NSF Activities in Smart Grids including Renewable Resources

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NSF Mission and Vision

The National Science Foundation Act of 1950 (Public Law 81-507) set forth

NSF's mission and purpose:

To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense....

The Act authorized and directed NSF to initiate and support:

- basic scientific research and research fundamental to the engineering process,
- programs to strengthen scientific and engineering research potential,
- science and engineering education programs at all levels and in all the various fields of science and engineering,
- programs that provide a source of information for policy formulation,
- and other activities to promote these ends.

NSF Vision

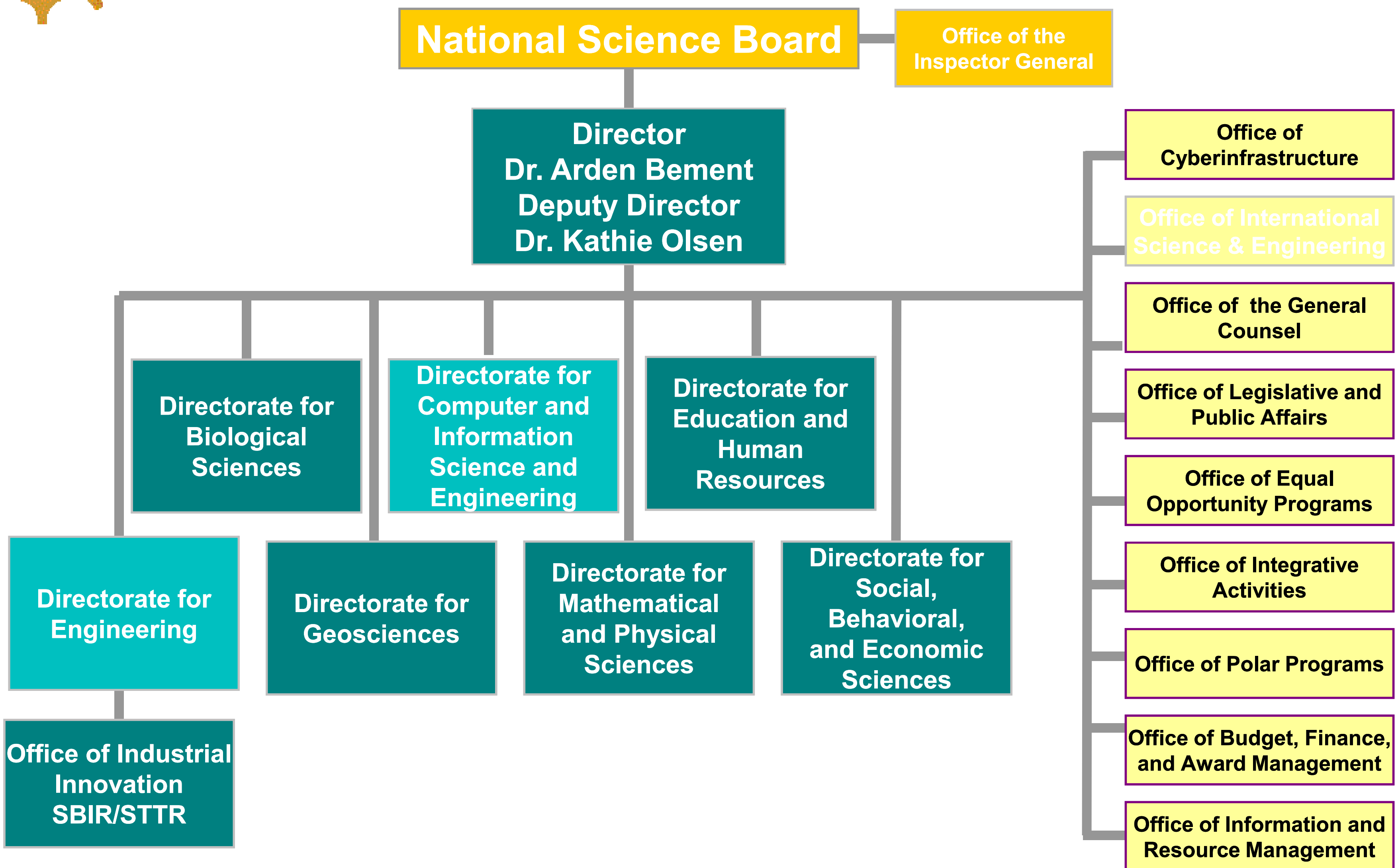
The National Science Foundation is a catalyst for progress through investment in science, mathematics, and engineering.

Guided by its longstanding commitment to the highest standards of excellence in the support of discovery and learning, NSF pledges to provide the stewardship necessary to sustain and strengthen the Nation's science, mathematics, and engineering capabilities and to promote the use of those capabilities in service to society.

