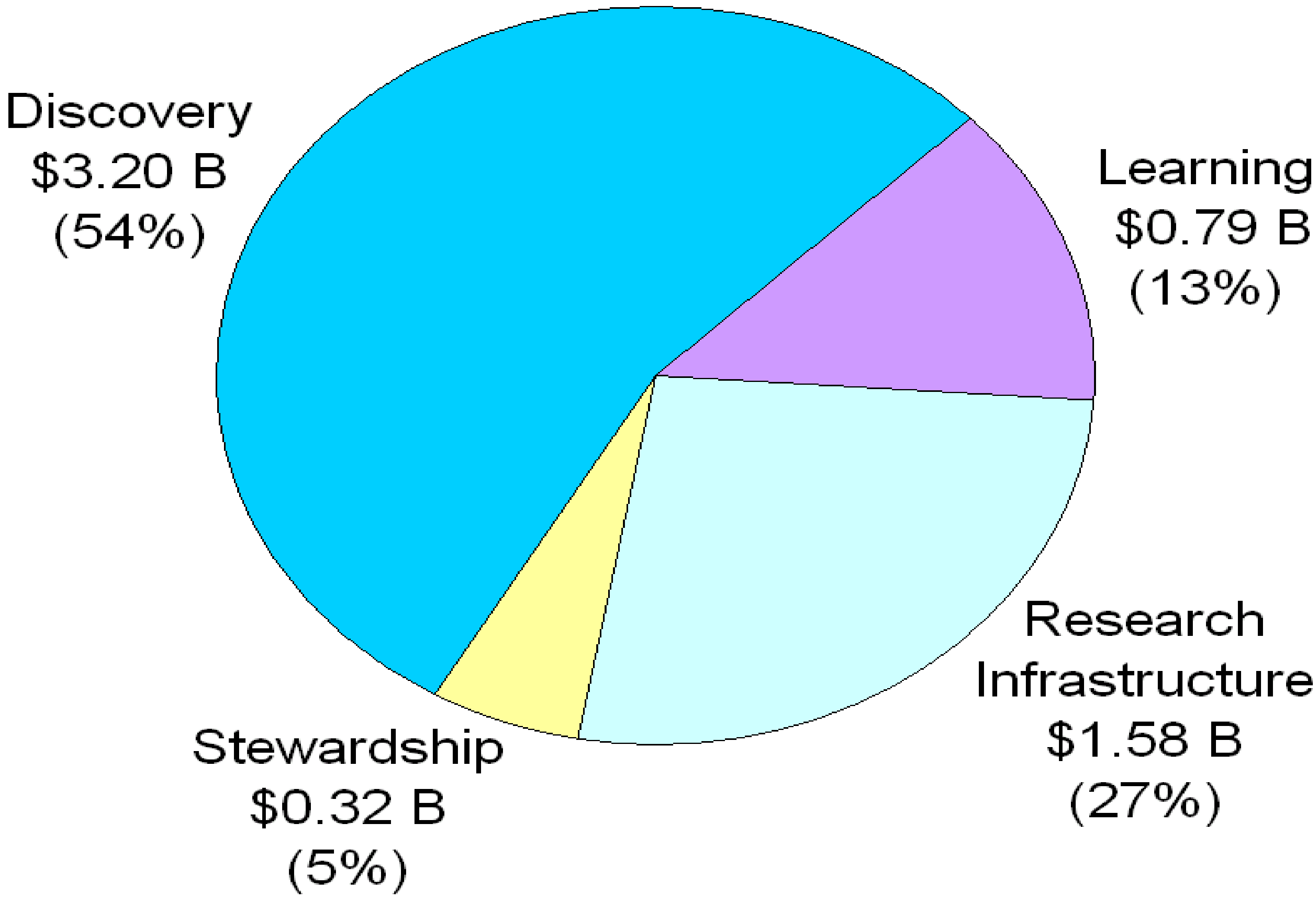
Looking Ahead at CISE

Jeannette M. Wing

Assistant Director
Computer and Information Science and Engineering

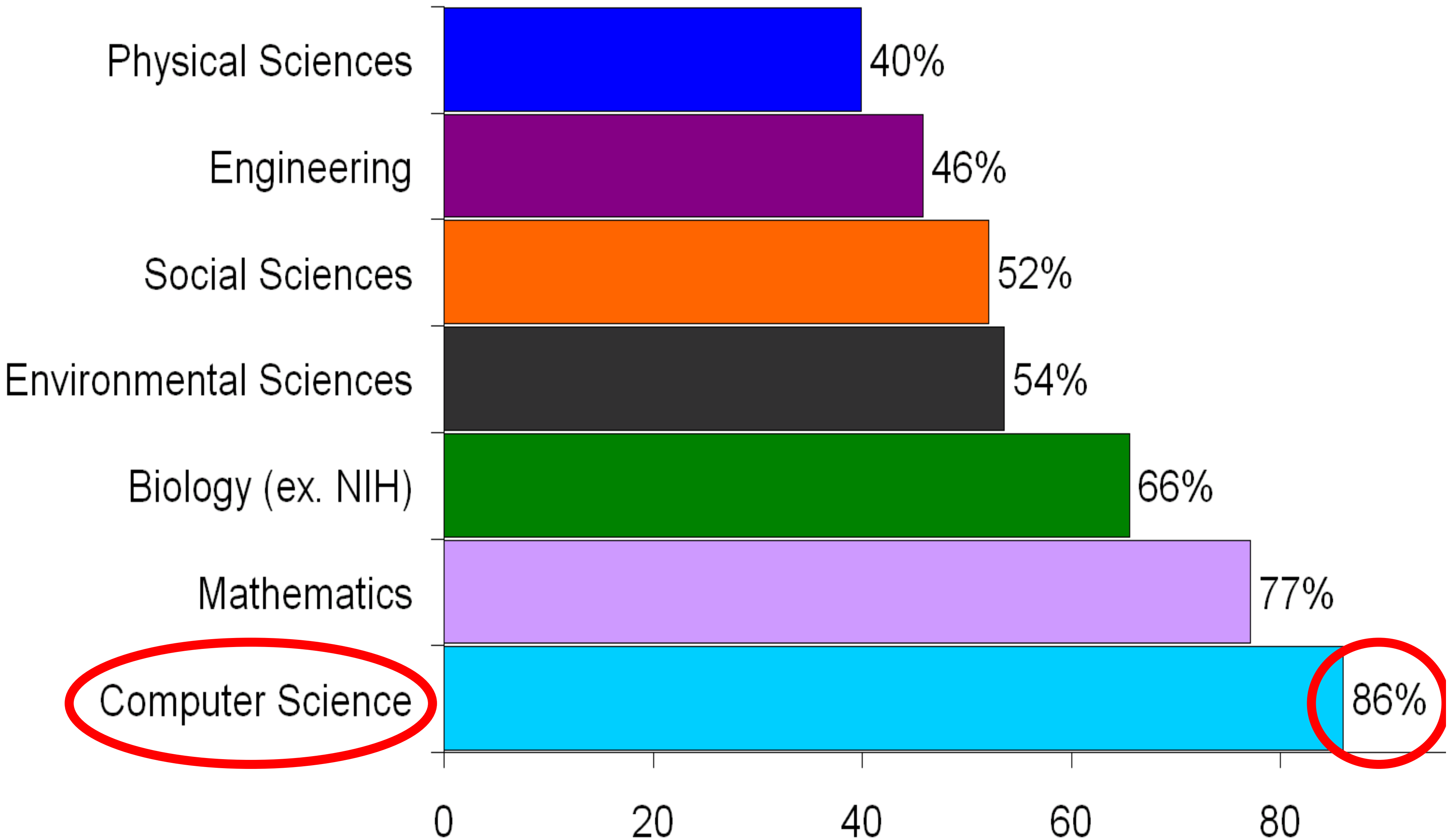
Executive Leadership Summit
23 February 2009

FY 2007 Budget Obligations, $5.88 Billion*



Stewardship for the Field

NSF support as a percent
of total federal support
of academic basic research



CISE

Core and Cross-Cutting Programs

CCF

Core

- Algorithmic F’ns
- Communications & Information F’ns
- Software & Hardware F’ns

