

Wireless Sensors and Networks for Advanced Energy Management

2005 ACEEE Summer Study on Energy Efficiency in Industry
July 19-22, 2005

Wayne W. Manges, Jim Hardy, Teja Kuruganti; ORNL
Jose Gutierrez, Eaton Corporation



Why Here, Why Now, Why Us?

- **History – Why a DOE Program, Why ORNL, Why Eaton?**
- **Goals – Program charter, mission, approach**
- **Path – Where program is today, Partners involved; Integrating wireless and microsensors**
- **Future – Where technology is headed and why.**
- **Key Players – WINA, NIST, Suppliers, End Users, ISA, IEEE, Researchers**



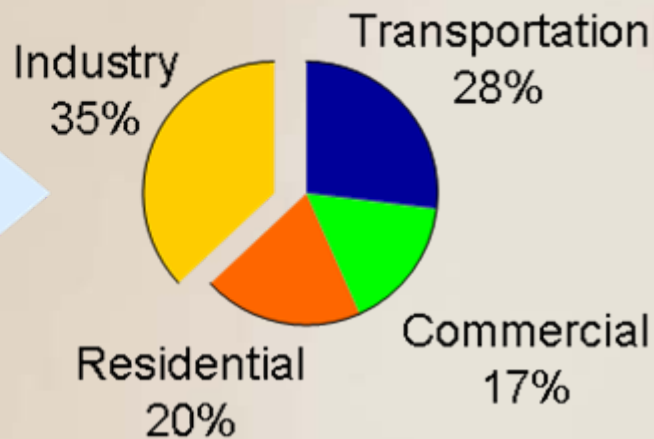
*A key player in the wireless business!
Guess Who?*



Why Work with Industry?

Industry is the largest single energy-consuming sector in the Nation.

2001 Energy Use

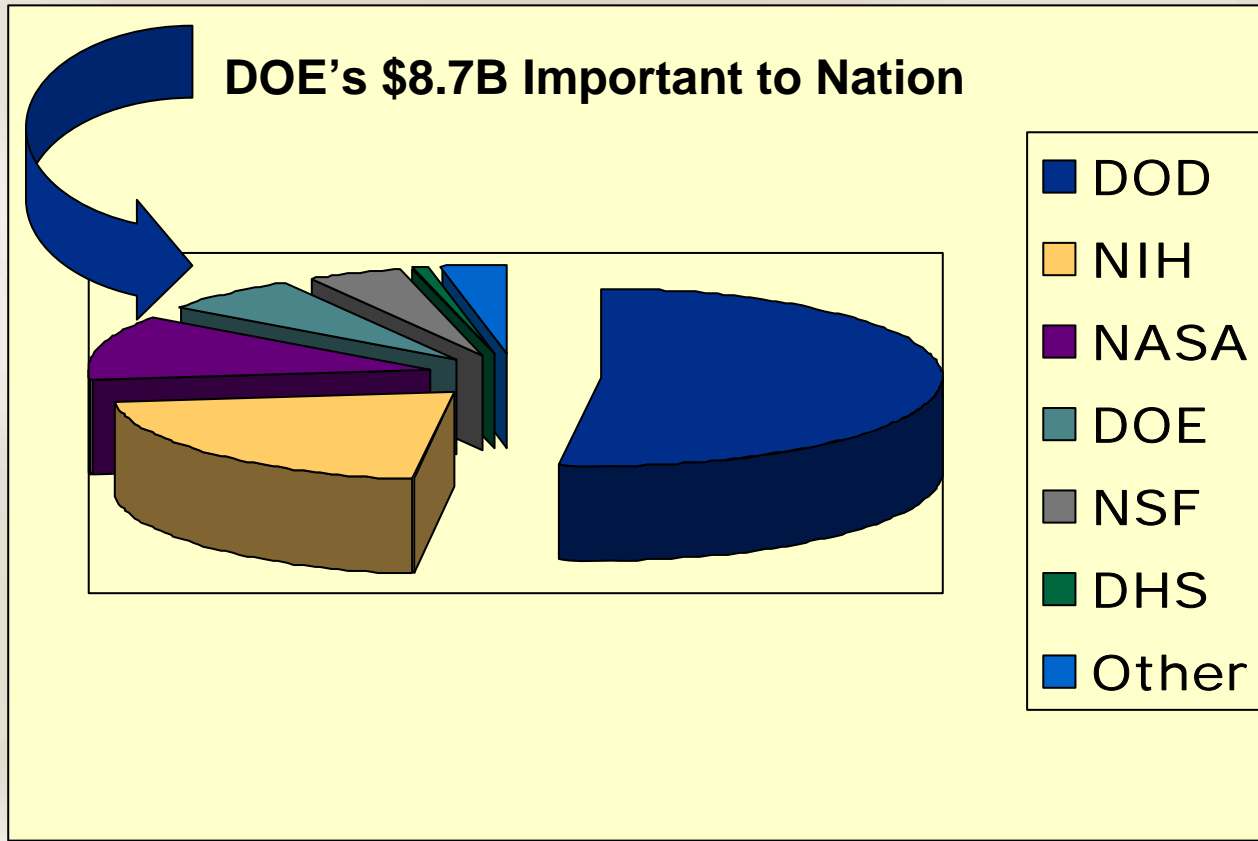


Energy Savings Benefits

- Lower production costs
- Environmental compliance
- Reduced waste
- Increased productivity
- Improved competitiveness
- Economic Strength
- Environmental Quality
- National Security