NSF in a Nutshell

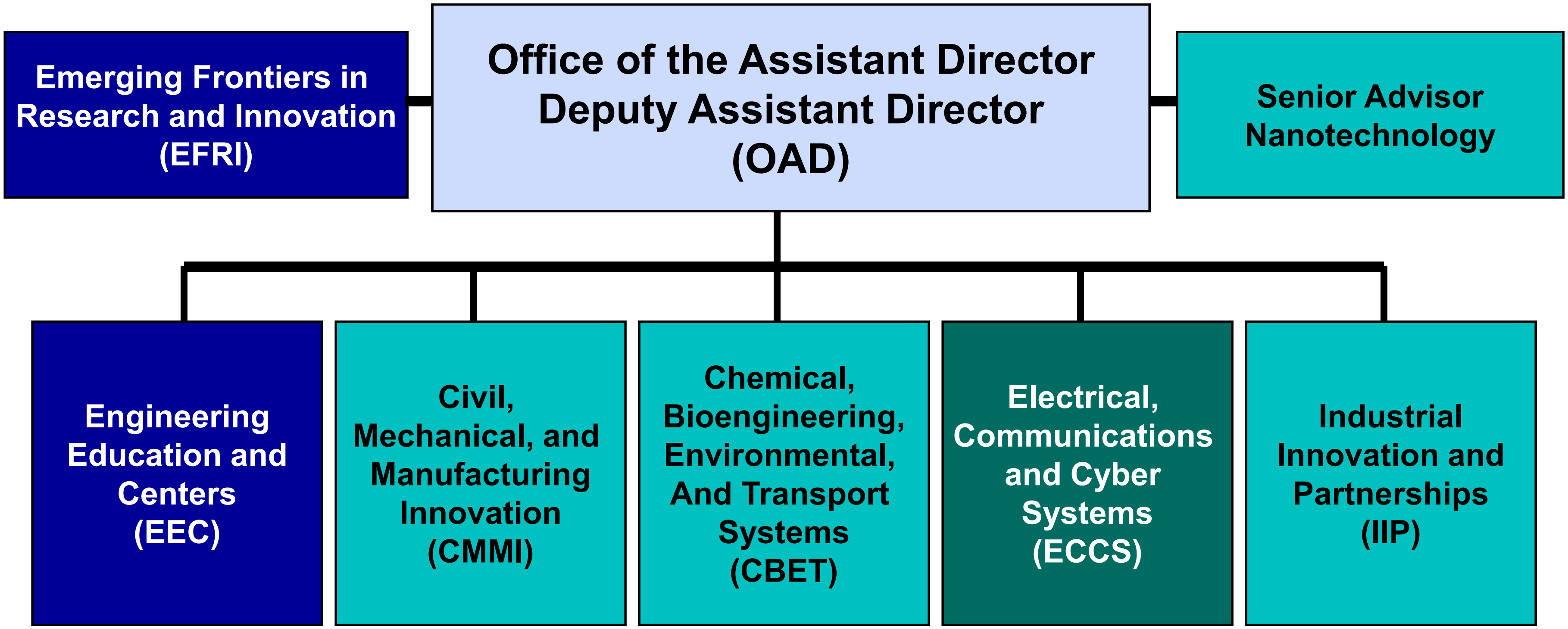
- Independent USG Agency
- Funds basic research & education
- Uses peer-review in selecting proposals to fund
- Low overhead; highly automated grant management processes
- Discipline-based structure complemented by cross-disciplinary mechanisms
- Bottom-up proposal driven
- Use of Rotators/IPAs
- Overseen by National Science Board

NSF Organizational Structure



http://www.nsf.gov

Directorate for Engineering FY'07



Division of Electrical Communication and Cyber Systems - Program Research Areas

Electronics, Photonics and Device Technologies

Optoelectronics/Photonics:
- Nanophotonics;
- Plasmonics and Metamaterials;
- Large-Scale Photonic Integration;
- Ultrafast Phenomena

Dr. Eric Johnson

- Micro/Nanoelectronics;
- Advanced Integrated Circuits;
- Beyond Silicon CMOS;
- Quantum-Level Devices

Vacant

- Molecular Electronics;
- Organic and Flexible Electronics;
- Energy-Efficient Green Electronics and Photonics

Dr. Pradeep Fulay

- Bioelectronics and Biomagnetics;
- Spintronics and Magnetics;
- Sensor Technologies

Dr. Usha Varshney

Integrative, Hybrid and Complex Systems

MEMS/NEMS Systems-on-a-Chip:
- Diagnostic and Implantable Devices;
- Environmental Monitoring;
- Micro Power and Energy

Dr. Yogesh Gianchandani

- RF to Optical Communication Systems;
- Inter- and Intra-chip Communication/Network;
- Mixed Signal Systems;
- Millimeter Wave and Terahertz Systems

Dr. Andreas Weisshaar

- Cyber Physical Systems;
- Next-Generation Cyber Systems;
- Signal Processing

Dr. Scott Midkiff

Power, Controls and Adaptive Networks

Control Theory and Applications:
- Networked Control Systems;
- Sensing and Imaging Networks;
- Biological and Medical Systems;
- Robotic and Embedded Systems

Dr. Radhakisan Baheti

Power and Energy Systems:
- Modeling/Control of Flexible Electric Power Grids, including Micro Grids, Smart Grids;
- Renewable/Alternative Energy Conversion and Storage;
- Interdependencies of Critical Infrastructures

