New Frontiers
Through Computer and Information Science

June 4, 2012

ICCS2012

Dr. Frederica Darema

Air Force Office of Scientific Research

Integrity ★ Service ★ Excellence

Transformation Inducing Directions

- **Multidisciplinary Research**
  - **Fostering Transformative Innovations**
  - **Expanding Fundamental Knowledge and Capabilities**
- ***Unification Paradigms* – Multidisciplinary *Thematic Areas***
  - **InfoSymbiotic Systems**

    The Power of *DDDAS – Dynamic Data Driven Applications Systems*
  - **Multicore-based Systems**

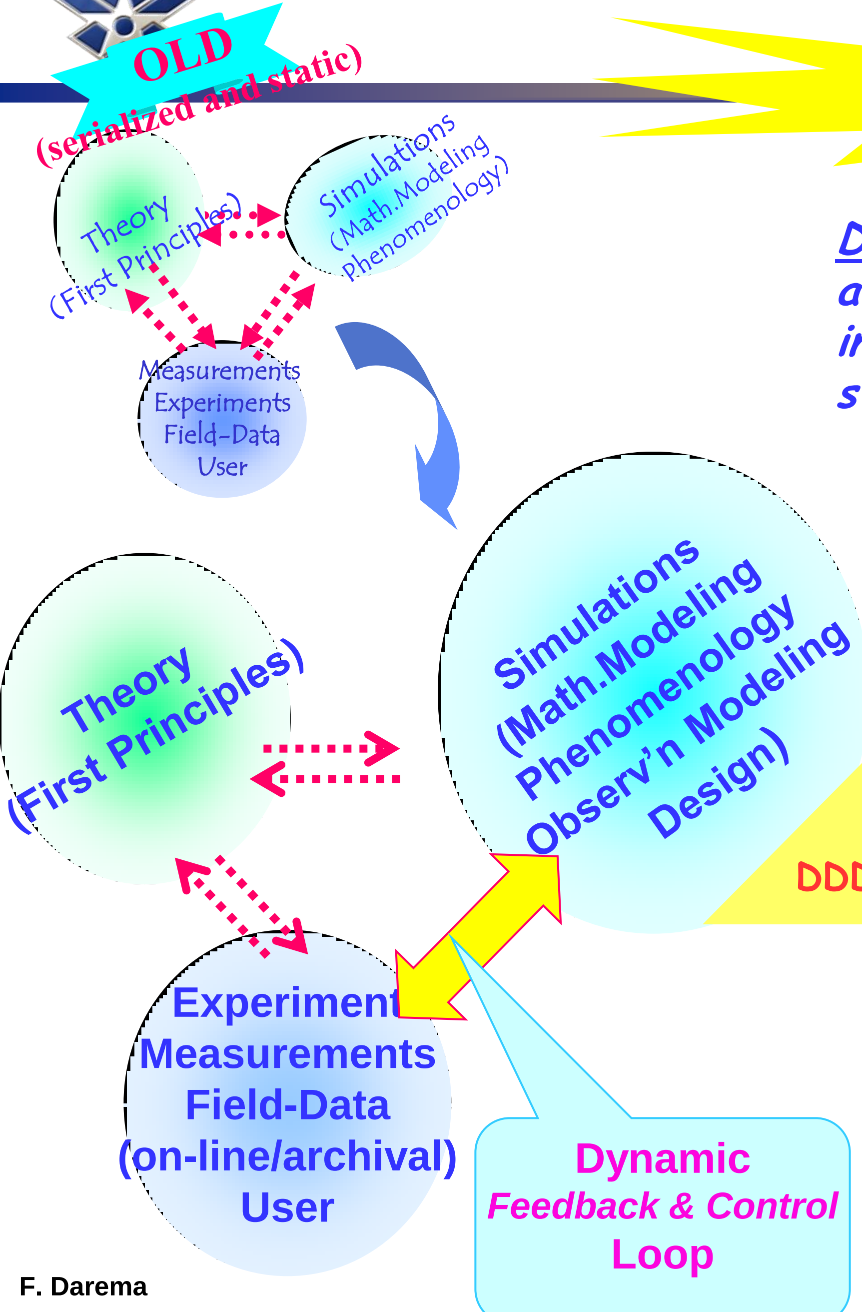
    Unification of HEC w RT Data Acquisition & Control Systems
  - **Systems Engineering**

    ***Engineering Systems of Information* (design-operation-maintenance-evolution)**
  - **Network Systems Science (Network Science)**

    Discover Foundational/Universal Principles across Networks
  - **Understanding the Brain and the Mind**

    From Cellular Networks … to Human Networks
- **Transformative Partnerships across Academe-Industry**
- **Summary**

Dynamic Data Driven Applications Systems (DDDAS)



InfoSymbiotic 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**

a "revolutionary" concept enabling to design, build, manage and understand complex systems

Dynamic Integration of
Computation & Measurements/Data
(from the High-End, to the RT, to the PDA)
Unification of
Computing Platforms & Sensors/Instruments
DDDAS – architect & adaptive-mngmnt sensor/cntrl systems

Challenges:
Application Simulations Methods
Algorithmic Stability
Measurement/Instrumentation Methods
Compu[illegible]t

Software Architecture Frameworks
Synergistic, Multidisciplinary Research

Advances in Capabilities through DDDAS

- **DDDAS: integration of application simulation/models with the application instrumentation components in a dynamic feed-back control loop**

Advanced modeling methods

- **speedup of the simulation, by replacing computation with data in specific parts of the phase-space of the application**
  enable ~decision-support capabilities w simulation-modeling accuracy
  and/or
- **augment model with actual data to improve accuracy of the model, improve analysis/prediction capabilities of application models**

Advanced instrumentation methods

- **dynamically targeted data collection (rather than ubiquitously)**
- **dynamically manage/schedule/architect heterogeneous resources of:**
  networks of heterogeneous sensors, or networks of heterogeneous controllers

- **unification from the high-end to the real-time data acquisition and control**

Advances in Capabilitie AS

Computational Science – the 3rd paradigm

Data – the 4th paradigm

- DDDAS: integration o application
  instru -back con ol loop

Advan

acing computation wi
-space of t application
pport capabilities w ation-

model w to im
nalysis/prediction cap

Advanced instrumentation meth

➢ dynamically target
➢ dynamically
networks of heteroge

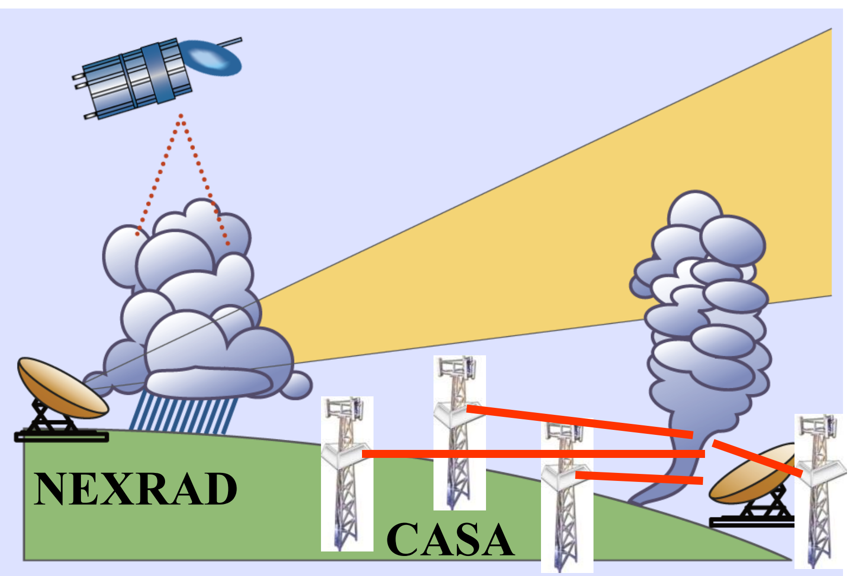
DDDAS /InfoSymbiotics

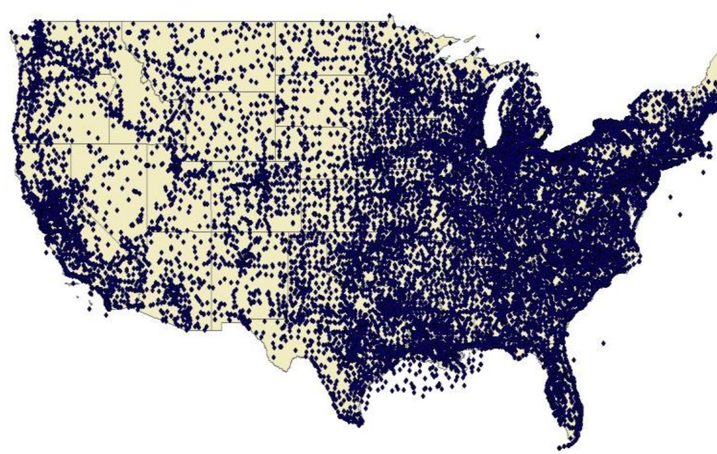
is the unifying paradigm

- unification from the high-e rol

LEAD: Users INTERACTING with Weather
Infrastructure:
NSF Engineering Research Center
for Collaborative Adaptive Sensing of the Atmosphere (CASA)

- **Current (NEXRAD) Doppler weather radars are high-power and long range – Earth's curvature prevents them from sensing a key region of the atmosphere: ground to 3 km**
- **CASA Concept: Inexpensive, dual-polarization phased array Doppler radars on cellular towers and buildings**
  - **Easily view the lowest 3 km (most poorly observed region) of the atmosphere**
  - **Radars collaborate with their neighbors and dynamically adapt to the changing weather, sensing multiple phenomena to simultaneously and optimally meet multiple end user needs**
  - **End users (emergency managers, Weather Service, scientists) drive the system via policy mechanisms built into the optimal control functionality**

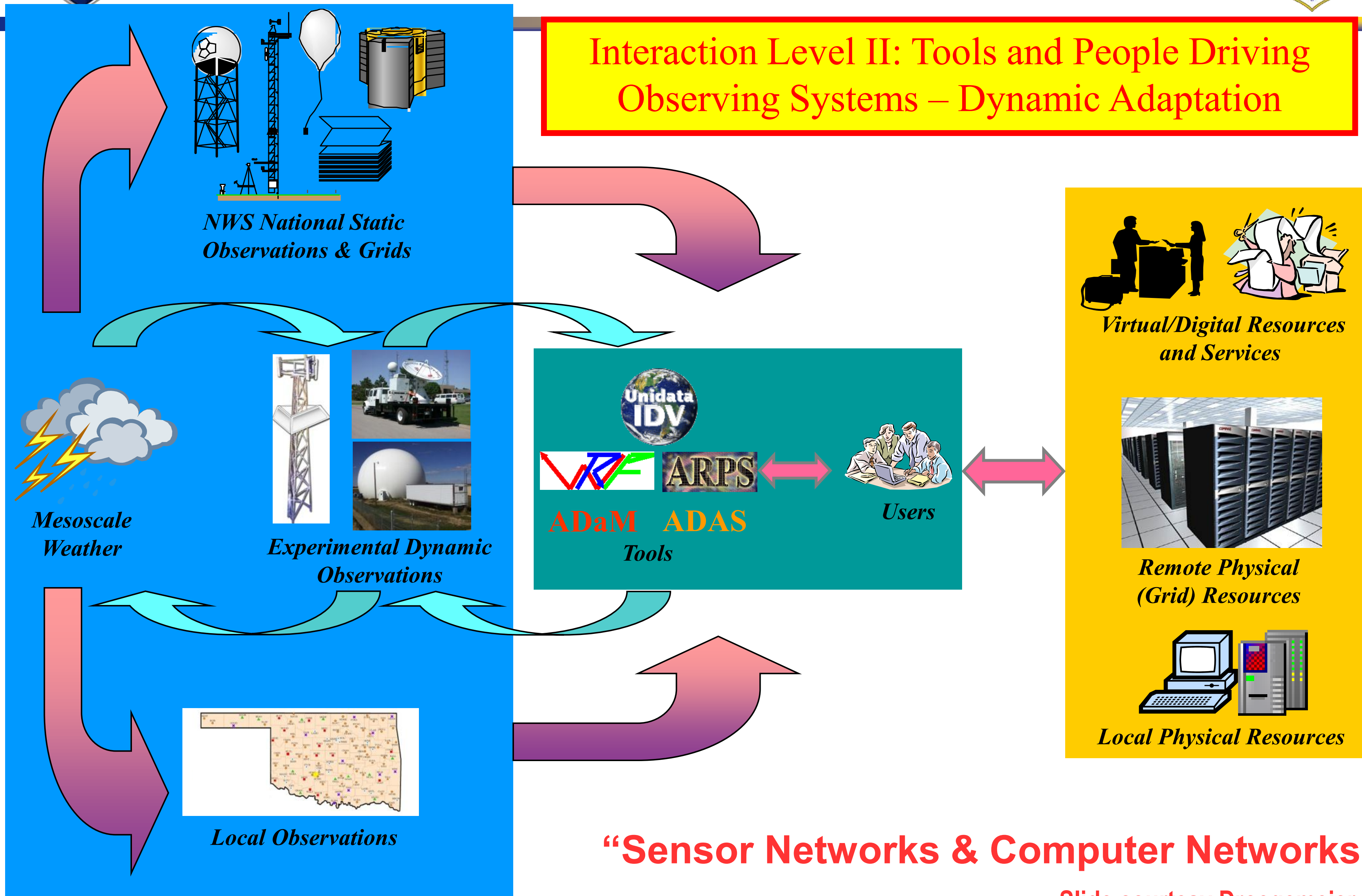




Slide courtesy Droegemeier

LEAD: Users INTERACTING with Weather

"The LEAD Goal Restated - to incorporate DDDAS " - Droegemeier



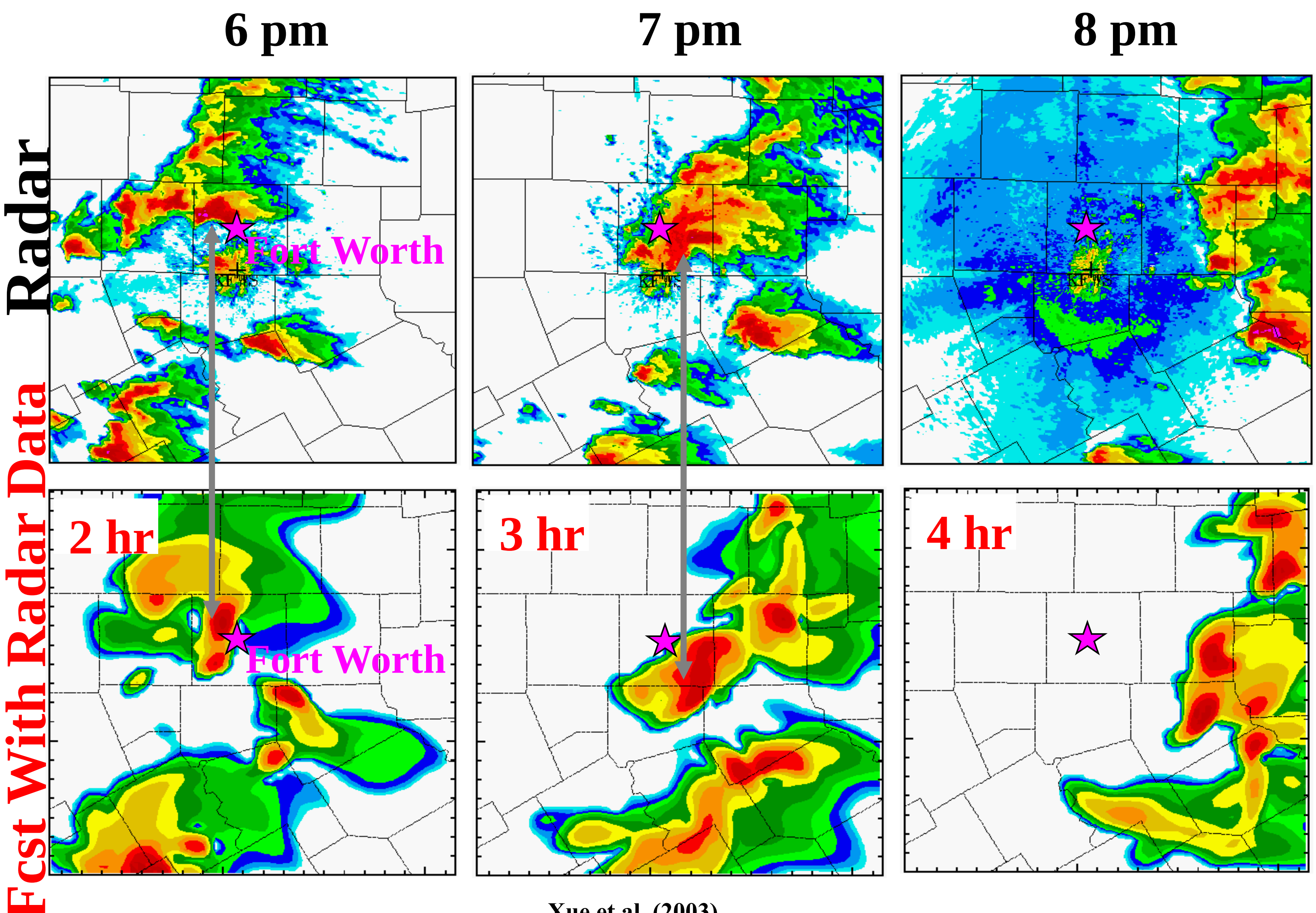
"Sensor Networks & Computer Networks"

