



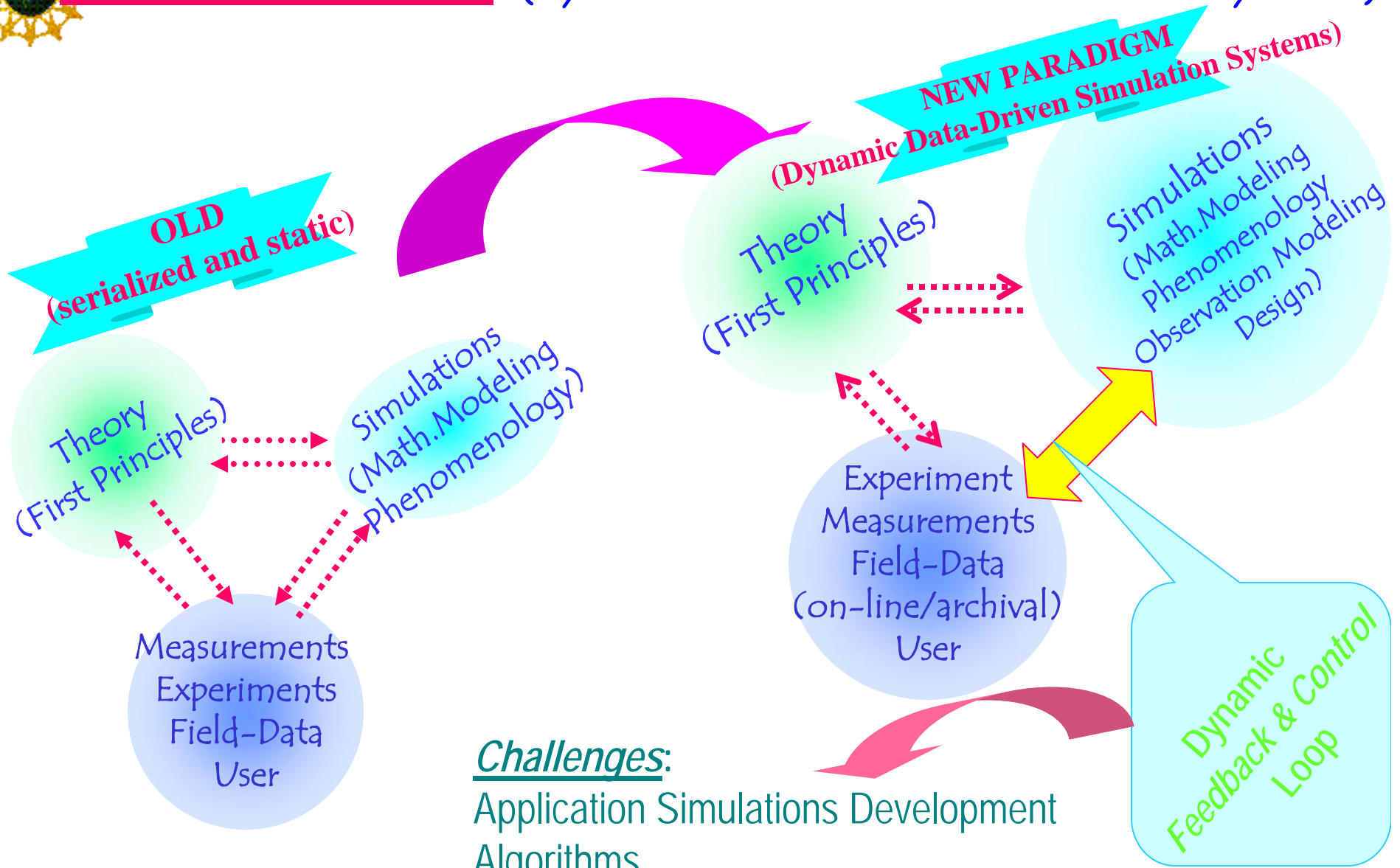
# *ICCS'07 Workshop on Dynamic Data Driven Application Systems (DDDAS)*

**New Direction for  
applications/simulations  
and  
measurement methodology**

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# What is DDDAS *(Symbiotic Measurement & Simulation Systems)*



## Challenges:

- Application Simulations Development Algorithms
- Measurement Instruments Interfaces
- Computing Systems Support



