Directorate for Engineering Funding Opportunity Areas

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Areas of Emphasis in Engineering

- Students and young investigators
- Potentially transformative research
- Innovation and translational research

Young Investigators

- Research Experiences for Teachers
- Research Experiences for Undergraduates
- Graduate Research Fellowships
- CAREER awards

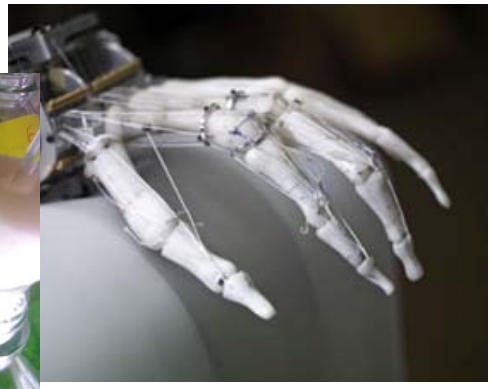
RET teachers introduce girls to infrastructure renewal concepts. *Credit: Univ. of Cincinnati College of Engineering and College of Applied Science.*

Student researchers sample contaminated sediment. *Credit: Karl Rockne, Univ. of Illinois at Chicago*

Potentially Transformative Research

- Emerging Frontiers of Research and Innovation
- Interdisciplinary research
- Disciplinary research

Growing microalgae for renewable fuel. *Credit: Phillip Savage, Univ. of Michigan*



An anatomically correct testbed hand. *Credit: Ellen Garvens, University of Washington*

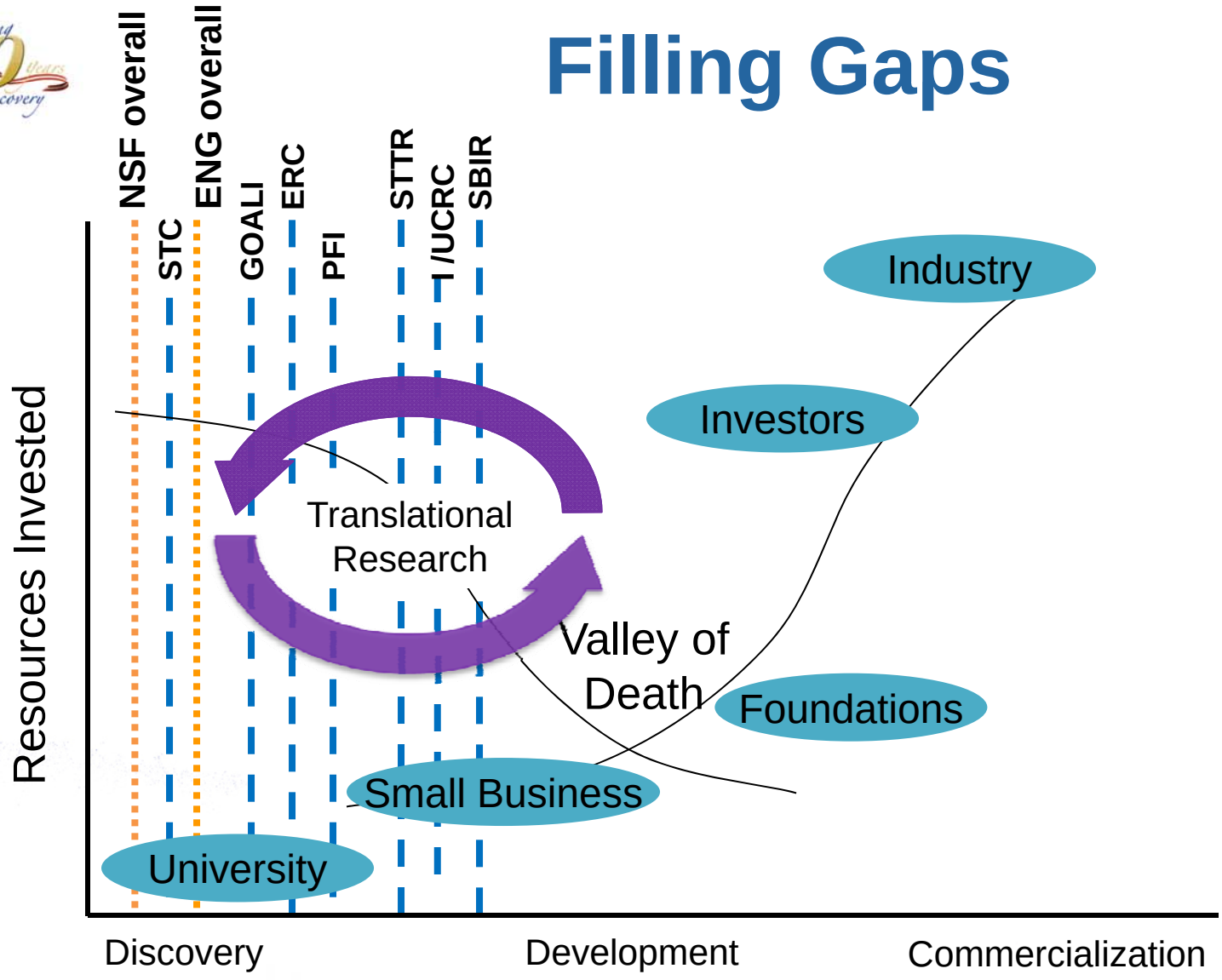
Engineers examine the scoured trench behind the concrete floodwall next to the catastrophic levee breach at the west end of the Lower Ninth Ward of New Orleans. *Credit: Rune Storesund*

