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
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)

➔ 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
Engineering Virtual Organizations (EVO)

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

- **Background**
  - 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

**Anticipated Activity**

OCI, ENG, MPS, CISE, GEO
CI Experiences for Graduate Students (CIEG)

- **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
**Cyberinfrastructure Training, Education (CI-TEAM)**

- **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
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

A Process-Oriented Approach to Engineering Cyberinfrastructure

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

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

<table>
<thead>
<tr>
<th>ENG CI Topics</th>
<th>NSF &amp; ENG Thrusts</th>
<th>CDI</th>
<th>Complex Systems</th>
<th>CI</th>
<th>SBES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamentals of complex systems</td>
<td></td>
<td>HR</td>
<td>HR</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Predictive modeling</td>
<td></td>
<td>HR</td>
<td>HR</td>
<td>R</td>
<td>HR</td>
</tr>
<tr>
<td>Cyber-physical systems</td>
<td></td>
<td>HR</td>
<td>R</td>
<td>HR</td>
<td>R</td>
</tr>
<tr>
<td>Engineering virtual organizations</td>
<td></td>
<td>HR</td>
<td>R</td>
<td>HR</td>
<td>HR</td>
</tr>
<tr>
<td>Education &amp; workforce development</td>
<td></td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
</tr>
</tbody>
</table>

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?