## Examples of Applications benefiting from the new paradigm

- Engineering (Design and Control)
  - aircraft design, **oil exploration(\*)**, semiconductor mfg, struct'l eng
  - computing systems hardware and software design and runtime  
(performance engineering and runtime compiler systems)
- Crisis Management and Environmental Systems
  - transportation systems (planning, accident response)
  - weather, hurricanes/tornadoes, floods, fire propagation
- Medical
  - Imaging, customized surgery, radiation treatment, etc
  - BioMechanics /BioEngineering
- Manufacturing/Business/Finance
  - Supply Chain (Production Planning and Control)
  - Financial Trading (Stock Mkt, Portfolio Analysis)

(\*) Darema 1980 (&Gedanken Laboratory - Darema 1987, 1990)

*"DDDAS has the potential to revolutionize science, engineering, & management systems"* - Darema 2000

DDDAS Featured as a *Very Important & Revolutionary Concept* in the NSF/ENG Blue Ribbon Panel (Report 2006 - Tinsley Oden)



# Some Technology Challenges in Enabling DDDAS

- **Application development**
  - interfaces of applications with measurement systems
  - dynamically select appropriate application components
  - dynamic hierarchical decomposition (compt'n-sensor) and partitioning
  - ability to switch to different algorithms/components depending on streamed data,
- **Algorithms**
  - tolerant to perturbations of dynamic input data
  - handling data uncertainties
- **Measurements**
  - Multiple modalities, space/time distributed, data management
- **Systems supporting such dynamic environments**
  - dynamic execution support on heterogeneous environments
  - Extended Spectrum of platforms: assemblies of Sensor Networks and Computational Grid platforms
  - Architect, management of sensor networks
  - GRID Computing, **and** Beyond!!!