Innovation

- Engineering Research Centers
- Industry/University Cooperative Research Centers
- Partnerships for Innovation
- Small Business Innovation Research/Small Business Technology Transfer

The leaves of *Artemisia annua*, the sweet wormwood tree, are the source of artemisinin. *Credit: Lawrence Berkeley National Laboratory*

Filling Gaps



ENG 2011 Request Overview

NSF R&RA Budget ($M)

Directorate	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request	FY 2011 Request			
					Change over FY 2009 Omnibus		Change over FY 2010 Estimate	
					Amt	%	Amt	%
BIO	$656.62	$260.00	$714.54	$767.81	$111.19	16.9	$53.27	7.5
CISE	574.50	235.00	618.83	684.51	110.01	19.1	65.68	10.6
ENG *(less SBIR/STTR)*	574.60	215.08	618.16	682.81	108.21	15.8	64.65	10.5
SBIR/STTR	90.39	49.91	125.77	142.86	52.47	36.7	17.09	13.6
GEO	808.53	347.00	889.64	955.29	146.76	18.2	65.65	7.4
MPS	1243.88	474.97	1,351.84	1,409.91	166.03	13.3	58.07	4.3
SBE	240.56	84.97	255.25	268.79	28.23	11.7	13.54	5.3
OCI	199.23	80.00	214.28	228.07	28.84	14.5	13.79	6.4
OISE	47.45	13.98	47.83	53.26	5.81	12.2	5.43	11.4
OPP	473.55	171.89	505.16	527.99	54.44	11.5	22.83	4.5
IA	241.58	129.85	275.04	295.93	54.35	22.5	20.89	7.6
U.S. Arctic Research Commission	1.50	0.00	1.58	1.60	0.10	6.7	0.02	1.3
Research & Related Activities	$5,152.39	$2,062.64	$5,617.92	$6,018.83	$866.44	16.8	$400.91	7.1

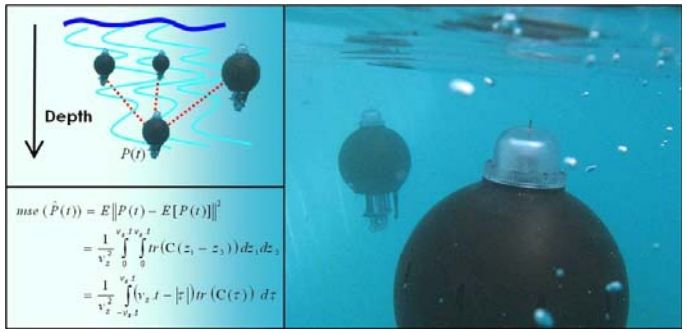
ENG Collaborative Investments

Advanced Manufacturing

- Transformative manufacturing technologies, including
  - **Nanomanufacturing** research and the application of nanotechnology to existing manufacturing industries;
  - Fundamental research associated with **Science and Engineering Beyond Moore's Law** (SEBML), its manufacturing challenges and opportunities; and
  - Basic research efforts on **manufacturing enterprise systems** and **complex systems design and manufacturing**