Slide courtesy Droegemeier

March 2000 Fort Worth Tornadic Storm
Local TV Station Radar

Corrected Forecast with LEAD(DDDAS)

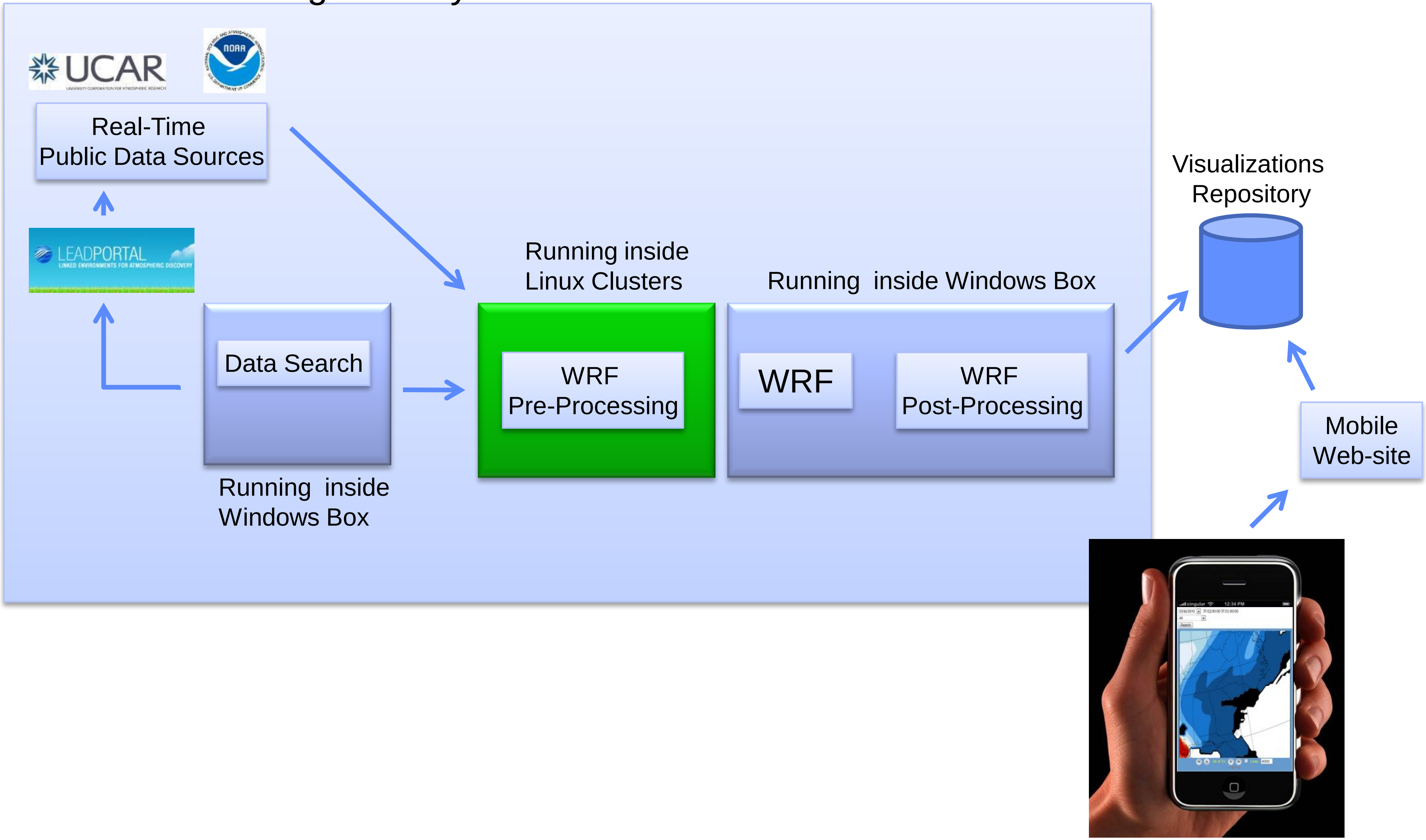
(Slide – Courtesy K. K. Droegemeier)



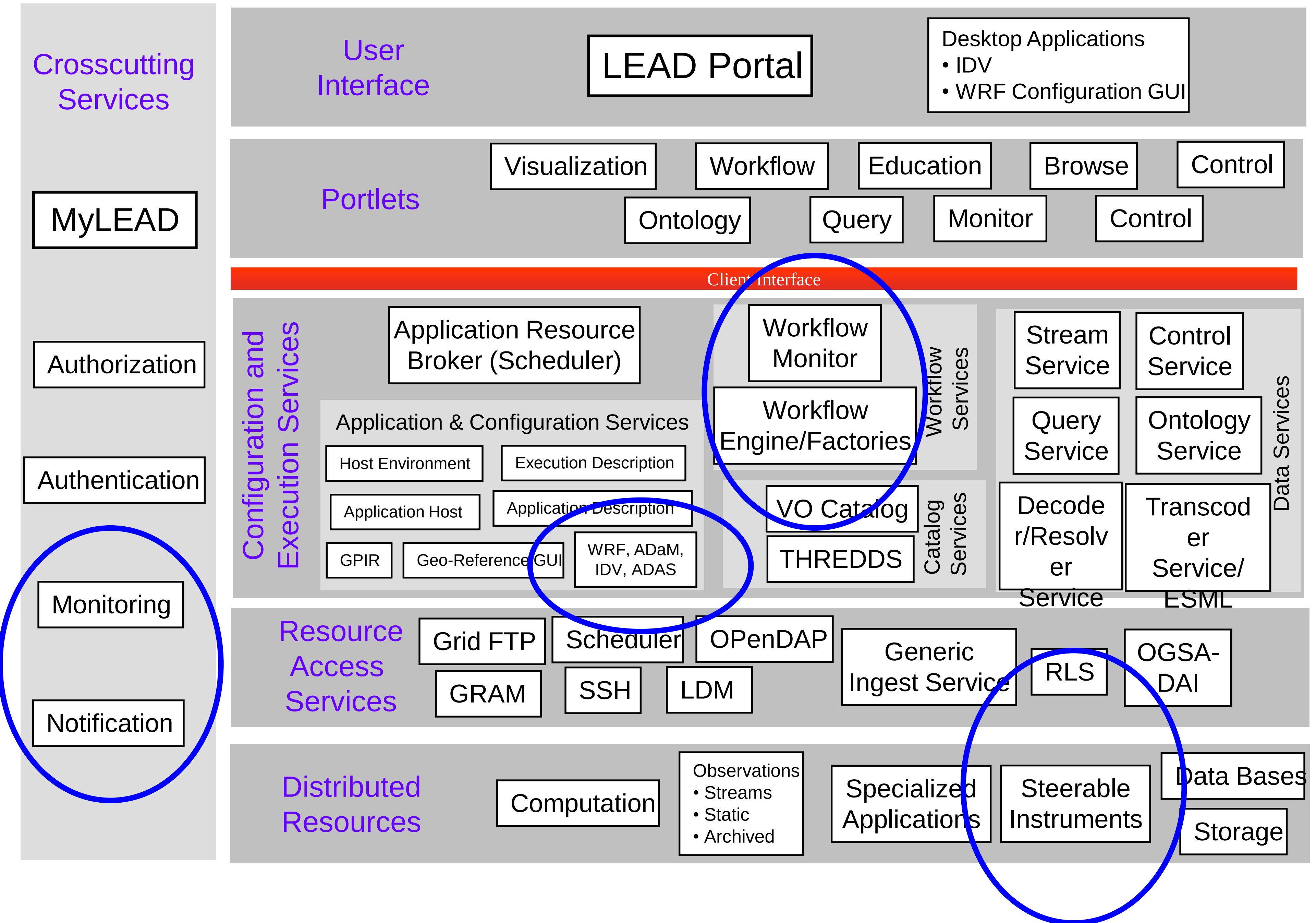
Xue et al. (2003)

Vortex2 Experiment with Trident

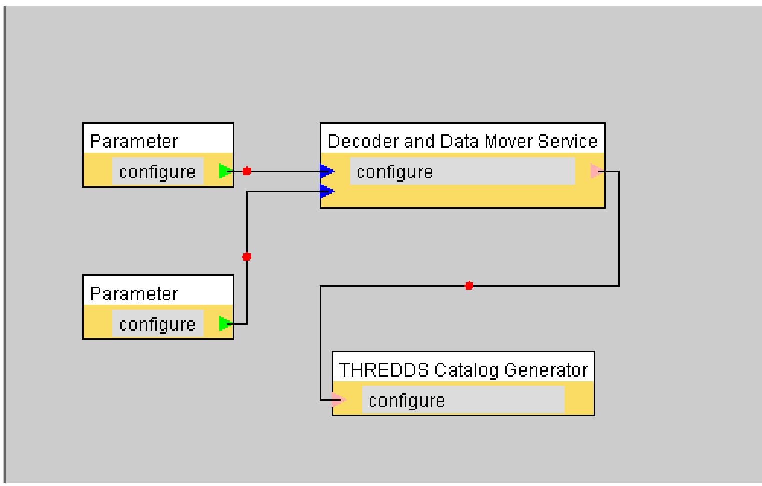
Vortex2 Workflow guided by Trident

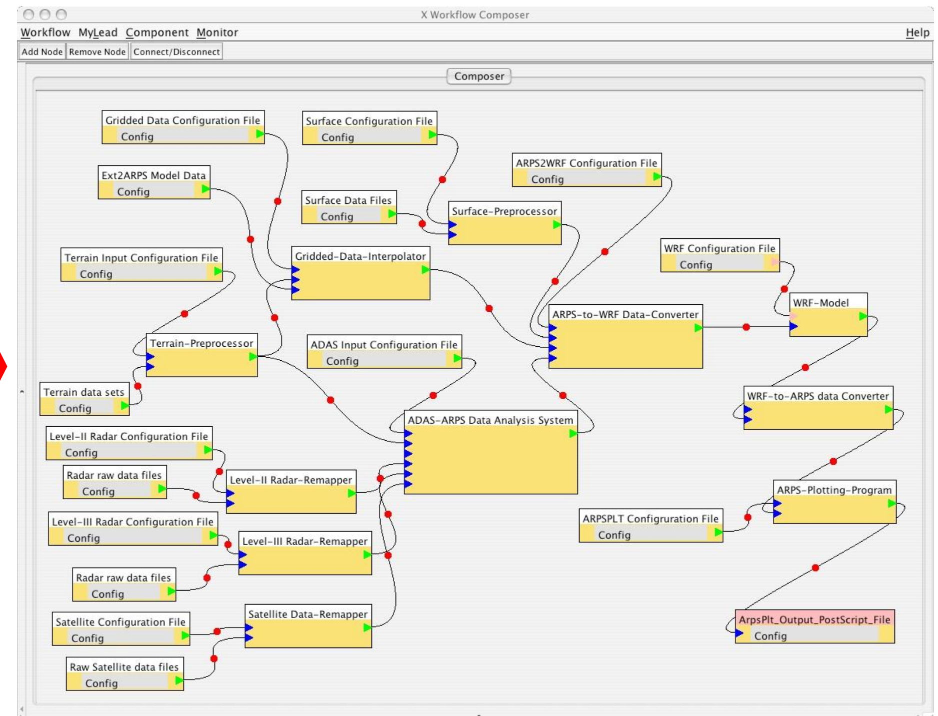


LEAD Architecture: adaptivity service interaction



Dynamic Workflow: THE Challenge





Automatically, non-deterministically, and getting the resources needed

Examples of Areas of DDDAS Impact

- Physical, Chemical, Biological, Engineering Systems
  - Chemical pollution transport (atmosphere, aquatic, subsurface), ecological systems, molecular bionetworks, protein folding..
- Medical and Health Systems
  - MRI imaging, cancer treatment, seizure control, …
- Environmental (prediction, prevention/mitigation of adverse effects, and response)
  - Earthquakes, hurricanes, tornados, wildfires, floods, landslides, tsunamis, …
- Critical Infrastructure systems
  - Electric power s… ms, water supply systems, t… n networks and vehicles (ai… ater, space)

"revolutionary" concept enabling to design, build, manage and understand complex systems

NSF/ENG Blue Ribbon Panel (Report 2006 – Tinsley Oden)

"DDDAS … key concept in many of the objectives set in Technology Horizons"

Dr. Werner Dahm, (former) AF Chief Scientist (DDDAS Workshop, Aug 2010)

- …
  - Robust and D… arge-Scale system…
  - Large-Scale Con… ational Environments

List of Projects/Papers/Workshops in www.cise.nsf.gov/dddas, www.dddas.org

+ (AFOSR-NSF joint) August2 010 MultiAgency InfoSymbiotics/DDDAS Workshop

The AirForce 10yr + 10 Yr Outlook:

Technology Horizons Report

Top Key Technology Areas

- Autonomous systems
- Autonomous reasoning and learning
- Resilient autonomy
- Complex adaptive systems
- V&V for complex adaptive systems
- Collaborative/cooperative control
- Autonomous mission planning
- Cold-atom INS
- Chip-scale atomic clocks
- Ad hoc networks
- Polymorphic networks
- Agile networks
- Laser communications
- Frequency-agile RF systems
- Spectral mutability
- Dynamic spectrum access
- Quantum key distribution
- Multi-scale simulation technologies
- Coupled multi-physics simulations
- Embedded diagnostics
- Decision support tools
- Automated software generation
- Sensor-based processing
- Behavior prediction and anticipation
- Cognitive modeling
- Cognitive performance augmentation
- Human-machine interfaces

http://www.af.mil/shared/media/document/AFD-100727-053.pdf

Fundamental Science and Technology Challenges for Enabling DDDAS Capabilities

- **Application modeling (in the context of dynamic data inputs)**
  - **interfacing applications with measurement systems**
  - **dynamically invoke/select appropriate application components**
    multi-modal, multi-scale – dynamically invoke multiple scales/modalities
  - **switching to different algorithms/components depending on streamed data**
    dynamic hierarchical decomposition (computational platform - sensor) and partitioning
- **Algorithms**
  - **tolerant to perturbations of dynamic input data**
  - **handling data uncertainties, uncertainty propagation, uncertainty quantification**
- **Measurements**
  - **multiple modalities, space/time-distributed, heterogeneous data management**
- **Systems supporting such dynamic environments**
  - **dynamic execution support on heterogeneous environments**
    new fundamental advances in compilers (runtime-compiler)
    integrated architectural frameworks of cyberifrastructure encompassing app-sw-hw layers
  - **extended spectrum of platforms (*beyond traditional computational grids*)**
    grids of: sensor networks and computational platforms
  - **architect and manage heterogeneous/distributed sensor networks**

DDDAS environments entail new capabilities but also new requirements and environments

***…* beyond GRID Computing -> SuperGrids**

and… beyond the (traditional) Clouds

What makes DDDAS(*InfoSymbiotics*) TIMELY NOW MORE THAN EVER?