CNS

Core

- Computer Systems
- Network Systems

- Infrastructure
- Education & Workforce

IIS

Core

- Human-Centered
- Information Integration & Informatics
- Robust Intelligence

Cross-Cutting

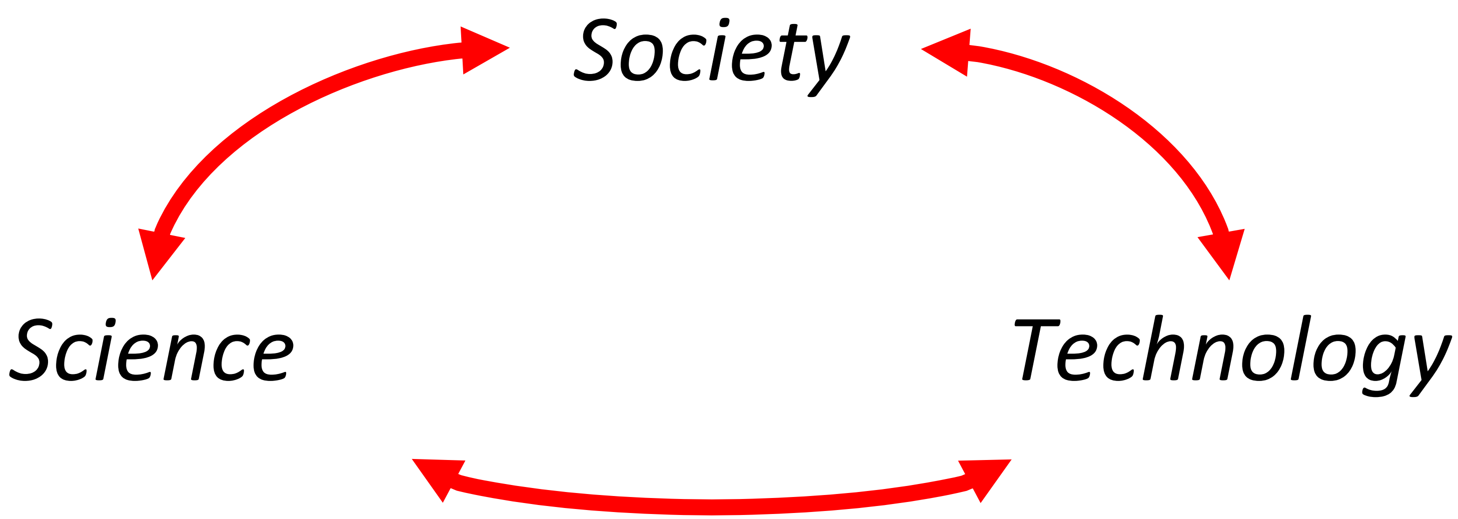
- Cyber-Physical Systems
- Data-intensive Computing
- Network Science and Engineering
- Trustworthy Computing

Plus many many other programs with other NSF directorates and other agencies

CISE FY08-FY09 Research Initiatives

- New FY09 Initiatives
  - Data-Intensive Computing
  - Cyber-Physical Systems (joint with ENG)
- Enhanced Initiatives
  - Network Science and Engineering
  - Trustworthy Computing
- Continued from FY08
  - Cyber-enabled Discovery and Innovation
  - Expeditions
  - Multicore Chip Design and Architecture

Drivers of Computing



Data Intensive Computing

How Much Data?

- NOAA has ~1 PB climate data (2007)
- Wayback machine has ~2 PB (2006)
- CERN's LHC will generate 15 PB a year (2008)
- HP is building WalMart a 4PB data warehouse (2007)
- Google processes 20 PB a day (2008)
- "all words ever spoken by human beings" ~ 5 EB
- Int'l Data Corp predicts 1.8 ZB of digital data by 2011

Slide source: Jimmy Lin, UMD

Convergence in Trends

- Drowning in data
- Data-driven approach in computer science research
  - graphics, animation, language translation, search, …, computational biology
- Cheap storage
  - Seagate Barracuda 1TB hard drive for $195

- Growth in huge data centers
- Data is in the “cloud” not on your machine
- Easier access and programmability by anyone
  - e.g., Amazon EC2, Google+IBM cluster, Yahoo! Hadoop

Data-Intensive Computing
Sample Research Questions

Science

- What are the fundamental capabilities and limitations of this paradigm?
- What new programming abstractions (including models, languages, algorithms) can accentuate these fundamental capabilities?
- What are meaningful metrics of performance and QoS?

Technology

- How can we automatically manage the hardware and software of these systems at scale?
- How can we provide security and privacy for simultaneous mutually untrusted users, for both processing and data?
- How can we reduce these systems' power consumption?

Society

- What (new) applications can best exploit this computing paradigm?

Cyber-Physical Systems

Smart Cars

A BMW is "now actually a network of computers"
[R. Achatz, Seimens, Economist Oct 11, 2007]

Credit: PaulStam

Cars drive themselves

Smart parking

Credit: Dash Navigation, Inc.

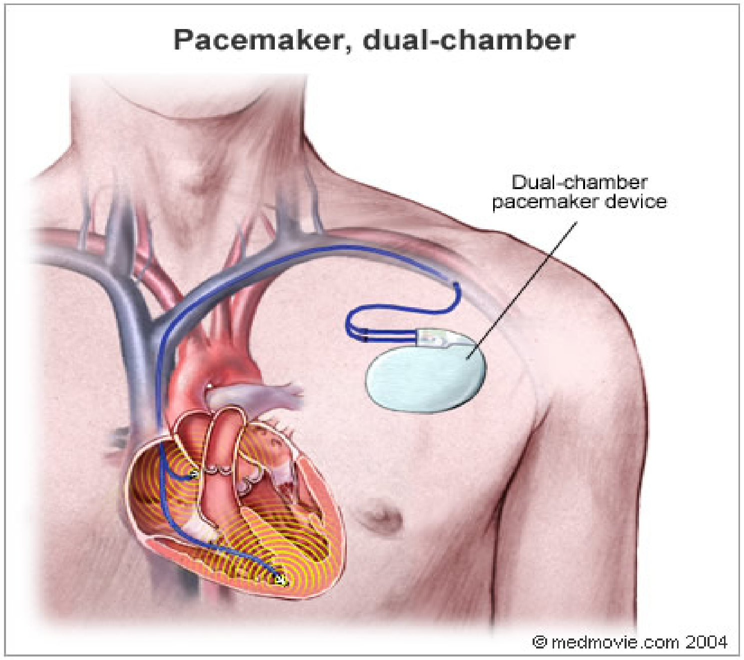
Dash Express:
Cars are nodes in a network