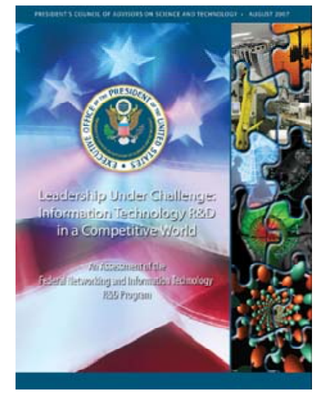
Dr. Dagmar Niebur

- Neuromorphic Engineering;
- Bio-Inspired Complex Systems;
- Quantum Systems Engineering;
- Multi-Scale Modeling/Simulation of Devices and Systems

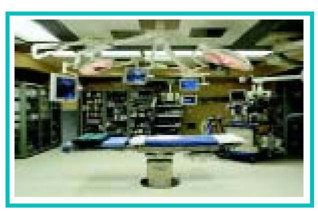
Dr. Pinaki Mazumder

Special Emphasis Area: Cyber-Physical Systems (CPS)

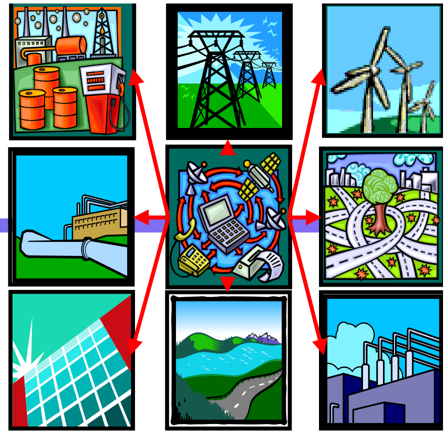
- PCAST priority for "Network and Information Technology (NIT) systems connected with the physical world" – cyber-physical systems
- Addressed through cross-cutting activities in ENG and CISE
- ECCS and CISE/CNS jointly supported workshops
  - CPS Summit (April 2008)
  - National Workshop on High-Confidence Automotive Cyber-Physical Systems (April 2008)
  - **Cyber-Physical Systems for Energy (June 2009)**
- Investments
  - ECCS/IHCS core program
  - ENG EFRI ARES theme (FY 2007)



President's Council of Advisor's on Science and Technology (PCAST), Computational Science: America's Competitiveness Leadership Under Challenge: Information Technology R&D in a Competitive World, August 2007.

NSF/ENG/ECCS/PCAN
Power and Energy Thrust



- **Electric power devices and their control**
  - Wind turbines, ocean wave generators, solar panels
  - Advanced motor drives, power electronic devices
  - Energy storage including batteries, fuel cells
- **Electric and electronic power systems and their control**
  - Power management systems, power electronic systems
  - Micro-grids, distribution & transmission systems, electric building systems, plug-in hybrid electric vehicles
- **Electric power grid as a critical civil & cyber infrastructure**
  - Smart grids, water, transportation
  - Resilience to natural hazards, physical and cyber attacks
  - Sustainability of electric power generation, integration of renewables
  - Interdependence of policies, markets and power system efficiency

Examples of research areas:

- Multi-time and space scale modeling, simulation and control
- Wide area monitoring, real-time dynamic system awareness, protection
- Large data sets aggregation, data mining, intelligent decision tools
- Integration of research and education, microgrids and renewable test beds

ECCS FY10 Budget Priorities and Investments

New/Enhanced Program Investments

- **Energy-Efficient Green Electronics and Photonics: +$2M**
  - Critical to Energy Conservation in New Technologies (EPDT-Fulay, Johnson, PCAN-Niebur)
- **Cyber-Enabled Electric Power Grid Management: +$2M**
  - Critical to Efficient Electric Power Distribution in a new Energy Economy (PCAN-Niebur, IHCN-Midkiff)
- Millimeter-Wave Technology for Broadband Wireless Access: +$2M
  - Enabling technology for Pervasive High-Speed Wireless Service Links (IHCS-Weisshaar)
- Diagnostic and Implantable Biomedical Devices: +$2M
  - Advancing innovation in Health Services through micro/nano systems technologies (IHCS-Gianchandai, EPDT-Varsney)
- Large-Scale Photonics Integration: +$2M
  - Technology driver for advancing Information Technologies, analogous to advances in electronics integration (EPDT-Johnson)

EFRI Topics Selected for FY 2010

Each year, the NSF's ENG Office of Emerging Frontiers in Research and Innovation select 2 topics, to be funded by a combined amount of $22M.