- **Emerging scientific and technological trends/advances**
  - ***ever more complex applications – systems-of-systems*** **(Natural, Engineered, and Societal Systems)**
  - **increased emphasis in complex applications modeling (multi-scale/multi-modal modeling)**
  - **increased computational capabilities (multicores; peta-, exa-scale)**
  - **increased data volumes (Big Data) and increased bandwidths for streaming data, and…**
  - **…Sensors– Sensors EVERYWHERE…** ***(data intensive Wave #2)***
    - ***Swimming in sensors and drowning in data*** **- LtGen Deptula (2010)**

  Analogous experience from the past:
    - ***"The attack of the killer micros(****microprocessors****)"*** **- Dr. Eugene Brooks, LLNL (early 90's)**

      about microprocessor-based high-end parallel systems

      then seen as a problem – have now become an opportunity for advanced capabilities

  Back to the present and looking to the future:
    - ***"Ubiquitous Sensoring – the attack of the killer micros(****sensors****) – wave # 2"***

      Dr. Frederica Darema, AFOSR (Aug 2011, LNCC)

      challenge: how to deal with heterogeneity, dynamicity, large numbers of such resources

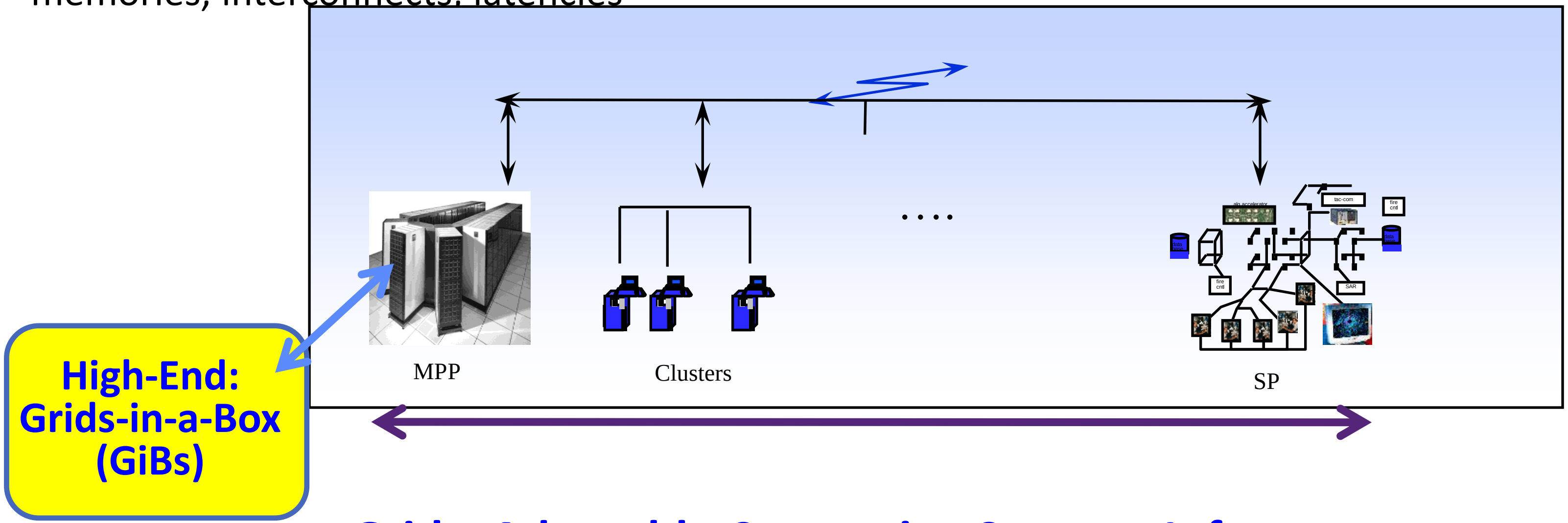
      opportunity: "smarter systems" – InfoSymbiotics DDDAS provides methods for such capabilities

- **Need capabilities for adaptive management of such resources**
  - **advances have been made,can be furthered in an accelerating way**

A while back we talked about Computational Grids…

Heterogeneity within and across Platforms

- Multiple levels of hierarchies of processing nodes, memories, interconnects, latencies



Grids: Adaptable Computing Systems Infrastructure

Fundamental Research Challenges & Needs in Applications and Systems Software

- **Map the multilevel parallelism in applications to the platforms multilevel parallelism and for multi-level heterogeneity and dynamic resource availability**
- **New programming models and environments, new compiler/runtime technology**
- **Adaptively compositional software at all levels (applications/algorithms/sys-sw)**
- **Systematic "performance-engineering" methods – systems & their environments**

Multicore-based Systems (InfoGrids)
(Multicores everywhere!)

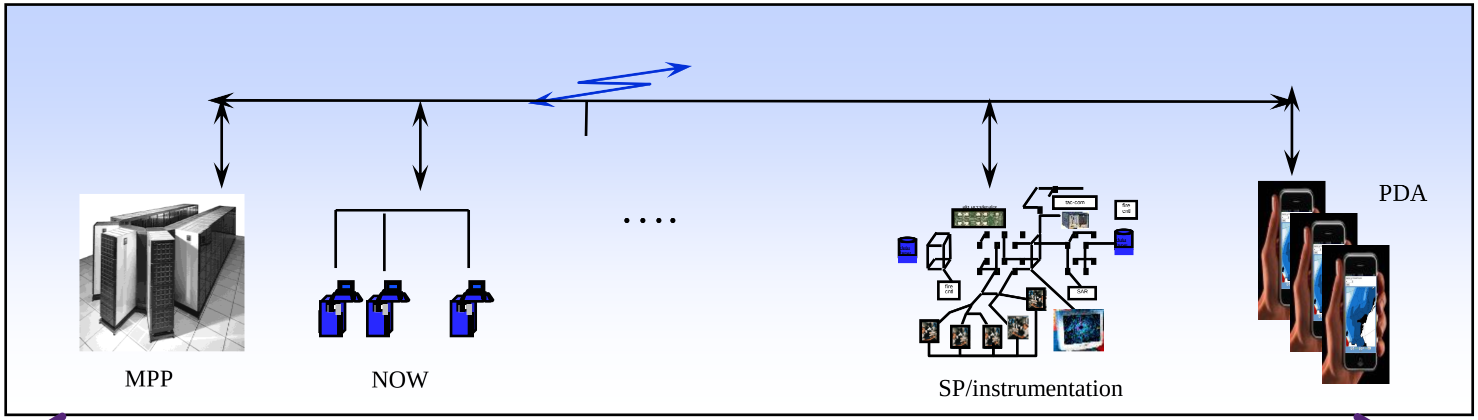
Multicores in High-End Platforms

- Multiple levels of hierarchies of processing nodes, memories, interconnects, latencies

Multicores in "measurement/data" Systems

- Instruments, Sensors, Controllers, Networks, …

Multiple levels of muticores



DDDAS - Integrated/Unified Application Platforms

Adaptable Computing and Data Systems Infrastructure
spanning the high-end to real-time data-acquisition & control systems
manifesting heterogeneous multilevel distributed parallelism
system architectures – software architectures

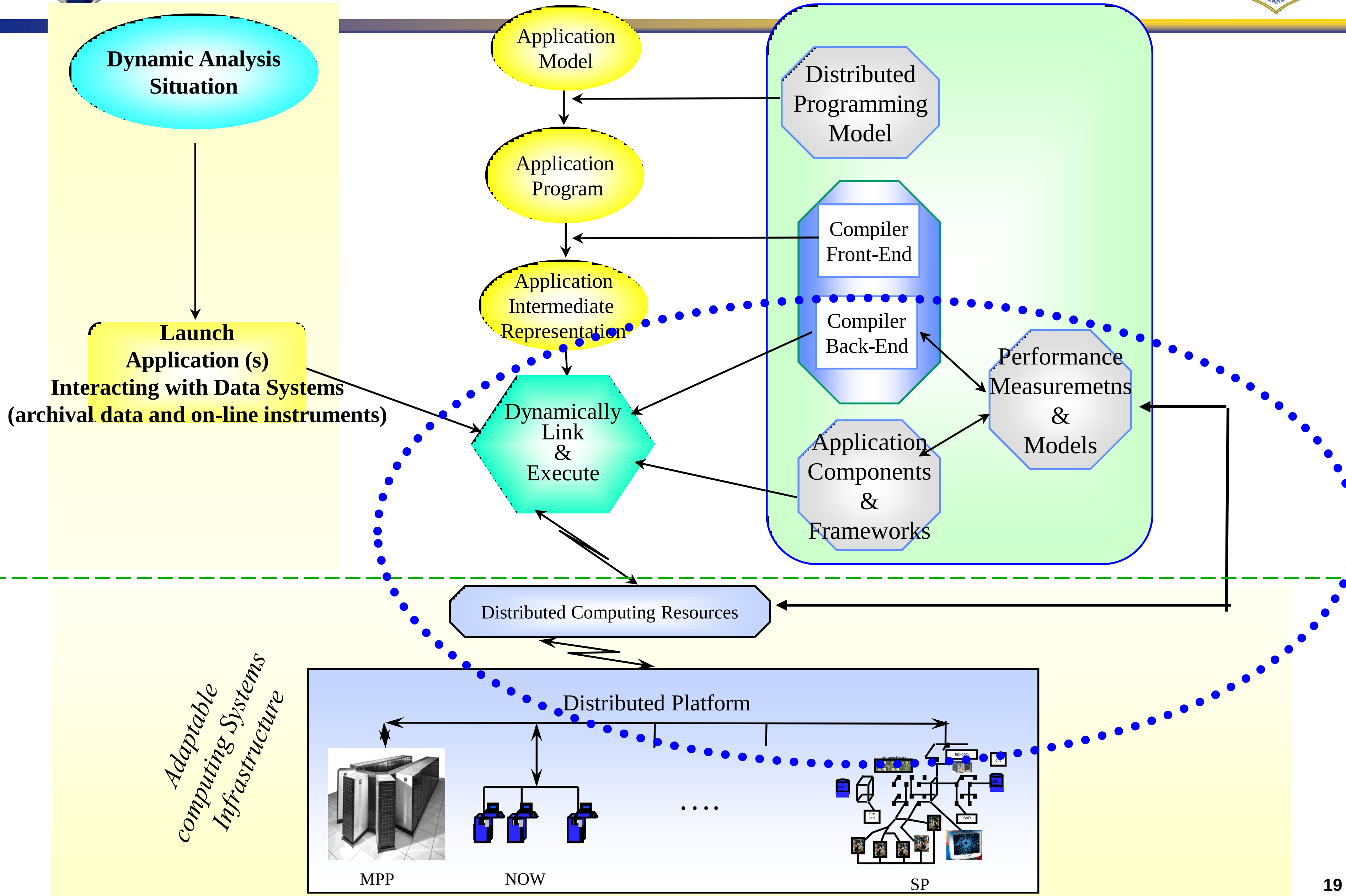
Fundamental Research Challenges in Applications- and Systems-Software

- **Map the multilevel parallelism in applications to the platforms multilevel parallelism and for multi-level heterogeneity and dynamic resource availability**
- **Programming models and environments, new compiler/runtime technology for adaptive mapping**
- **Adaptively compositional software at all levels (applications/algorithms/ systems-software**
- **"performance-engineering" systems and their environments**

SuperGrids: Dynamically Coupled Networks of Data and Computations

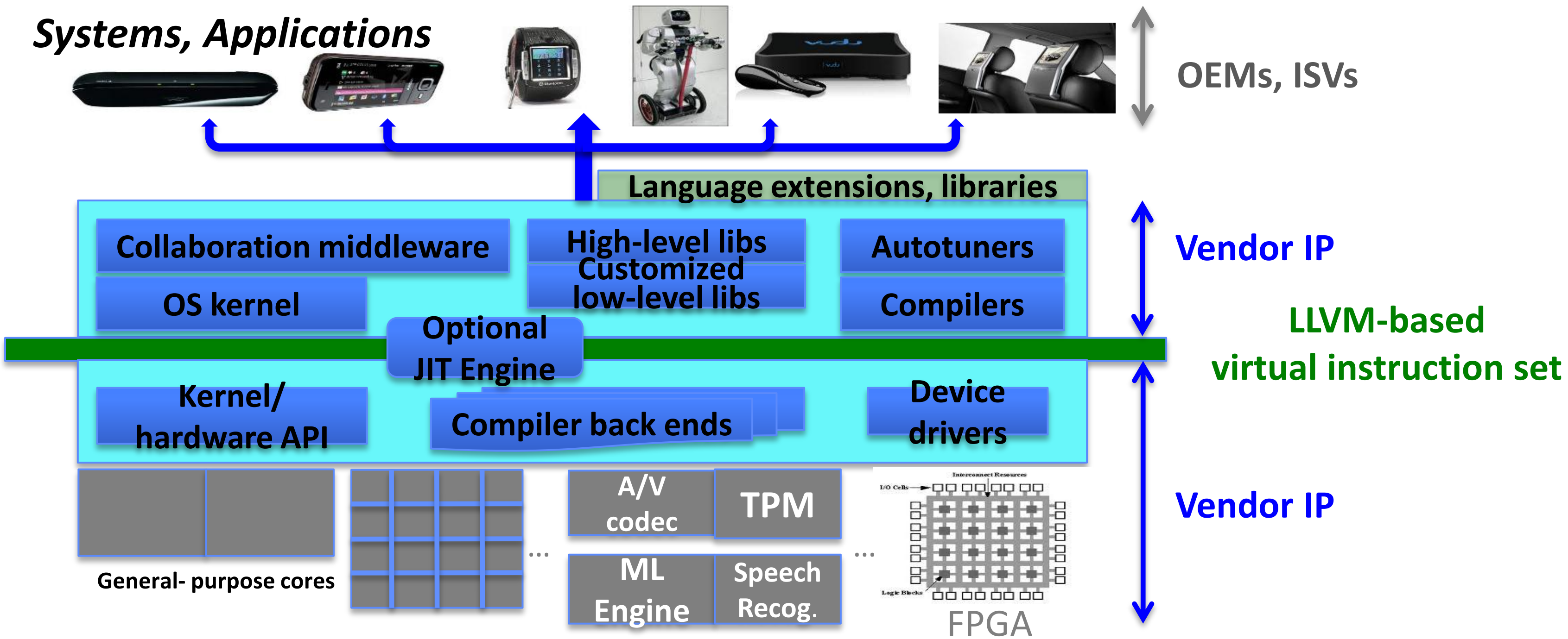
Dynamic Runtime Support needed for DDAS environments

Runtime Compiling System (RCS) and Dynamic Application Composition (NSF/NGS Program)



Example of Runtime-Compiler effort I started in ~2000 (NSF/NGS Program)
Programming Heterogeneous Systems

LLVM: Compiler Infrastructure for compile-, link-, run-time , iterative program optimization



LLVM in the Real World Today

Major companies using LLVM: Adobe, AMD, Apple, ARM, Cray, Intel, Google, Nokia, nVidia, Qualcomm, Sony

- **MacOS X 10.7, iOS 5: LLVM is the primary compiler on both platforms, replacing GCC**
  Nearly all MacOS 10.7 application software compiled with LLVM
- **OpenCL: *All* known commercial implementations based on LLVM**
  AMD, Apple, ARM, Intel, nVidia, Qualcomm
- **HPC: Cray using LLVM for Opteron back-ends, e.g., in Jaguar (ORNL)**
  New Sandia Exascale project using LLVM as compiler system

Systems Engineering

- Methods to design, build, and manage the operation, maintenance, extensibility, and interoperability of complex systems
- in ways where the systems' performance, fault-tolerance, adaptability, interoperability and extensibility is considered throughout this cycle.
- Such complex systems include:
    - heterogeneous and distributed sensor networks
    - large platforms & other complex instrumentation systems & collections thereof
  - need to exhibit:
    - adaptability and fault tolerance under evolving internal and external conditions
    - extensibility/interoperability with other systems in dynamic and adaptive ways
- Systems engineering requires novel methods that can:
  - model, monitor, & analyze all components of such systems
  - at multiple levels of abstraction
  - individually and composed as a system architectural framework

