Ubiquitous Computing and Monitoring System (UCoMS) for Discovery and Management of Energy Resources

Overview

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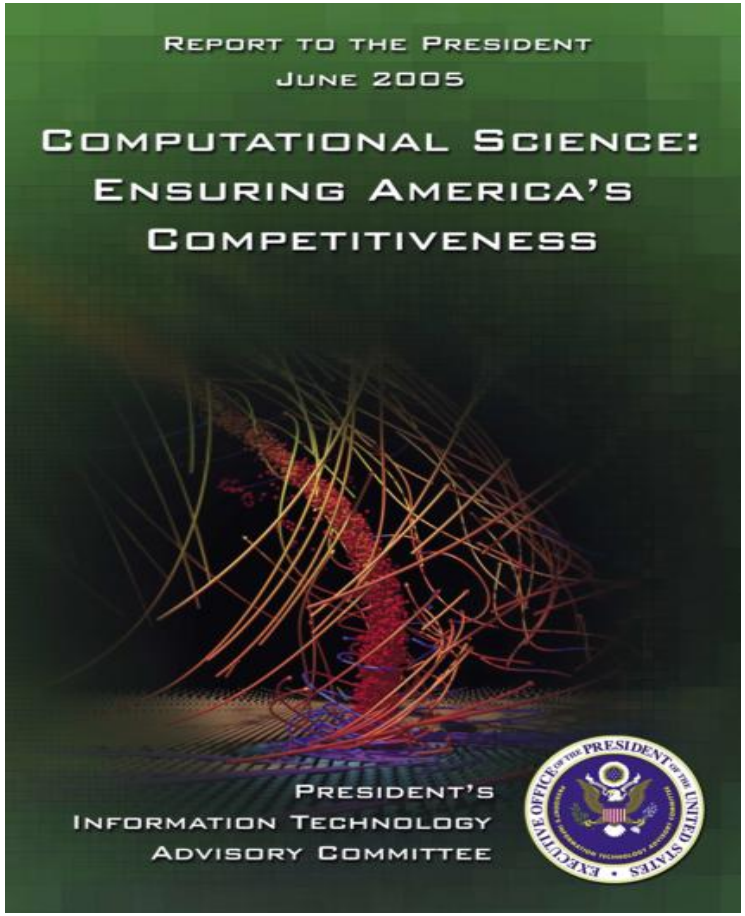
PITAC Report Summary:

"*Universities must significantly change organizational structures: multidisciplinary & collaborative research are needed [for US] to remain competitive in global science*"

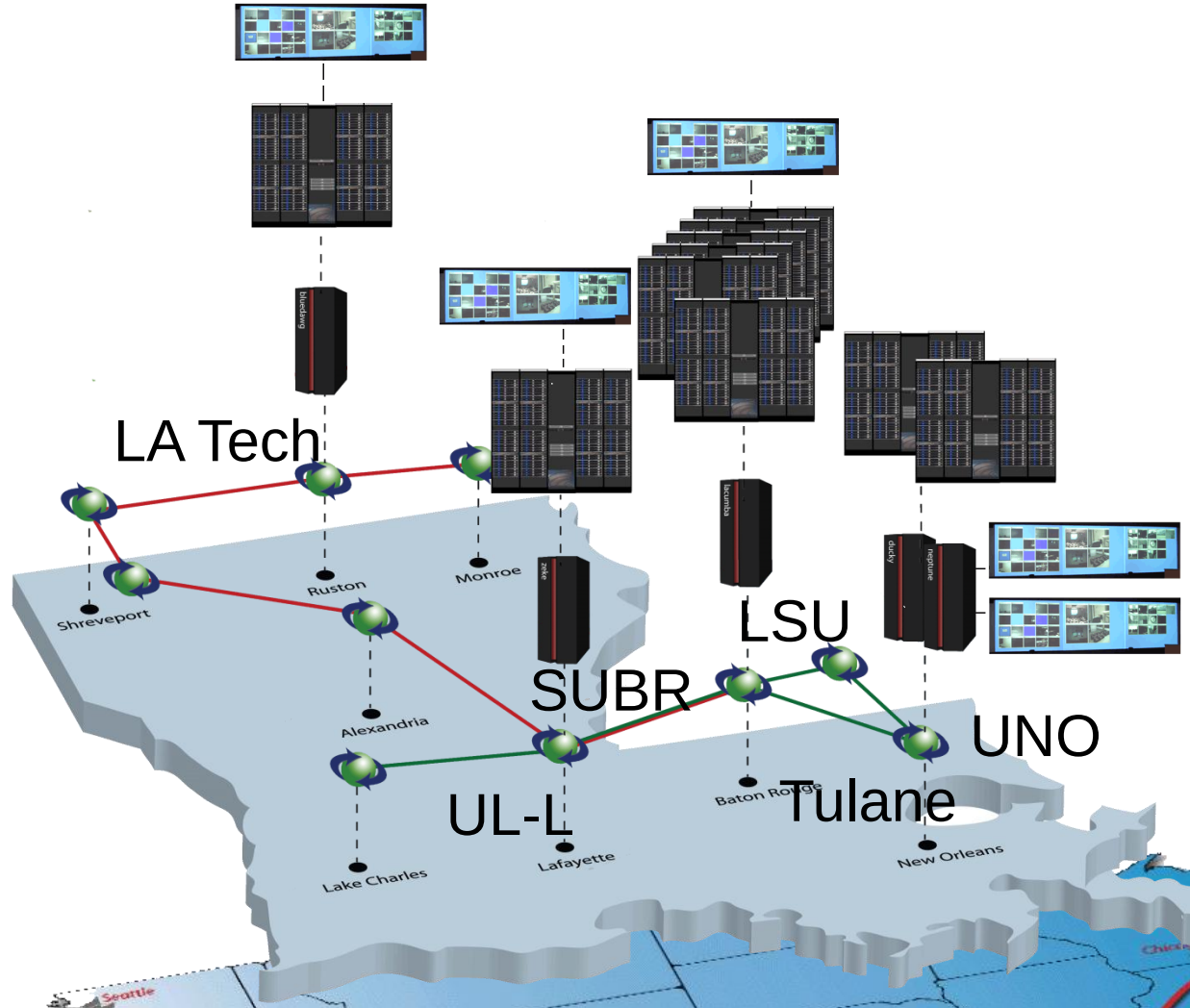


State's Strategic Investments

- *Louisiana: Vision 2020*
- IT drives Economic development:
  - Gov. Foster *Vision 2020* initiative : $25M annually to five campuses in 2001
  - Gov. Blanco: $40M <u>over the next ten years</u> to create Louisiana Optical Network Initiative (LONI) in 2004