Department of Energy – A Major Player in US R&D Landscape

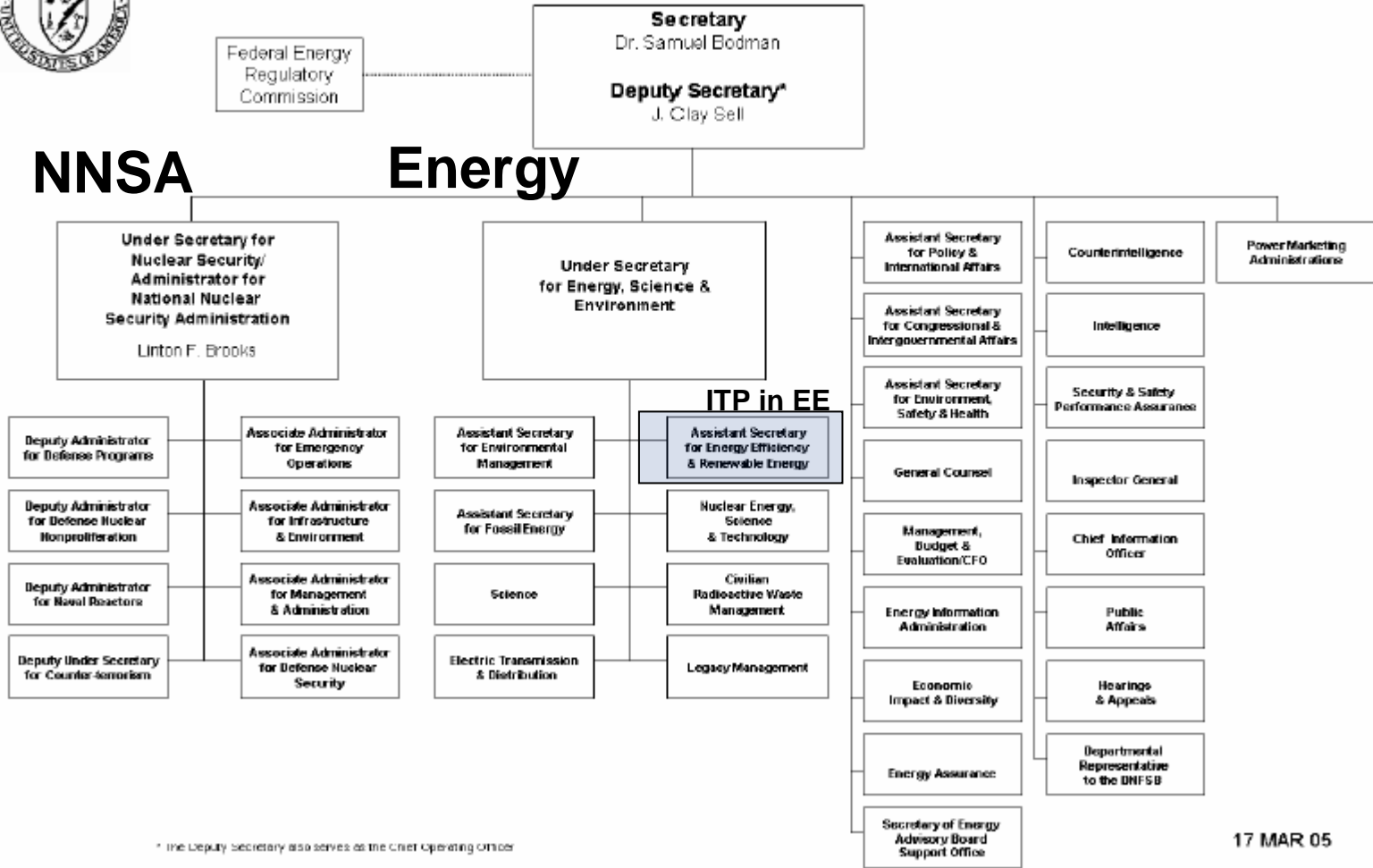




DOE Has Broad Mission



DEPARTMENT OF ENERGY



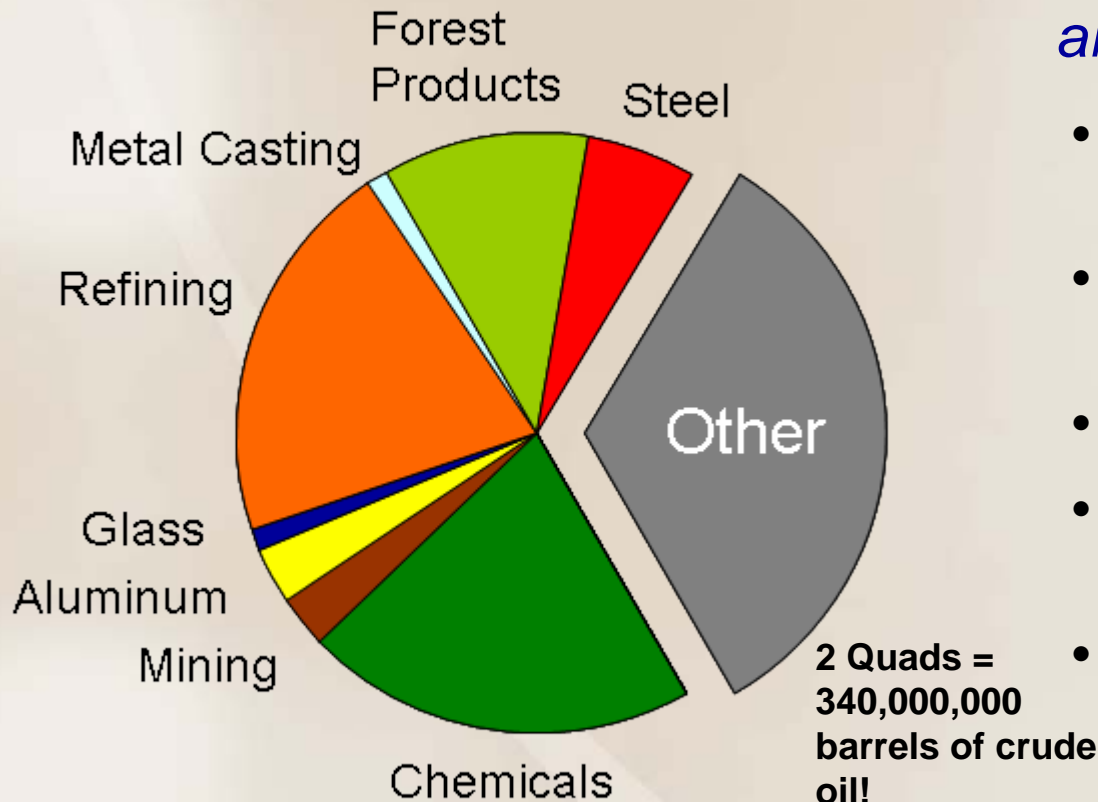
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Energy Efficiency – Specific Industry + Cross-Cutting

Focus on energy-intensive industries...

Industrial Energy Use: 35 Quads



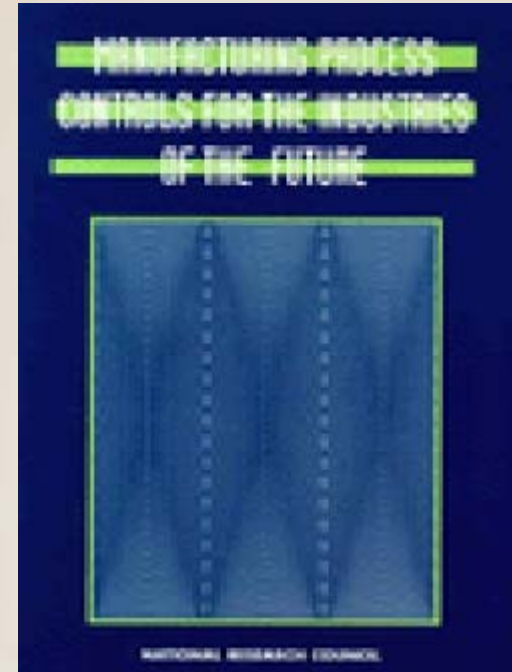
...and cross-cutting areas:

- **Sensors & Automation**
- **Advanced Materials**
- **Combustion**
- **Industrial Energy Systems**
- **Technology Delivery**



National Research Council (NAS) Identified Wireless Research Needs

- Interference Rejection – self-interference from metal surfaces, lots of sparks and other sources
- Integrated Intelligence – reduces need for host communication
- Reliable Networks – ad hoc routing, security
- Power – harvesting and new batteries
- Standards – communication, interfaces, and protocols



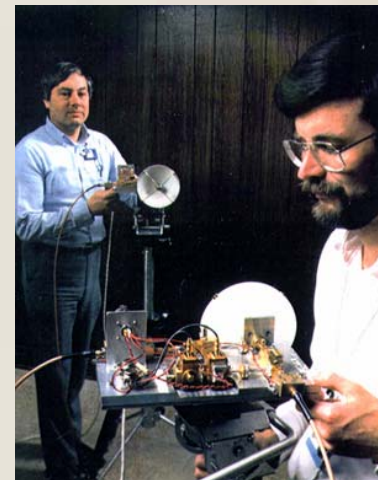
Manufacturing Process Controls for the Industries of the Future - Free PDF version at NAS

Presidential Advisory Committee report identifies industrial wireless with potential for 10% energy reduction and 15% emission reduction.