2010 EFRI Topics:

1. **Renewable Energy Storage (RESTOR)**
2. **Science in Energy and Environmental Design (SEED): Engineering Sustainable Buildings**

Deadline: LOI End of September

Multiple FACTS Devices Coordination Using Synchronized Wide Area Measurements

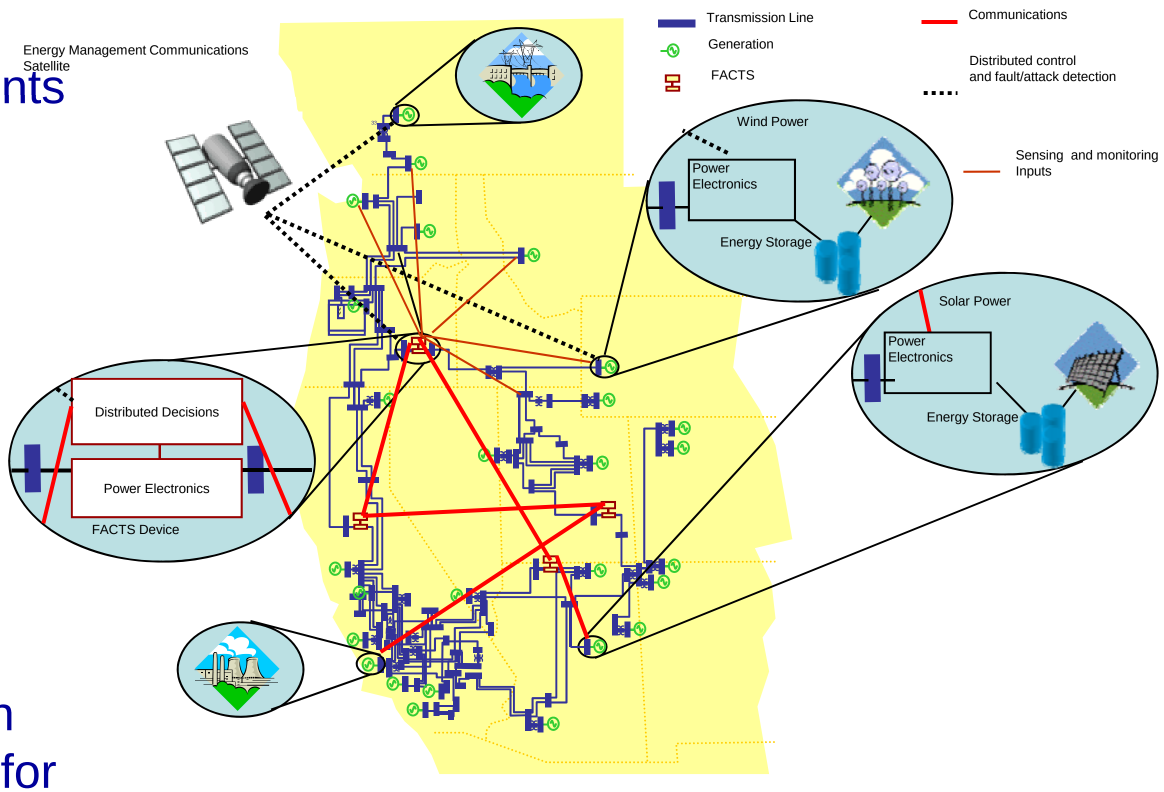
(0701643 and 0701744, M. Crow, MUT and Y. Liu, VT)

- **Objectives**

  Integrate wide area measurements and Flexible AC Transmission Systems (FACTS) (i.e. Power Electronic Devices) to improve power system dynamic control

- **Tasks**

1. Correlate the observability and controllability for FACTS in a large power system
2. Develop an appropriate coordinated control approach
3. Develop a method of on-line oscillation detection and location
4. Develop a placement approach for FACTS and PMUs
5. Analyze the impact of PMU signal integrity on system control
6. Validate the WAMS-based coordinated control of FACTS on a large scale system



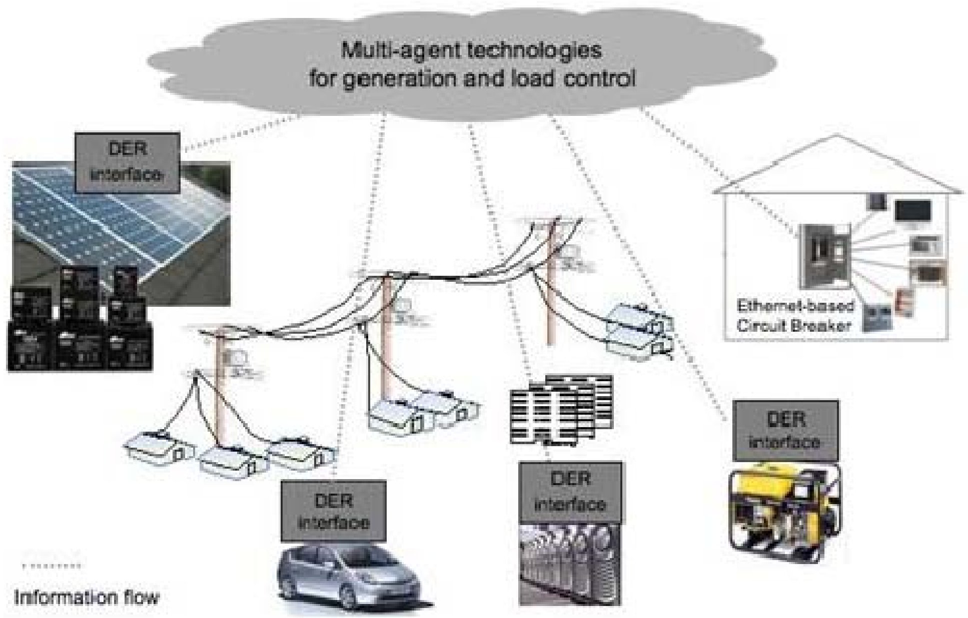
Cyber-Physical Systems Distributed Control: The Advanced Electric Power Grid

