ENG Cyberinfrastructure
Activities and Plans

April 19, 2007

National Science Foundation
Directorate for Engineering

Abhijit Deshmukh
PD, Manufacturing Enterprise Systems/CMMI
Office of Cyberinfrastructure
ENG Cyberinfrastructure Working Group

Recent Developments

Cyber-enabled Discovery and Innovation

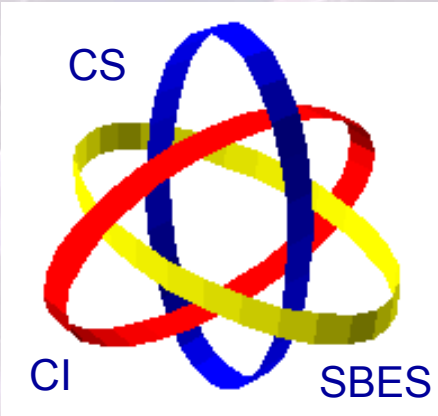
NSF Priority Area (FY 2008 – 2012)

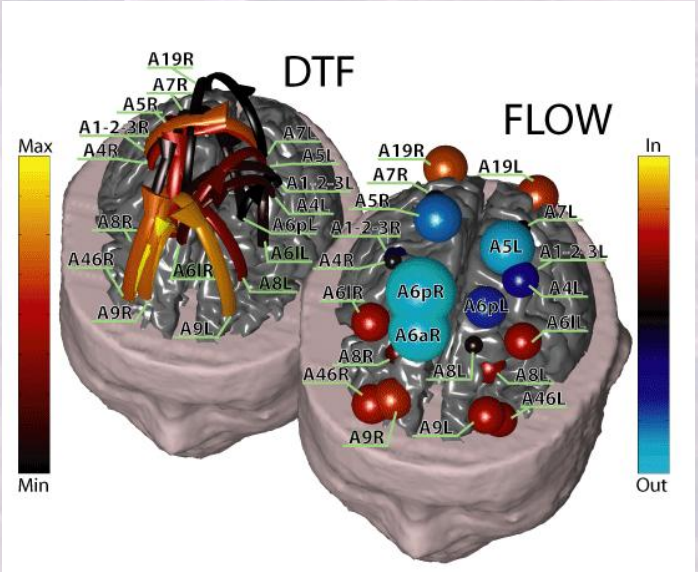
Cyber-enabled Discovery and Innovation (CDI) will broaden the Nation's capability for innovation by developing a new generation of computationally based discovery concepts and tools to deal with complex, data-rich, and interacting systems.

- Conduct of science and engineering has been revolutionized by
  - the infusion of computational science and simulation in the traditional experimentation-observation-analysis-theory loop, and
  - by eliminating the geographic constraints for collaboration and experimentation.
- Primary CDI Themes
  - Knowledge Extraction
  - Complex Interactions
  - Computational Experimentation
  - Virtual Environments
  - Educating Researchers and Students in Computational Discovery

Convergence of CI, Complex Systems and Simulation Based Engineering

- Significant overlap in the core intellectual issues:
  - Predictive models – design and control of complex systems
- Advances in each area depend on others
  - Tight coupling between theory, algorithms, modeling, computation, data and control
- Relevant CDI focus areas
  - Complex interactions
  - Computational experimentation
  - Virtual Environments
- Impact on ENG community
  - Enabling engineering frontiers
  - Resource pooling





ITR: High-Resolution Cortical Imaging of Brain Electrical Activity. Bin He, U Minnesota

ENG CI Focus Areas

- **Fundamentals of Complex Systems**
  - Theoretical framework for understanding complexity
  - Managing, mitigating, reducing complexity
- **Predictive Modeling**
  - Prediction and decision-making under uncertainty in complex systems
  - Multi-scale, multi-phenomenon modeling and simulation
- **Cyber-Physical Systems**
  - Integrating cyber capabilities with physical dynamics and uncertainties
  - "Live" data for real-time modeling, decision-making and control
- **Engineering Virtual Organizations**
  - Infrastructure for predictive modeling and cyber-physical systems
  - Supporting research communities to address grand challenges
- **Education and Workforce Development**
  - Training next generation of researchers
  - Incorporating CI-enabled tools in engineering curriculum

Autonomously Reconfigurable Engineered Systems Enabled by CI (EFRI: ARES-CI)