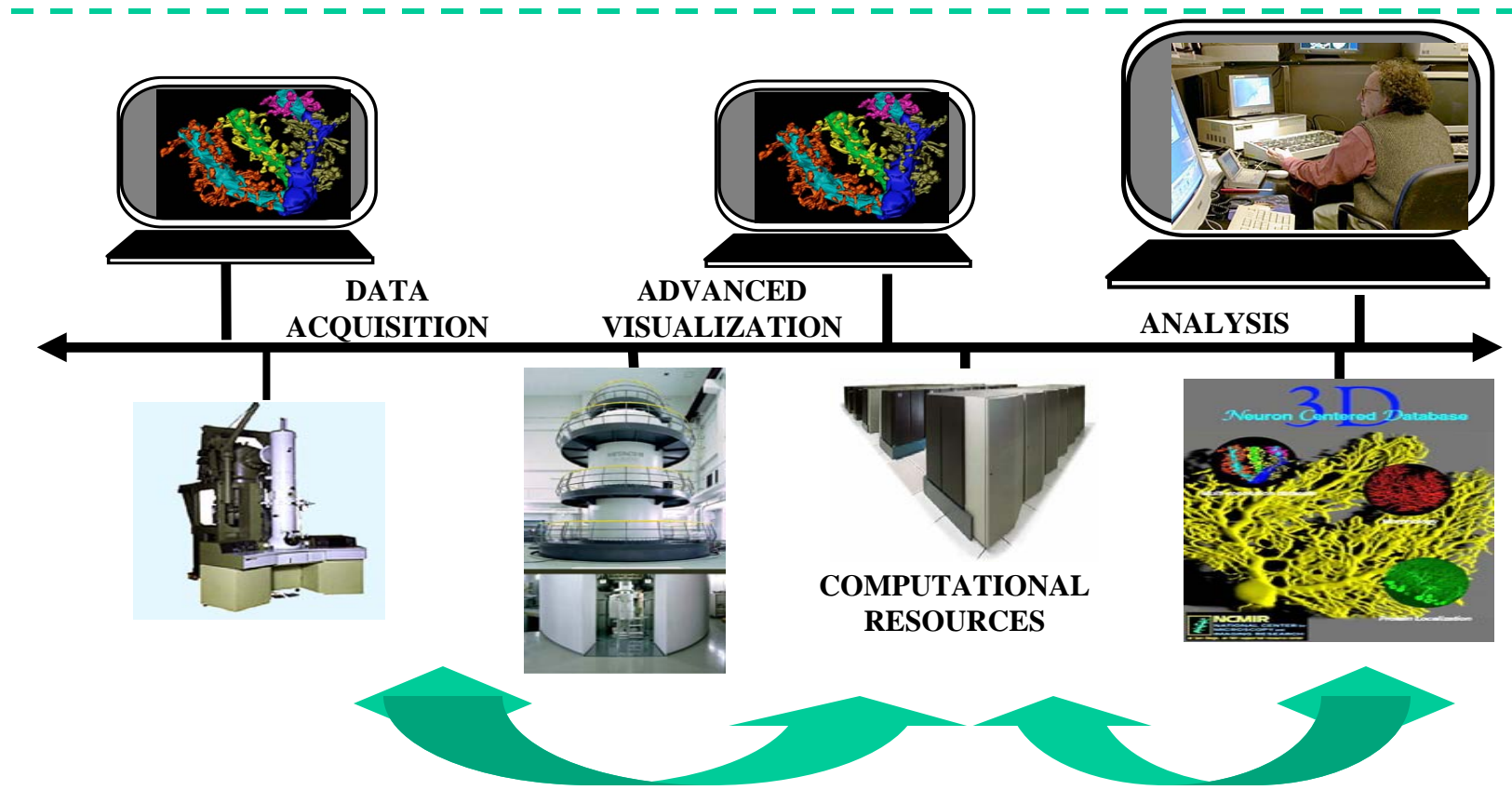
# Why Now is the Time for DDDAS

- Technological progress has prompted advances in some of the challenges
  - Computing speeds advances (uni- and multi-processor systems), Grid Computing, Sensor Networks
  - Systems Software
  - Applications Advances (parallel & grid computing)
  - Algorithms advances (e.g.: parallel & grid computing, numeric and non-numeric techniques: adaptive, asynchronous algorithms, dynamic meshing, data assimilation, chaotic Monte-Carlo)
- The Workshop talks will provide examples of efforts in:
  - Applications, Algorithms, Instrumentation, Systems Software



# DDDAS: Beyond Grid Computing

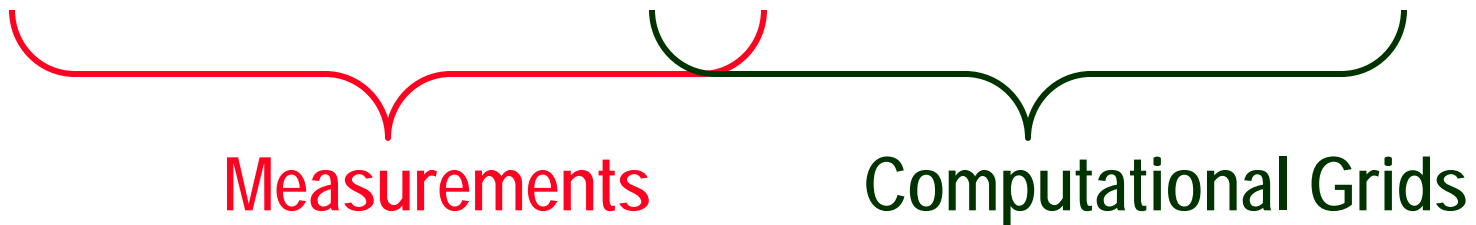
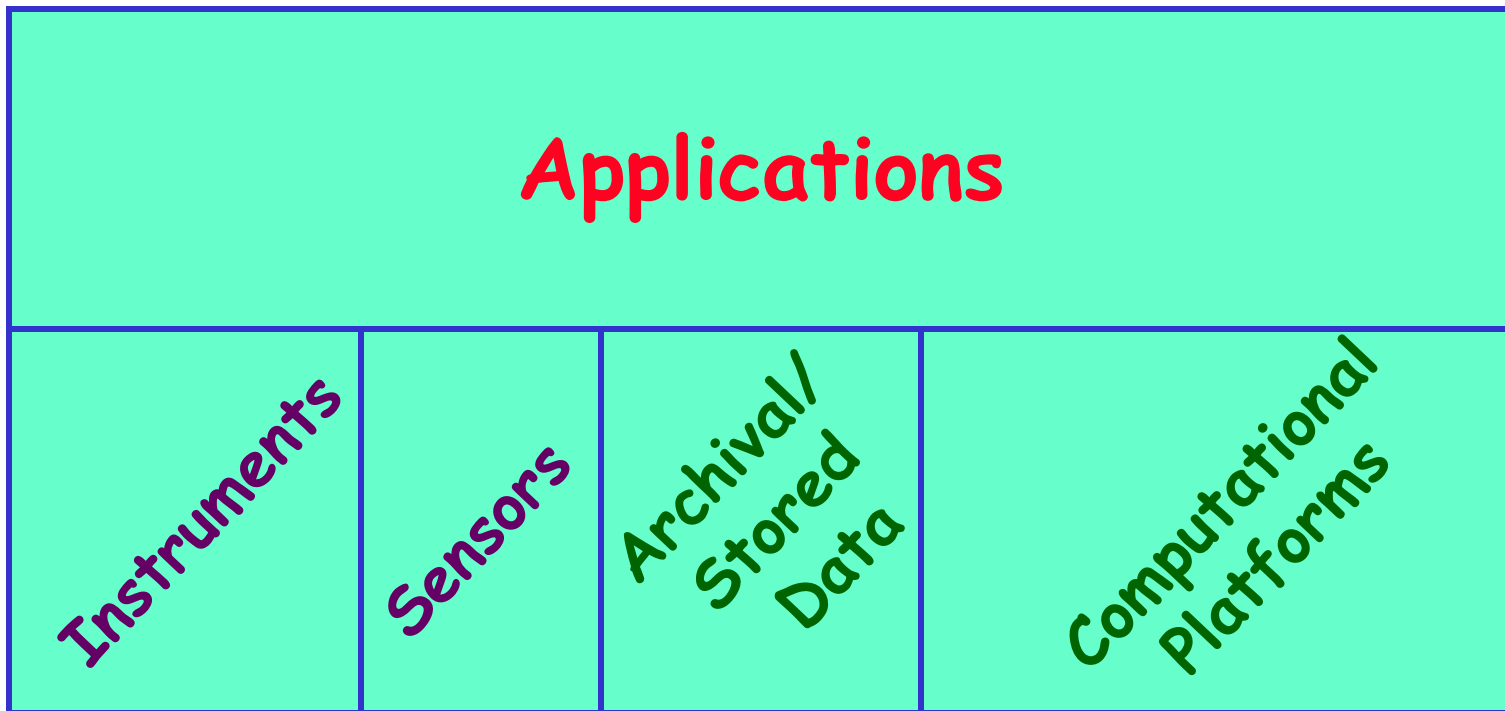
New Capabilities in Applications and Measurements