Lampson's Grand Challenge:

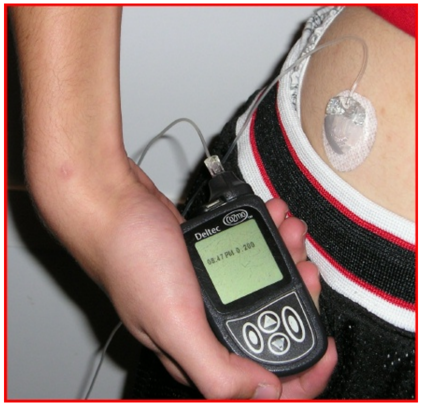
Reduce highway traffic deaths to zero.

[Butler Lampson, Getting Computers to Understand, Microsoft, *J. ACM* 50, 1 (Jan. 2003), pp 70-72.]

Embedded Medical Devices



pacemaker

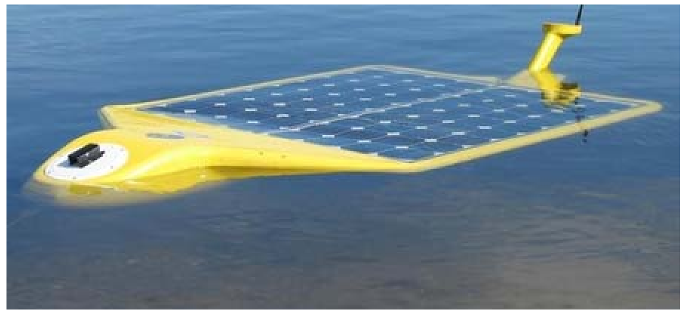


infusion pump

scanner

Sensors Everywhere

Sonoma Redwood Forest



Credit: Arthur Sanderson at RPI

Hudson River Valley

Kindly donated by Stewart Johnston

smart buildings

Credit: MO Dept. of Transportation

smart bridges

Robots Everywhere

Credit: Honda

At work: Two ASIMOs working together in coordination to deliver refreshments

Credit: Paro Robots U.S., Inc.

At home: Paro, therapeutic robotic seal

Credit: Carnegie Mellon University

At home/clinics: Nursebot, robotic assistance for the elderly

At home: iRobot Roomba vacuums your house

Assistive Technologies for Everyone

brain-computer interfaces of today

memex of tomorrow

U.S Broader Research Agenda and Priorities

Dan Reed and George Scalise, editors
August 2007

#1 Priority: Cyber-Physical Systems
Our lives depend on them.

Credit: http://www.ostp.gov/pdf/nitrd_review.pdf

Cyber-Physical Systems
Sample Research Challenges

Science

- Co-existence of Booleans and Reals
  - Discrete systems in a continuous world
- Reasoning about uncertainty
  - Human, Mother Nature, the Adversary

Technology

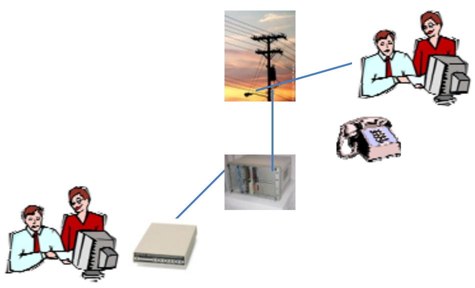
- Intelligent and safe digital systems that interact with the physical world
  - Self-monitoring, real-time learning and adapting