NSF 06-596

From Complexity to Reconfigurability

- Complexity arises from the need to be robust in presence of anticipated faults
- Complex systems are robust to known uncertainty – yet fragile to unknown events
- Reconfigurable or topologically modifiable systems enable robustness to unknown failures

Core Unanswered Questions

- What are the fundamental principles underlying design and control of reconfigurable systems?
- How much reconfigurability is enough?
- What/when to change/reconfigure?
- Continuum of adaptability, reconfigurability and evolvability

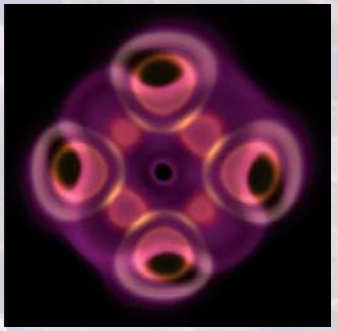
ENG

Engineering Virtual Organizations (EVO)

NSF 07-558

- Primary purpose of this solicitation is to promote the use of Virtual Organizations (VOs) in ENG communities
  - flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resources
- Early ENG experience with gateways has been very positive
  - nanoHUB.org for nanotechnology researchers
  - NEES for earthquake engineering researchers
- EVO will provide seed grants to ENG communities for:
  - Defining user needs for shared community resources
  - Formulating organizing principles and VO structure
  - Building a prototype and developing a plan for full-scale implementation
- Program size: 10-15 awards, $100-200K
- Letter of Intent: May 31, 2007; Full Proposal: July 3, 2007

TeraGrid™



NanoHub

ENG, OISE

Accelerating Discovery in Science and Engineering Through Petascale Simulations and Analysis (PetaApps)

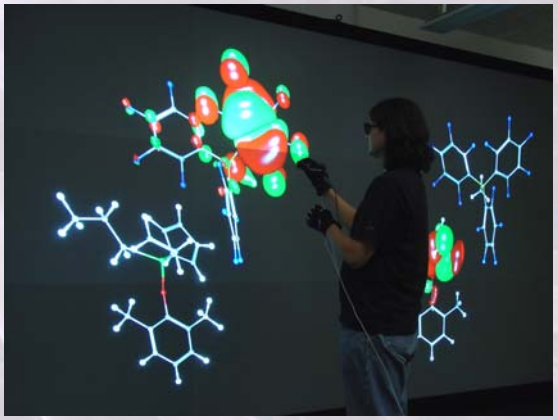
- **Background** — Anticipated Activity
  - Sustained petascale computing capability by 2011
  - High-end HPC architectures will consist of hundreds of thousands of processors, each with multiple cores, each core capable of multiple threads
  - Very few current simulation, optimization and analysis algorithms/tools are capable of using petascale computing capabilities
- **Potential research areas**
  - Enhancing algorithmic scalability exploiting multi-threaded, highly parallel, hierarchical architectures
  - Improving and creating data sampling, analysis and clustering algorithms for large data sets
  - Developing innovative modeling, simulation or optimization algorithms suitable for petascale systems
  - Innovative computational techniques that were previously not viable due to hardware capability

OCI, ENG, MPS, CISE, GEO

CI Experiences for Graduate Students (CIEG)

NSF 06-044

- **Goal**
  - Training next generation of engineering researchers in state-of-the-art CI tools and techniques
- **Boot camp for Cyberinfrastructure**
  - Immersive experience during summer term
  - Continued interaction in following semesters
  - Students work closely with mentors at selected CI centers on projects relevant to their dissertations



- **CIEG Program in Summer 2007**
  - 12 students – supplements to existing awards in three ENG programs
  - 10 week summer residency at the San Diego Supercomputer Center
  - Faculty advisors and SDSC mentors involved in project selection
- Anticipate expanding to other facilities and other programs in the future

ENG

Cyberinfrastructure Training, Education (CI-TEAM)

Anticipated Activity

- **Goals**:
  - Develop a diverse cyberinfrastructure workforce
  - Foster inclusion in cyberinfrastructure activities of diverse groups
- **Demonstration Projects**: Exploratory with the potential to serve as pathfinder for larger-scale implementation activities in the future
- **Implementation Projects**: Expected to deliver sustainable learning and workforce development activities that complement ongoing NSF investment in cyberinfrastructure
- Multidisciplinary teams, significant impact from partnerships
- Leveraged cyberinfrastructure, replicable and (potentially) scalable
- FY06 program funds ~ $10 M for two types of awards:
  - Demonstration Projects ≤ $250,000
  - Implementation Projects ≤ $1,000,000