ORNL's History of Harsh Environment Wireless and Microsystems Pushes On

- Robust Communications in Extreme Environments
 - Markets: Energy, National Security, and Transportation
- Tagging and Tracking Systems
 - Markets: Energy, National Security, and Transportation
- RF and Microwave Measurements
 - Markets: Energy, National Security, and Science
- Microsensors
 - Microcantilevers
 - Ultra-low power electronics



94 GHz Reflective-Environment Communications System



Video Intercept Receiver

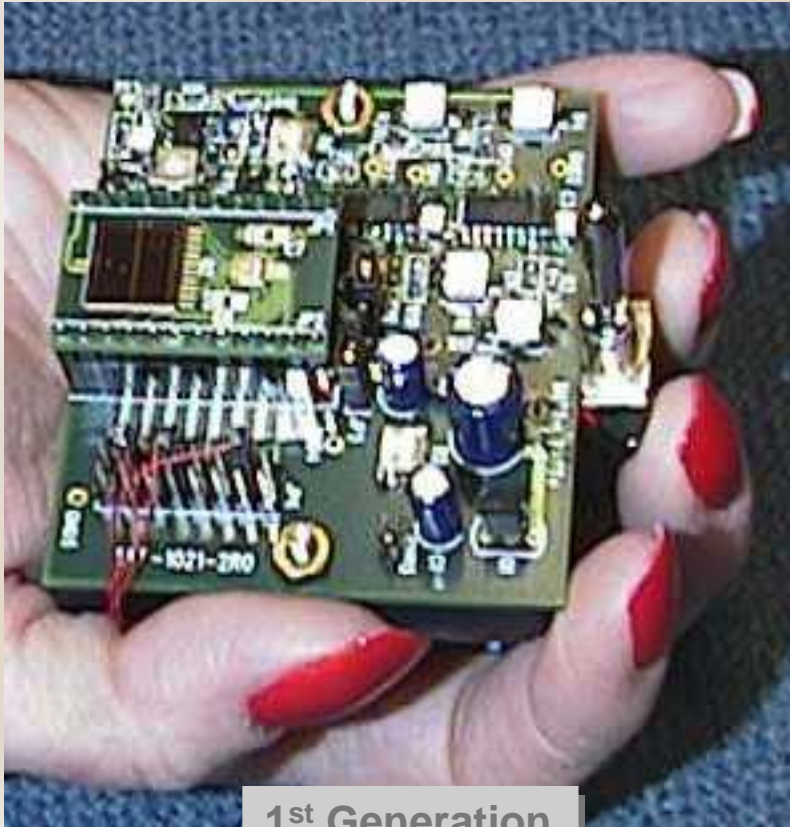
Innovative Technology Base



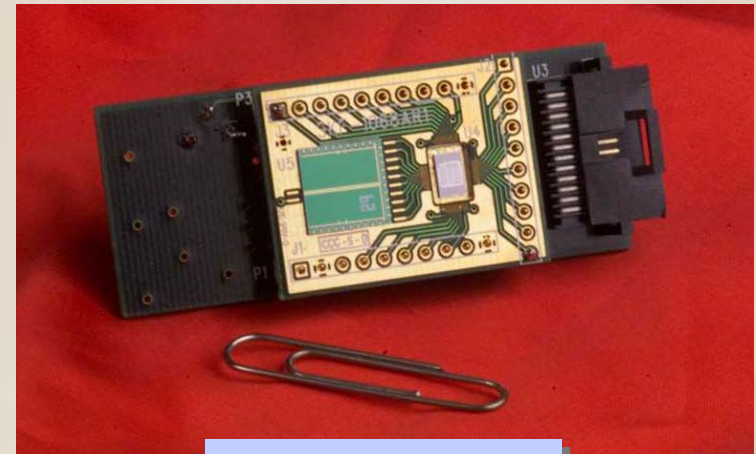
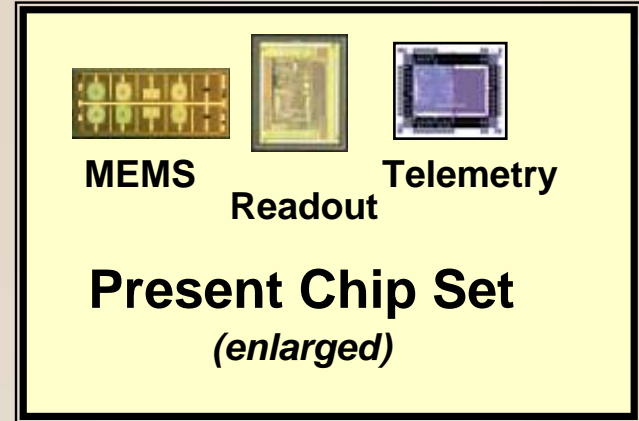
Shipboard Cargo Tracking System



Electronic Readout/Telemetry Miniaturization by ORNL



1st Generation



2nd Generation



Integrated Microsensor Array - Platform for Low-Cost, Widespread Application

Applications

- **Buildings can realize energy conservation and improved indoor air quality (IAQ)**
 - Cost-effective sensors and networks estimated to save 20%-30% while improving IAQ
- **Motor-driven systems**
 - Advanced energy management monitoring and diagnostics can achieve significant savings if monitoring and communications are available

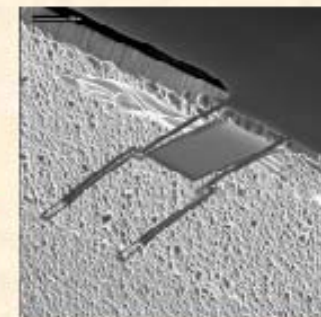
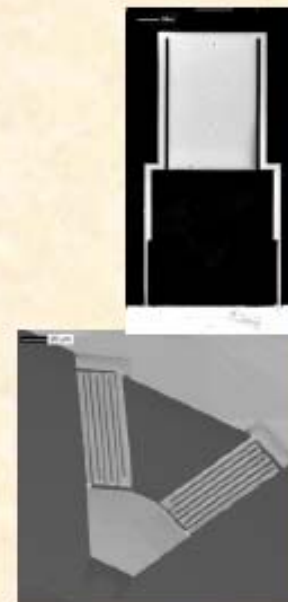
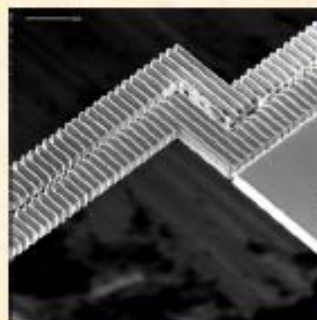
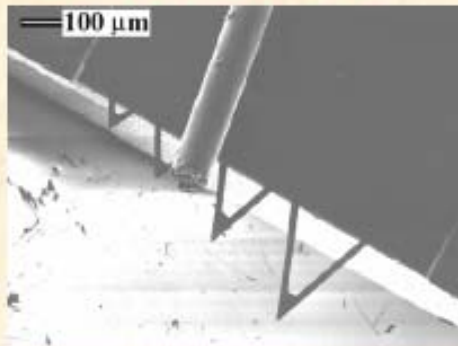
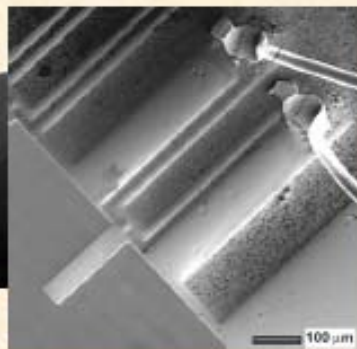
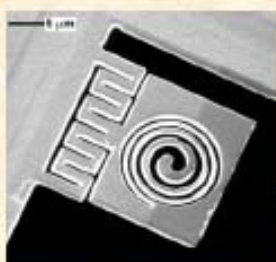
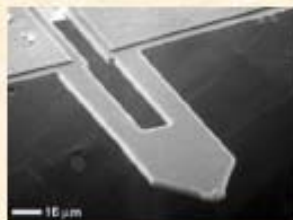
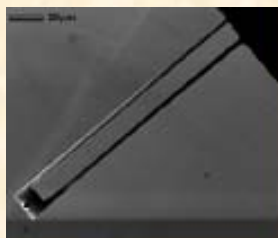


Microsensor Array monitors CO₂, humidity, temperature, and room occupancy



Microsensor Arrays – Ubiquity?