# Beyond Grid Computing

## "Extended Grid's" / "Super-Grids": the Application Platform is the computational & measurement system





# DDDAS - New Directions & Capabilities

## Dynamic Integration of Computation & Measurements/Data

- "Pervasive computing **&** pervasive data/monitoring"
- "from the Real-Time to the High-End"
- "from the sensors to the High-End"
- "from the PDA to the High-End"

## Unification of Computing Platforms & Sensors/Instruments

### Dynamic Data Driven

- at the application level
- at the systems level (computational platforms, networks)
  - Pervasive monitoring of resources and dynamic adaptation

## DDDAS for management and control of sensor-network systems

- architecture (e.g combining network)
- optimization of configuration of heterogeneous sets of sensors
  - Placement (mobile sensors); re-configuration
  - Prioritization of which sensors to monitor, at what frequency
- Power management (which sensors to turn on/off, frequency of measurement, etc)
- ...



## Impact to CyberInfrastructure (or e-Infrastructure)

- The CyberInfrastructure that will result when one thinks of the present paradigm of (disjoint) simulations and measurements will be different than the CyberInfrastructure needed to support DDDAS
- For example, bandwidth requirements, resource allocation and other middleware and systems software policies, prioritization, security, fault tolerance, recovery, QoS, etc..., will be different when one needs to guarantee data streaming to an executing simulation or control of measurement process
- DDDAS will impact the kind of underlying infrastructure that needs to be provided



# What about Industry & DDDAS

- Industry has history of
  - forging new research and technology directions and
  - adapting and productizing technology which has demonstrated promise
- Need to strengthen the joint academe/industry research collaborations; joint projects / early stages
- Technology transfer
  - establish path for tech transfer from academic research to industry
  - joint projects, students, sabbaticals (academe <----> industry)
- Initiatives from the Federal Agencies
- Cross-agency co-ordination
- Success stories: VLSI, Networking, and Parallel and Scalable Computing, etc
- Industry is interested in DDDAS

*Opportunity for synergistic co-operation among  
Academe, Gov.Labs, Gov.Agencies, Industry*



# Enabling DDDAS ...

## Need for Multidisciplinary Research

Phys, Math,  
Eng, Bio,...  
Research

CS  
Research

Applications  
& Modeling  
& Measurements

Multidisciplinary  
Research

Systems Software  
(NGS: 1998-2004)  
(CSR/AES&SMA: 2004-todate)  
(CSR/CSI: 2007)

Performance  
Engineering

Dynamic  
Compilers  
&  
Application  
Composition

Dynamic Data-Driven  
Application Systems  
--  
Symbiotic  
Measurement & Simulation  
Systems