OCI

Summary of Recent Activities

- Cyber-enabled Discovery and Innovation Initiative (CDI)
- CI, Complex Systems and Simulation Based Engineering
- EFRI: Autonomously Reconfigurable Systems Enabled by CI (ARES-CI)
- Engineering Virtual Organizations (EVO)
- Petascale Simulation and Analysis (PetaApps)
- CI Experiences for Graduate Students (CIEG)
- CI Training, Education (CI-TEAM)

ENG Advisory Committee Subcommittee on CI (EAC-CI) Report

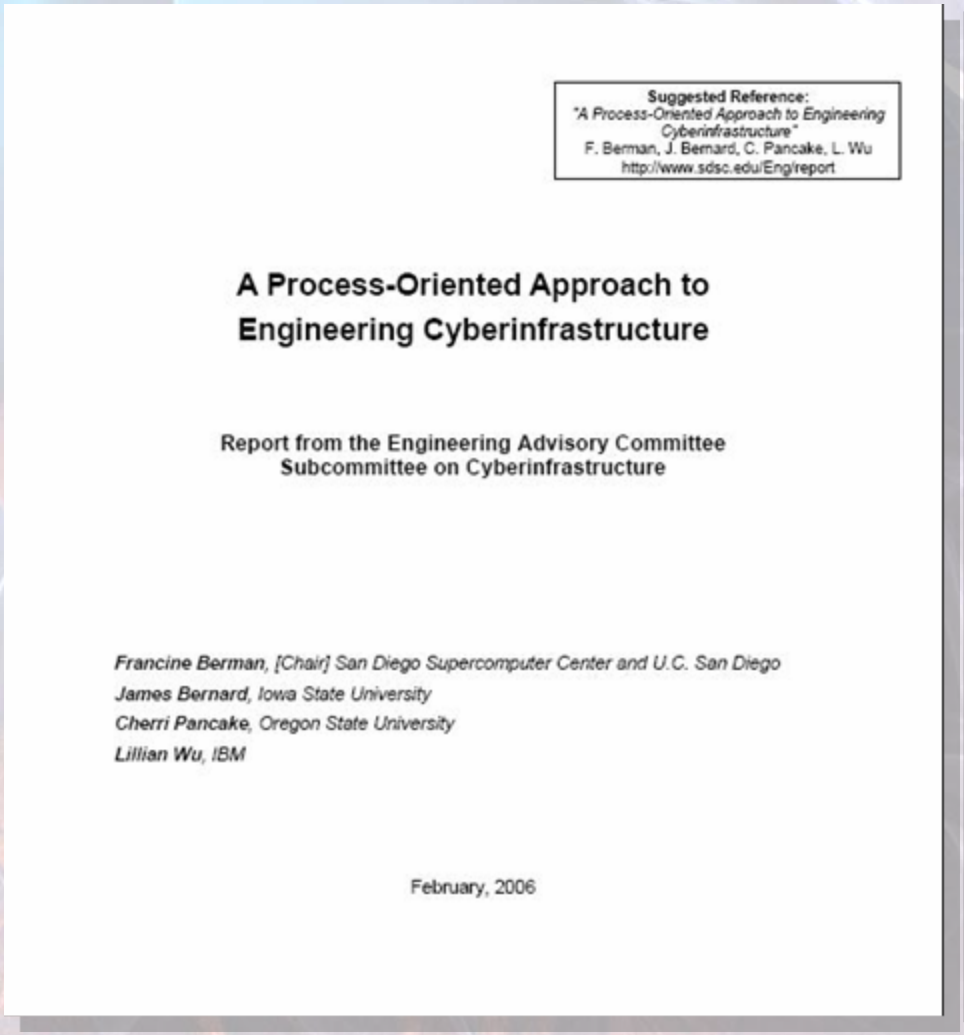
A Process-Oriented Approach to Engineering Cyberinfrastructure

EAC-CI Charge

- The EAC-CI will **work with the Engineering Directorate's Cyberinfrastructure Working Group** (CIWG) to help assess the opportunities and challenges for the Engineering Directorate in Cyberinfrastructure.
- The EAC-CI **will provide advice** on how the Engineering Directorate can contribute to the design, development, deployment, and use of Cyberinfrastructure to promote discoveries and innovations in engineering.
- Particular areas of discussion will include:
  1. What **milestones** should be used to measure progress of CI, and what **metrics** should be used to assess the impact of CI on Engineering research, education, and innovation?
  2. What kinds of activities should ENG encourage to **build a Cyberinfrastructure community** among Engineers?