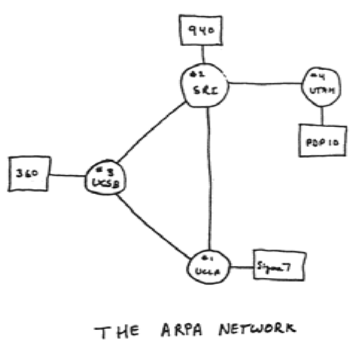
Society

- Systems need to be unintrusive, friendly, dependable, predictable, …

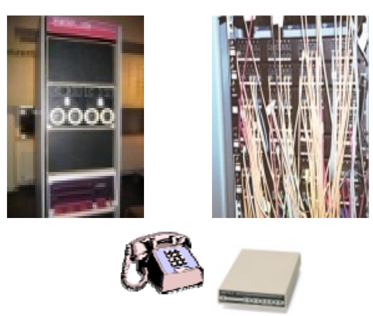
Enhanced Initiatives

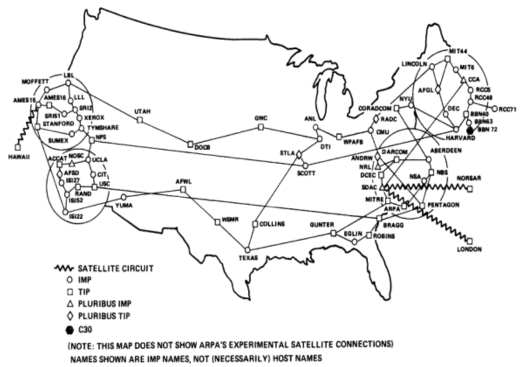
Our Evolving Networks are Complex





1970





1980

1999

Network Science and Engineering

- Fundamental Question: Is there a science for understanding the complexity of our networks such that we can engineer them to have predictable behavior?
- Deepen and broaden research agenda of original GENI concept
- Includes CISE's current networking programs: SING, FIND, NGNI

Network Science and Engineering
Sample Research Challenges

Science → **Understand the complexity of large-scale networks** → **Network science and engineering researchers**

- Understand emergent behaviors, local–global interactions, system failures and/or degradations
- Develop models that accurately predict and control network behaviors

Technology → **Develop new architectures, exploiting new substrates** → **Distributed systems and substrate researchers**

- Develop architectures for self-evolving, robust, manageable future networks
- Develop design principles for seamless mobility support
- Leverage optical and wireless substrates for reliability and performance
- Understand the fundamental potential and limitations of technology

Society → **Enable new applications and new economies, while ensuring security and privacy** → **Security, privacy, economics, AI, social science researchers**

- Design secure, survivable, persistent systems, especially when under attack
- Understand technical, economic and legal design trade-offs, enable privacy protection
- Explore AI-inspired and game-theoretic paradigms for resource and performance optimization

Trustworthy Computing

- Trustworthy = reliability, security, privacy, usability
- Deepen and broaden Cyber Trust
- Three emphases for FY09
  - Foundations of trustworthy
    - Models, logics, algorithms, metrics
  - Privacy
  - Usability

Continued from FY08

CDI: Cyber-Enabled Discovery and Innovation

Computational Thinking for Science and Engineering

- Paradigm shift
  - Not just computing's metal tools (transistors and wires) but also our mental tools (abstractions and methods)
- It's about partnerships and transformative research.
  - To innovate in/innovatively use *computational thinking*; and
  - To advance more than one science/engineering discipline.
- FY08: $48M invested by all directorates and offices
  - 1800 Letters of Intent, 1300 Preliminary Proposals, 200 Final Proposals, 36 Awards

Range of Disciplines in CDI Awards

- Aerospace engineering
- Atmospheric sciences
- Biochemistry
- Biophysics
- Chemical engineering
- Communications science and engineering
- Computer science
- Geosciences
- Linguistics
- Materials engineering
- Mathematics
- Mechanical engineering
- Molecular biology
- Nanocomputing
- Neuroscience
- Robotics
- Social sciences
- Statistical physics

… advances via Computational Thinking

Range of Societal Issues Addressed

- Cancer therapy
- Climate change
- Environment
- Visually impaired
- Water

Expeditions

- Bold, creative, visionary, high-risk ideas
- Whole >> $\sum_{i}$ part $_{i}$
- Solicitation is deliberately underconstrained
  - Tell us what YOU want to do!
  - Response to community
    - Loss of ITR Large, DARPA changes, support for high-risk research, large experimental systems research, etc.
- FY08: 4 awards, each at $10M for 5 years
  - 122 LOI, 75 prelim, 20 final, 7 reverse site visits

4 Awards

- Computational Sustainability
  - Gomes, Cornell, Bowdoin College, the Conservation Fund, Howard University, Oregon State University and the Pacific Northwest National Laboratory
- Intractability
  - Arora, Princeton, Rutgers, NYU, Inst for Adv. Studies
- Molecular Programming
  - Winfrey, Cal Tech, UW
- Open Programmable Mobile Internet
  - McKeown, Stanford

Multicore Chip Design and Architecture

- “Beyond Moore’s Law” (but hardware focus)
- Joint with ENG and Semiconductor Research Corporation (SRC)
- $6M, 15-19 awards