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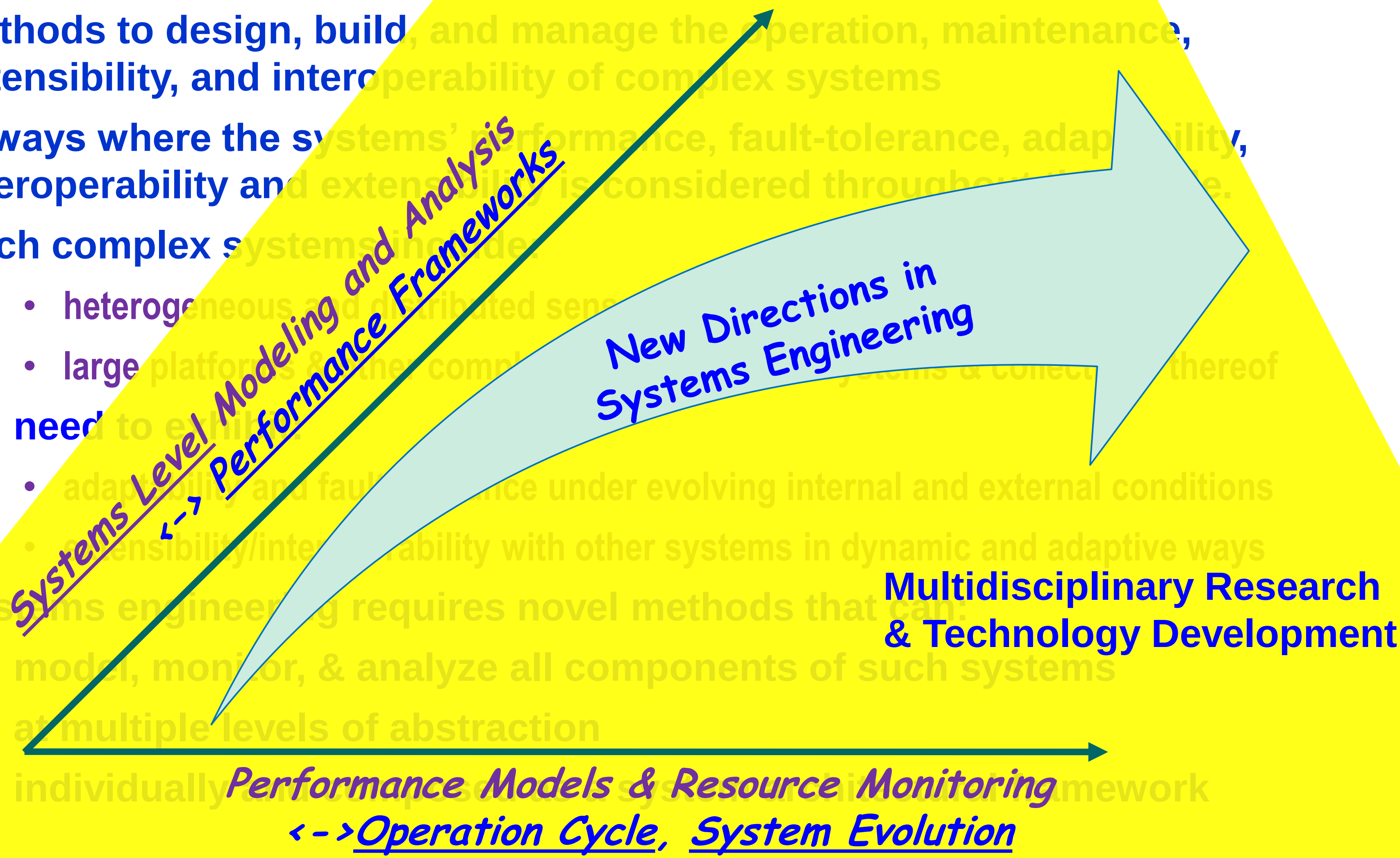
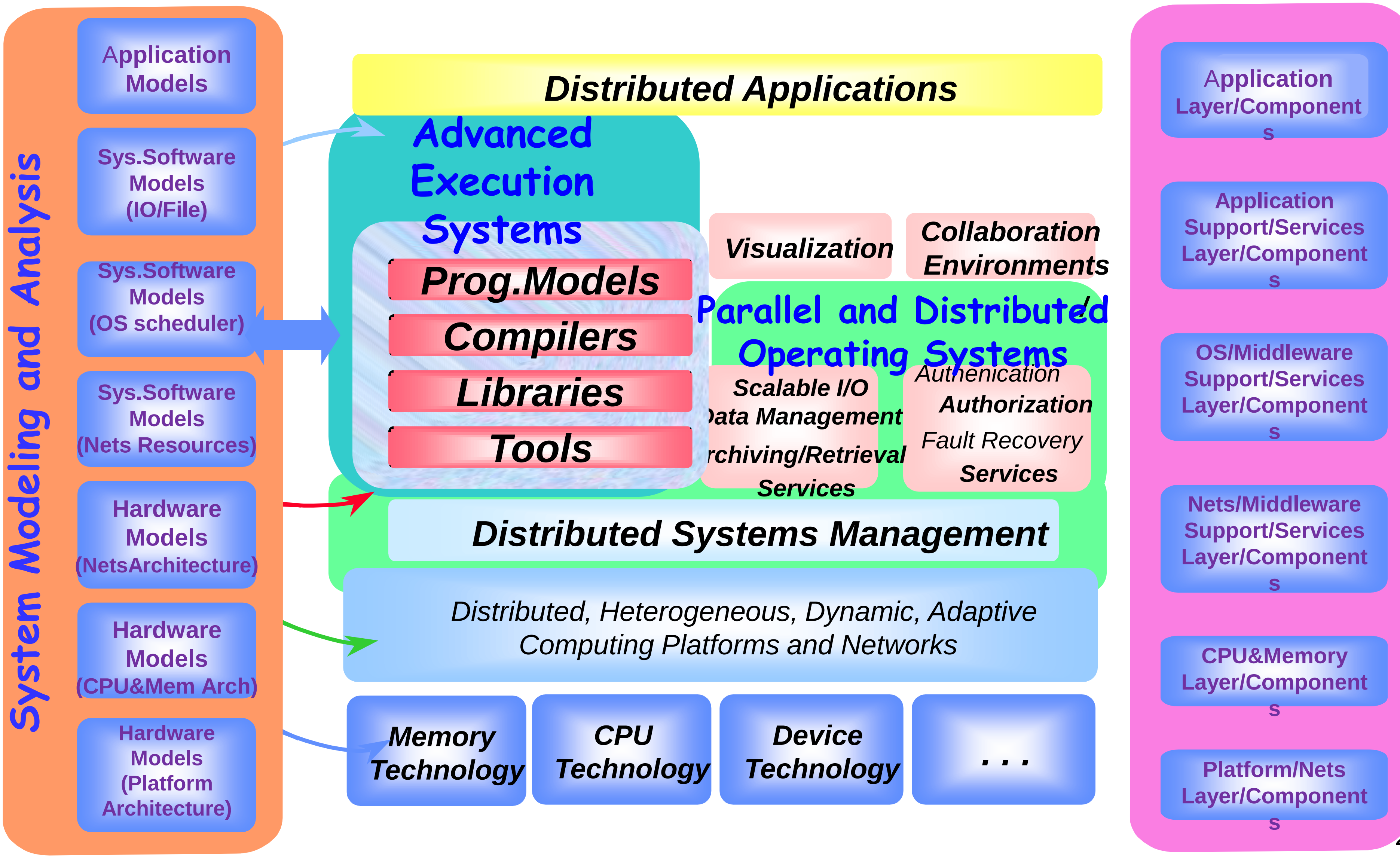


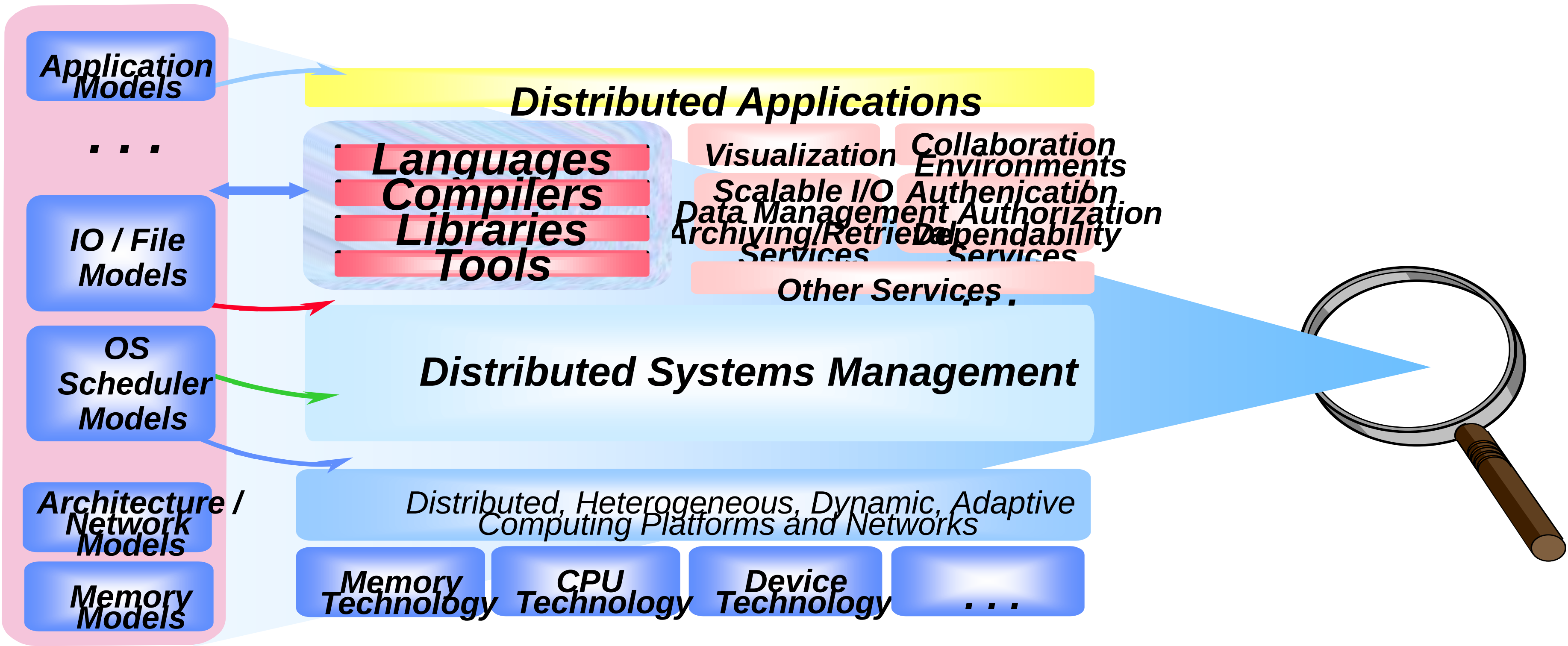
Systems Engineering

Example:

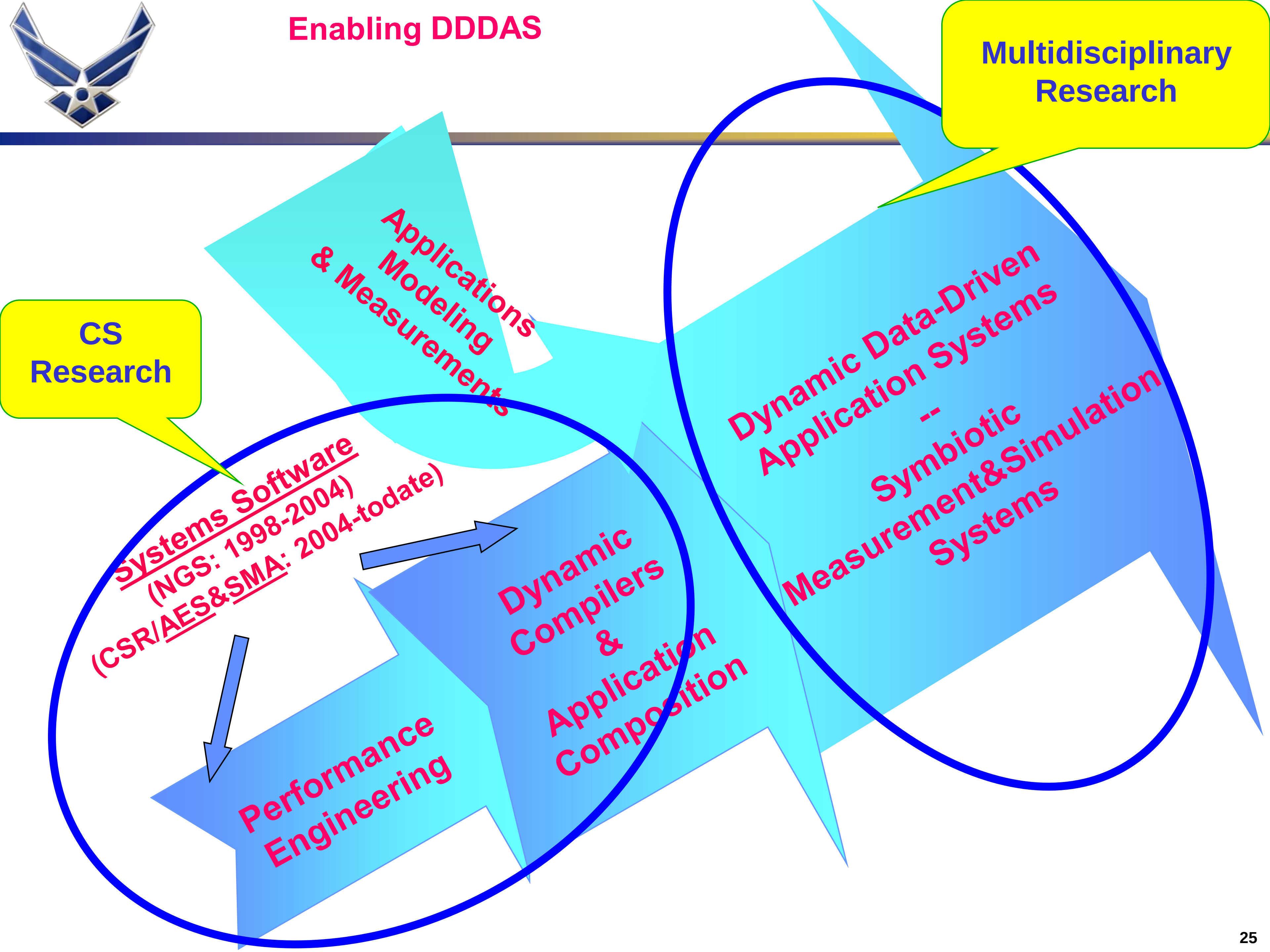
sw/hw Performance Modeling and Analysis Framework



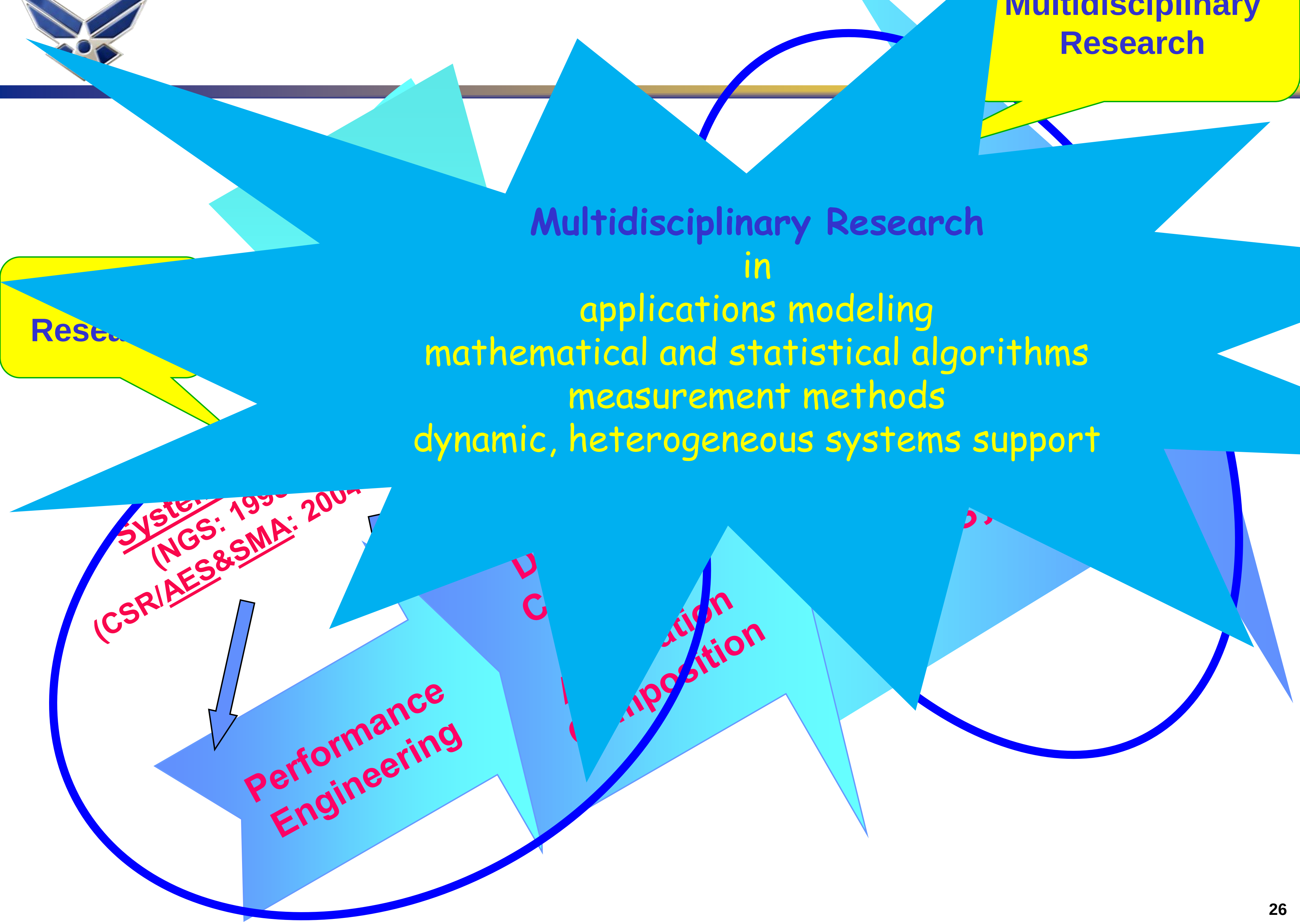
Modeling Multiple views of the system
The Operating Systems' view