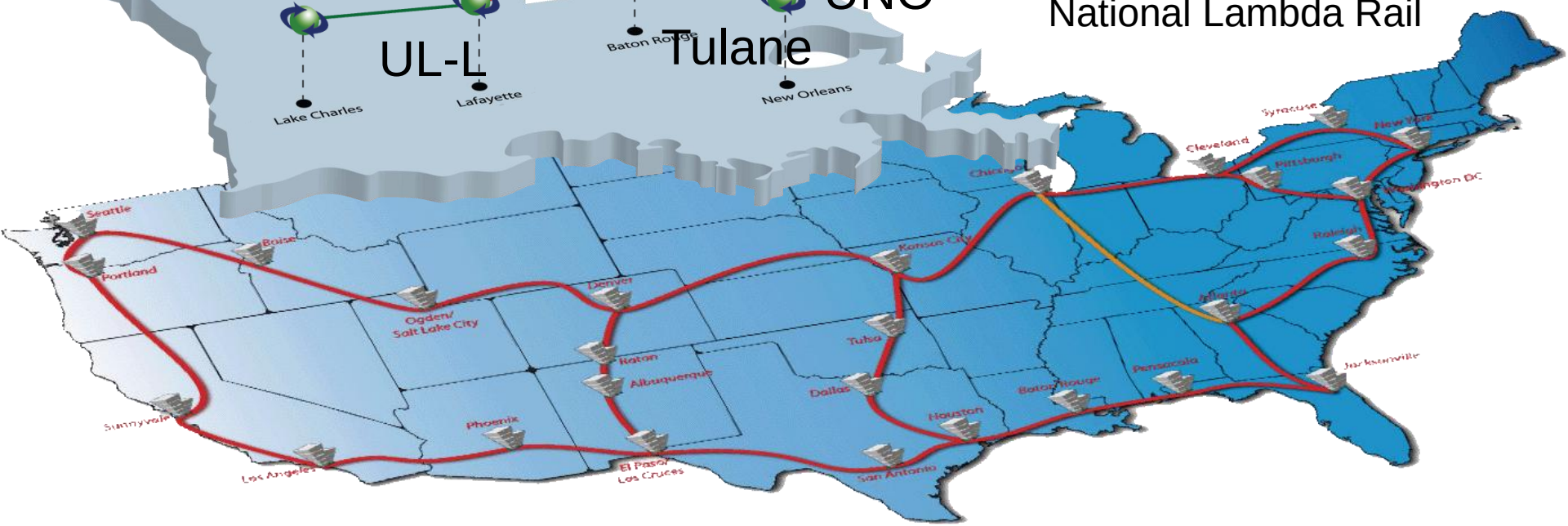
Louisiana Optical Network Initiative (LONI)

- LONI connects Louisiana to the National LamdbaRail, a high-powered nationwide fiber-optic network.
- LONI connects the State's major research institutions with optical fiber delivering up to 40 Gigabits per second.



~ 100TF IBM, Dell Supercomputers

National Lambda Rail



UCoMS Objectives

- Foster interdisciplinary research spanning computer science and computer engineering, computational science, geosciences, and petroleum engineering
- Establish national prominence in the development of Grid computing technology with applications in oil and gas exploration and production