Micro-Cantilevers



Length : 50- 500 μm

Width : 10-50 μm

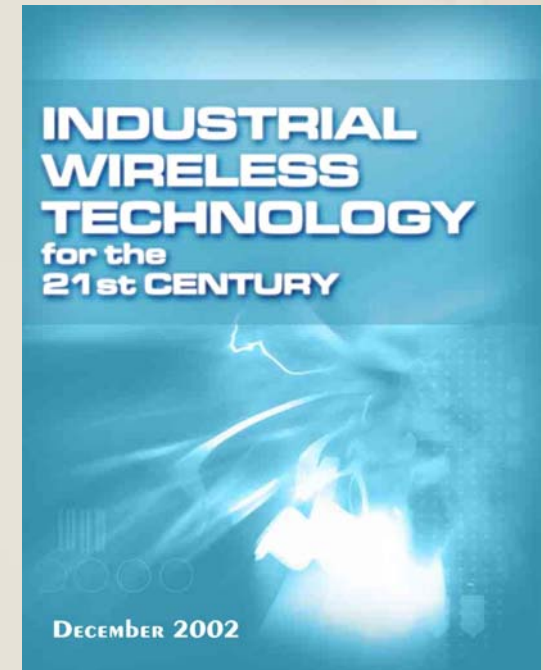
Thickness : 0.1-4 μm



Vision: Industrial Wireless – Moving Forward

Industrial wireless technology will be

- **robust,**
- **reliable**
- **cost-efficient**
- **totally secure**
- **often integral to the measurement device**
- **the *obvious choice* for monitoring and controlling industrial processes to optimize resource efficiency and productivity.**



Get pdf at [WINA web site](#)



Industrial Wireless – Deployment!

- **Standards – ISA SP100, IEEE 802.15.4, IEEE 1451.5!**
- **Suppliers – growing group but still struggling to meet real requirements**
- **Government – Looking for impact on environment, energy efficiency, global competitiveness and even jobs!**



So, What's the Holdup??!



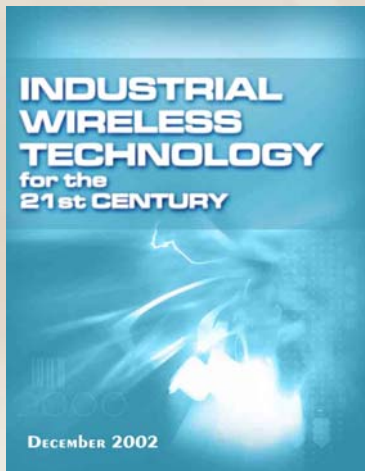
We're In It Together!



imagination at work

Honeywell

- **Project Success – credibility, cash flow, profit, impact**
- **Project Focus – Standards and WINA**
- **Project Status – Prototypes ready**



OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY





Standards – Maximum Impact

DOE Program Impact on Standards – permit introduction of entire suite of wireless products from many vendors supporting the “ubiquitous sensing” model in vision.

- **Standardized methodology to**
 - **Assess environment – light to harsh, RF and other**
 - **Assess application – latency, throughput, etc.**
 - **Assess options – technologies, products, standards**
 - **Assess deployment – initial stability, ease**
 - **Assess performance – against requirements**
 - **Maintain – tools, costs, upgrades**





Wireless Industrial Sensor Networks – Multidisciplinary!

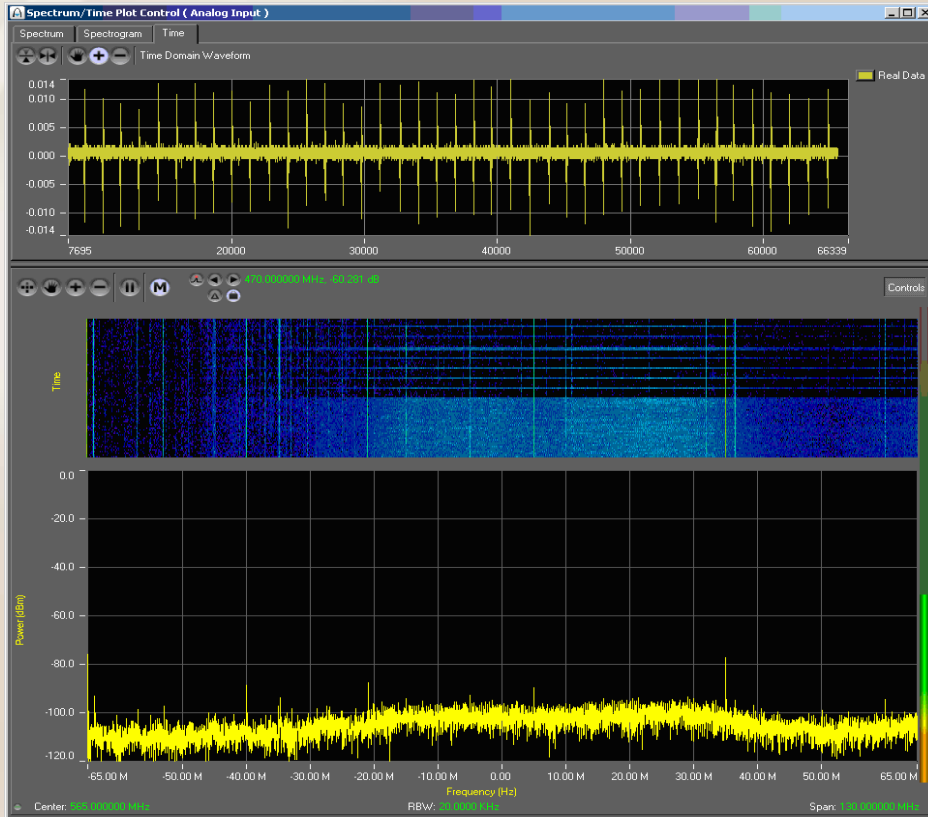
- **Wireless** – radio, packaging, antenna
- **Industrial** – harsh environment, fault tolerant, safety related, cost
- **Sensor** – filters, sampling, sensitivity, interferers, controls
- **Networks** – real-time, latency, throughput, security, integrity, vertical integration



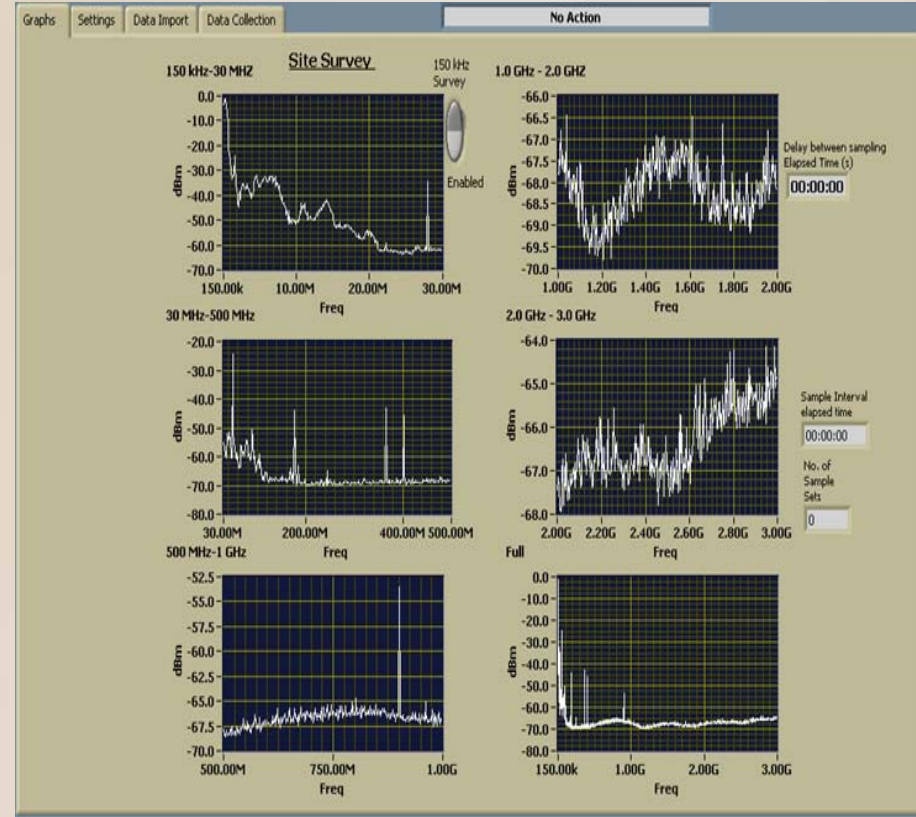
Data – The Coin of the Realm!