Enabling DDDAS



Enabling DDDAS



Some Examples of DDDAS/InfoSymbiotics Efforts

(more examples in Workshop W17/ICCS2012)

Critical Infrastructure Systems

Critical Infrastructure Systems
Electrical PowerGrids

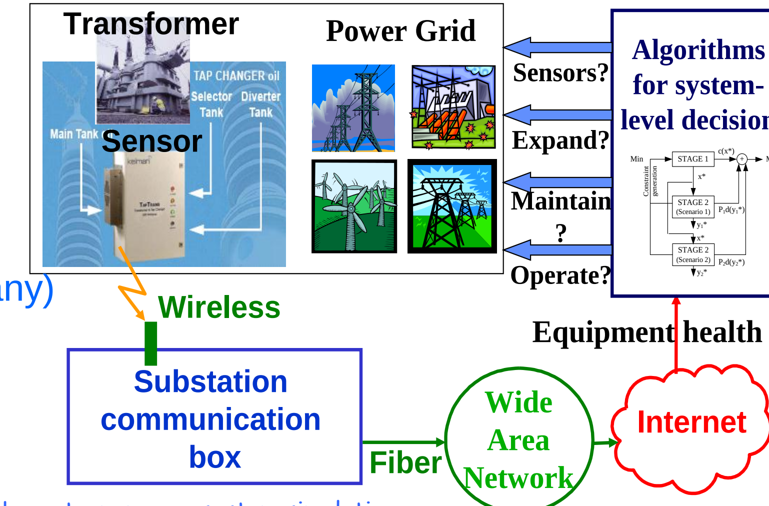
<u>Auto-Steered Information-Decision Processes</u>
<u>for Electric System Asset Management</u>

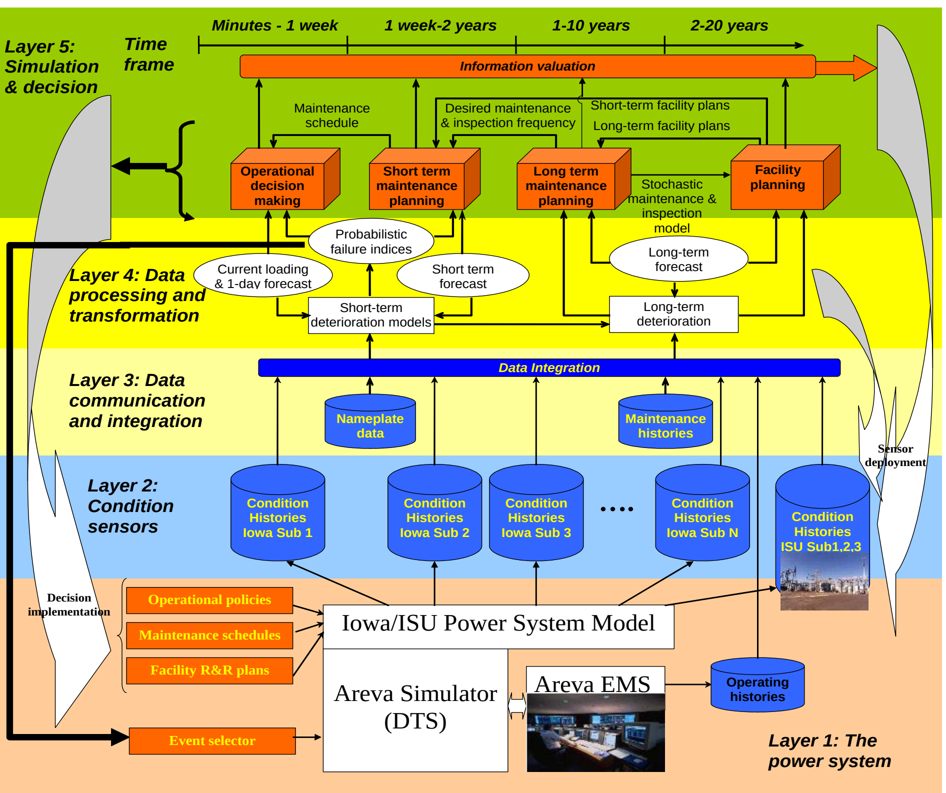
James McCalley, et al (Iowa State University)

Multi-disciplinary research and industry collaboration

- •Electrical Engineering – Power Systems
- •Computer Sciences – Data Integration, ML, Agents
- •Statistics – Reliability, Decision
- •Computer Engineering – Sensor Networks
- •Aerospace Engineering – Nondestructive Evaluation
- •Industrial Engineering – Stochastic Optimization

AREVA
(Energy Company)





- Layer 1: Long-term power system simulation
  - Areva commercial grade simulator (DTS), Iowa/ISU grid
- Layer 2: Sensing and communications
  - One or two field installations on campus, wireless sensors
- Layer 3: Data integration
  - Ontology-based, query-centric, federated
- Layer 4: Converting condition data into failure predictors
  - Steady-state & transient failure probabilities
- Layer 5: Integrated decision algorithms
  - Interacting, rolling, multi-objective, stochastic optimization
  - Two stage analysis for uncertainty reduction to decide new sensor measurements

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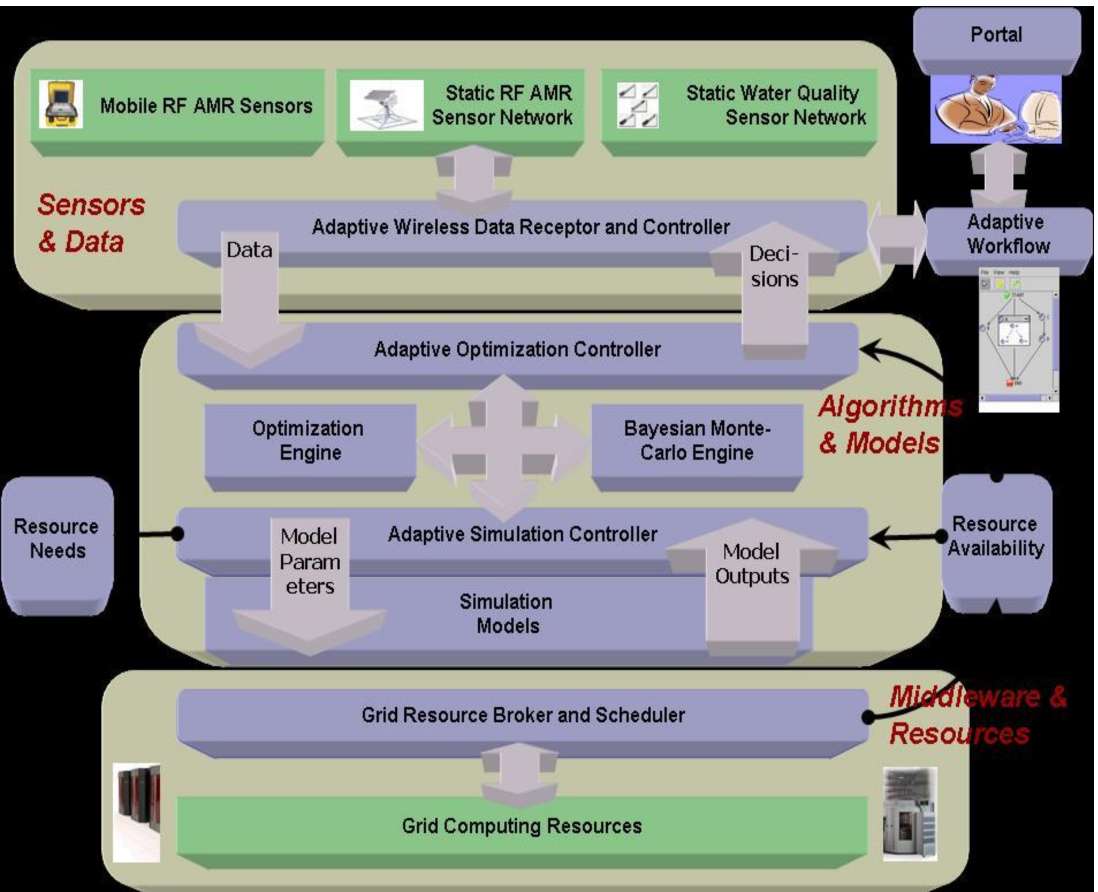
Advances through the project are aimed to enable enhanced electrical power-systems management

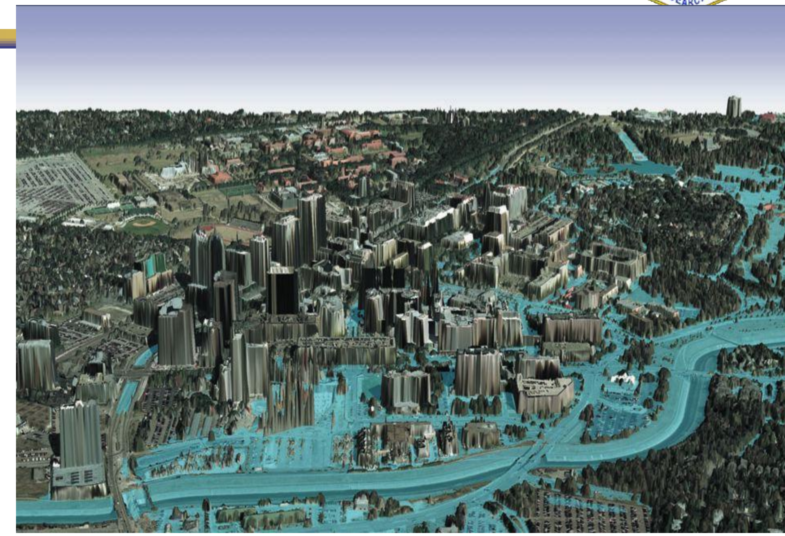
Enable economic and efficient management of electrical power-grids, foresee and mitigate failures and widespread blackouts.

Enhance the nation's electrical energy distribution health and preparedness in cases of natural and man-made disasters

Critical Infrastructure Systems
Urban Water Distribution Management Systems (WDS)

- **Kumar Mahinthakumar, et. al. (NCState U., U of Chicago, U.of Cincinnati, and U of South Carolina)**
- **<u>Multidiciplinary research</u> collaboration with industry partners from the Greater Cincinnati Water Works and the Neptune Technology Group to implement and test the cyberinfrastructure for a working WDS.**





- Threat management in WDSs involves real-time characterization of any contaminant source and plume, design of control strategies, and design of incremental data sampling schedules.
- Requires dynamic integration of time-varying measurements along with analytical modules that include simulation models (evolutionary algorithms), adaptive sampling procedures, and optimization methods.
- A live demonstration of this preliminary cyberinfrastructure using Suragrid resources was carried out at the Internet2 meeting in Chicago in December 2006.

Critical Infrastructure Systems
SurfaceTransportation

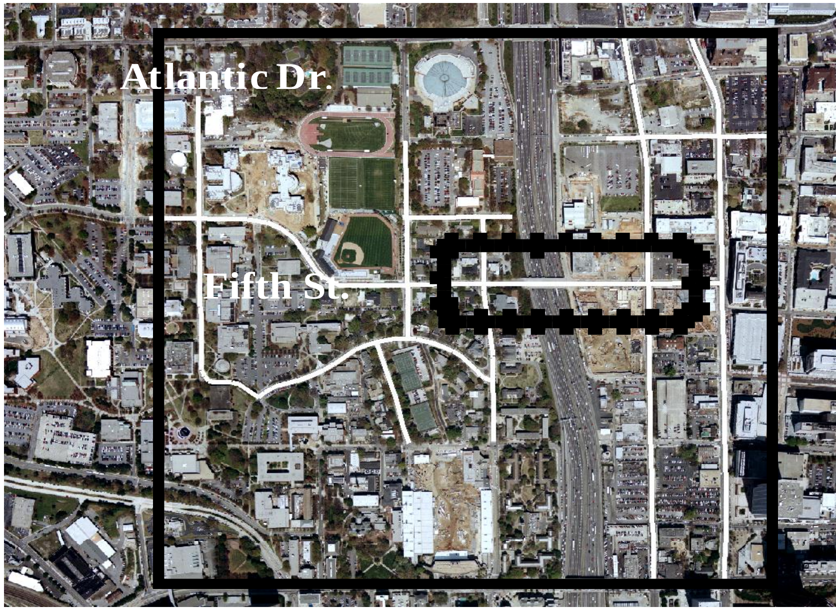
(eliminating the tyranny of commuters; safer response & evacuation of cities in crisis situations)

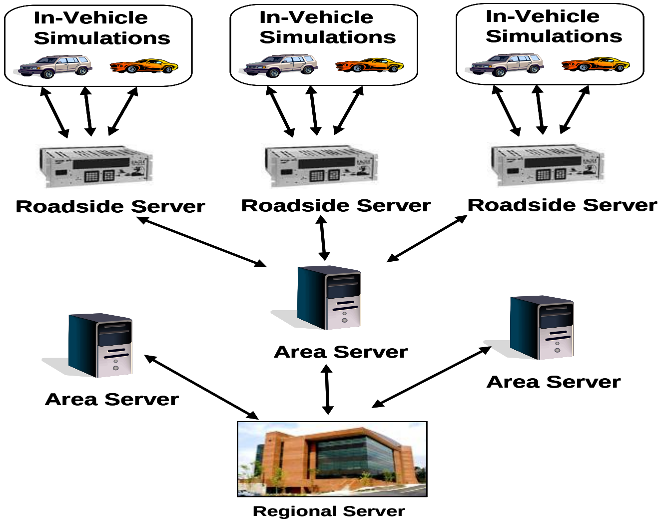
Richard Fujimoto, et al (Georgia Inst of Tech)

Delays in surface transportation systems today cost tens of billions of dollars annually in the U.S. in lost productivity, wasted fuel, and pollution. In times of crisis, delays can result in lost lives.

The project developing novel <u>ad hoc distributed simulations that feature dynamic collections of autonomous in-vehicle simulations</u> <u>interacting with each other and real-time data in a continuously running distributed simulation environment.</u> Each simulator models some portion of the transportation network, and exchange data with other simulators through a mobile, wireless network to predict future states of the overall system.

Ad hoc distributed simulations combine elements of conventional distributed simulations and replicated simulation runs, together with dynamic and continuous monitoring. Incorporating dynamically monitoring data poses challenges of data distribution and synchronization; a synchronization protocol based on rollback mechanisms has been designed for use in these systems.