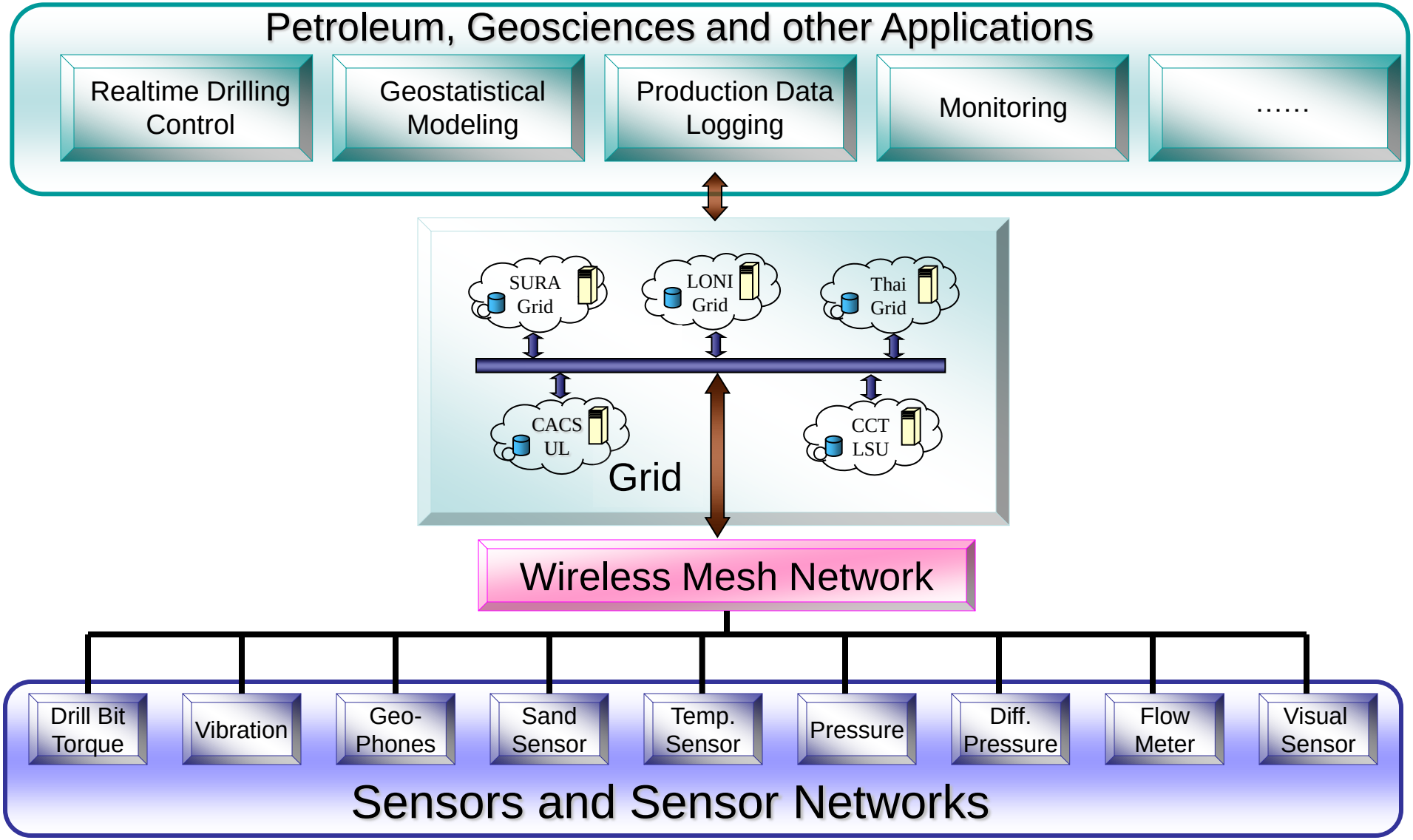
UCoMS Objectives

Address key research issues to arrive at appropriate technical solutions for:

- wireless and sensor network systems,
- geoscience data integration,
- Grid computing and storage, and
- application and monitoring software.

UCoMS System Overview

Key Research Components

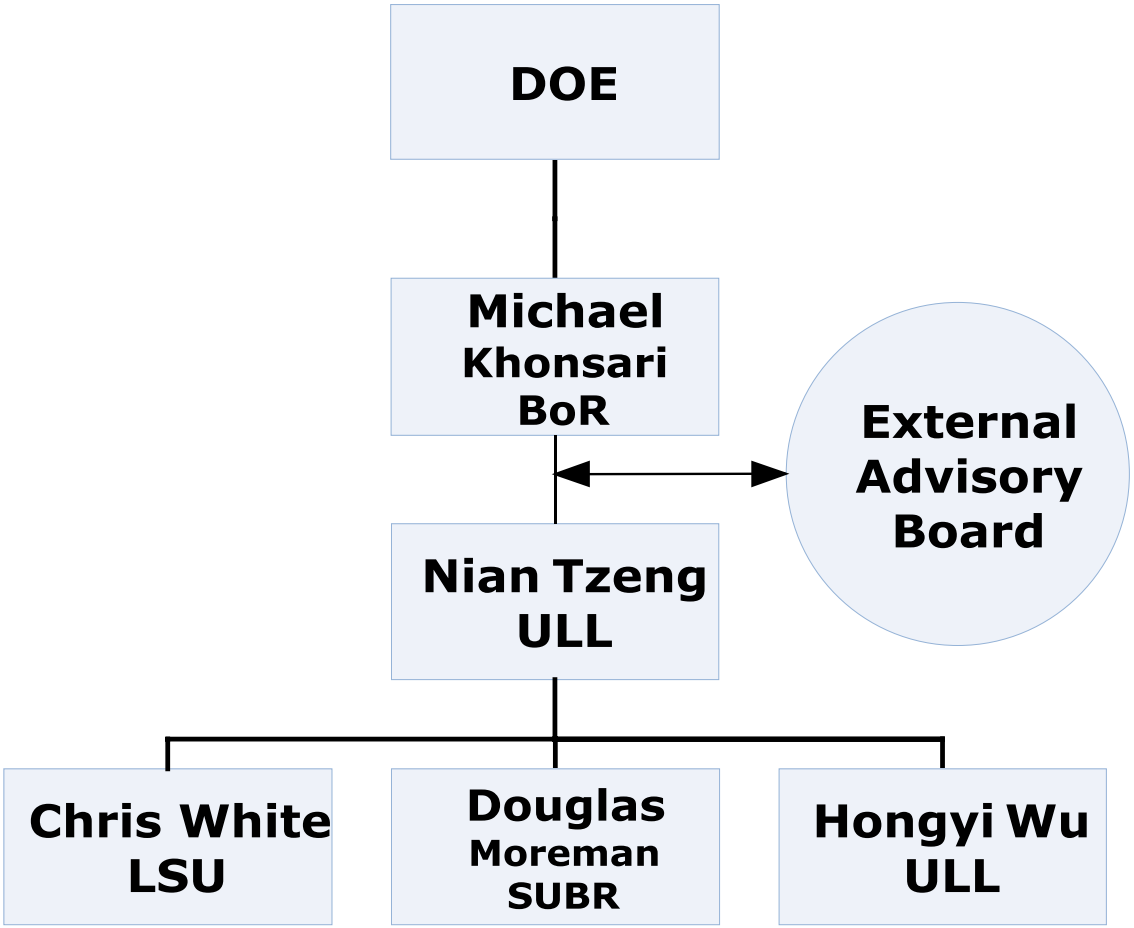


Funding Amounts

- Phase I – DOE ($1.2 M)
  BoR ($1.2 M)
  Institutional ($1.55 M)

- Phase II – DOE ($900,000)
  BoR ($1.2M)
  Institutional ($1.3 M)

Organizational Chart



UCoMS Institutions & Personnel

TEAM WORK OF PARTICIPATING INSTITUTIONS

- University of Louisiana at Lafayette (lead institution)
  - + 6 faculty members (7 for Phases I & II), in CS/CE, PE, ECE areas
  - + 1 research scientist (2 for Phases I & II)
  - + 15 GRAs (24 for Phases I & II)
- Louisiana State University
  - + 5 faculty members (7 for Phases I & II), in CS, PE, Geo areas
  - + 1 research scientist
  - + 13 GRAs and undergraduates
- Southern University, Baton Rouge
  - + 2 faculty members (3 for Phases I & II), in CS
  - + 5 GRAs and undergraduates

Technical Collaboration (Phase I)

Educational Collaboration (Phase I)