RF Environment – Surprise!



A Broadband Noise Source detected



PSD from 150KHz – 3GHz



Can Commercial Grade Cut It?

**Wireless
Intelligent
Network**



**Manufacturing/
Industrial
Markets**

**High Quality
Low Cost
High Volume
High Integrity**

**Government Labs
Academia
Industry/Consortia**

**Consumer
Market**

**High Quality
High Volume
Low Cost
Low Integrity**

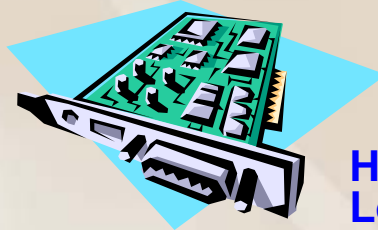


**National
Defense**

**High Cost
Low Volume
High Quality
High Integrity**



**Wireless
Warrior**



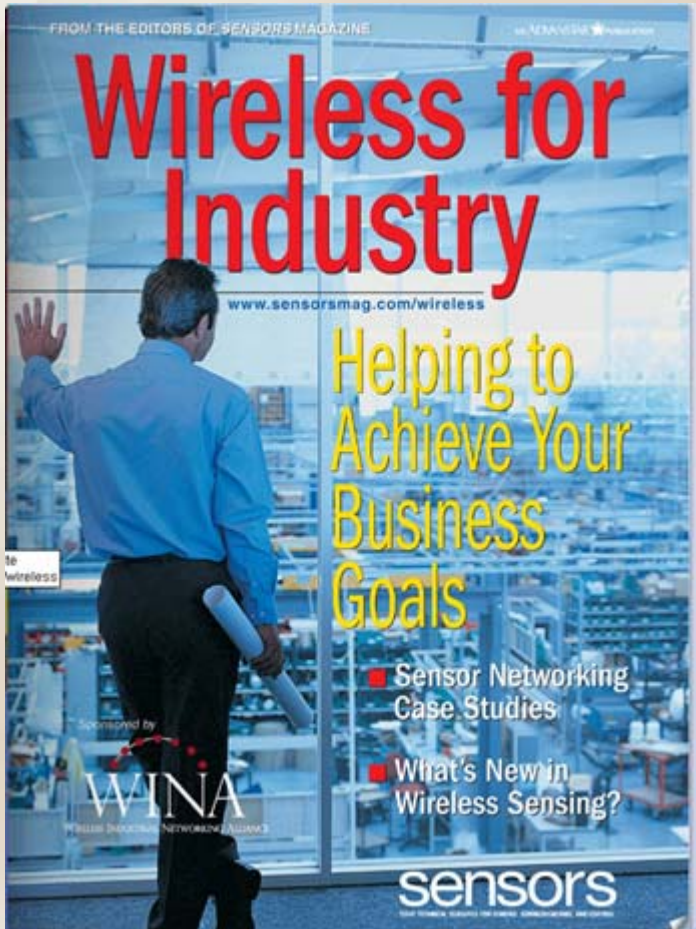


Exploiting Defense and Commercial Wireless For Industrial Applications

- **Reliability -**
 - **Mesh – Billions of \$ from DOD**
 - **Spread Spectrum – FHSS, DSSS, Ultra-Wideband**
- **Power**
 - **Harvesting – vibration, RF, PV**
 - **Low-power Designs – ASICs, FPGAs, DSP**
 - **Protocols – Low-duty cycle - ZigBee**
- **Security**
 - **Encryption – AES, WPA, WEP**
 - **Physical – RF layer, FIPS 140-2**
 - **Integrated – impacts on throughput, latency, reliability**



Barriers and Pathways – Acceptance and Deployment



- **Demonstrations – DOE Three Projects at refineries and other processing sites**
- **Publications/Presentations – EPRI and Comanche Peak, Sensors Magazine, ISA Show and Sensors Expo**
- **Standards – IEEE 1451.5 to be voted this year, ISA SP100 draft in early 2006**
- **Qualification – against standards, environments, interoperability, co-existence**
- **Simulations – vs “Can you hear me now?”**

Strong Relationships with SA & Sensors

SIGNALS SIGNALS SIGNALS SIGNALS SIGNALS SIGNALS

Growth Forecasts

According to a new study from the Wireless Data Research Group (WDRG, San Mateo, CA, www.wirelessdataresearch.com) the market for hardware, software, professional, and wireless network services for machine-to-machine (M2M) communications will grow at a 27% compound annual growth rate, expanding from \$9.3 billion in 2004 to \$31 billion in 2008. M2M communications allow users to remotely monitor and control key business processes and functions via installed devices, resulting in improved performance and enterprise efficiencies from systems and remote management in such areas as plant operations, maintenance, and supply management.

Now a number of wireless technologies, from very short range technology like RFID all the way to satellite systems, that are readily available to integrators and adapters as solution components to meet specific industry and applications with respect to distance, throughput, and reliability. Mike Peterson, president of WDRG and author of the study, "This means that companies can remotely manage their operations, track inventory or automate manufacturing processes and acquisition." Peterson indicated that much of the current activity in M2M is around wireless sensor networks that will transform the way companies produce, track, and directly create a knowledge base that can be used to refine and optimize operations.

John Altman, CEO of ZigBee, Inc. (www.zigbee.com) says that while ZigBee, one flavor of wireless communications, has today, "ZigBee-based devices will see explosive growth in less than three years. ZigBee is a wireless sensor and control technology."

And 802.15.4 Wireless Networks, "provides a technology overview along with market forecasts. The study forecasts shipment of ZigBee-based devices at 2005 at about more than 30 million units worldwide by the end of 2006."

New Capabilities

SyVetel, Inc. (www.syvetel.com) has specifically designed its SyVetel M-Mer, which it says is the world's smallest RFID reader, to connect with the MICA200T microchip wireless sensor network made by Crossbow Technology Inc. (www.crossbow.com). The combination of "the smallest wireless commercial grade smart dust mote in the market with the smallest wireless RFID tag in the world will revolutionize what ubiquitous computing really means," says Mike Horton, CEO of Crossbow. The sensor and the reader are each about the size of three stacked quarters. The MICA200T can run up to seven years on a coin cell battery. With active two-way smart tags, the MICA200T is used for temperature and emission monitoring and data logging in hard-to-reach places. It is also used to create smart badges and can be tailored for wearable computing.

WADPackets Inc. (www.wadpackets.com), provider of advanced network services, fault analysis, has entered a strategic partnership with Cognis, Inc. (www.cognis.com), provider of RF spectrum management technology. The first product resulting from this partnership is the OmniRF wireless sensor, which provides both packet stream and RF spectrum analysis in one

New Positioning



When Crossbow Technology, Inc. (www.crossbow.com), accepted its second 2004 Best of Sensors Expo award, a company representative announced Crossbow's Smart Dust Challenge, which will award thousands of dollars in prizes, including a \$10,000 grand prize. The competition is open to both domestic and international individuals and teams who demonstrate a successful sensor networking application running on three or more Crossbow Smart Dust Motes. The company's Smart Dust wireless mesh networking products are small, self-configuring, intelligent monitoring devices. The submission deadline is January 1, 2005. Rules, timeline, and judging details are available at the company's Web site.