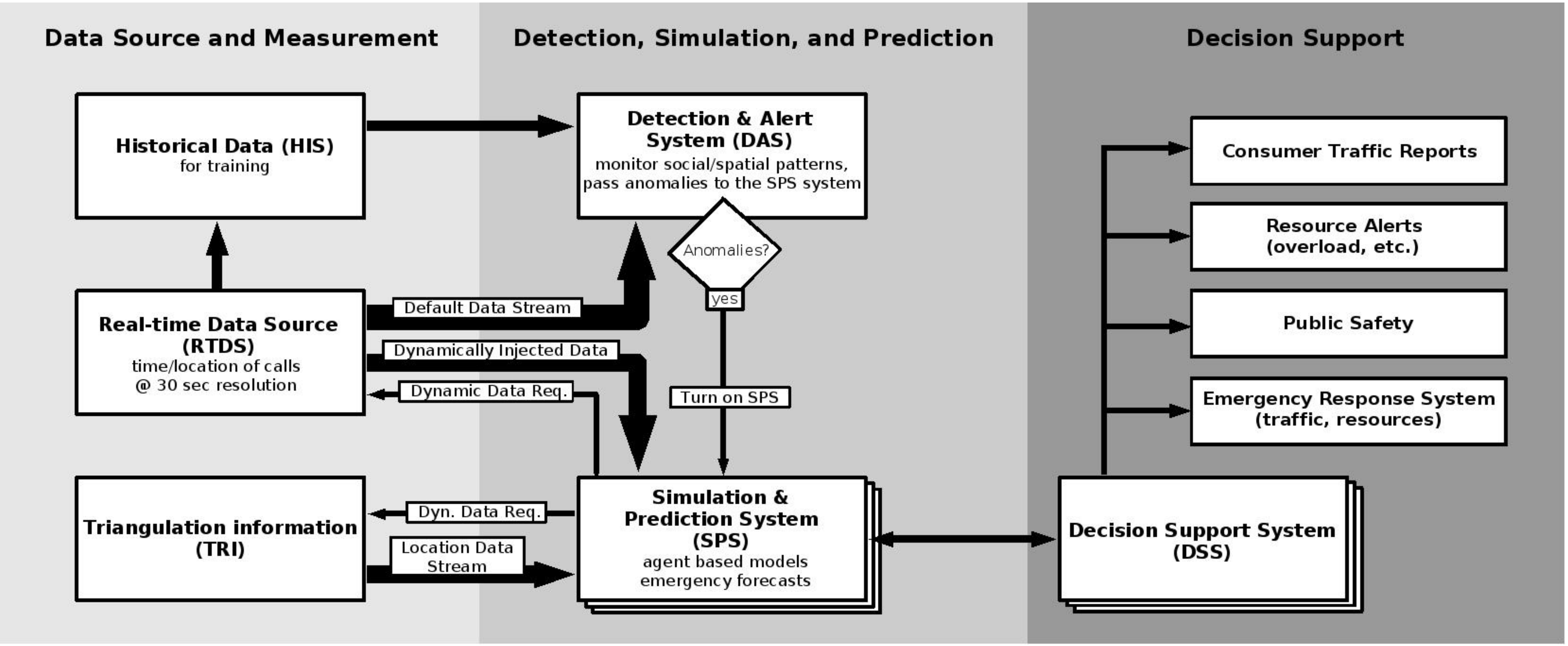
WIPER – DDDAS

Integrated Wireless Phone Based Emergency Response System

L. Barabasi
Greg Madey
et. al.

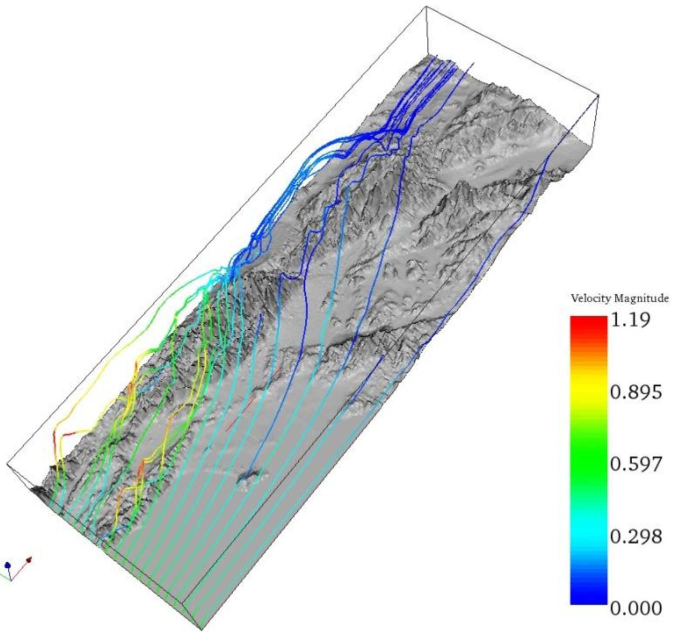
Three Layer Architecture

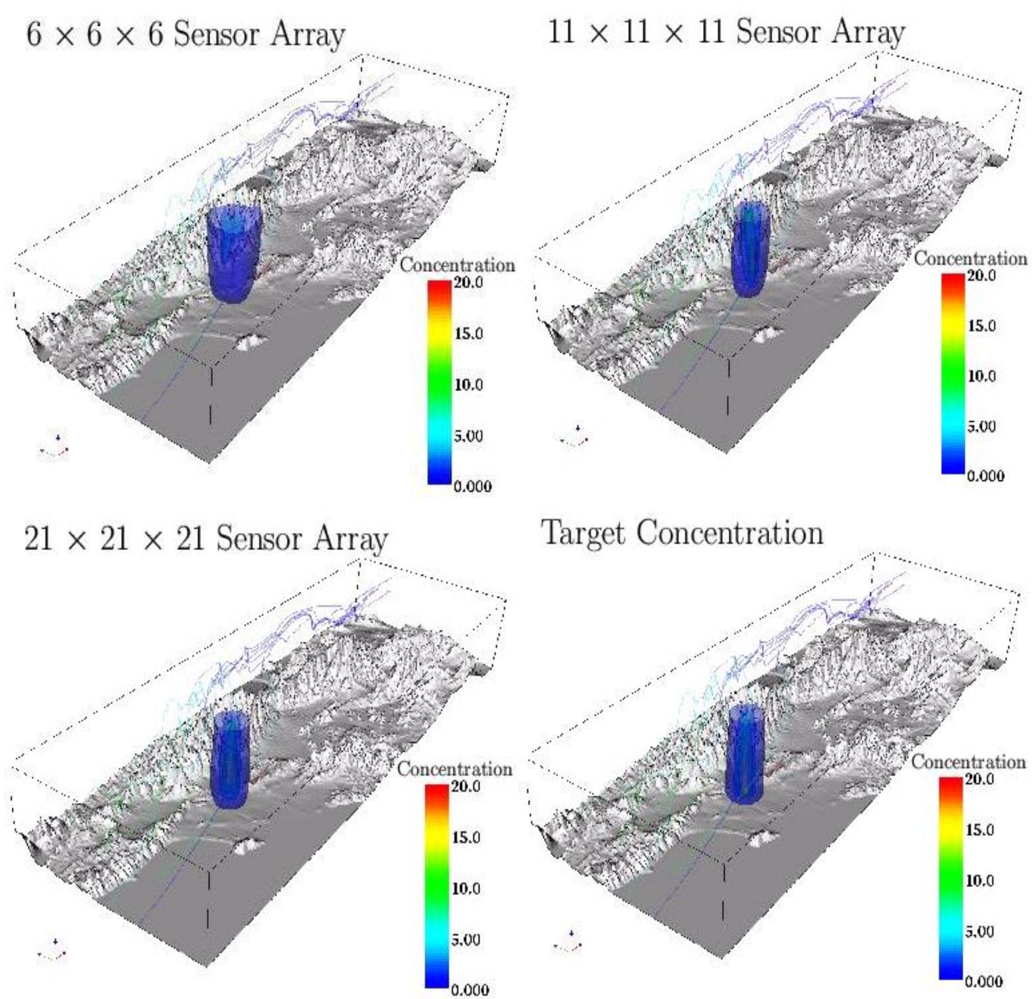
- Data Source and Measurement
- Detection, Simulation, and Prediction
- Decision Support System (DSS)



Emergency Response Systems

MIPS:
A Real-Time Measurement-Inversion-Prediction-Steering Framework for Hazardous Events

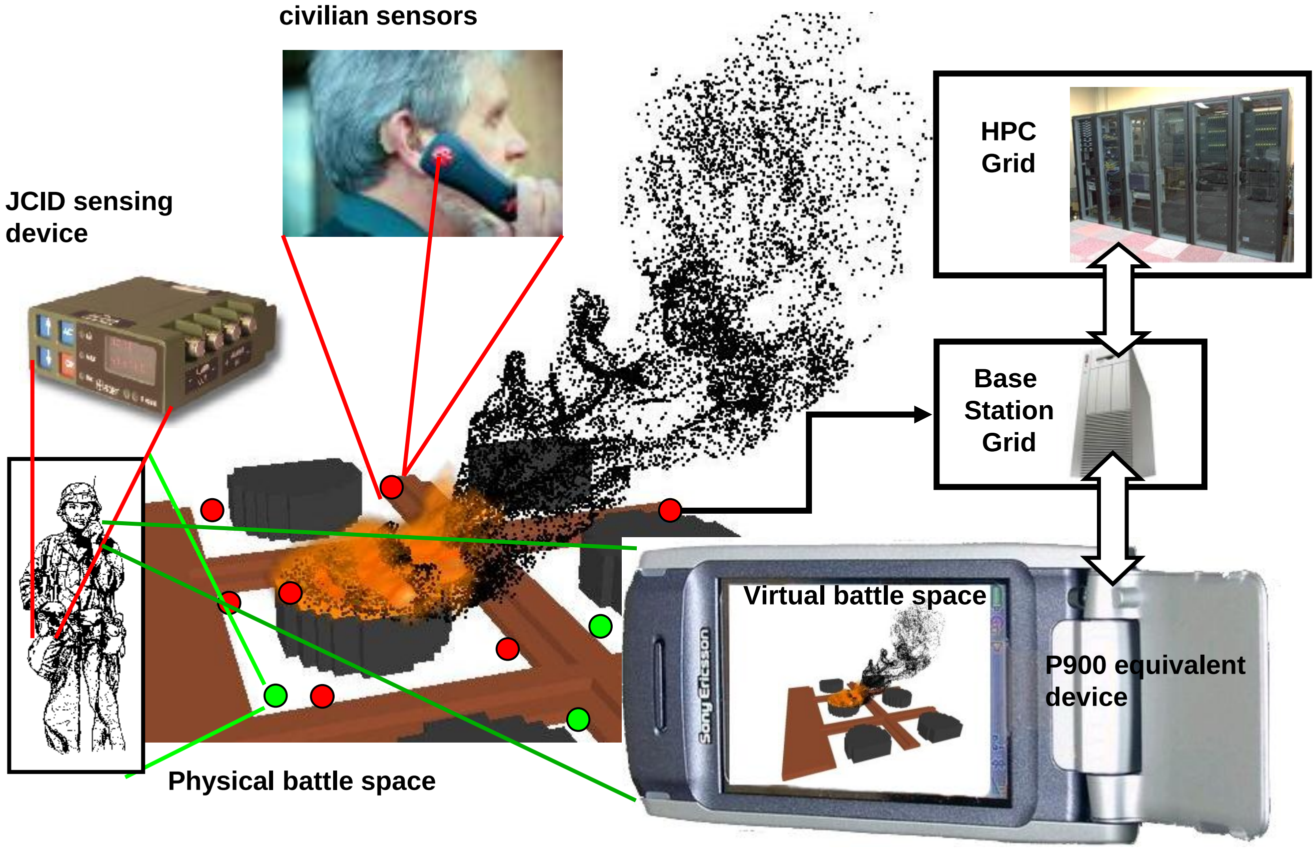




Slide Courtesy O. Ghattas (UT Austin)

Sensor and Computational Grids for Dynamic Data-Driven Contaminant Dispersion Prediction

Farhat & Michopoulos, Naval Research Laboratory

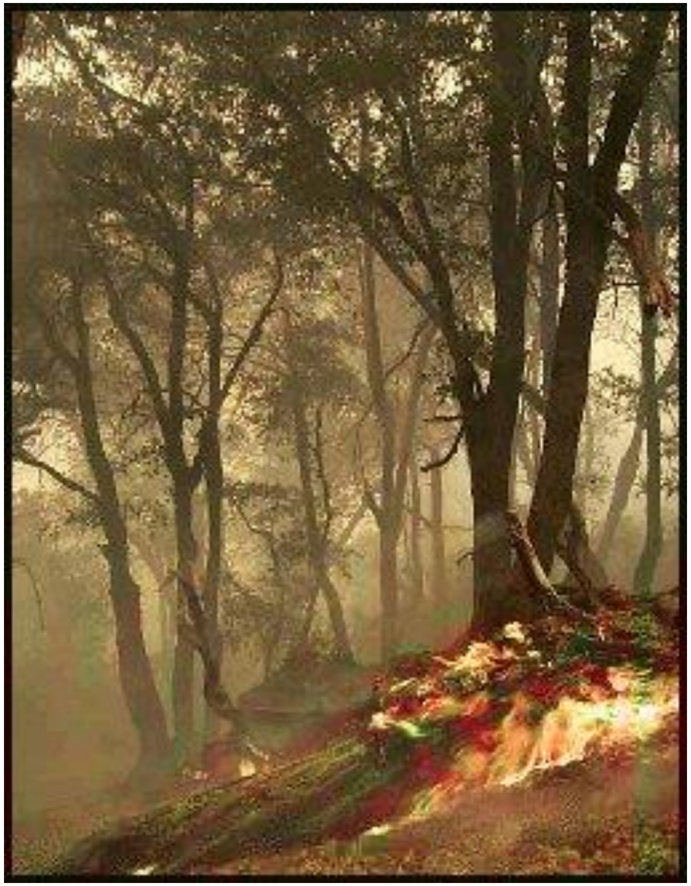


Objective:
Development of methodology for achieving real time detection and prediction of Chemo/Bio-contaminant dispersion under various weather conditions, enabling the protection of warfighters and civilians in urban or industrial environments.

Benefit to warfighter: Information superiority, C4IR integration, rapid and accurate assessment of COP and CBRN, and automated decision support.

Forrest Fire Modeling

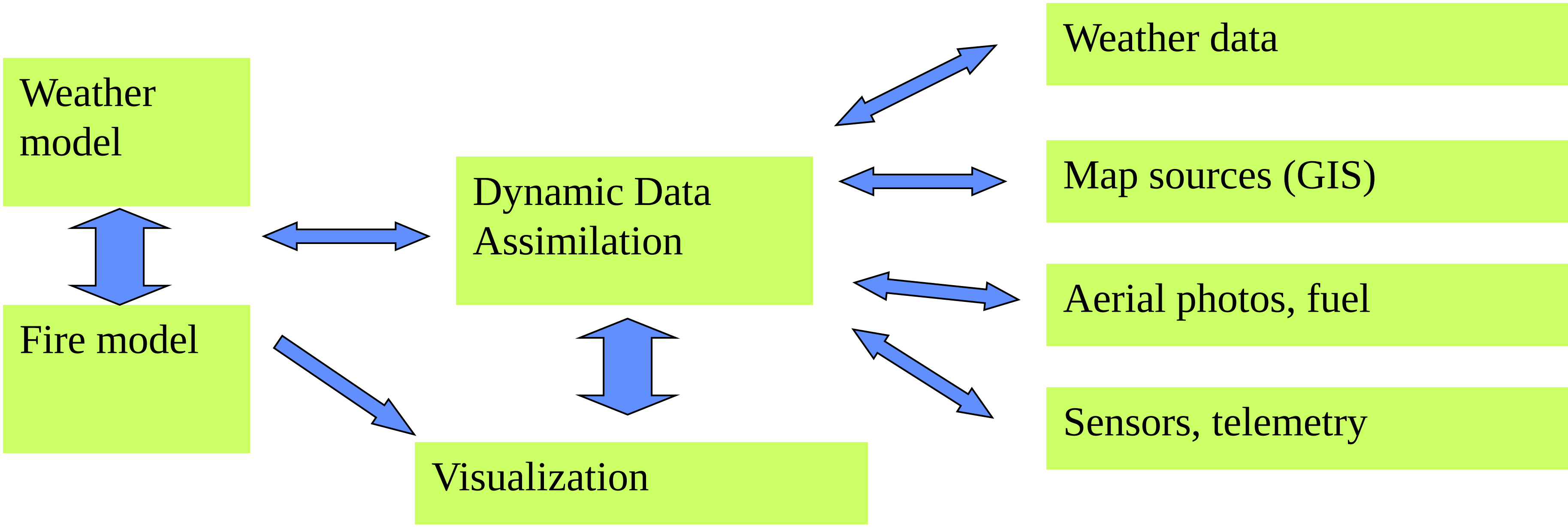
- Sensible and latent heat fluxes from ground and canopy fire -> heat fluxes in the atmospheric model.
- Fire's heat fluxes are absorbed by air over a specified extinction depth.
- 56% fuel mass -> H_20 vapor
- 3% of sensible heat used to dry ground fuel.
- Ground heat flux used to dry and ignite the canopy.