Phase II collaborative efforts to span all campuses on both

Advisory Committee

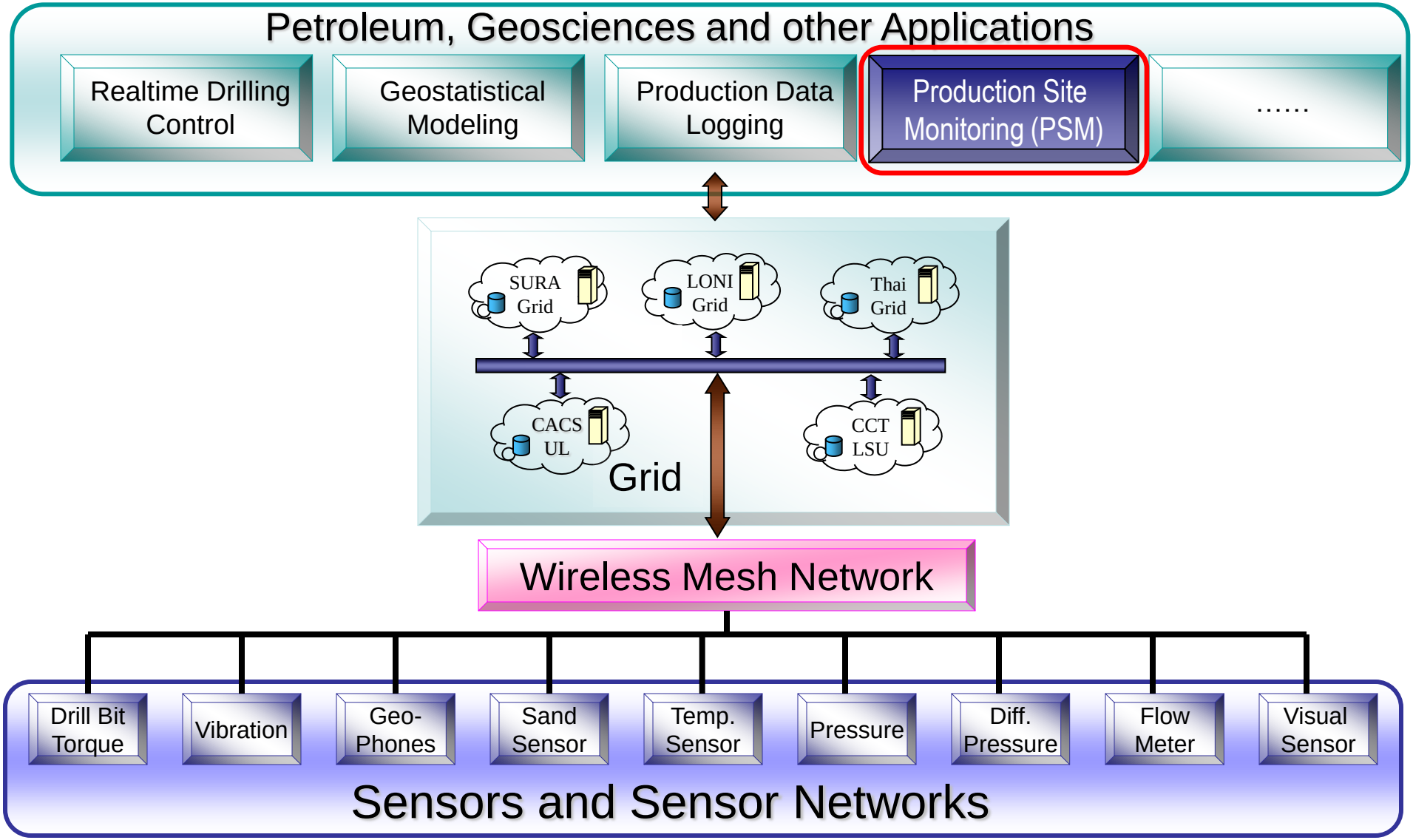
- Sudhir Dixit, Director HP labs, India, formerly Nokia Research Center (Chair)
- Douglas Blankenship, Sandia National Laboratory
- William Fenstermaker, C. H. Fenstermaker & Associates, Inc.
- Cully Firman, Baker Hughes ProductionQuest
- David Kennedy, Stone Energy Corporation
- Mary Wheeler, UT Austin
- H. T. Kung, Harvard

UCoMS Accomplishments

1. Investigated enormous challenges and potentials of applying novel IT to oil/gas industry
2. Implemented a simple end-to-end prototype with interdisciplinary collaboration
3. Developed enabling technologies for sensors, networks, grids, and HPC.
4. Demonstrate comprehensive end-to-end solutions to targeted oil and gas scenarios