Canadian firm Sycon International (www.sycon.com) and Sensor Wireless Inc. (www.sensorwireless.com) have agreed to jointly develop new applications combining their separate technologies, and then market the products throughout the American and Europe. Sycon specializes in delivering RFID-based products for asset tracking, temperature monitoring, and quality control in industries such as food, health care, and transportation. Sensor Wireless designs, develops, and produces patented real-time wireless products and sensors, and integrates handheld computers and data management software to produce and display information that monitors production and transportation logistics of the food chain.

Adaptive Instruments, LLC (www.adaptiveinstruments.com), provider of process control instrumentation, has named Gene Yun, Ph.D., as president following the retirement of Angelo Finazzo. Adaptive says that Yun will guide the company into new market opportunities. Yun says he sees "a significant opportunity for Adaptive to establish a leading position in the rapidly emerging industrial wireless market."



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List of Standards for Committee

ISA-SP100, Wireless Systems for Automation

A Word from the Chairman

In working to assure confidence in, and the integrity of, wireless technology, and to provide criteria for implementation in manufacturing automation and control systems, the ISA-SP100 Committee recently launched four project teams. Each team's goal is to develop documents that will help users make the right decision on industrial wireless implementations.

The first project team will develop an educational technical report that covers the basic concepts of radio transmission—the physics of radio. The report will cover free space communication of a transmitter and receiver under ideal conditions; address real earth propagation effects such as moving objects or multiple path communication; and deal with issues such as interference related to sharing the license-free band spectrum with others. This technical report will provide new users with a better understanding of the choices and tradeoffs offered with wireless applications in industrial environments. For more information on this activity or to volunteer, please contact Ake Severinson, (800) 663-8806, ake@omniconcontrols.com.

To address the many levels of industrial environments, ranging from the benign to the extremely harsh, the second project team will develop an industrial wireless requirements document. Based on a USDaE-funded program involving Eaton, General Electric, and Honeywell that collected data on customer wireless requirements, this document will cover wireless applications, such as monitoring and control, and will develop a taxonomy of wireless automation networks. The team's objective is to provide end users with a better feel for where their application fits in the overall industrial environment hierarchy. For more information on this activity or to volunteer, please contact Tom Phinney, (602) 313-5989, tom.phinney@honeywell.com.

The third project team will develop a technical report that covers interoperability issues and how sensor networks should interact in an industrial environment. While some of these issues will be addressed in the requirements document, this report will examine co-existence and performance in greater depth. Work is currently underway within this project team to develop a matrix identifying levels of interoperability and providing the rationale for their use. For more information on this activity or to volunteer, please contact Bill Drake, (301) 944-1300, bluelynxwireless@yahoo.com, or Peter Fuhr, (831) 588-7558, peter.fuhr@apprion.com.

The fourth project team will create a "User Guide," providing sufficient guidance to allow users to deploy and use wireless networks in an industrial environment. The guide is intended to be comprehensive, not only helping users achieve a wireless solution but also assisting them in making the right decision on their wireless implementation through tools such as a "buyers checklist." For more information on this activity or to volunteer, please contact Wayne Manges, (865) 574-8529, mangesww@ornl.gov, or Anoop Mathur, (612) 951-7734, anoop.mathur@honeywell.com.

Wayne Manges
ISA-SP100 Committee Chair

For wireless expertise at www.wina.org.

Events

5000 wireless transmitter series for offering significant advantages over traditional transmitters, says "Newly introduced 800 Series transmitters are sure to play a major role in increasing the number, frequency, and type of automated measurements taken at various processing plants." To qualify for this award, candidates must demonstrate an ability to manufacture innovative products at a low cost to customers. A team of industry analysts tracks companies' new product launches and R&D spending, reviews products in development and examines new product features and modifications, evaluates innovation levels, and studies customer satisfaction.

Don Jones, Vice President, selected Millennial Net (www.millennial.net) as one of 10 "winners" Choice Award winners at its annual Wireless Ventures conference this spring. Millennial Net, maker of hardware and software for self-organizing wireless sensor networks was recognized as being well positioned for long-term success in the wireless

space. Conference attendees, official judging panel, selected Award winners from among 500 technology presenters, wireless industry is getting better investors' Choice Award winners to take advantage of the Richard A. Shaffer, president and Financial Information Services. Millennial Net demonstrate sensor networking technology opportunities to capitalize on for machine-to-machine (M2M) ubiquitous monitoring applications. Themes of the conference, A impressed attendees and judges provide solutions regardless of structure requirements, while efficiency requirements of low work.

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Sensors Express
Sensors Buyer's Guide
Wish List
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Industry Links
Events Calendar

Vendors
Reader Service
Literature Showcase
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Biodetection Technologies 2005
Baltimore, MD

DATAFORTH

Isolated Signal Conditioning
Quick Shipment-Modular or Din Package

Wireless Sensors

The publishers of Sensors launch *Wireless Sensors* in 2005!

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Wireless for Industry

In 2004, Sensors published two *Wireless for Industry* supplements. Sponsored by the *Wireless Industrial Networking Alliance* (WINA), the publications focus on wireless sensor networks of all stripes for industrial use. For 2005, we expand our coverage of wireless sensor networks beyond industrial applications to include medical, asset tracking, and more.

Sensors Covers

Wireless

Here's a sampling of articles *Sensors* has done on wireless data communications. We hope you find them helpful. Need further assistance? Contact us: sensorswireless@advanstar.com.

- **Wireless Sensors—Buyer Beware**
- **Standards-Based Wireless Networking Alternatives**
- **Is Wireless Ethernet Safe to Use?**
- **Using Wireless Sensors to Measure Gaps Efficiently**
- **Wireless Sensor Network Topologies**
- **Secure, Low-Power Operation of Wireless Sensor Networks**
- **Reducing Scrap with Wireless Data and Power**
- **How Secure Is Secure?**
- **Meet the ZigBee Standard**
- **Power Considerations for Wireless Sensor Networks**
- **The Sensor Web: A Distributed, Wireless Monitoring System**
- **Battery Power for Remote Wireless Sensors**
- **MICA: The Commercialization of Microsensor Motes**

Wireless Sensors

Sensors
The News You Choose
EXPRESS
NEW PRODUCT INFO

May 30, 2005

Industry News
Updated Twice Weekly

- Carbon Nanotubes Already Impacting Sensing
- HART Plant Of The Year Nominations Due June 30
- Sypris Offers Uncertainty Measurement Training
- Center for Electro-Optic Sensors Being Investigated
- New Launch Part of PerkinElmer's HomeCar Strategy
- Phoenix Contact Unveils New Infomobile
- more news ...