Cyber–Physical Systems

- Integration of information and control agents with physical hardware.
  - Devices
  - Components
  - Systems with built-in intelligence
- Applications in
  - Medicine
  - Energy distribution and control
  - Environmental monitoring and sensing
  - Education and training
- Joint activity between ENG and CISE



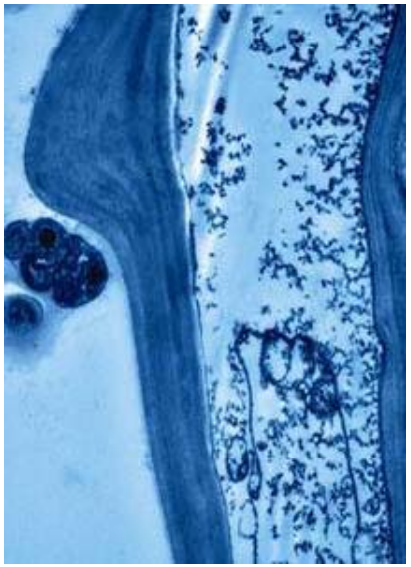
Sensor-equipped underwater drifters self-localize through networked underwater communications and smart formation selection. *Credit: UCSD*

Innovation Ecosystem

- Partnerships for Innovation will provide research grants to universities in partnership with other institutions to increase the economic and social impacts of university research to:
  - Increase the engagement of faculty and students across all disciplines in the innovation and entrepreneurship process;
  - Increase the impact of the most promising university innovations through commercialization, industry alliances, and start-up formulation; and
  - Develop a regional community that supports the “innovation ecosystem” around the university.

National Nanotechnology Initiative

- Nanomaterials and nanodevices
  - Computing
  - Communications
  - Sensing
  - Energy (for example, solar)
- Nanosystems
- Nanomanufacturing
- Environment, health, and safety



Uptake of C70 nanoparticles and their aggregation within a rice plant leaf cell.
Credit: JoAn Hudson, Sijie Lin, and Pu Chun Ke, Clemson University

Science and Engineering Beyond Moore's Law (SEBML)

- Doubling ENG support to $20 million for investigations into:
  - Devices
  - Systems and architecture
  - Multi-scale modeling and simulation research
  - Quantum information science and engineering
  - Design of efficient and sustainable manufacturing equipment, processes, and facilities

RE-ENERGYSE

- Collaboration with DOE to support undergraduate and graduate research in sustainable energy, including the areas of:
  - Manufacturing for energy
  - Energy-efficient materials processing
  - Energy supply chain and logistics

Cornell University home for Solar Decathlon 2009.
Credit: Jim Tetro, U.S. Department of Energy Solar Decathlon

Cyber-Enabled Discovery and Innovation (CDI)

- Multi-disciplinary research seeking contributions to more than one area of science or engineering, by innovation in, or innovative use of computational thinking
- Computational thinking refers to computational…
  - …Concepts
  - …Methods
  - …Models
  - …Algorithms
  - …Tools

CDI is Unique within NSF

- five-year initiative: minimum of $26M in FY 2009 and 2010 (promised min of $26M in FY 2008, awarded $40M)
- all directorates, programmatic offices involved
- to create *revolutionary* science and engineering research outcomes
- made possible by innovations and advances in computational thinking
- emphasis on bold, multidisciplinary activities
- radical, paradigm-changing science and engineering outcomes through computational thinking

Three CDI Themes

CDI seeks transformative research in the following general themes, via innovations in, and/or innovative use of, computational thinking:

- **From Data to Knowledge:** *enhancing human cognition and generating new knowledge from a wealth of heterogeneous digital data;*
- **Understanding Complexity in Natural, Built, and Social Systems:** *deriving fundamental insights on systems comprising multiple interacting elements;* and
- **Building Virtual Organizations:** *enhancing discovery and innovation by bringing people and resources together across institutional, geographical and cultural boundaries*.