UCoMS Production Site Monitoring

Building Integrated Solutions

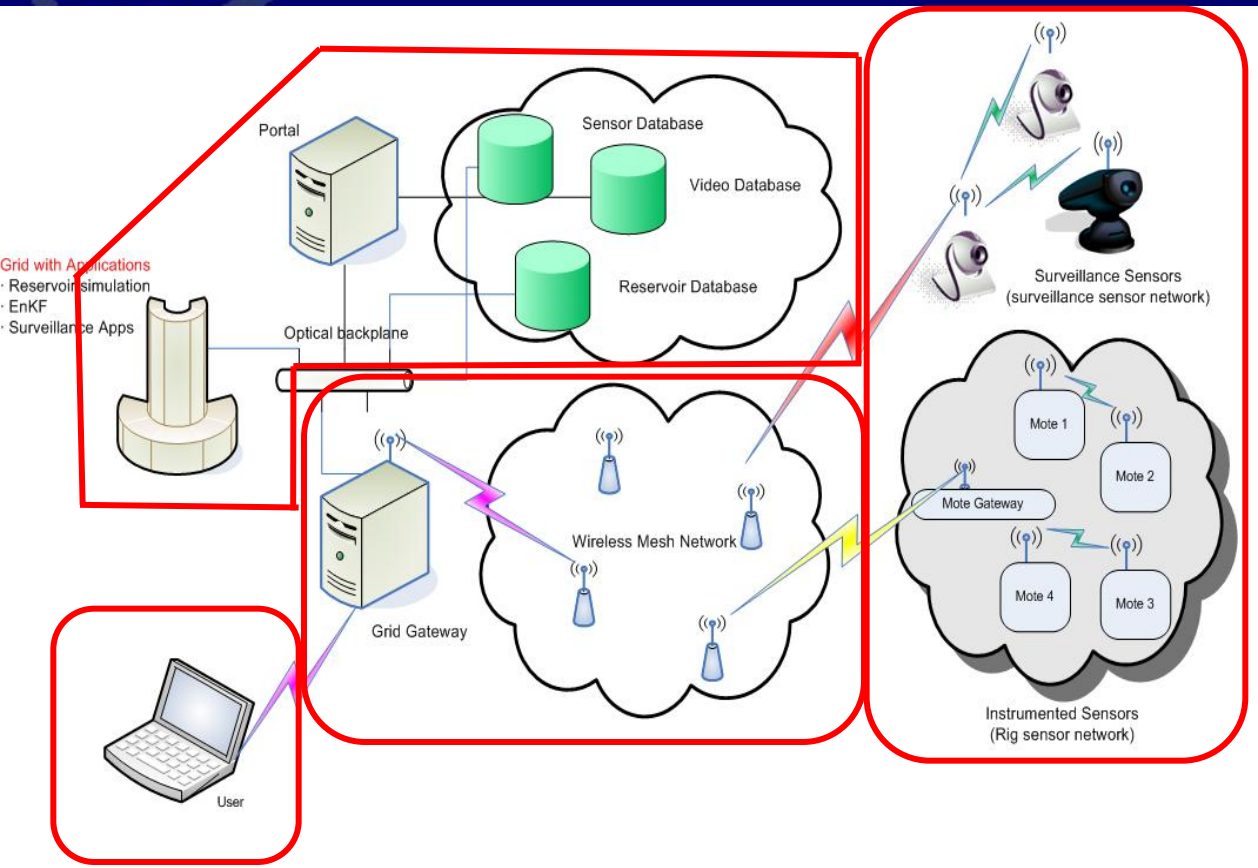


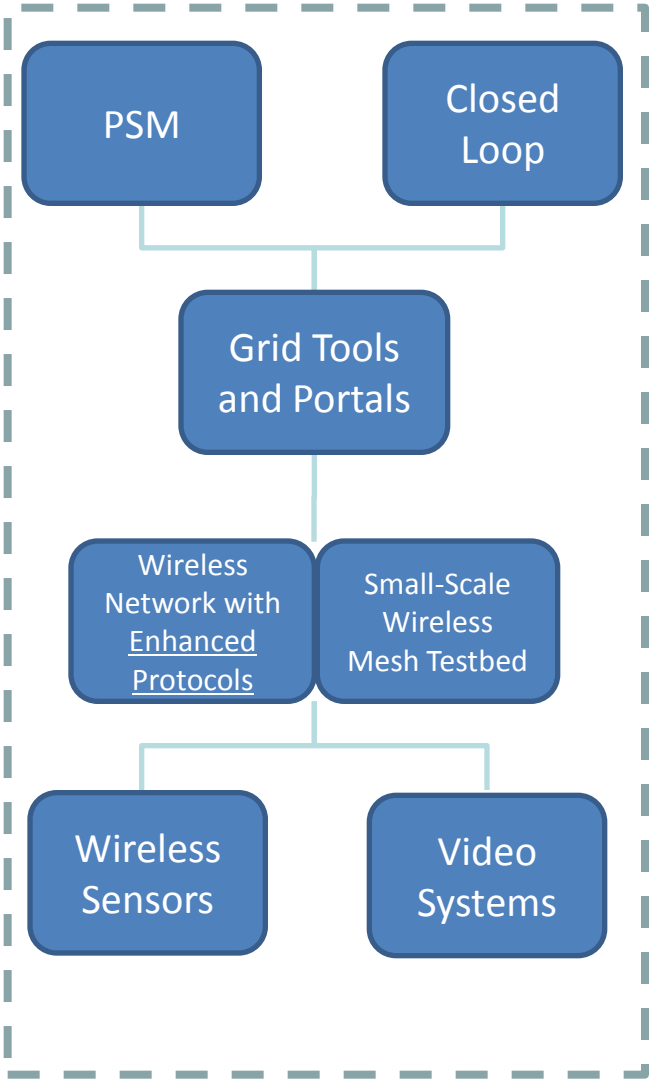
Production Site Monitoring Objectives

- Operations monitoring of remote sites from central control
- Slow oil and gas leak monitoring
- Automated structural defect and wear monitoring
- Emergency monitoring of assets (e.g., during hurricanes, etc.)
- Correlated visual, IR, thermal, acoustic and other sensor-based production and structural monitoring.

Ubiquitous Computing and Monitoring System

System Architecture and Demonstration Flow





Integrated E2E System

Building End-to-End PSM Systems: Challenges and Solutions

Inherent R&D issues

SENSORS
Retrofitting electronics
Sensor development
Low-energy processing
Synchronized telemetry

WIRELESS
Wireless channel effects
Limited-bandwidth
High Traffic Load
Client Mobility
Multi-Hop Wireless

GRID APPs
Portal functionalities
Database Synchronization

Non-Trivial System Deployment

Development Challenges

SENSORS
Heterogeneous sensors
Data conversion
Embedded Hw/Sw Dev.
Power / RF / Wireless issues

WIRELESS
Strong Interference
Congestion
Data Loss
Reliability, Low QoS
Long Delays
Fault Management