- **Francine Berman** (SDSC and UCSD) (Chair)
- **James Bernard** (Iowa State University)
- **Cherri Pancake** (Oregon State University)
- **Lilian Wu** (IBM Corporation)
- **Jo Culbertson** (NSF ENG)
- **Abhi Deshmukh** (NSF Eng)
- Thanks to **Suvrajeet Sen,** formerly of NSF ENG, for all his help

EAC-CI Report



Suggested Reference:
"A Process-Oriented Approach to Engineering Cyberinfrastructure"
F. Berman, J. Bernard, C. Pancake, L. Wu
http://www.sdsc.edu/Eng/report

A Process-Oriented Approach to Engineering Cyberinfrastructure

Report from the Engineering Advisory Committee
Subcommittee on Cyberinfrastructure

Francine Berman, [Chair] San Diego Supercomputer Center and U.C. San Diego
James Bernard, Iowa State University
Cherri Pancake, Oregon State University
Lillian Wu, IBM

February, 2006

Recommendations

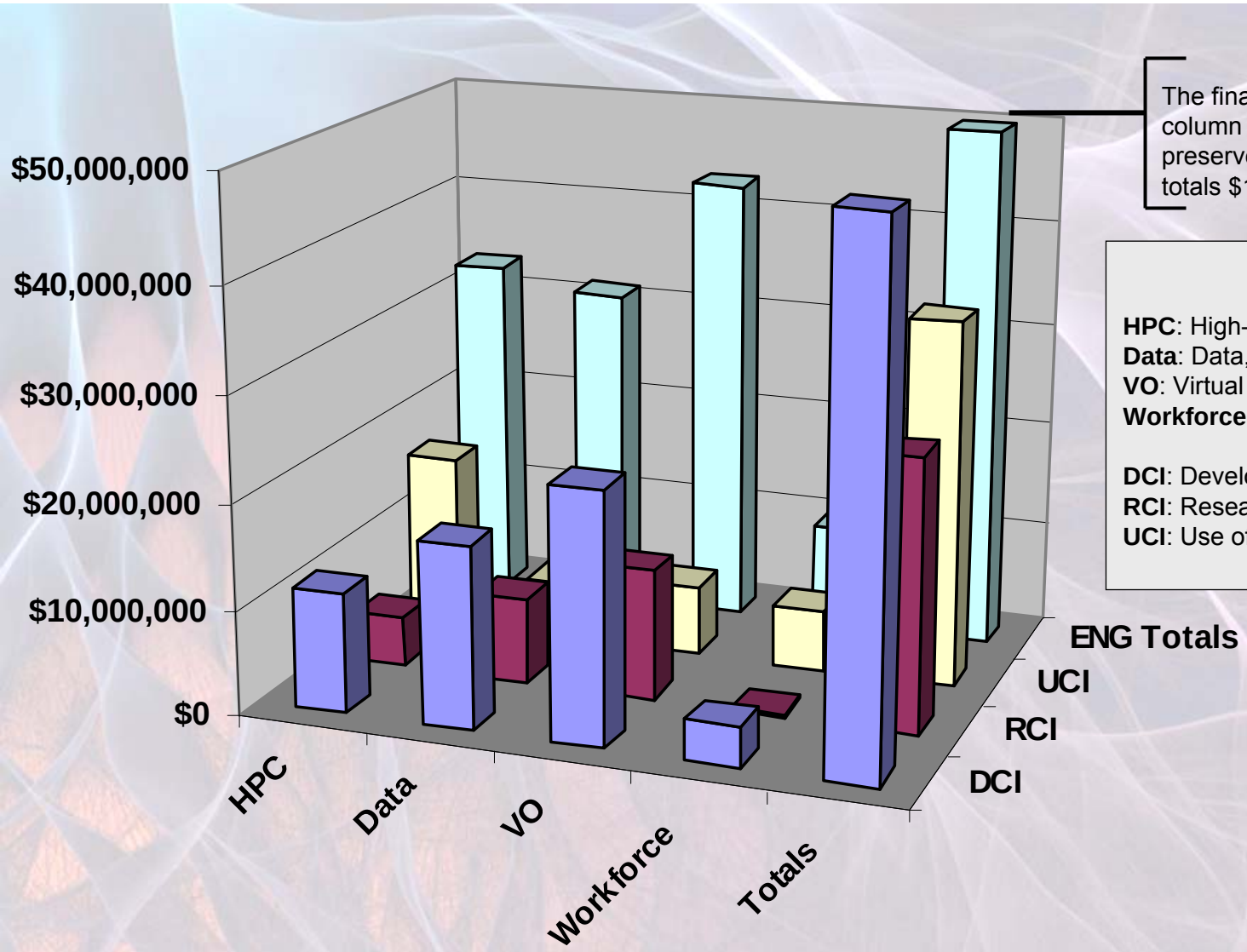
- Assessment of ENG investments in CI and user community needs
- Coordination with OCI and other directorates
- Planning process to determine ENG priorities and investment plans
- Building the Innovation Loop to enable engineering grand challenges, and coordinate CI research, development and deployment