Kirk Complex Fire. U.S.F.S. photo

Coen/NCAR; Jan Mandel, Craig Douglas, Tony Vodacek, et al

Dynamic Data Driven Application System: Wildfire Modeling



Communication

Supercomputing

Software engineering

Jan Mandel and Team

Measured Response (A Homeland Security Simulation)
Synthetic Environments for Analysis and Simulation (SEAS)

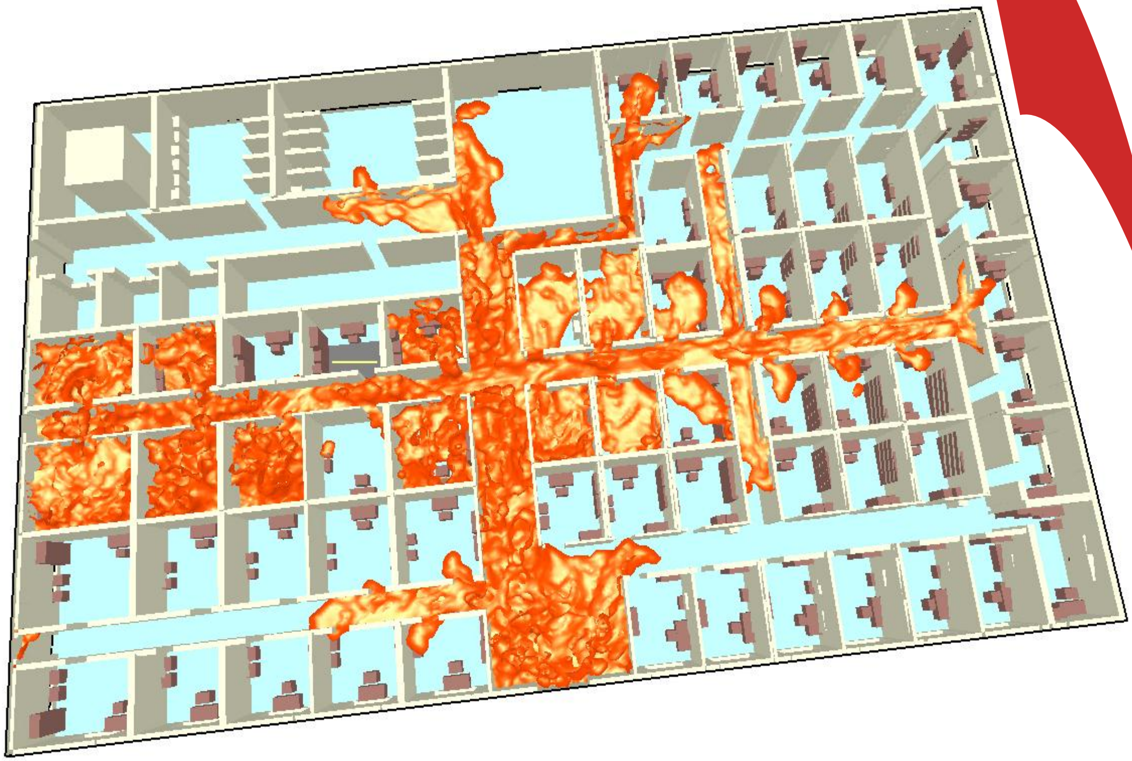
Shared Reality Engine

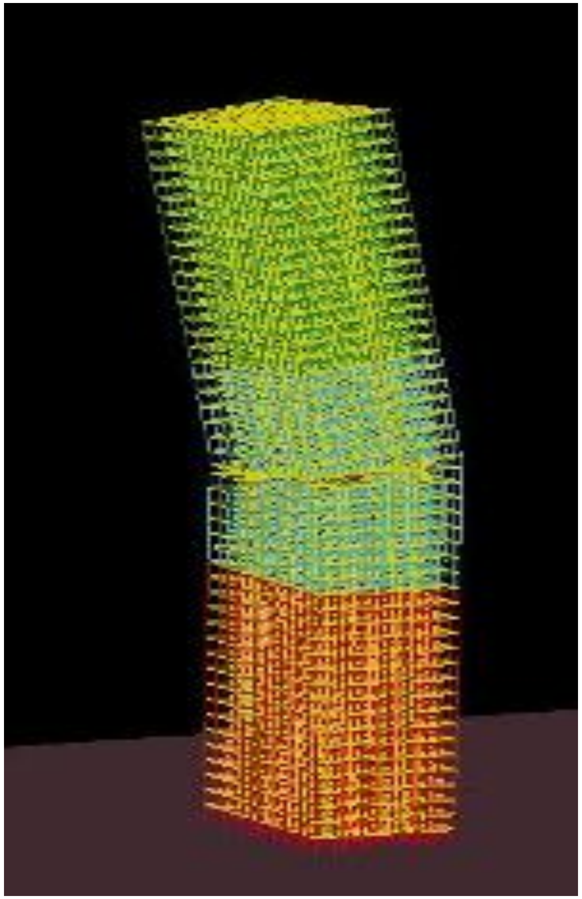
Alok Chaturvedi, Director
Shailendra Mehta, co-Director
Purdue Homeland Security Institute

Interaction between Fire, Structure, Agent-Based Models

Network of sensors coupled with computational network for fire modeling

Network of sensors coupled with computational network for structural analysis



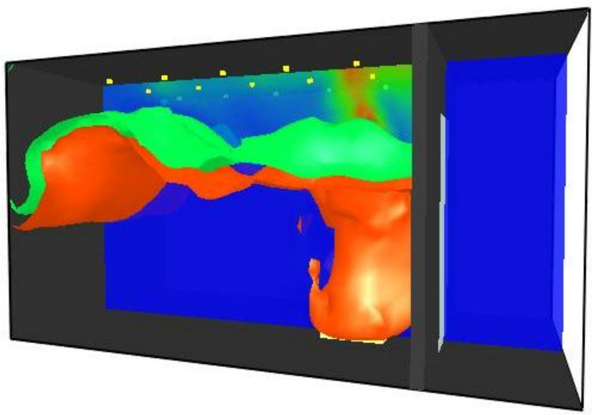


Purdue University Projects
PI: Alok Chaturvedi and Team
PI: Ahmed Sameh and Team

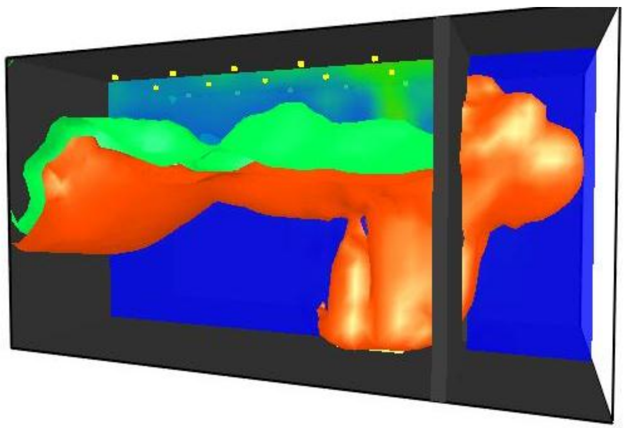
Micro-future Simulation of Submarine Room fuel-leak fire

Location aware mobile or static distributed sensor network

Before Door Opening



After Door Opening

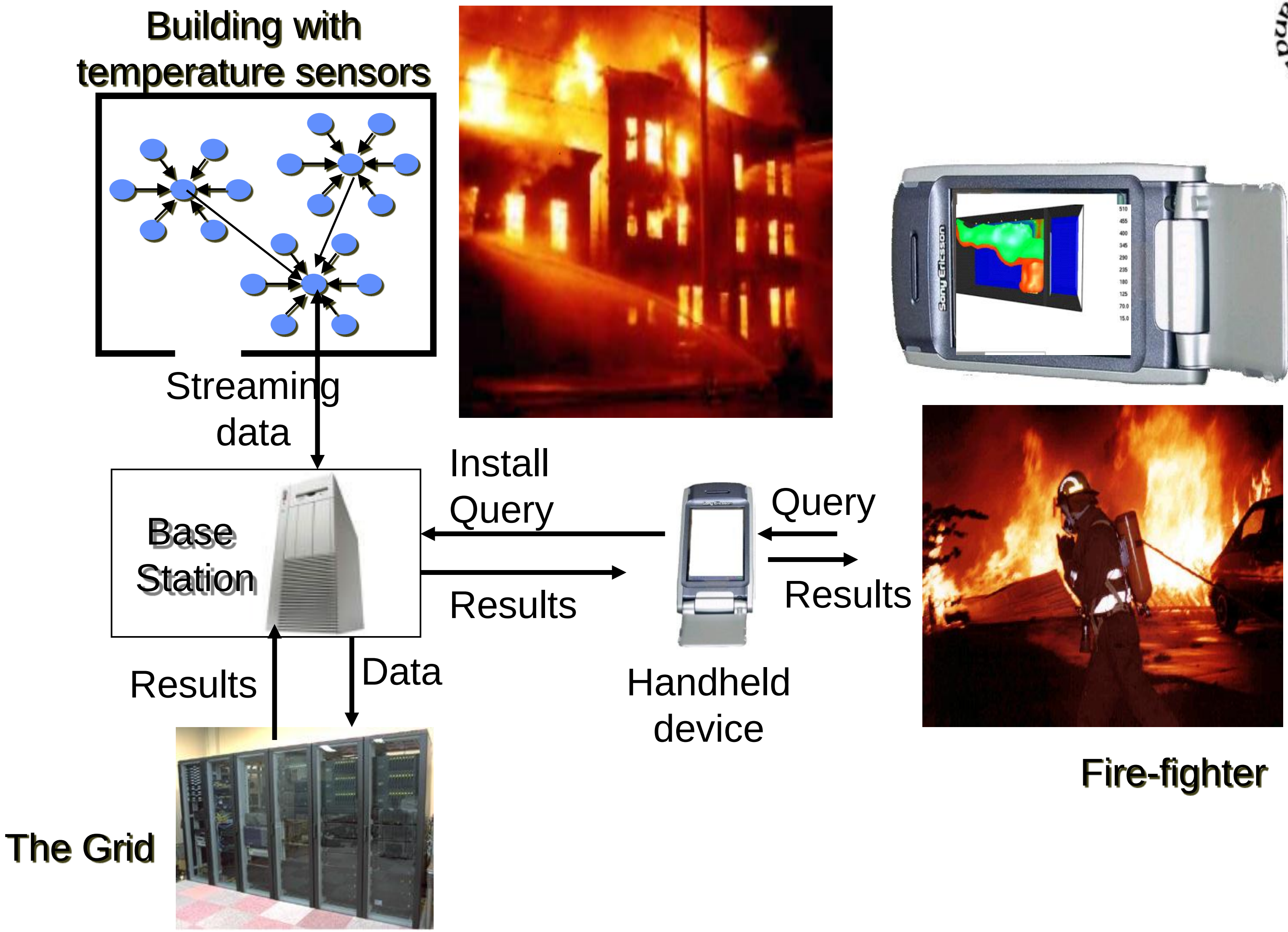


Red surface: 25 C
Green Surface: 55 C

Frame: 310
Time: 5.0

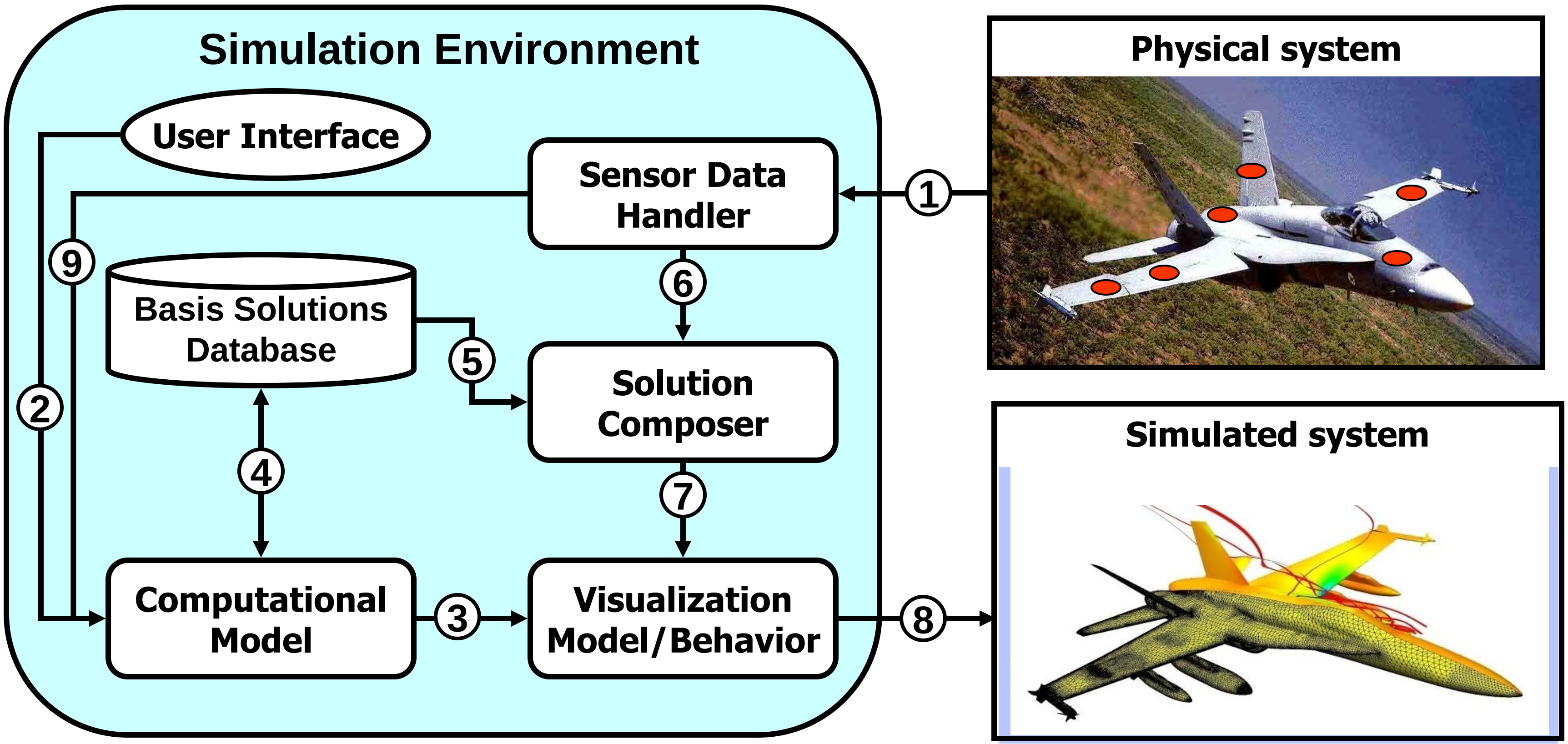
Frame: 354
Time: 5.5

DDEMA: Fire-Fighting Scenario (enclosed and ambient environments)