GRID APPs
Portal Development
Applications development
Database Management

Flexible and accessible Deployment,
Reliable Data Acquistion

UCoMS work

Phase I Research Solutions

+

Phase II integration, implementation, & deployment

Deliverables

Fully Functional PSM Prototype

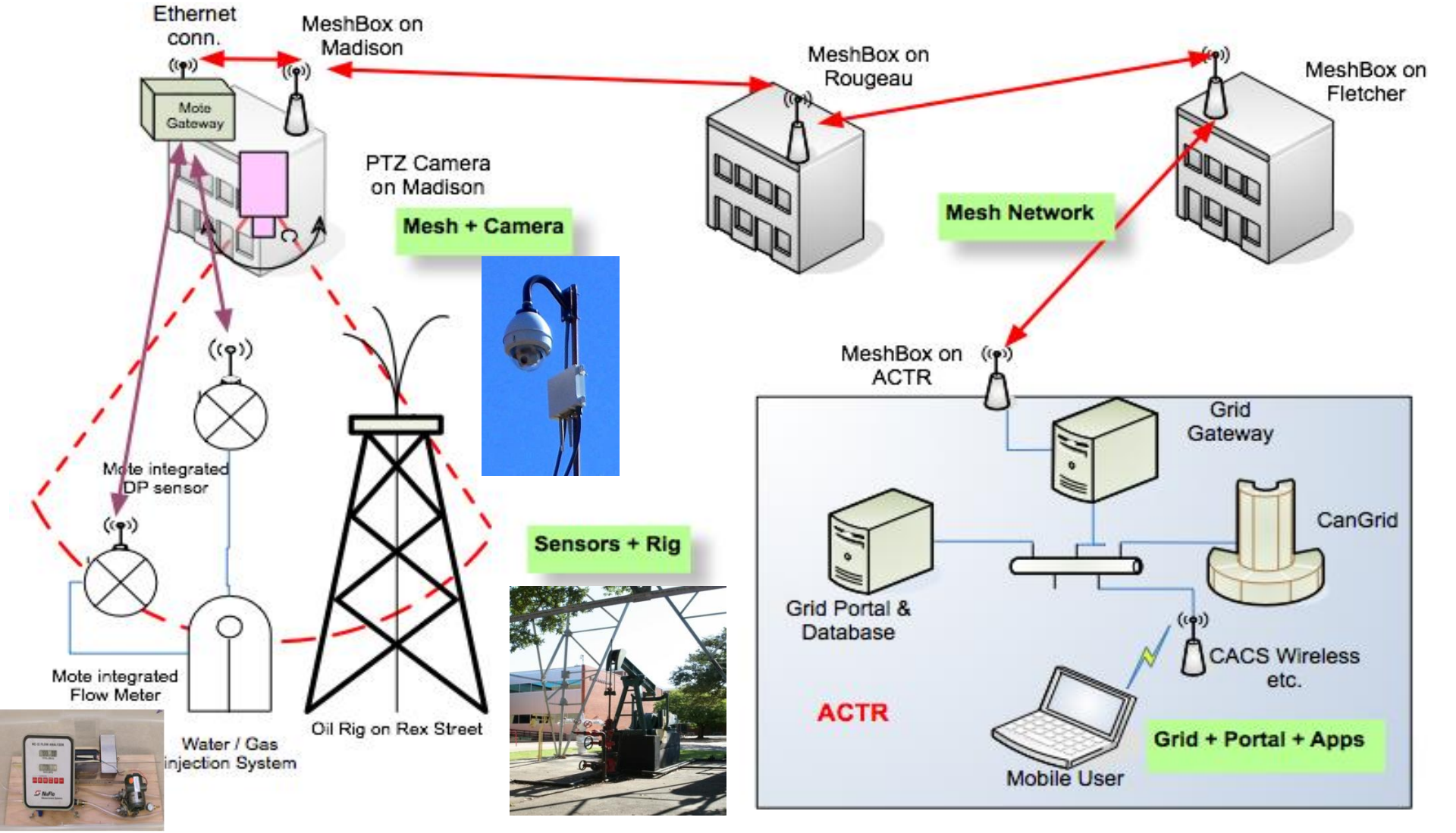
Sensors
Wireless Integrated Sensors
Remote telemetry
Visual sensor
wireless DAQ from multiple sensors

Wireless
Sustained data rates 10 Mbps
Delay tolerant data delivery
QoS-support
Self-configurability
Fault tolerant

Grid Apps
WITSML based sensor DAQ
Sensor Data charting on Portal
Unified Portal
Surveillance control through Portal
Grid Apps through portal