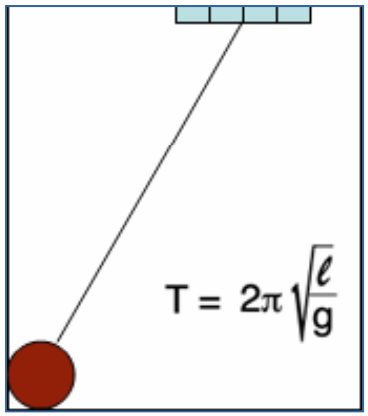
Long-term Funding for Cyber-enabled Discovery and Innovation

- All NSF directorates are participating in this activity (*subject to budget approval*)

	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
Total request/plan	$48M ($52M)	$77M ($100M)	~$103M ($150M)	? ($200M)	? ($250M)?
In Solicitation	$26M	**$26M**	**$26M**	**?**	**?**
Actual	**$40M**	**>$40M**	**?**	**?**	**?**

Simple, Complicated, Complex Systems

Simple



Credit: E. Dow

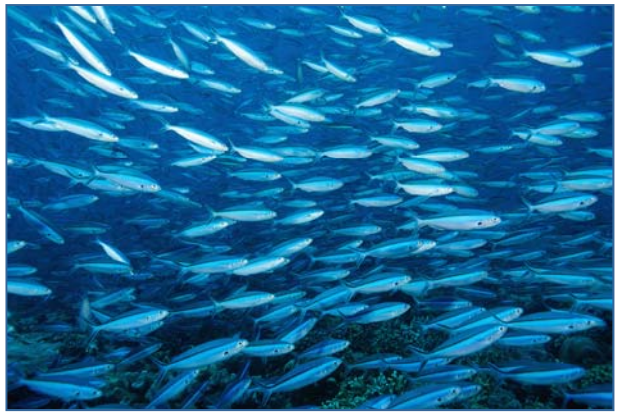
Credit: Microsoft

Complicated

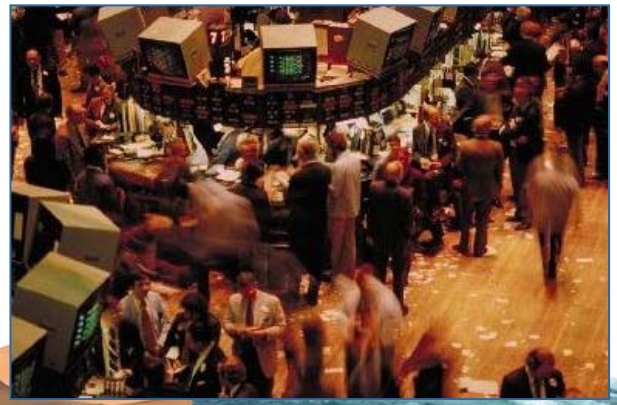
Credit: Boeing Corporation

Credit: Microsoft

Complex

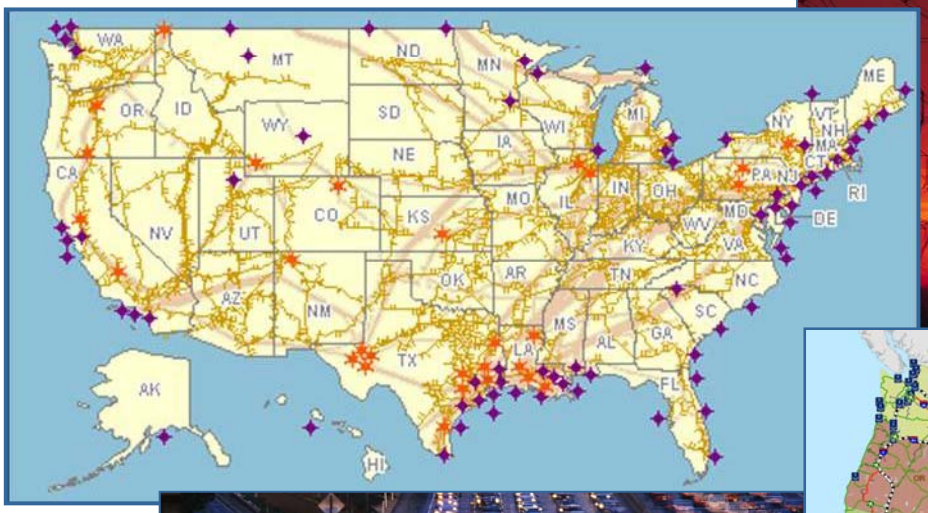


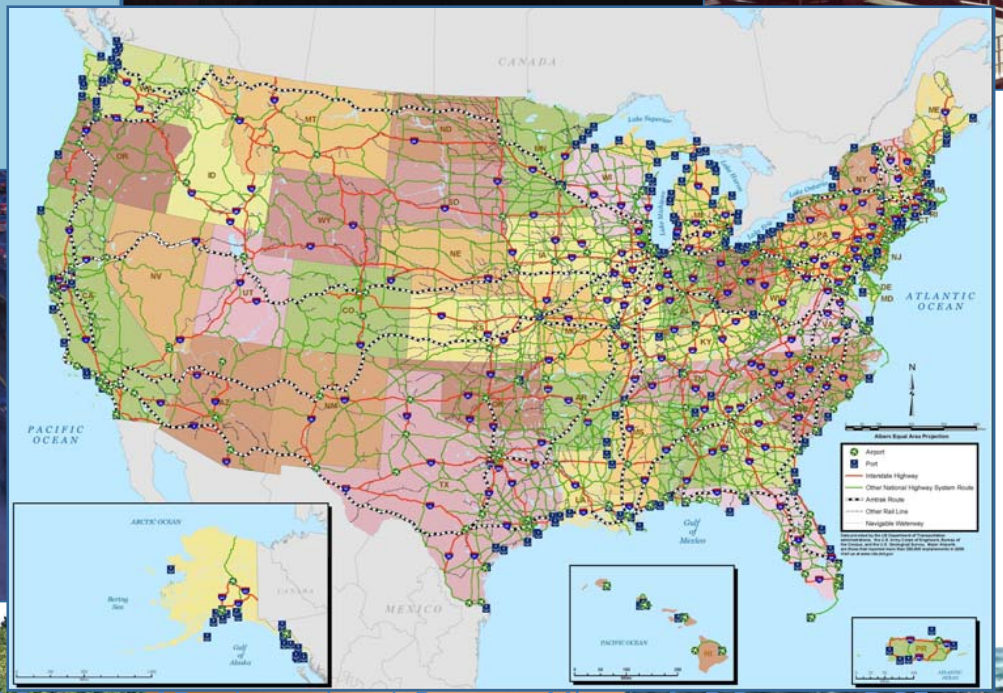
Credit: Microsoft



Credit: NIST

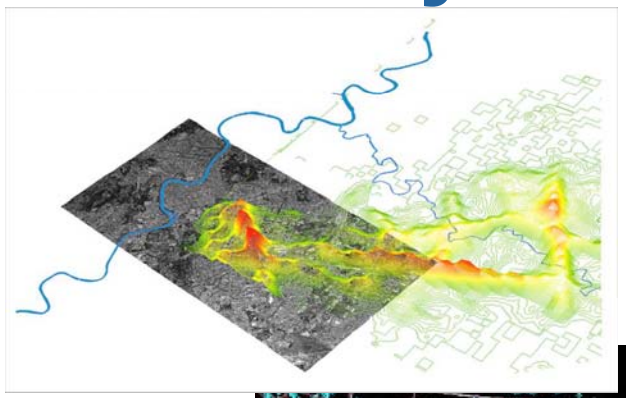
Complex Engineered Systems

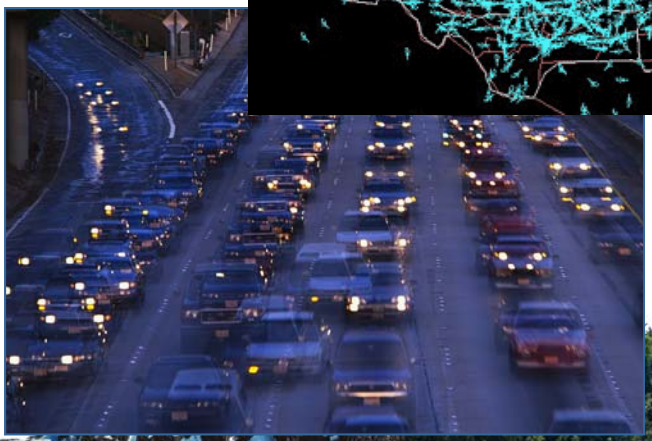




Credits: L Top: DOE; Center Top: Microsoft; R Top: US Bureau of Reclamation; L Bottom: Microsoft; R Bottom: DOT

Building Engineered Complex Systems





Oden (SBES) Report, May 2006