Others

- Joint with other directorates and offices
  - CISE + BIO + SBE + MPS: Computational Neuroscience (with NIH)
  - CISE + EHR: Advanced Learning Technologies
  - CISE + ENG: Cyber-Physical Systems, Multi-core (with SRC)
  - CISE + MPS: FODAVA (with DHS), MCS
  - CISE + OCI: DataNet
  - OCI + CISE + ENG + GEO + MPS: PetaApps
  - Creative IT (co-funding with other directorates)
- Activities with other agencies, e.g., DARPA, DHS, IARPA, NGA, NIH, NSA
- Partnerships with companies
  - Google+IBM, HP+Intel+Yahoo!: Data-Intensive Computing
  - SRC: Multi-core
- Research infrastructure: CRI, MRI
- …

Please see website www.cise.nsf.gov for full list.

Research Ideas in the Works

Clickworkers
Collaborative Filtering
Collaborative Intelligence
Collective Intelligence
Crowdsourcing
Human-Based Computation
Recommender Systems
Reputation Systems
Social Commerce
Swarm Intelligence
Wikinomics
Wisdom of the Crowds

Human-Computer Intelligence

- Multiple dimensions
  - Numbers and types of people
  - Numbers and types of devices and services
  - Numbers and types of communications and interactions
- Examples
  - Individual Memexes, personalized robots, social networks, Second Life++, human computation

- <u>Question:</u> Can we harness these capabilities to make humans and computers work effectively in harmony, solving problems neither can solve alone?

Green IT

IT as part of the problem and IT as part of the solution

- IT as a consumer of energy
  - 2% (and growing) of world-wide energy use due to IT
- IT as a helper to solve problems
  - Direct: reduce energy use, recycle, repurpose, …
  - Indirect: e-commerce, e-collaboration, telework -> reduction travel, …
  - Systemic: computational models of climate, species, … -> inform science and inform policy
- Broader context: Sustainability, Energy, Climate Change, Economy, Human Behavior

Computational Economics

Computer Science influencing Economics
Economics influencing Computer Science

- Automated mechanism design underlies electronic commerce, e.g., ad placement, on-line auctions, kidney exchange

- Internet marketplace requires revisiting Nash equilibria model

- Use intractability for voting schemes to circumvent impossibility results

- Emphasis on foundational aspects (e.g., algorithms, game theory)

  but clearly contributions/participation from AI (multi-agents) and systems communities (and hence overlaps a bit with Human-Computer Intelligence and NetSE)

Education

Education

Challenge to Community: What is an effective way of teaching (learning) computational thinking to (by) K-12?

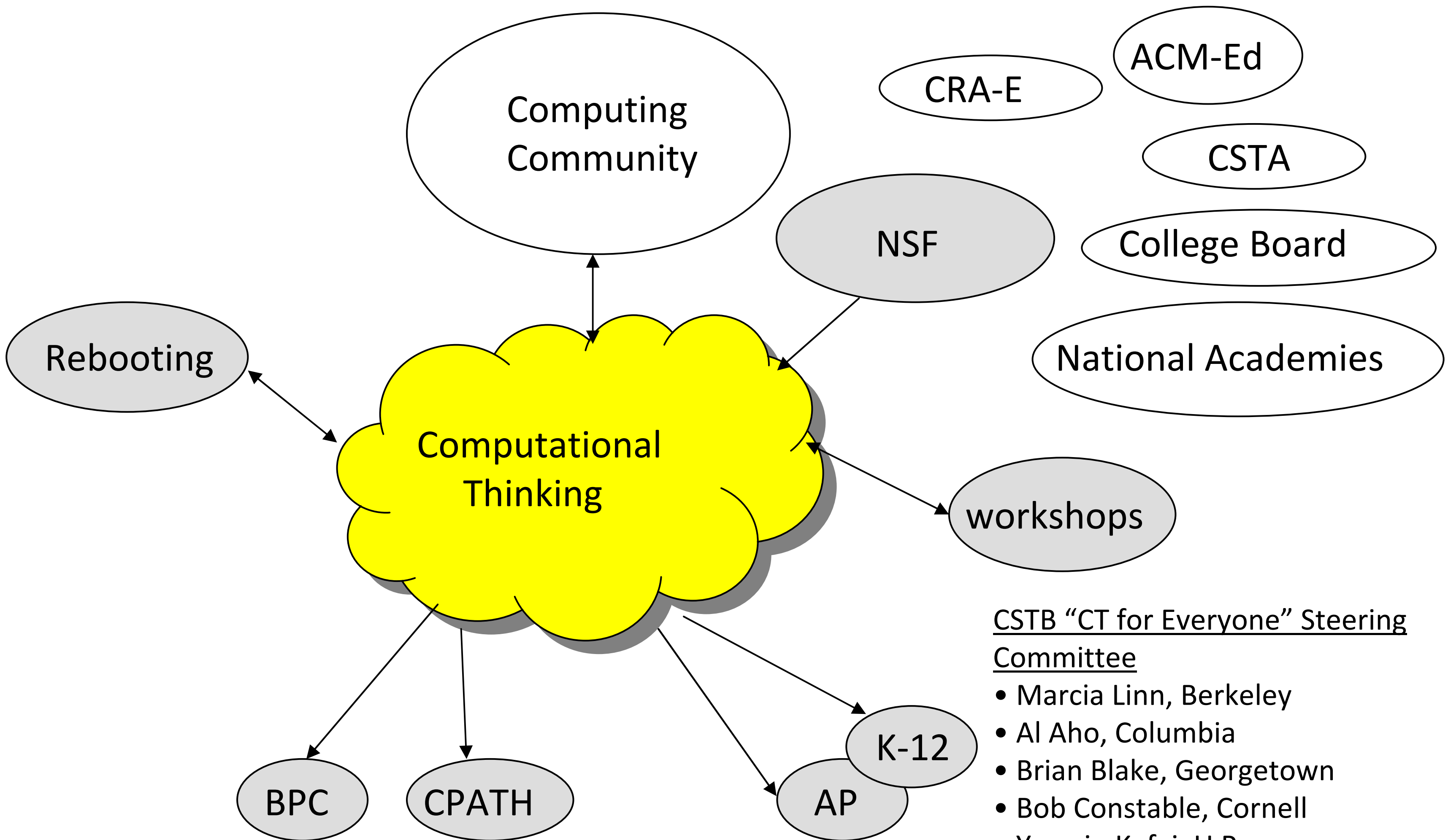
- Computational Thinking for Everyone
  - National Academies Computer Science and Telecommunications Board (CSTB)
    - Workshops on CT for Everyone (last week)
    - Collaborating with Board on Science Education
  - Internal working group at NSF
    - CISE, EHR, SBE, OCI, MPS