# DDDAS Funding Opportunities

## NSF

- NGS: The Next Generation Software Program (1998- )
  - develops systems software supporting dynamic resource execution
- Scalable Enterprise Systems Program (1999, 2000-2003)
  - geared towards "commercial" applications
- Sensors and BITS Programs
- NSF Workshop, March 2000 (& ICCS'03/'04/'05/'06, '07, ...)
- ITR: Information Technology Research (NSF-wide, FY00-04)
  - has been used as an opportunity to support DDDAS related efforts
  - FY00 (1/1)\*; FY01(24/8); FY02 (31/8); FY03(76/8); FY04(100/10)  
\*(submitted/awarded); proposal sizes range from \$400K-\$12M
  - Total amount of funding over these 5 yrs ~\$60M

## Multi-agency DDDAS program in FY05 ([www.cise.nsf.gov/dddas](http://www.cise.nsf.gov/dddas))

- US: multiple NSF Directorates, other agencies (NIH, NOAA, DoD...) and cooperating with EU/IST & e-Sciences Programs
- + industry participation
- 248 proposals received (June 13); total requested amount \$175M
- 32 projects awarded; total amount of funding \$16M (US)



## FY05 Multi-Agency DDDAS Program

NSF, NIH, NOAA (&DoD/AFSOR)

with International cooperation with the EU/IST & e-Sciences Programs  
& industry participation (SBIR, Large Industry Partnerships)

EU & e-Sciences Funded Projects

FY06 - Jan 2006 NSF Workshop

NSF, NIH, NIST, NOAA, NASA,  
DOE, DoD(JFCOM, ...), DHS, CIA

FY07 - Cross Systems Integration

Thematic Area in CSR/CNS/CISE/NSF Program

FY07 - Continuing Discussions with US Agencies and International

[www.cise.nsf.gov/dddas](http://www.cise.nsf.gov/dddas)

Solicitation, Projects, March 2000 & Jan2006 Workshops

[www.dddas.org](http://www.dddas.org) - DDDAS papers, Conference Proceedings, Slid

(including DDDAS International Workshop Series @ ICCS'03, '04. 05' 06, '07...)



# Examples of Areas of DDDAS Impact

DDDAS Funded Projects span many areas, including:

- Physical, Chemical, Biological
  - Chemical pollution transport, molecular bionetworks, protein folding..
- Medical and Health Systems
  - MRI imaging, cancer treatment, seizure control
- Environmental - Hazard prevention, mitigation, and response
  - Earthquakes, hurricanes, tornados, wildfires, floods, landslides, tsunamis, terrorist attacks
- Manufacturing, Transportation, Critical Infrastructure systems
  - Electric power systems, water supply systems, transportation networks and vehicles (air, ground, underwater, space) - condition monitoring, mitigation, ...

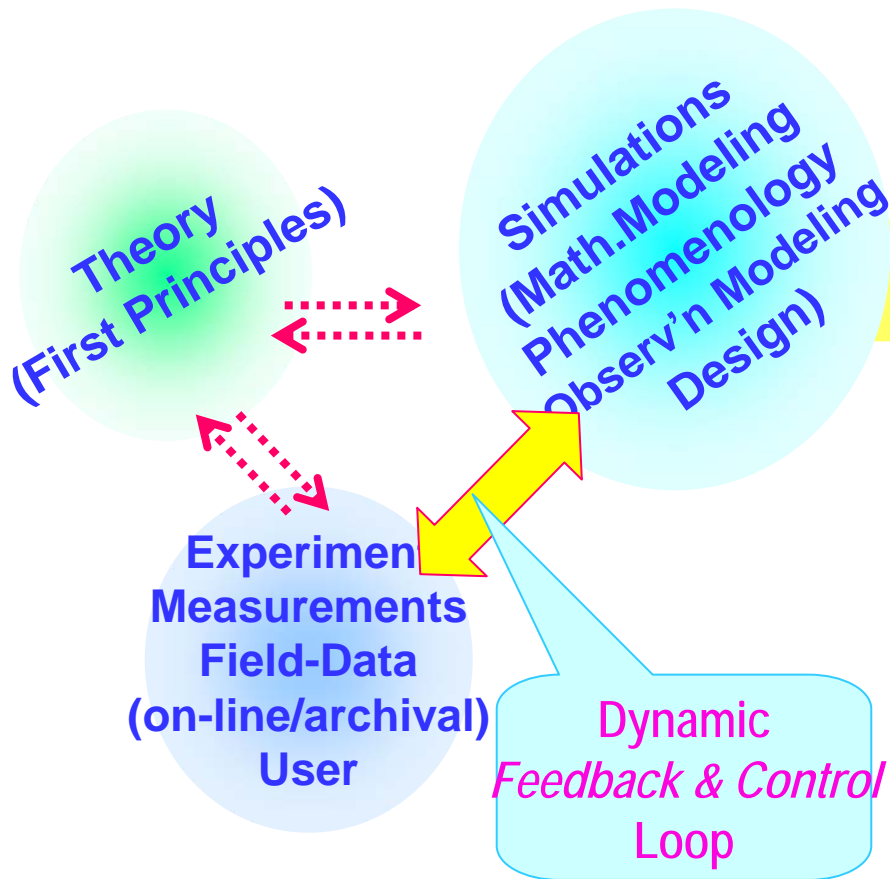
List of Projects in [www.cise.nsf.gov/dddas](http://www.cise.nsf.gov/dddas)