- Blue Ribbon panel commissioned by John Brighton of NSF
- Panel composed of Tinsley Oden, Ted Belytschko, Jacob Fish, Thomas Hughes, Chris Johnson, David Keyes, Alan Laub, Linda Petzold, David Srolovitz, and Sidney Yip
- Study focused on modeling and simulation for prediction of physical events and behavior of complex engineered systems
- “Advances in mathematical modeling, in computational algorithms… competitiveness of our nation may be possible”
- “… advances… require basic research...”
- “Competitors in Europe and Asia… are making major investments in simulation research… much concern that the US is rapidly losing ground.”

SBE&S Study - Structure

- Intended to build on Oden report and expand breadth to include both science and engineering
- Focused on three thematic pillars: materials, energy and sustainability, and life sciences and biomedicine

➔ Initiated July 2007

➔ US Baseline Workshop held in November 2007

➔ Bibliometric analysis performed to identify “hot spots”

➔ Panel visited 57 sites in Europe and Asia

➔ Sites included universities, national labs, industrial labs

➔ Public workshop on study findings held in April 2008

➔ Final report published in April 2009 (wtec.org/sbes)

➔ Followed by Research (Strategic) Directions Workshop in April 2009 (at NAS)

SBE&S Study – Major Findings

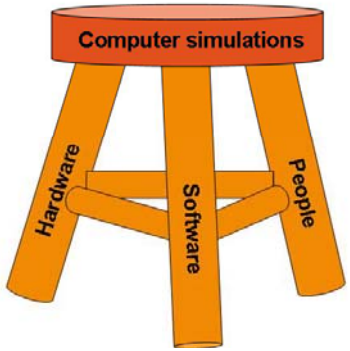
- Inadequate education & training threatens global advances in SBE&S
  - Insufficient exposure to computational science & engineering
  - Multicore/gpu architectures introduce significant challenges for algorithm and software paradigms
  - Insufficient training in HPC; educational gap between domain and computer science ~ treatment of codes by domain scientists as “black boxes”
- Investment in algorithm, middleware, software development lags behind investment in hardware
- Lack of support and reward for code development & maintenance
- Progress in SBE&S requires crossing disciplinary boundaries
- Talented students are choosing curricula that prepare them for lucrative careers in finance, for example, rather than in STEM disciplines