1st Quarter 2005
Wireless for Industry
Special Supplements

Fall 2004

Summer 2004

TechNow!
Special Issue

Resources

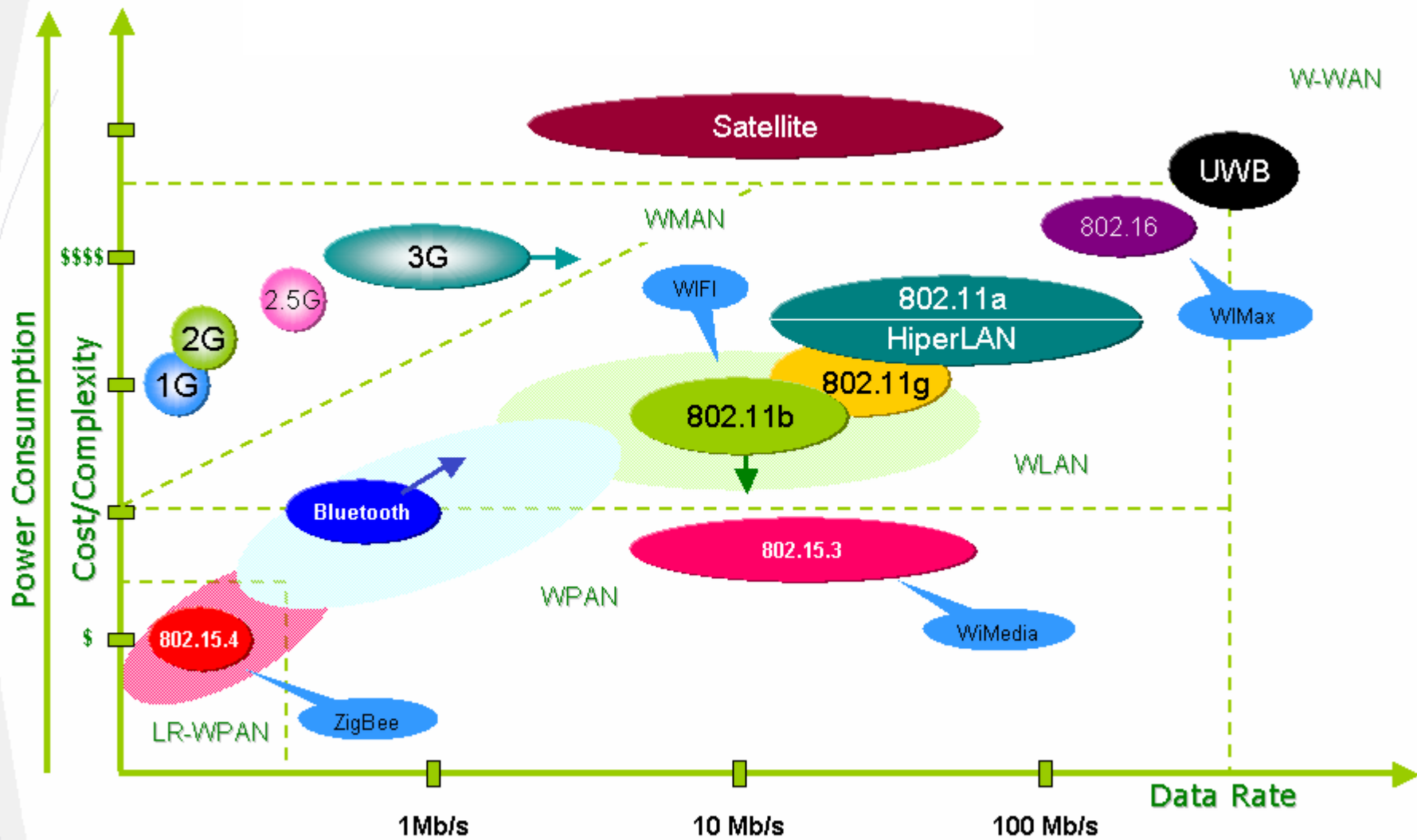
- Business Sense
- Online Exclusives
- Sensors Express
- Web Picks
- Wish List

CELEBRATING 20

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Standard Wireless Technology Map - 2004



Eaton Wireless Sensor Network for Advanced Energy Management Solutions

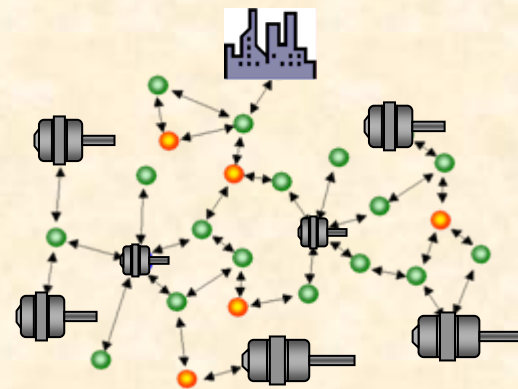
Project Summary

Goal: Enable significant energy savings for Advanced Energy Management Solutions (AEMS) in the Industries of the Future (IoF).

Challenge: Creation of an open architecture, low-cost, robust, self-configuring wireless network that will gather relevant data in the industrial environment for the IoF.

Benefits: The wireless-enabled power management system is broadly applicable to all 8 IoF. Deploying WSN to the electrical distribution and power control system enables quantifiable energy savings. Estimated energy savings greater than 279 trillion Btu/year in 2020 for targeted IoF.

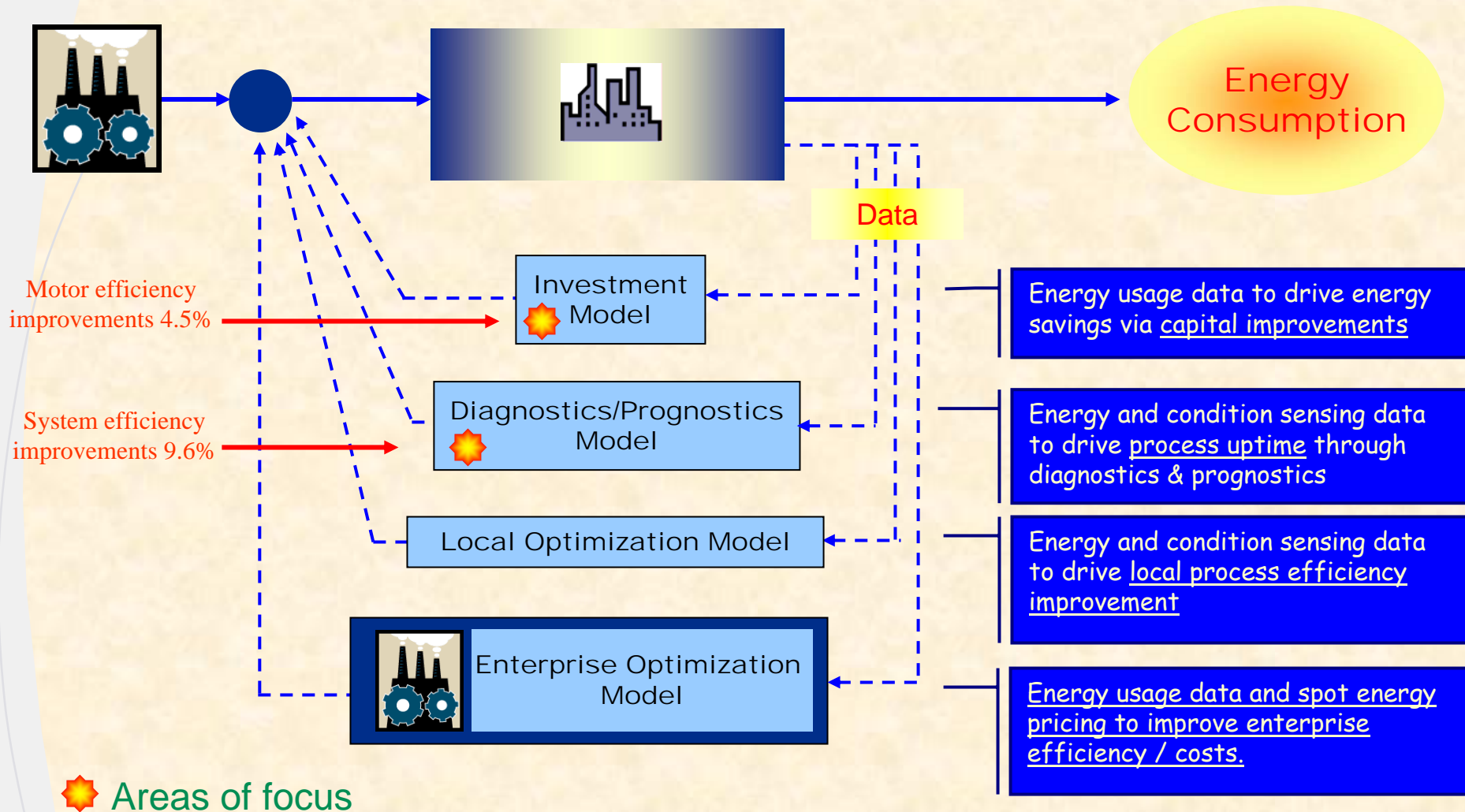
FY05 Activities: This phase will extend the baseline by addressing four issues critical to fielding a robust wireless industrial network: Ultra low-power sensors/Power harvesting, Security, RF transmission in industrial environments, and Power-Aware routing.



