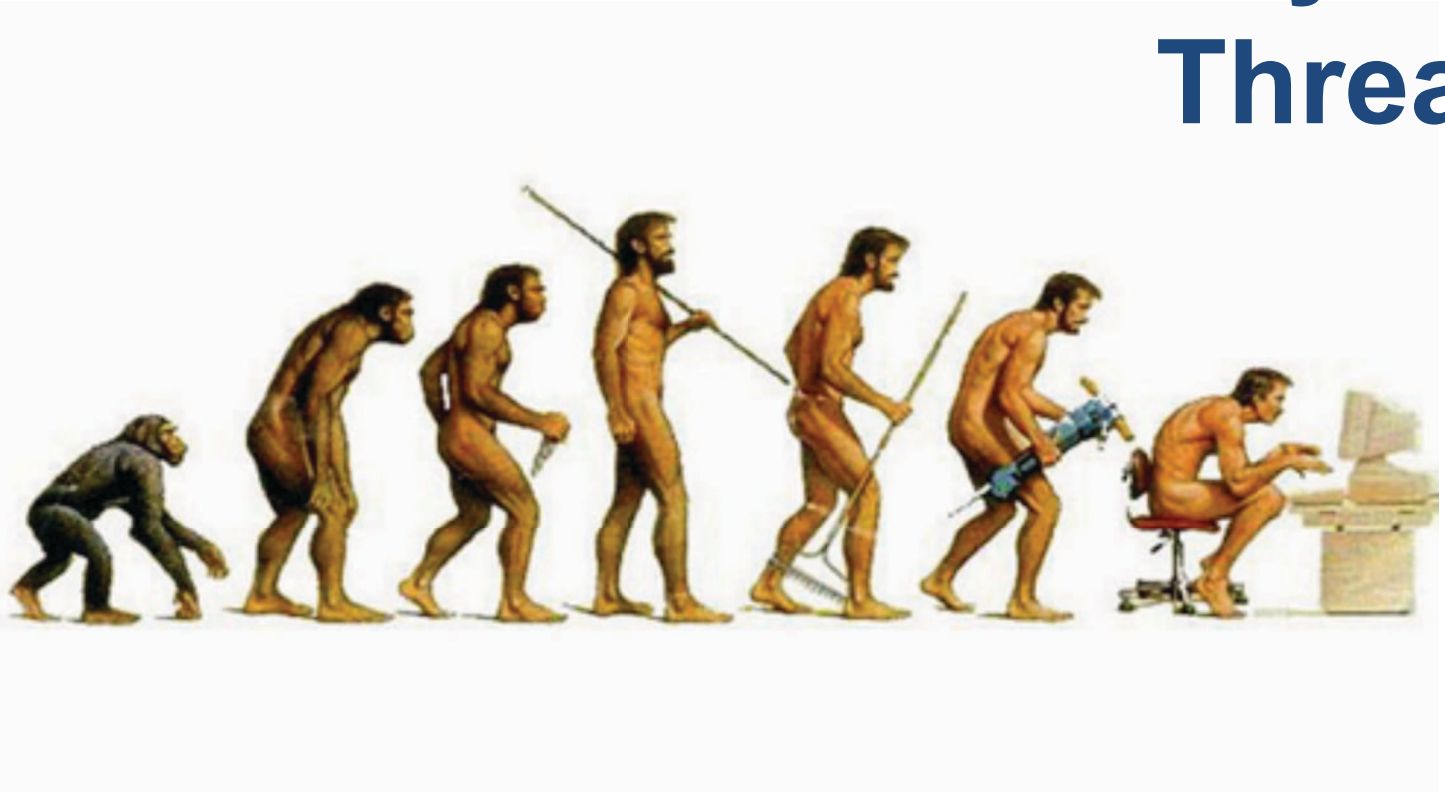
Evolution of Cyber Threats



Why is the Cyber Security Challenge so Difficult?

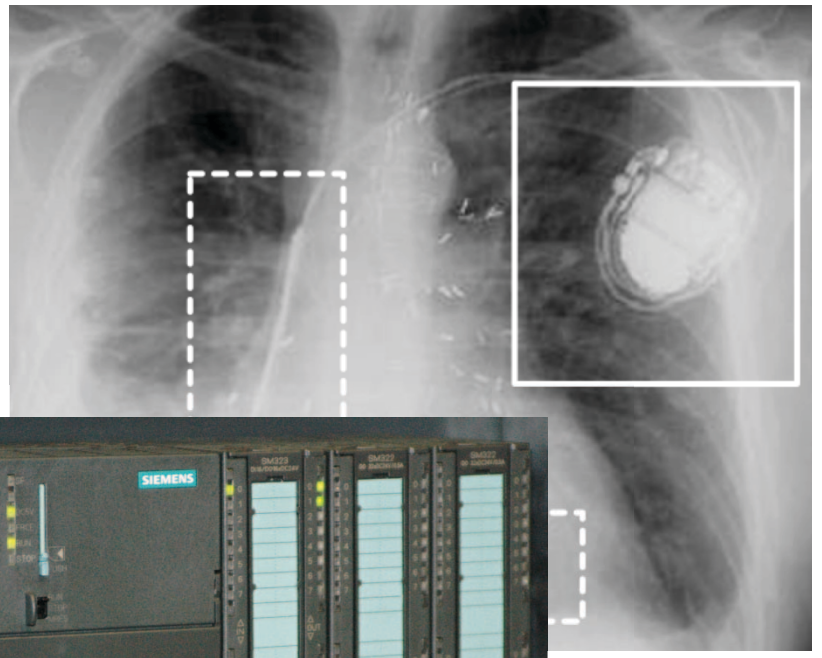
- **Attacks and defenses co-evolve**: a system that was secure yesterday might no longer be secure tomorrow.
- The technology base of our systems is frequently updated to improve functionality, availability, and/or performance. **New systems introduce new vulnerabilities** that need new defenses.
- The **environments** in which our computing systems are deployed and the functionality they provide are **dynamic**, e.g. cloud computing, mobile platforms.
- As **automation pervades new platforms**, vulnerabilities will be found in critical infrastructure, automotive systems, medical devices.
- The **sophistication** of attackers is increasing as well as their sheer **number** and the **specificity** of their targets.
- Cyber security is a **multi-dimensional** problem requiring expertise from CS, mathematics, economics, behavioral and social sciences.

Future Cyber-Physical Systems

Public safety radio

Vehicle systems

Medical devices



Industrial control

Evolution of Cyber Threats

Future security challenges will follow Internet adoption patterns:

Credit: Nicolle Rager Fuller, National Science Foundation

- Botnets will continue to dominate how attacks are launched; attribution and forensics is increasingly difficult.
- Distributed attacks increasing in size and sophistication, targeting specific applications.
- Proliferation of attacks spurred by financial gains and now political motives.
- Proliferation of wireless devices and social media platforms open new avenues for hackers.
- Protecting cloud infrastructure key to long-term adoption.
- The trend toward increasingly cyber-enabled systems expands the scope of attacks to physical infrastructure – manufacturing, energy production, healthcare and transportation.

Thanks!