List of Papers/presentations in [www.dddas.org](http://www.dddas.org)



# Dynamic Data Driven Application Systems (DDDAS) (Symbiotic Measurement & Simulation Systems)

*DDDAS: ability to dynamically incorporate additional data into an executing application, and in reverse, ability of an application to dynamically steer the measurement process*



**Dynamic Integration of  
Computation & Measurements/Data  
(from the Real-Time to the High-End)**  
**Unification of  
Computing Platforms & Sensors/Instruments**  
**DDDAS guides sensor systems architectures**

### Challenges:

Application Simulations Methods  
Algorithmic Stability  
Measurement/Instrumentation Methods  
Computing Systems Software Support

**Software Architecture Frameworks**  
**Synergistic, Multidisciplinary Research**



**DDDAS has potential  
for significant impact to  
science, engineering, and commercial world,  
akin to the transformation effected  
since the '50s  
by the advent of computers**

**... This Workshop provides some examples  
of this kind of impact**

**7 Sessions – 38 Presentations – Mon-Wed  
International Projects/Presentations/Participation**



back-up slides



# Steve Flynn - The Edge of Disaster

CNN Report  
Feb 20, 2006

- Chaturvedi - Bio-terror Preparedness Exercise in a Mixed Reality Environment (9/11; pandemic)
- Metaxas - Deception Detection
- Barabasi - Enhanced Situational Awareness: Application of DDDAS Concepts to Emergency and Disaster Management
- Ghattas - Real-Time RCBN Contaminant Transport
- Douglas - Dynamically Identifying and Tracking Contaminants in Water Bodies
- Mandel - Dynamic Data Driven Wildland Fire Model
- Fujimoto - Ad Hoc Distributed Simulation of Surface Transportation Systems
- Seltzer/Gaynor - Emergency Medical Services
- McCalley - Electrical Power-Grids
- Allen - "Katrina"-like Scenario



# "~DDDAS" proposals awarded in FY00 ITR Competition

- Pingali, Adaptive Software for Field-Driven Simulations



# "~DDDAS" proposals awarded in FY01 ITR Competition

- Biegler - Real-Time Optimization for Data Assimilation and Control of Large Scale Dynamic Simulations
- Car - Novel Scalable Simulation Techniques for Chemistry, Materials Science and Biology
- Knight - Data Driven design Optimization in Engineering Using Concurrent Integrated Experiment and Simulation
- Lonsdale - The Low Frequency Array (LOFAR) - A Digital Radio Telescope
- McLaughlin - An Ensemble Approach for Data Assimilation in the Earth Sciences
- Patrikalakis - Poseidon - Rapid Real-Time Interdisciplinary Ocean Forecasting: Adaptive Sampling and Adaptive Modeling in a Distributed Environment
- Pierrehumbert- Flexible Environments for Grand-Challenge Climate Simulation
- Wheeler- Data Intense Challenge: The Instrumented Oil Field of the Future



# "~DDDAS" proposals awarded in FY02 ITR Competition

- Carmichael - Development of a general Computational Framework for the Optimal Integration of Atmospheric Chemical Transport Models and Measurements Using Adjoints
- Douglas-Ewing-Johnson - Predictive Contaminant Tracking Using Dynamic Data Driven Application Simulation (DDDAS) Techniques
- Evans - A Framework for Environment-Aware Massively Distributed Computing
- Farhat - A Data Driven Environment for Multi-physics Applications
- Guibas - Representations and Algorithms for Deformable Objects
- Karniadakis - Generalized Polynomial Chaos: Parallel Algorithms for Modeling and Propagating Uncertainty in Physical and Biological Systems
- Oden - Computational Infrastructure for Reliable Computer Simulations
- Trafalis - A Real Time Mining of Integrated Weather Data