Intelligent Distributed Autonomous Power Systems

(#0742832, S. Rahman, P. Pipattanasomporn, Virginia Tech)

Objectives

- Framework for a resilient and environmentally-friendly micro-grid with demand-side participation
- Identification of features and functionalities of enabling technologies that allow customer-owned devices to communicate internally within an IDAPS microgrid



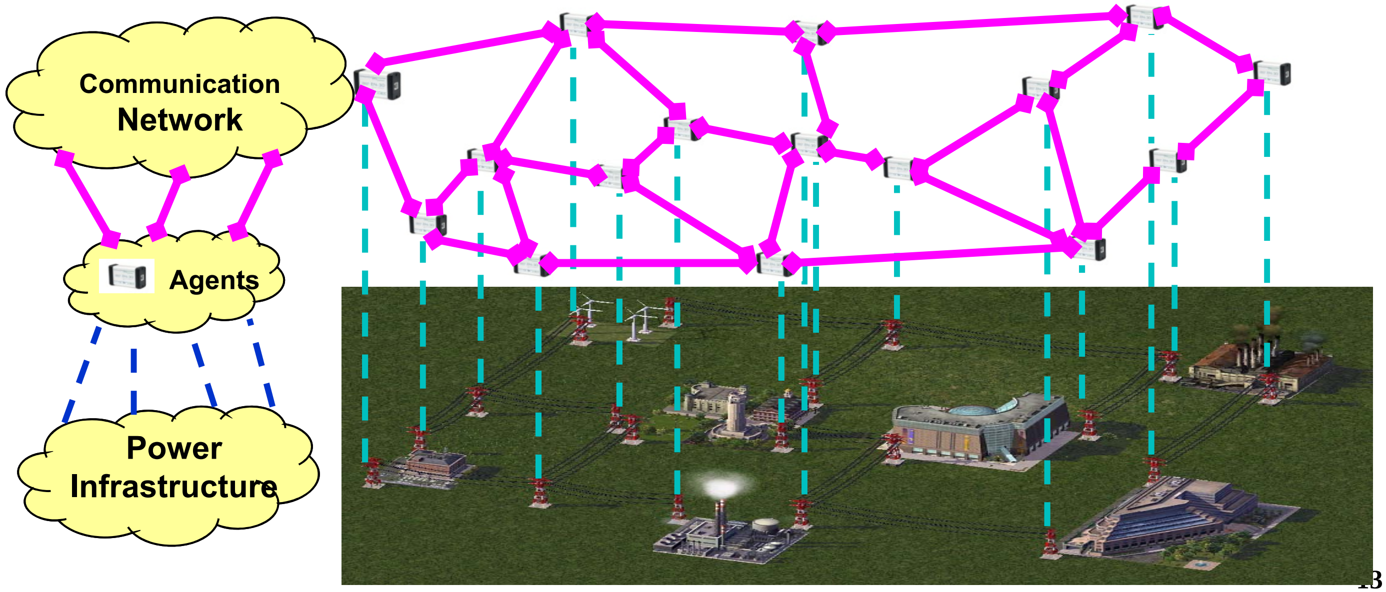
Applications

- Electric power systems with distributed resources
- Smart Grids
- Microgrids

EFRI-RESIN: Development of Complex Systems Theories and Methods for Resilient and Sustainable Electric Power and Communications Infrastructures

L. Mili, Virginia Tech, EFRI-RESIN #0803875

- **Model and investigate cascading failures within and across interdependent cyber and power infrastructures;**
- **Optimally place resources on interdependent cyber and power infrastructures to minimize the risk of catastrophic failures;**
- **Develop a robust and resilient cyber infrastructure for microgrids supervised by a multiagent system;**
- **Develop a two-level sustainability assessment framework (SAF) for cyber and power infrastructures.**



Vehicle to Grid Integration: Cyber-Enabled Coupled Infrastructures

Faculty Participants: J.L. Stein, H. Fathy, H. Peng, et al. (COE & SNRE), M. Crow, MST