CISE Education Programs

- CPATH
  - Goal: Revisiting undergraduate computer science curricula
  - FY08-09: Enlarge scope to include outreach to K-12
  - FY09: More focus on computational thinking, not just curricula models/frameworks.

- Broadening Participation in Computing
  - Focus: Women, underrepresented minorities, people with disabilities
  - Award types: Alliances and Demo Projects
  - FY08: Special projects on image of computing
  - FY09: Re-envisioning the Computer Science AP exam

C.T. in Education: Community Efforts



<u>CSTB "CT for Everyone" Steering Committee</u>

- Marcia Linn, Berkeley
- Al Aho, Columbia
- Brian Blake, Georgetown
- Bob Constable, Cornell
- Yasmin Kafai, U Penn
- Janet Kolodner, Georgia Tech
- Larry Snyder, U Washington
- Uri Wilensky, Northwestern

Report Card: 1.5 Years Later

- Immediate Priorities
  - CDI, CCC, GENI
- Major Themes
  - Emerging Models of Computation
    - Multi-core (MDCA, CCF/SHF), ubiquitous sensing and actuation (CPS), data-intensive computing (CluE and DiC), …
  - Complex Systems and Software
    - NetSE, CPS, Trustworthy Computing
    - Software for Real-World Systems, Rethinking Software DCL
  - Human + Machine Intelligence (coming soon)
  - Computational Thinking for All
    - Science and engineering (CDI)
    - Education (CPATH, BPC, CSTB)

Budget

Thank you!

Stimulus (America Reinvestment and Recovery Act)

- $3B for NSF from Stimulus
  - $2.5B for R&RA, including
    - $300M Major Research Instrumentation (MRI)
    - $200M Academic Research Infrastructure (ARI)
  - $100M EHR
  - $400M MREFC

- Priorities
  - Increase success rate
  - New investigators
  - Create new jobs and preserve jobs (e.g., undergraduates, graduate students, post-docs, junior faculty)
  - Infrastructure, especially "shovel-ready"
  - *No compromise to merit review process and other NSF procedures*

- DCL from me to come

Reminders

- NSF is going to have to process $3B in a **shorter amount of time** than it processes its normal $6B budget **WITH THE SAME NUMBER OF PEOPLE**

- Accountability and reporting for both NSF and the universities will be like what none of us has ever seen before
  - $2M for the NSF Inspector General

- We are in this together: academia and government (and industry).