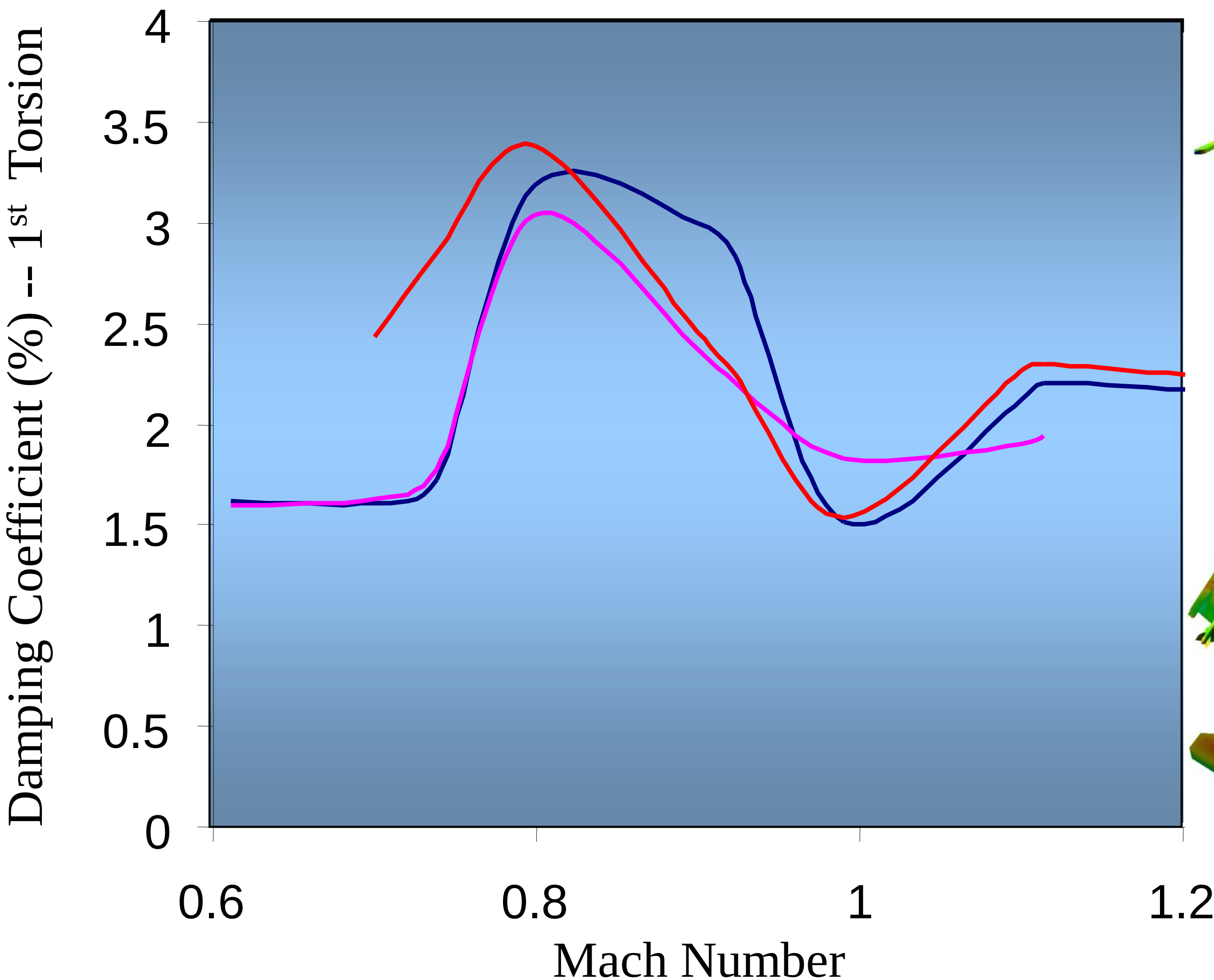
PROGNOSIS

Real-Time Support for *supersonic/hypersonic multiphysics simulation* -based platform management
(Flutter, Temperature & Softening of Skin Material Degradation, ...)

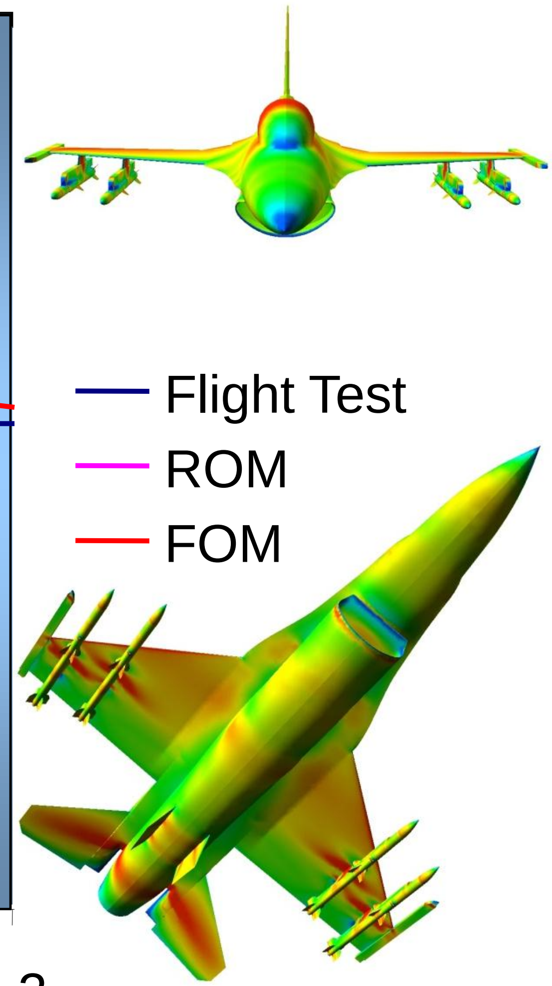


Slides Courtesy C. Farhat

VALIDATION



Damping Coefficient (%) -- 1st Torsion
4
3.5
3
2.5
2
1.5
1
0.5
0
0.6
0.8
1
1.2
Mach Number
Flight Test
ROM
FOM



(1998- … precursor Next Generation Software Program)

SystemsSoftware – Runtime Compiler – Dynamic Composition – Performance Engineering

(2000 -Through NGS/ITR Program)

Pingali, Adaptive Software for Field-Driven Simulations

(2001 -Through ITR Program)

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

(2002 -Through ITR Program)

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

(2003 -Through ITR Program)

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}

(2004 -Through ITR Program)

Brogan – Simulation Transformation for Dynamic, Data-Driven Application Systems (DDDAS)
Baldridge – 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

(2005 DDDAS Multi-Agency Program - NSF/NIH/NOAA/AFOSR)

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
Chryssostomidis - 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
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
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

+ . . .

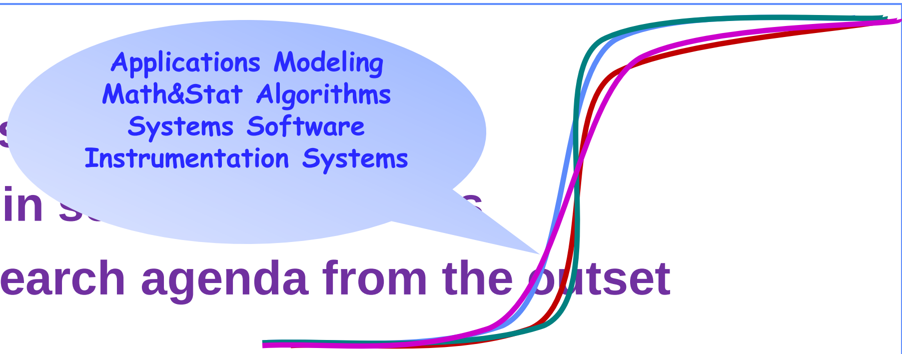
* projects, funded through other sources and "retargeted by the researchers to incorporate DDDAS"

* ICCS/DDDAS Workshop Series, yearly 2003 – todate
•other workshops organized by the community…

•2 Workshop Reports in 2000 and in 2006, in www.cise.nsf.gov/dddas & www.dddas.org

* www.dddas.org (maintained by Prof. Craig Douglas)

Where we are … & QUO VADIMUS



- **DDDAS/InfoSymbiotics**
  - high pay-off in terms of new capabilitie
  - need fundamental and novel advances in s
  - well-articulated and well-structured research agenda from the outset
- **Progress has been made – it's a "multiple S-curves" process**
  - experience/advances cumulative - accelerating pace of progress in the future
  - we have started to climb the upwards slope of each of these S-curves
  - need of sustained, concerted, synergistic support
  - timely, now more than ever – multicores, ubiquitous sensoring, BigData, …
- **Workshop and Report (August 30&31, 2010) – in www.dddas.org**
- **New projects launched through AFOSR BAA – www.afosr.af.mil**

Multi-Agency Interest

- **DDDAS/InfoSymbiotics Multi-agency Workshop (August 2010)**
  - **AFSOR – NSF co-sponsored**
  - **Report posted at www.dddas.org (academic community website)**

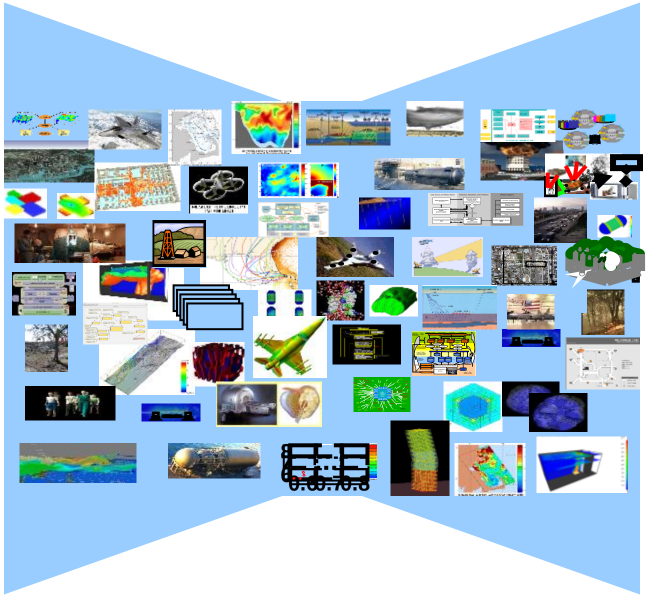
Cross-Agencies Committee

DOD/AFOSR:
F. Darema
R. Bonneau
F. Fahroo
K. Reinhardt
D. Stargel
DOD/ONR: Ralph Wachter
DOD/ARL/CIS: Ananthram Swami
DOD/DTRA: Kiki Ikossi

NASA: Michael Seablom

NSF:
H. E. Seidel (MPS)
J. Cherniavsky (EHR)
T. Henderson (CISE)
L. Jameson (MPS)
G. Maracas (ENG)
G. Allen (OCI)

NIH:
Milt Corn (NLM),
Peter Lyster (NIGMS)



Report Outline

Some recently funded AFOSR DDDAS projects
… *from the nano-scale to the "Terra"-scale*

- Development of a Stochastic Dynamic Data-Driven System for Prediction of Materials Damage
- Dynamic Data-Driven Modeling of Uncertainties and 3D Effects of Porous Shape Memory Alloys
- DDDAS: Computational Steering of Large-Scale Structural Systems Through Advanced Simulation, Optimization, and Structural Health Monitoring
- Dynamic Data Driven Methods for Self-aware Aerospace Vehicles
- Bayesian Computational Sensor Networks for Aircraft Structural Health Monitoring
- DDDAS for Object Tracking in Complex and Dynamic Environments (DOTCODE)
- Dynamic Data Driven Machine Perception and Learning for Border Control
- Dynamic Predictive Simulations of Agent Swarms
- Fluid SLAM and the Robotic Reconstruction of Localized Atmospheric Phenomena
- Energy-Aware Aerial Systems for Persistent Sampling and Surveillance
- DDDAMS-based Urban Surveillance and Crowd Control via UAVs and UGVs
- A Framework for Quantifying and Reducing Uncertainty in InfoSymbiotic Systems Arising in Atmospheric Environments
- Application of DDDAS Ideas to the Computation of Volcanic Plume Transport
- Transformative Advances in DDDAS with Application to Space Weather Monitoring
- An Adaptive Property-Aware HW/SW Framework for DDDAS
- Active Data: Enabling Data-Driven Knowledge Discovery through Computational Reflection
- Adaptive Steam Mining: A Novel Dynamic Computing Paradigm for Knowledge Extraction
- DDDAS-based Resilient Cyberspace (DRCS)
- PREDICT: Privacy and Security Enhancing Dynamic Information Monitoring with Feedback Guidance

In the future expect to explore other AF important areas e.g. energy efficiency, combustion, …

Some recently funded AFOSR DD AS projects
… from the nano-scale to the erra"-scale

- Deve of a Stochastic Dynan riven Syste tion of Materials Damage
- Dynamic Modeling of nd 3 rous Sh Alloys
- DDDAS: Co ring d Simulation, Optimization, a
- Dynamic Data Dri
- Bayesi
- Dy
- Dynam
- Fluid SLAM
- Energy-Aw
- DDDA
- rising in Atmospheric Environm
- Application of DDDAS of Transp
- Transformative Advar DDAS ation ather Monit
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- Adaptive Steam Mining: A Novel Dyn omputing Paradi or Knowledge Extraction
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- PREDICT: Privacy and Security Enhan g Dynamic Information Monitoring with Feedback Guidance

Sample of these and other projects
in the ICCS2012/DDDAS Workshop
(W17)
Co-chaired by Profs. Douglas and Patra
(June 4th and 3rd)

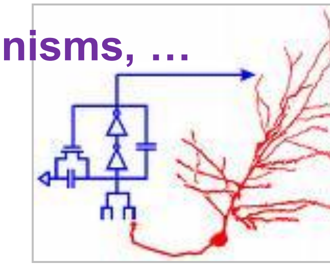
In the future expect to explore other AF i portant areas e.g. energy efficiency, combustion, …

Complex Networks / Network Science

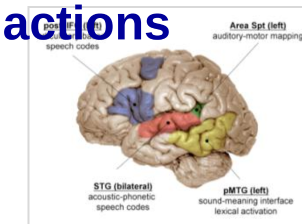
- Understanding, architecting, building, managing, exploiting complex networks
- Foundational properties and unifying principles across classes of networks
  - biological, networks in materials & other physical systems, infrastructure systems, computer and other engineered networks, animal, and human networks
  - Examples of such networks:
    neural networks in the brain, neuronal pathways in living systems, ..., networks in collections of biological organisms, ecological systems; systems of molecules, granular systems and grain boundaries in solids, porous media networks in materials, …; engineered and critical infrastructure networks - communication networks, electrical power-grids, water-distribution grids, transportation grids, ..., operations and components involved in production planning in manufacturing systems and plants; human social and business networks, …
- Seemingly diverse networking systems
  - differ in their realization infrastructure and their function and behaviors
  - but also exhibit behaviors and patterns that are common among such systems
  - dynamic, interactive, mutually interdependent, self-organizing, self-configuring, self-healing; neither closed nor static; exhibit heterogeneity & dynamicity;
  - are not isolated systems, may be interrelated with other classes of networks, and in a hierarchical, multi-scale, multi-level, or multi-modal fashion
- Is there a universality, complementarity, uncertainty principle for networks?
- Design/performance tradeoffs in engineered systems
  - Exploit or discover new properties in networks through understanding of characteristics and behaviors observed in other classes of networks

Understanding the Brain and the Mind
(from cellular networks … to human networks)

- **Neural and Brain models, processes and functions**
  - architecture/macroscopic models, neural pathways, chemical mechanisms, …



- **Neural, perceptual , learning and decision processes**
  - organization, categorization, classification, aggregation, …
- **Connection of brain processing with sensory systems and their actions**
  - memory, vision, auditory, olfactory, speech, …, eco-location, …



- **Cognition, inference, reasoning, decision making**
  - learning processes and algorithms, planning/control, reinforced learning, …
- **Human (individual and collective) behavior – Socio-Cultural dynamics**
  - alertness, learning, deception, influence, competition, collaboration, …

- **Enhancing Human ability**
  - human-machine interaction, individual capabilities, humans in extremes
- **Enhancing Engineered Systems**
  - new computer architectures/algorithms/software, engineered sensory systems, …

Transformative Partnerships between Academe and Industry/Business

What will drive these U-I/B partnerships?

Address and Solve Hard Problems, that

Industry alone cannot do

Universities alone cannot do

Methods and Tools to *enable Advanced Research in Academe*

Methods and Tools for *New Capabilities for Industry*

Combine broad expertise in Academe

With Industry/Business know-how for building robust systems(prototypes)

Examples: CyberInfrastructures for Complex Applications Systems

(Need comprehensive systems frameworks – not just system components)

Models exist for long-term viability of such partnerships in self-sustaining ways (and where government funding contribution becomes minimized)

New Capabilities - New Directions through Advanced CyberInfrastructures (★)

***"Innovation through CyberInfrastructure Excellence" (ICIE)* (★)**

(★) **Darema, Report on:** ***CyberIfrastructures of Cyber-Applications-Systems & Cyber-Systems-Software***

(★) **Darema, Report on: Industrial Partnerships in Cyberinfrastructure , *October 2009***

Summary

New discoveries and research and technology advances
at the interface and confluence of multiple science and engineering areas
through multidisciplinary approaches and multidisciplinary efforts

Computer Sciences and Information Technologies have become
key for advances in any other Scientific, Engineering, Societal fields

Transformative Innovations
through
University-Industry/Business partnerships catalyzed by Government

International component is important!

Summary

…coveries and research and technology advances
…nfluence of multiple science and engi…ering areas
…approaches and multidiscipli… …fforts

Unification – High-End to RT/DA&Control

Systems Engineering

InfoSymbiotics/DDDAS

Network Science

Understanding the Brain and the Mind

New Opportunities

New Capabilities

…catalyzed by Go…ment

…nal component is important!

Back-up slides