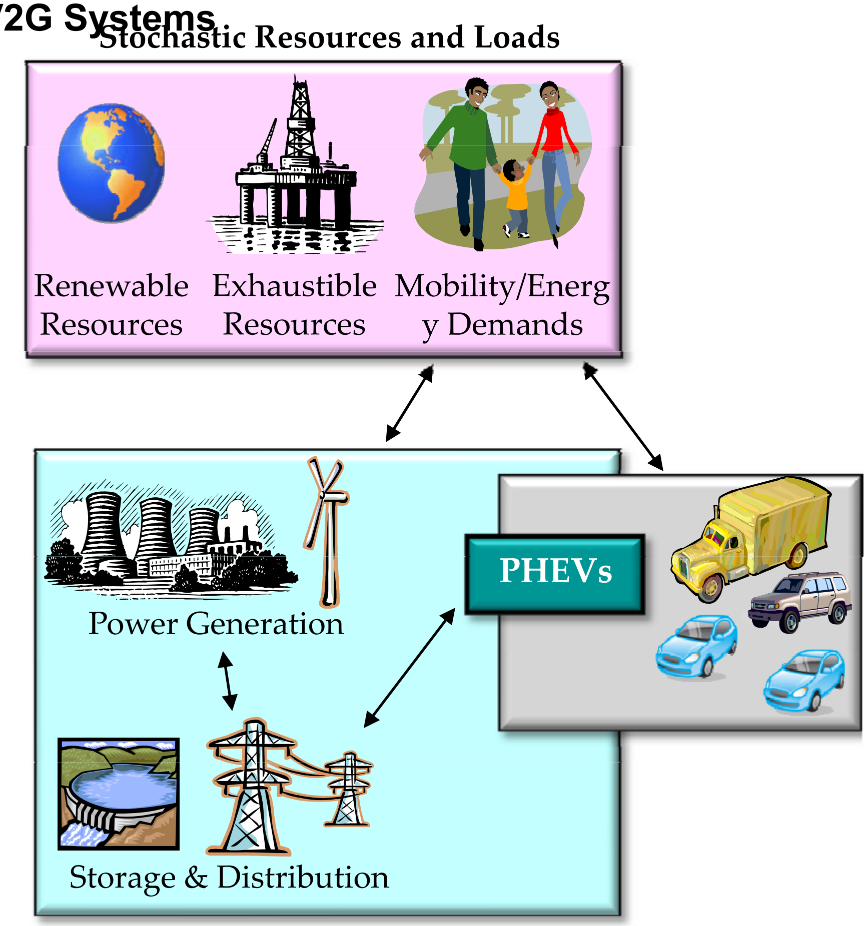
Lab/Center Name: Design & Control of V2G Systems

Sponsor (s): NSF EFRI-RESIN 0835995

Goal of project/program: Framework for Developing V2G Systems

Technical Highlights

- Stability of Power Grid to PHEV loads
- Health Conscious Battery Charging
- Naturalistic Driving Cycles for Assessing PHEV Emissions
- Assessment of Consumer Adoption of PHEVs and its Impact On Emissions
- Smart Grid: Blending PHEVs and Renewable Energy
- Cyber-enabled Control And Design For Resilience And Reliability

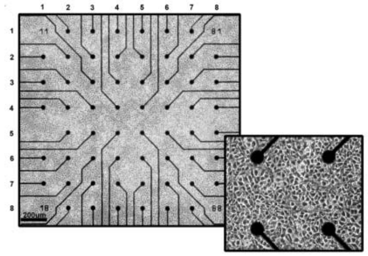


EFRI COPN #0836017 : Neuroscience and Neural Networks for Engineering the Future Intelligent Electric Power Grid

PIs: Ganesh K. Venayagamoorthy, UMST, S. Potter, R. Harley, D. Wunsch

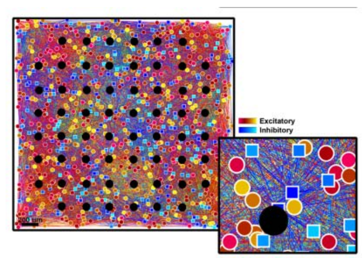
Neuro-inspired concepts:
From the NeuroLab to the Power Grid

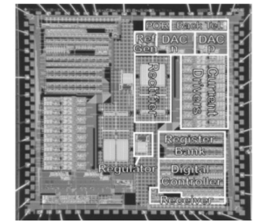
- Circular causality/feedback
- Massive parallelism
- Cellular diversity
- LOTS of sensors



Living networks on chips

Bio-morphic model networks





Ghovanloo 2004

Special-purpose hardware

Scientific Impact/Intellectual Merit

- Enhanced understanding of neural learning mechanisms
- New neural networks architectures
- Brain-like adaptive optimal control techniques
- Improved electricity reliability, stability, security and sustainability

Deliverables

- Neural data repository
- New algorithms
- New bio-morphic real-time control systems
- Software and hardware platforms
- Manpower

Broader Impacts

- Carbon reduction
- Applicable to other large scale nonlinear systems
- Train multi-disciplinary students, professionals and educators
- Attract underrepresented groups
- Industry and international collaboration

WIDE AREA MONITOR AND COORDINATING CONTROLLER (WAMCC)