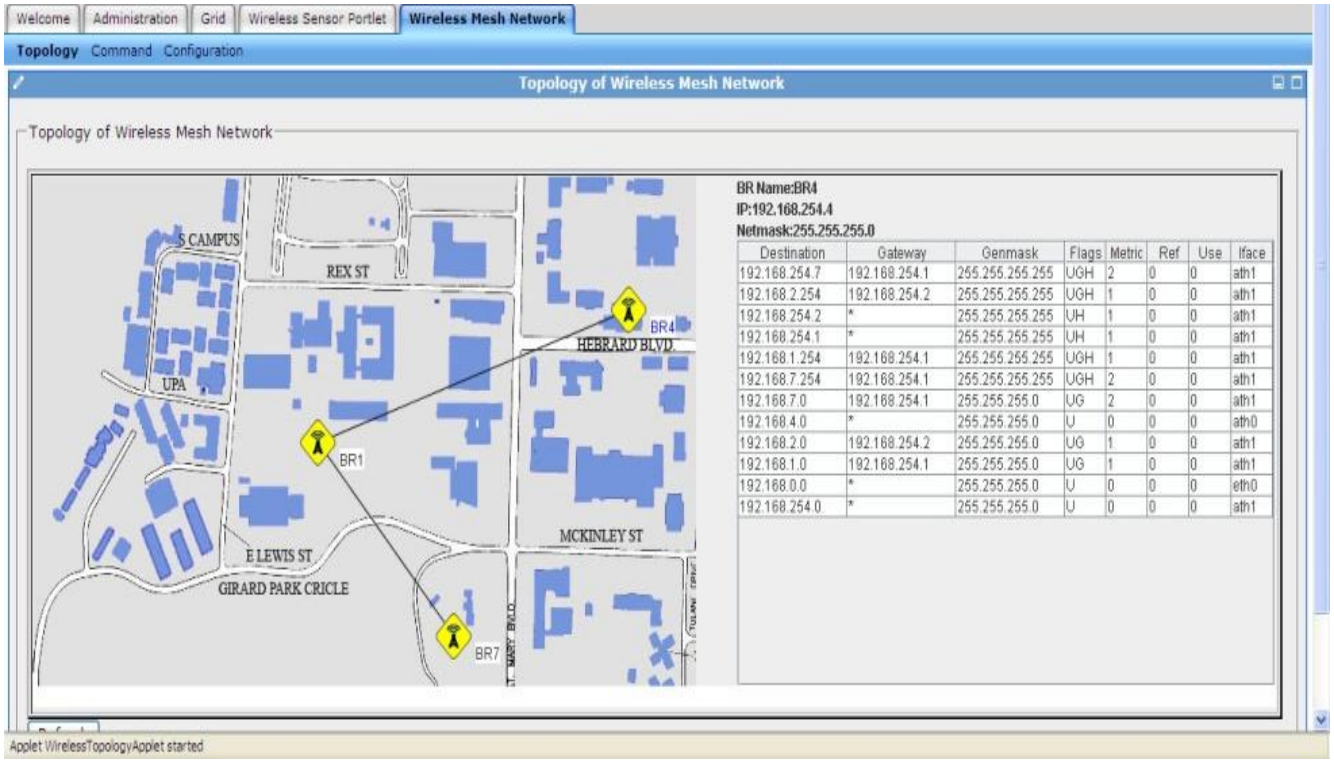
PSM Testbed for Fast Prototyping

PSM End-to-End Test-bed



Integrated Production Site Monitoring (PSM) Test-bed on ULL Campus

Layer – I : Sensors, Sensor Platforms, and Networks



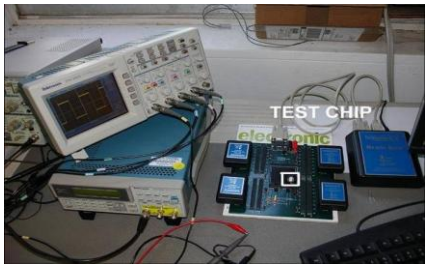
Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
192.168.254.7	192.168.254.1	255.255.255.255	UGH	2	0	0	ath1
192.168.2.254	192.168.254.2	255.255.255.255	UGH	1	0	0	ath1
192.168.254.2	*	255.255.255.255	UH	1	0	0	ath1
192.168.254.1	*	255.255.255.255	UH	1	0	0	ath1
192.168.1.254	192.168.254.1	255.255.255.255	UGH	1	0	0	ath1
192.168.7.254	192.168.254.1	255.255.255.255	UGH	2	0	0	ath1
192.168.7.0	192.168.254.1	255.255.255.0	UG	2	0	0	ath1
192.168.4.0	*	255.255.255.0	U	0	0	0	ath0
192.168.2.0	192.168.254.2	255.255.255.0	UG	1	0	0	ath1
192.168.1.0	192.168.254.1	255.255.255.0	UG	1	0	0	ath1
192.168.0.0	*	255.255.255.0	U	0	0	0	eth0
192.168.254.0	*	255.255.255.0	U	0	0	0	ath1

Grid-based Portal for Sensor Networks

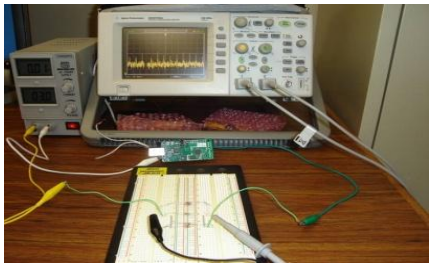
Video Sensor for surveillance

Differential Pressure Sensor With integrated wireless sensor node (WSN)