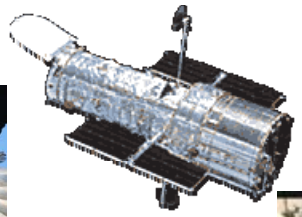
Other Relevant Workshops/Studies

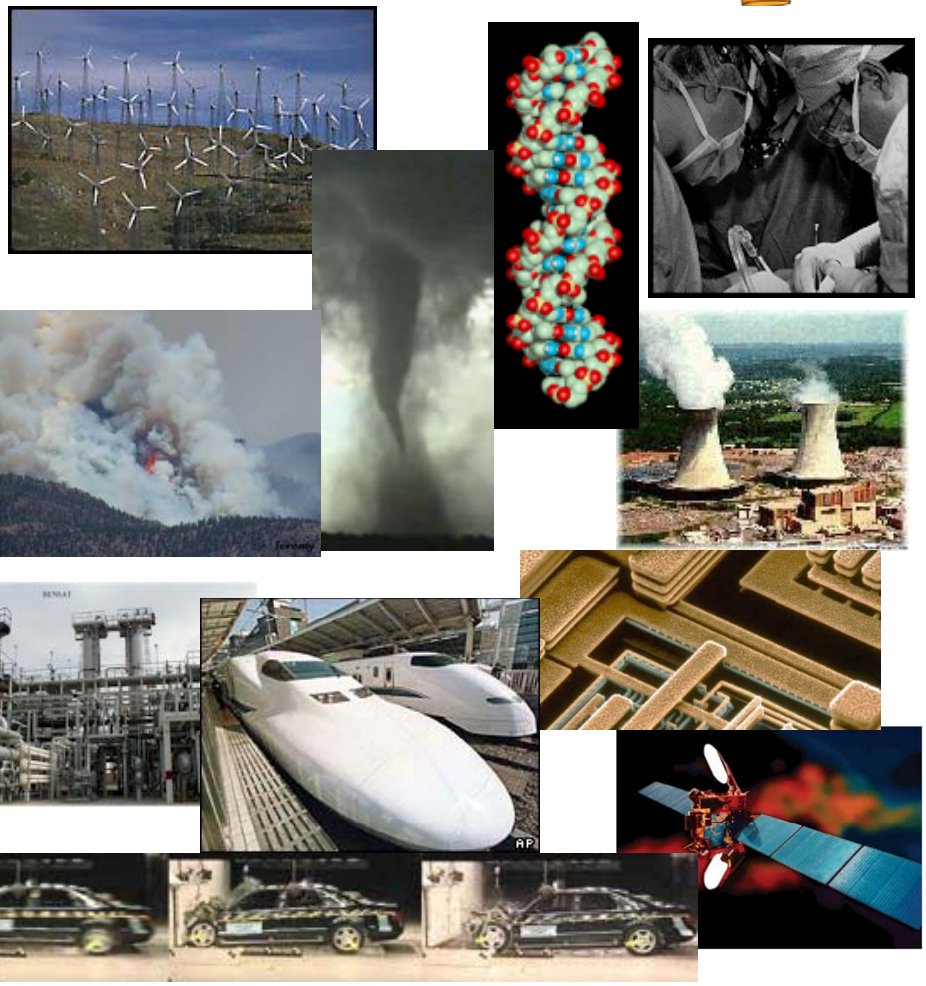
- Computation-Based Engineering (CBE) Summit: Transforming Engineering through Computational Simulation (September 2008 at NAS; http:/www.sandia.gov/tecs/TECSsummit.html)
- Integrated Computational Materials Engineering (NAS study; http://www.nap.edu/catalog.php?record_id=12199)
- OSTP-sanctioned Fast Track Action Committee on Computational Modeling and Simulation (direct follow-on to SBE&S RDW; currently active)

Simulation-Based Engineering and Science - Summary

- Interoperability of software and data are major hurdles
- Use of simulation software by non-simulation experts is limited
- In most S&E applications, algorithms, software and data are primary impediments
- Visualization of simulation outputs remains a challenge
- Treatment of uncertainty (UQ) is inadequate
- Links between physical and system level simulations are weak
- Training of engineers and scientists is inadequate to address simulation and modeling needs







Concluding Remarks

- Students and young investigators
- Potentially transformative research
- Innovation and translational research

- Opportunities in core programs, Engineering-wide and cross-directorate activities (e.g. CDI)
- Stay tuned for future activities…