Monitoring

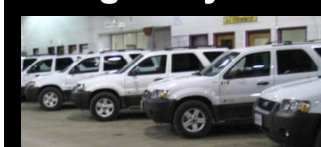
Control Signals

Future Intelligent Power Grid

Thermal Plants

Solar Farm

Plug-in Hybrids

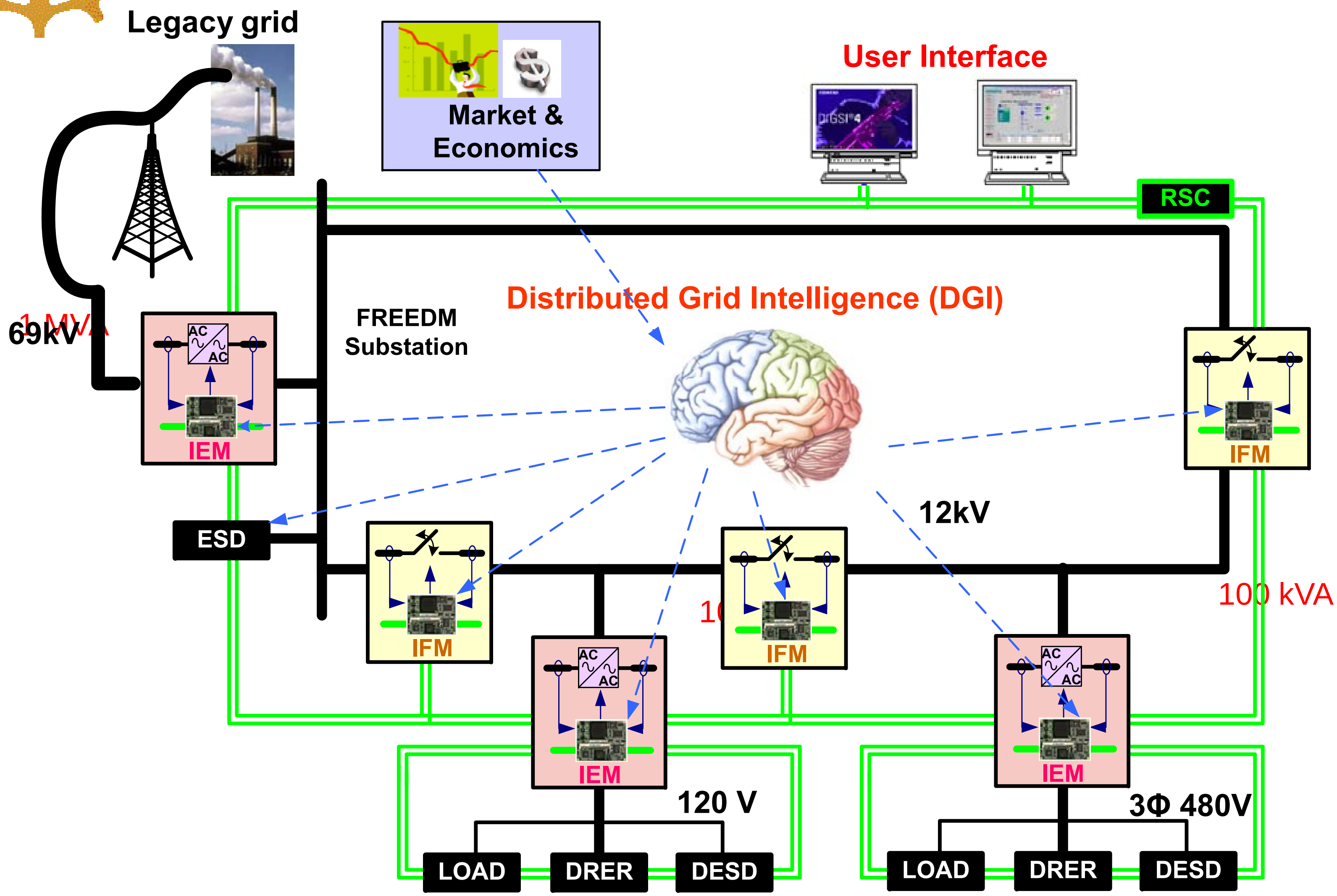


Pumped Storage

Wind Farm

Future Renewable Electric Energy Delivery and Management (FREEDM) Systems

A. Huang, NCSU and FSU, FAMU, MST, ASU



IEM: Intelligent Energy Management **IFM**: Intelligent Fault Management

DRER: Distributed Renewable Energy Resource **DESD**: Distributed Energy Storage Device

Integrated Decision Algorithms for Auto-steered Electric Transmission System Asset Management

0540293 James McCalley

Xfmrs, CBs, Lines

Monitor

Power Grid (Using Areva Operator Training Simulator)

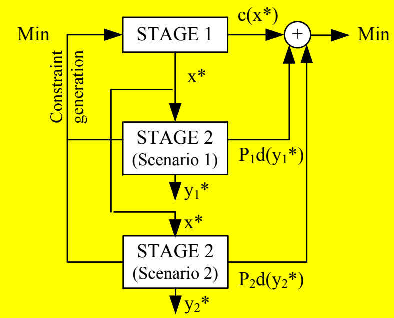
Monitors?

Expand?

Maintain?

Operate?