# "~DDDAS" proposals awarded in FY03 ITR Competition

- Baden - Asynchronous Execution for Scalable Simulation in Cell Physiology
- Chaturvedi- Synthetic Environment for Continuous Experimentation (Crisis Management Applications)
- Droegemeier-Linked Environments for Atmospheric Discovery (LEAD)
- Kumar - Data Mining and Exploration Middleware for Grid and Distributed Computing
- Machiraju - A Framework for Discovery, Exploration and Analysis of Evolutionary Data (DEAS)
- Mandel - DDDAS: Data Dynamic Simulation for Disaster Management (Fire Propagation)
- Metaxas- Stochastic Multicue Tracking of Objects with Many Degrees of Freedom
- Sameh - Building Structural Integrity
- {Sensors Program: Seltzer - Hourglass: An Infrastructure for Sensor Networks}



# "~DDDAS" proposals awarded in FY04 ITR Competition

- Brogan - Simulation Transformation for Dynamic, Data-Driven Application Systems (DDDAS)
- Baldrige - A Novel Grid Architecture Integrating Real-Time Data and Intervention During Image Guided Therapy
- Floudas-In Silico De Novo Protein Design: A Dynamically Data Driven, (DDDAS), Computational and Experimental Framework
- Grimshaw: Dependable Grids
- Laidlaw: Computational simulation, modeling, and visualization for understanding unsteady bioflows
- Metaxas - DDDAS - Advances in recognition and interpretation of human motion: An Integrated Approach to ASL Recognition
- Wheeler: Data Driven Simulation of the Subsurface: Optimization and Uncertainty Estimation



# DDDAS FY05 Competition Proposals awarded (cont'd)

- Farhat - A Dynamic Data Driven System for Structural Health Monitoring and Critical Event Prediction
- Ding - A Framework For the Dynamic Data-Driven Fault Diagnosis of Wind Turbine Systems
- Laidlaw - Interactive Data-driven Flow-simulation Parameter Refinement for Understanding the Evolution of Bat Flight
- Rawlings - Measuring and Controlling Turbulence and Particle Populations
- Knight - SEP: Application of DDDAS to Assessment of Thermal Systems Using Combined Experiment and Simulation
  
- Barabasi- Integrated Wireless Phone Based Emergency Response System (WIPER)
- Fujimoto - Dynamic, Simulation-Based Management of Surface Transportation Systems
- Mahinthakumar - An adaptive cyberinfrastructure for threat management in urban water distribution systems

+...



# DDDAS FY05 Competition

## Proposals awarded (cont'd)

- Ghattas - MIPS: A Real-Time Measurement-Inversion-Prediction-Steering Framework for Hazardous Events
- How - Coordinated Control of Multiple Mobile Observing Platforms for Weather Forecast Improvement
- Bernstein - Targeted Data Assimilation for Disturbance-Driven Systems: Space weather Forecasting
- McLaughlin: - Data Assimilation by Field Alignment
- Leiserson - Planet-in-a-Bottle: A Numerical Fluid-Laboratory
- Chrysostomidis - Multiscale Data-Driven POD-Based Prediction of the Ocean
- Ntaimo - Dynamic Data Driven Integrated Simulation and Stochastic Optimization for Wildland Fire Containment
- Allen - DynaCode: A General DDDAS Framework with Coast and Environment Modeling Applications
- Douglas - Adaptive Data-Driven Sensor Configuration, Modeling, and Deployment for Oil, Chemical, and Biological Contamination near Coastal Facilities



# DDDAS FY05 Competition

## Proposals awarded (cont'd)

- Clark - Dynamic Sensor Networks - Enabling the Measurement, Modeling, and Prediction of Biophysical Change in a Landscape
- Golubchik - A Generic Multi-scale Modeling Framework for Reactive Observing Systems
- Williams - Real-Time Astronomy with a Rapid-Response Telescope Grid
- Gilbert - Optimizing Signal and Image Processing in a Dynamic, Data-Driven Application System
- Liang - SEP: Intergrating Multipath Measurements with Site Specific RF Propagation Simulations
- Chen - SEP: Optimal interlaced distributed control and distributed measurement with networked mobile actuators and sensors

+...



# DDDAS FY05 Competition

## Proposals awarded

- Oden - Dynamic Data-Driven System for Laser Treatment of Cancer
- Rabitz - Development of a closed-loop identification machine for bionetworks (CLIMB) and its application to nucleotide metabolism
- Fortes - Dynamic Data-Driven Brain-Machine Interfaces
- McCalley - Auto-Steered Information-Decision Processes for Electric System Asset Management
- Downar - Autonomic Interconnected Systems: The National Energy Infrastructure
- Sauer- Data-Driven Power System Operations
- Ball - Dynamic Real-Time Order Promising and Fulfillment for Global Make-to-Order Supply Chains
- Thiele - Robustness and Performance in Data-Driven Revenue Management
- Son - Dynamically-Integrated Production Planning and Operational Control for the Distributed Enterprise