ASPEN V1 Asynchronous Sensor Processor

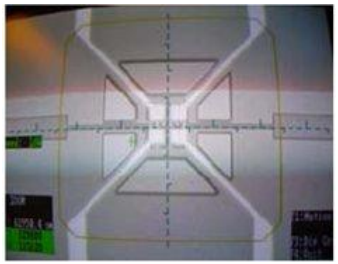


Temperature Sensor

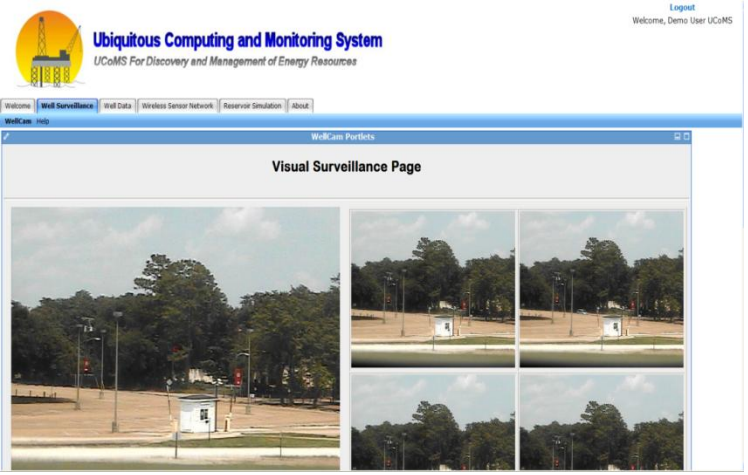


Flow Meter with WSN

MEMS Thermal Sensor



Automated Video-based Production Site Surveillance



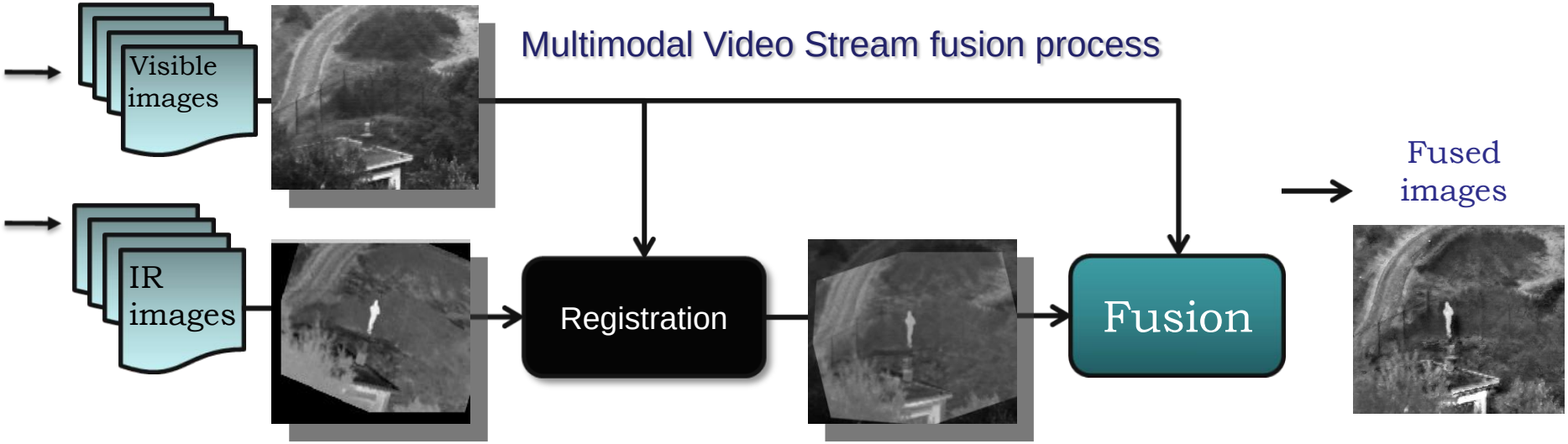
Surveillance Grid-Portal

Zaher1

zahertracked

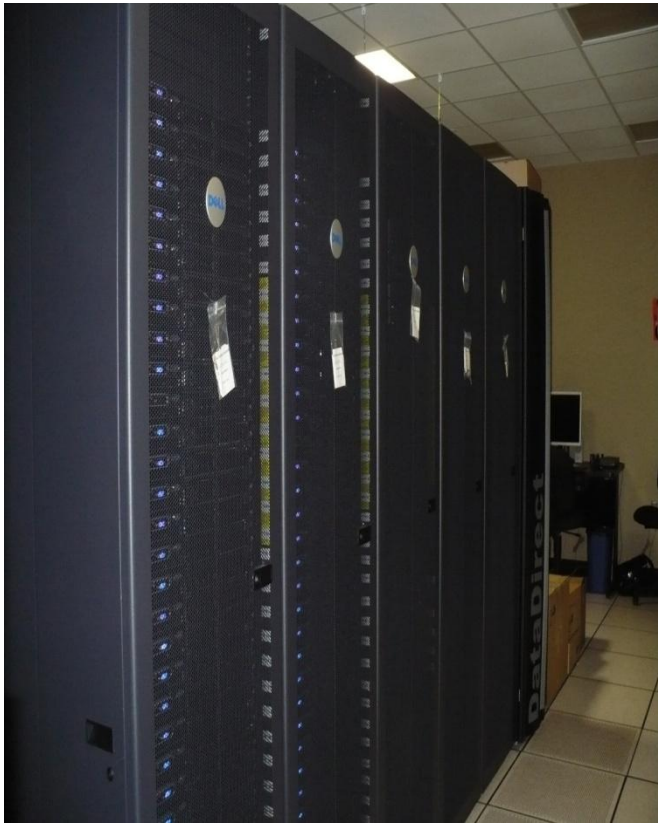
Tracking people beside well-head on ULL campus

Multimodal Video Stream fusion process



Layers 3 & 4 : Grid Computing and Application Development

Grid Computing and Storage



Fast and Scalable Resource Information Service

- Based on prefix hash tree over distributed hash table
- Able to handle range queries
- Dealing with multiple resource types effectively
- In fact, better performance for more resource types

Grid Computing Tasks

- Toolkit Development
  - Parallel Signal Processing Toolkit development and integration
  - Parallel Image processing Toolkit development
  - Parallel Video Processing Toolkit development
- Applications Development
  - Grid based & non Grid based Application development using developed toolkits

Summary of Achievements

- Software/tools/testbeds developed
  - Testbeds, software tools, prototypes
    - wireless mesh testbed
    - video monitoring testbed for well production site
    - data inversion and EnKF platform
    - task submission and execution control tool for heterogeneous clusters

Summary of Achievements

- Publications and software/tools/testbeds developed
  - + 25 journals
  - + 65 conference proceedings (2 joint publications)
  - + Testbed, software tools, prototypes
  - ‡ more than 10 journal submissions under review (1 joint article)
  - ‡ many conference submissions pending (3 joint articles)
  - ‡ proposal submissions
- Student Scholars and Presentations
  - + 4 graduate & undergraduate scholars
  - + 10 poster presentations

Summary of Achievements

- Partnerships
  + Tetra Technologies, Inc. & NuFlo Technologies
  + NSI Upstream (software & Services for Oil & Gas Upstream)
  + Stone Energy Corp.
  + Baker Hughes, Inc.

  + Institute for Scientific Computation, Texas A&M University
  + LSU Agriculture Center
  + LSU Mechanical Engineering Department
  + LSU Civil Engineering Department

- Sensor Programming Participation and Contest
  + Southern University at Baton Rouge

- Education
  + student training and lecturing on sensors
  + student tutorials on Grid computing
  + research materials used for various classes

Summary of Achievements

- Special award and recognition
  - 2006 Sidney Fernbach Award during Supercomputing 2006 – Ed Seidel
  - Elected VP, IEEE Circuits and Systems Society (2006) – Magdy Bayoumi

- Active Grants
  - Totally, 13 grants for some $24.6 million
  - 7 NSF Grants ($14.9 million)
    - Research Infrastructure Improvement, $12M (10/07 − 9/10); Khonsari
    - ALPACA: Cactus Tools, $587,070 (10/07 − 8/10); Allen & Tyagi
    - XiRel: Next Generation Infrastructure, $250,000 (9/07 − 8/10); Allen
    - NSF-MRI: PetaShare, $957,678 (8/06 – 7/10); Kosar & Allen
    - NSF-CRI: MEMS Integration, $298,848 (6/06 – 5/08); Bayoumi
    - NSF-CAREER: Wireless Cross-layer, $400,000 (9/05 – 8/10); Perkins
    - NSF-CAREER: Wireless Optimization, $460,000 (9/04 – 8/09); Wu
  - 2 DoD Grants
    - Unified Modeling Framework, $463,000 (6/07 – 5/10); Allen & Tyagi
    - Testing and Modeling, $300,000 (8/06 – 8/09); Lei