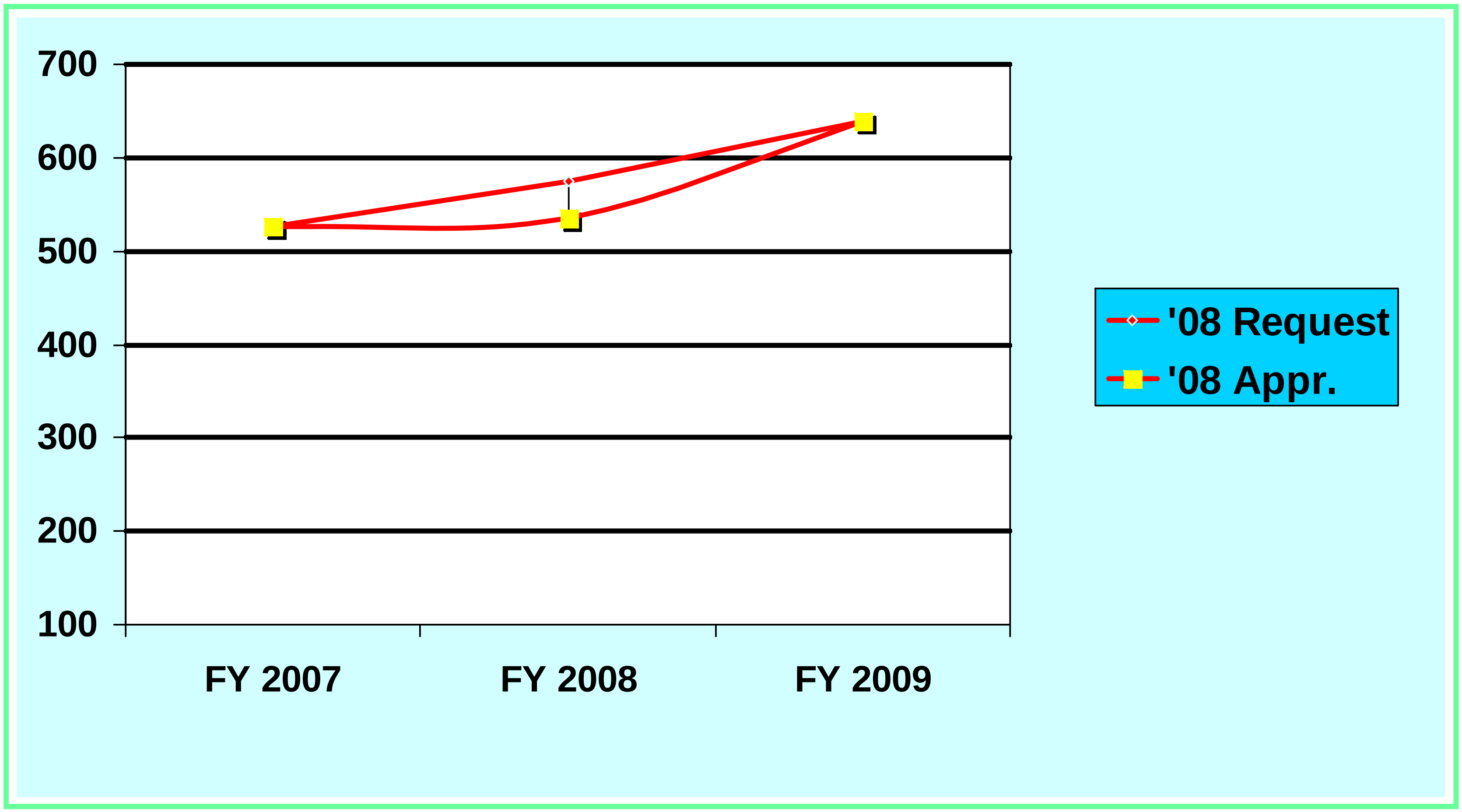
Meanwhile …

FY08 and FY09 CISE Funding

- FY08 (FY began 10/1/07)
  - CISE Request was $574 million, a **9%** increase over FY07
  - CISE Appropriate is $535 million, only a 1.5% increase
  - Missed opportunities of $39 million
    - E.g, ~325 awards or 400 grad students

- FY09 (FY begins 10/1/08)
  - CISE Request totals $639 million
  - Reflects a **$104** million increase, or **19.5%** over FY08 level.
  - Under Continuing Resolution now

CISE FY07 to FY09



Reality

- FY09 (started 10/1/08)
  - Lots of uncertainty now:

    What will Congress do for FY09's budget?

    How will the economy affect everything?
  - How will the $3B Stimulus affect us?
- FY10 (starts 10/1/09)
  - Planning now

These are exciting times.

Thank You!

Credits

- Copyrighted material used under Fair Use. If you are the copyright holder and believe your material has been used unfairly, or if you have any suggestions, feedback, or support, please contact: jsoleil@nsf.gov

- Except where otherwise indicated, permission is granted to copy, distribute, and/or modify all images in this document under the terms of the GNU Free Documentation license, Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation license" (http://commons.wikimedia.org/wiki/Commons:GNU_Free_Documentation_License)