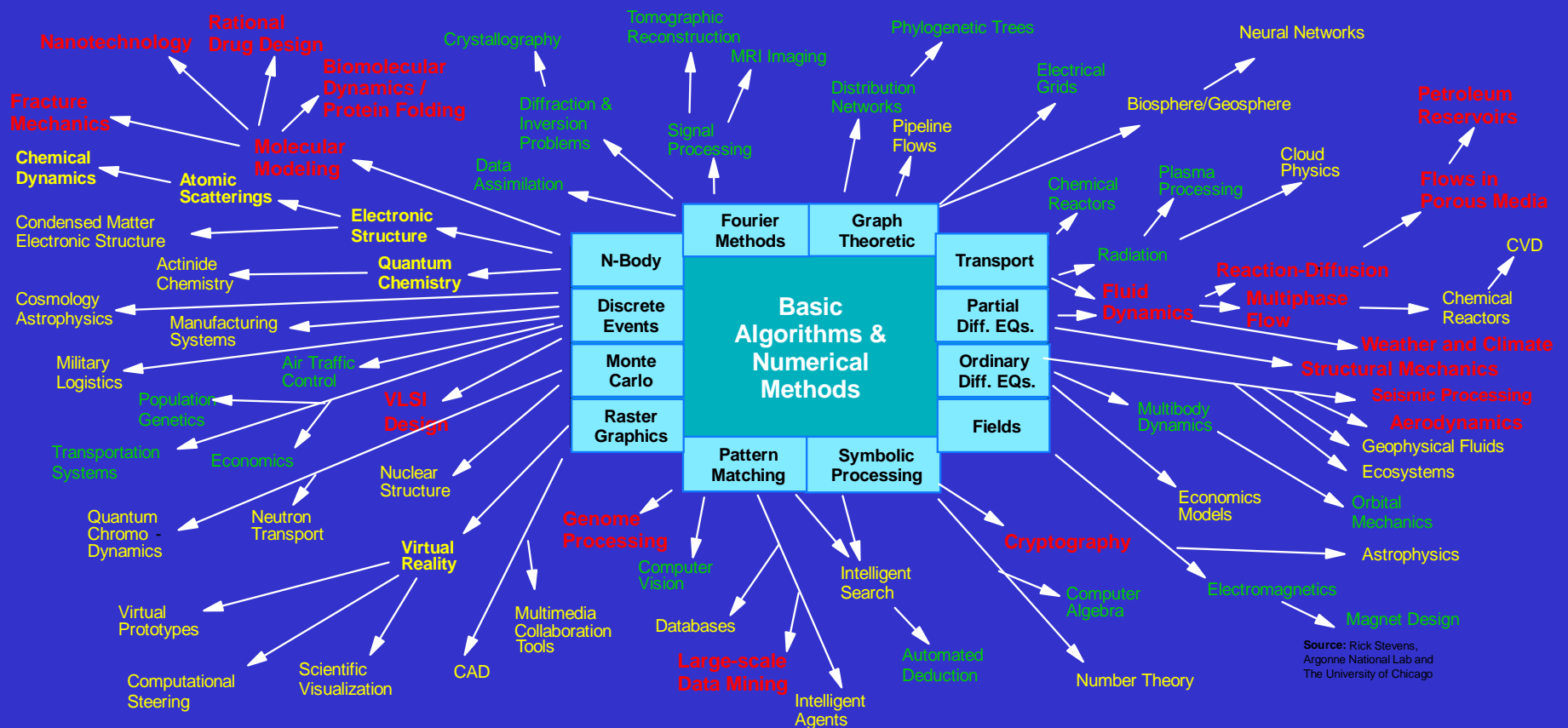
## FY05 Solicitation:

- Budget: \$15M +... -> \$16M
- Projects must have synergistic multidisciplinary research in:
  - Applications, Math&Stat Algorithms, Systems Software, and Measurements
- Categories of Projects to supported:
  - SMRP/"small": up to \$600K (total) for 3years
  - TMRP/"team": up to \$2M (total) for 4-5years
  - SEP/"exploratory": \$50K for 1 year
- Expected to fund:
  - 15-20 in "small" and "team"
  - 10 "exploratory"
- Funded 32: 15TMRP; 13SMRP; 4SEP



# Many Classes of Applications are Massively Parallel

Good Better Best



Source: Rick Stevens, Argonne National Lab and The University of Chicago



# Many Classes of Applications are Massively Parallel...

## ... but ALL FIT DDDAS --FD

Good Better Best