Algorithms for system-level decision



Condition Data

Failure Indices

Substation communication box

Wide area network

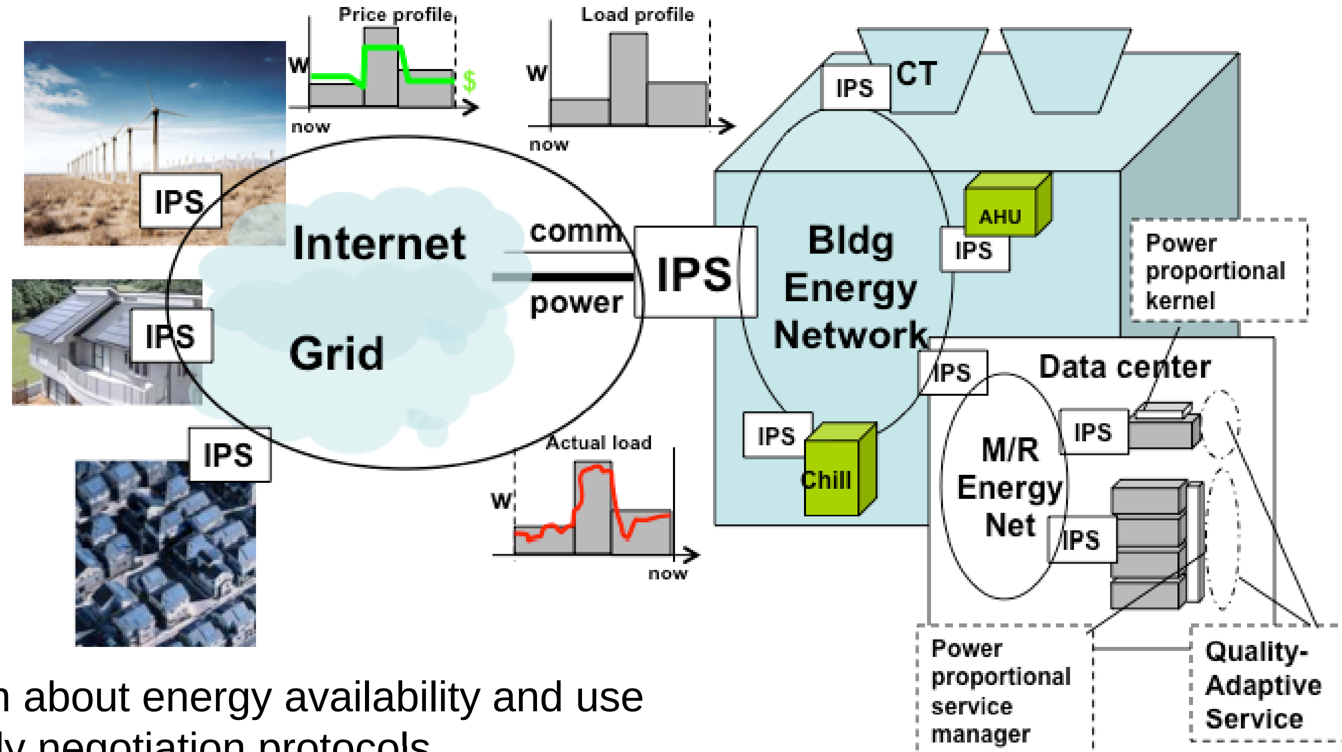
Data Integration - Transformation System

LoCal—A Network Architecture for Localized Electrical Energy Reduction, Generation and Sharing

R. H. Katz, D. E. Culler, S. Sanders, E. A. Brewer, UCB CNS-0932209

Energy network architecture where information follows wherever power is transferred

Intelligent Power Switches: points of monitoring aggregation and load-supply negotiation



Approach

- Pervasive information about energy availability and use
- Interactive load/supply negotiation protocols
- Controllable loads and sources
- Logically *packetized energy*, buffered and forwarded over a physical energy network

Tasks

- Develop LoCal-ized Machine Room monitoring/modeling/management algorithms
- Integrate with Building-scale facilities, use pre-cooling as energy storage
- Integrate Renewable Energy sources and develop building+machine room load following
- Develop "plug-and-play" LoCal IPS, renewable sources, and storage components

PPL Electric Utilities: DOE Smart Grid Demonstration – Keystone Smart Distribution
Drexel PI: K. Miu

PPL EU Team: Drexel University, GE, GE Energy, Alcatel·Lucent, Lockheed Martin

Goal: Smart distribution systems – integrating enabling technology from the substation to the customer

Drexel Activities:

- Enabling Smart Grid Functions
  - Development and implementation of control strategies for improving electric power service restoration in GE energy management systems
- Extensibility
  - Development of placement algorithms for advanced grid devices to support imminent and future smart grid deployments

http://www.theenergydaily.com/pressreleases/electricity/200910271407PR_NEWS_USPR_____PH00009.html

Drexel's Smart Grid Technology Test Bed

Drexel PI: C. Nwankpa

- Partners: Viridity Energy , PECO and Drexel University
- Virtual Power Generation to allow customers to sell back power to the grid
- Timeline: Three buildings on Drexel's campus beginning in January 2010

To Learn More

- Visit http://www.nsf.gov/
  - Funding opportunities – solicitations
    - for faculty
    - for students
  - Awards database
  - Policies and procedures

- Volunteer for panels and ad-hoc reviews

- Contact NSF program directors in PCAN

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