Assessment Recommendations

- Process for identifying an evolving portfolio of representative projects requiring CI should be developed
- Process for tracking ENG CI resources should be developed
- ENG should develop explicit metrics for success, evaluation processes and expectation for accountability for CI projects
- Selection, review and evaluation processes for CI programs should reward usability and usefulness, and disincentivize poorly designed infrastructure or infrastructure without a sufficient community

- ENG CIWG has a process for identifying and tracking CI related projects and investments
- Every two years Science Resource Statistics (SRS) conducts survey of research facilities – including computing and networking – 2007 survey will contain questions on network features, grid technology, data storage and large databases
- ENG and other directorates need to coordinate the development of NSF-wide CI project metrics – under OCI leadership
- EVO solicitation specifically targets community and infrastructure aspects

ENG Investments in CI (FY 04-06 by Category)



The final *ENG Totals* column is truncated to preserve scale, and totals $117,317,000.

Legend

HPC: High-performance Computing
Data: Data, Data Analysis and Visualization
VO: Virtual Organizations
Workforce: Learning and Workforce

DCI: Development and Deployment of CI
RCI: Research Enabling CI
UCI: Use of CI

Coordination Recommendations

- ENG should coordinate with OCI and CIC in provisioning CI
- In coordination with other directorates and OCI, ENG should develop a new funding/program model that specifically addresses the nature of infrastructure
- ENG, in coordination with OCI, should develop guidelines requiring that the products of funded CI projects be available in open domain

- ENG PD assigned part-time to OCI for coordination purposes
- Chair of ENG CIWG serves on the newly formed CI Coordinating Council (CICC) – that reports to CIC
- ENG and other directorates need to develop funding models and metrics for CI – under OCI leadership
- Several joint solicitations and programs are being developed – CI Team, PetaApps

Planning Recommendations

- ENG should determine where cross-cutting CI activities fit within the directorate
- ENG should develop a framework of priorities and apply it purposefully to the CI portfolio
- ENG should discuss and resolve an appropriate set of framing questions for evaluating CI programs

- ENG CIWG has an annual planning and prioritizing process
- ENG CI priorities map on to ENG and NSF-wide initiatives
- Framing questions and metrics are correlated – this issue needs to be tackled at the Foundation level

Relevance to NSF and ENG Priorities

ENG CI Topics \ NSF & ENG Thrusts	CDI	Complex Systems	CI	SBES
Fundamentals of complex systems	HR	HR	R	R
Predictive modeling	HR	HR	R	HR
Cyber-physical systems	HR	R	HR	R
Engineering virtual organizations	HR	R	HR	HR
Education & workforce development	HR	HR	HR	HR

HR – Highly relevant ; R – Relevant

Building the Innovation Loop

- A small set of Engineering CI Research Challenges should be identified
- ENG should adopt guidelines to distinguish CI from other types of research
- Linking programs should be developed to ensure synergistic coordination of CI-related research, development and deployment

- The EFRI Autonomously Reconfigurable Engineered Systems Enabled by CI was a CI related research challenge
- EVO solicitation defines VO/CI differently than other research projects

Questions?