Participants:

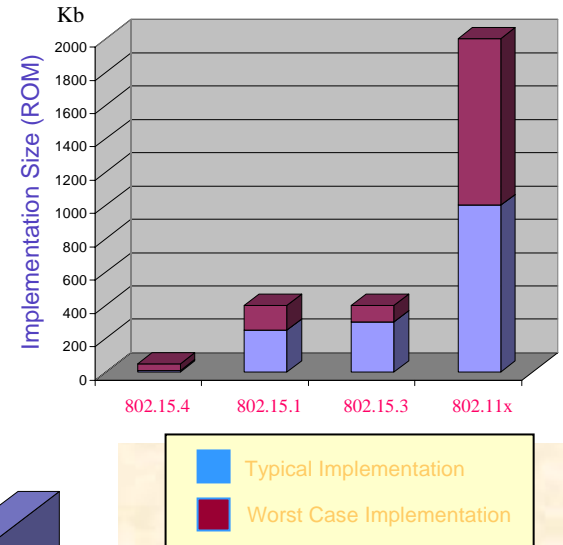
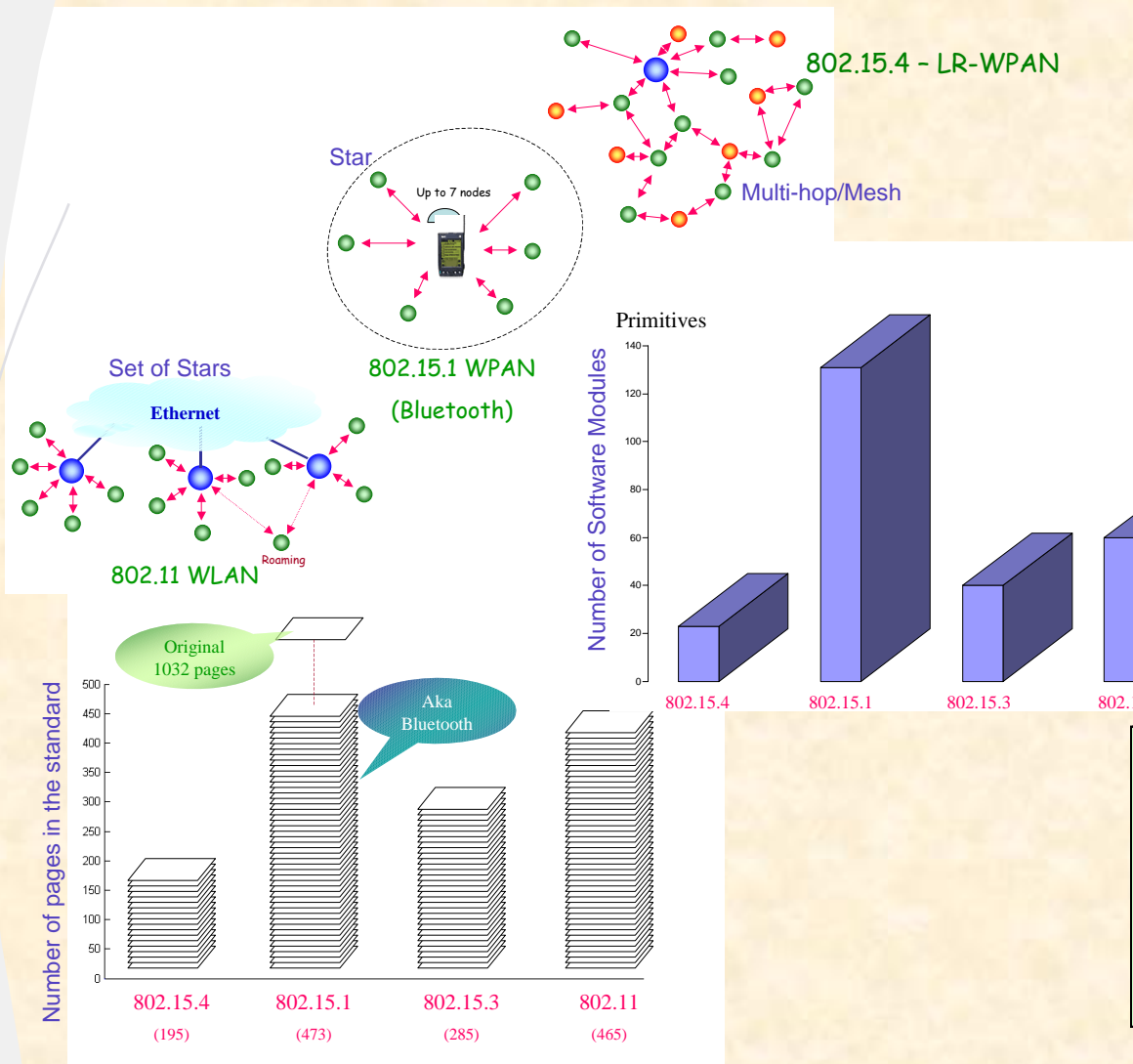


Closing the Loop on Energy Savings



**Eaton's WSN enables continuous energy savings!
98% of motors < 200 HP, consume 85% of energy!**

Standard WSN Technology Comparison

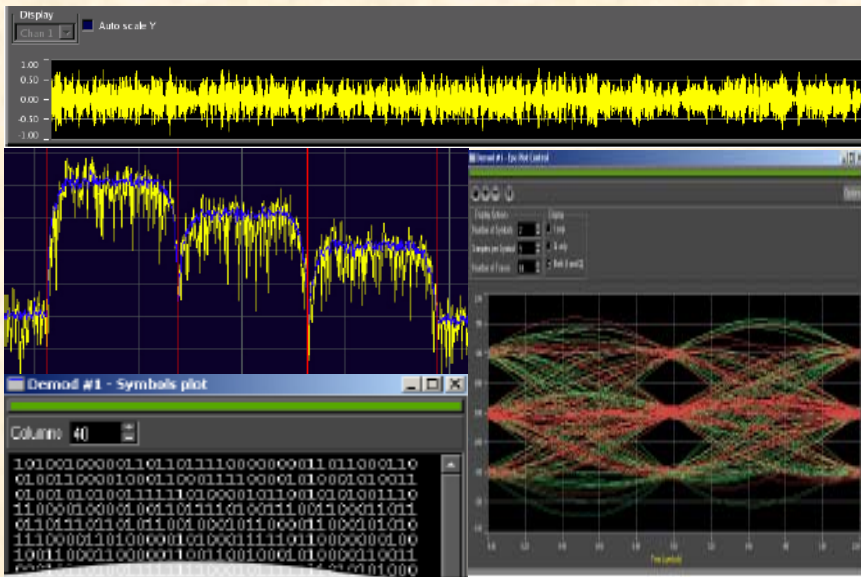


	LR-WPAN	Bluetooth™	WLAN
Range	~100 m	~100 m	~100 m
Data Throughput	0.25 Mb/s 0.04 Mb/s	1 Mb/s	~2-11 Mb/s
Power Consumption	1	1000	5000
Size	Smallest	Smaller	Larger
Cost	1	10	20

Eaton (\$9.8B/yr sales) a leader in development of standard wireless technologies for the industrial application space



Extreme Measurement Communications Center (EMC²)



Operational Capability

The DoE EMC² provides modeling, simulation and characterization support for industrial wireless networks.

This facility is equipped with parallel computing resources as well as state-of-the-art measurement equipment for high performance wireless and wired network characterization from the physical layer to the application layer

Broadband RF record and playback instrument can simulate and generate characteristic waveforms to help in-lab study of the wireless device's behavior in harsh industrial environments

EMC² Program Benefits:

- EMC² formalizes the testing of industrial wireless networks to quantify the latency, throughput, security and fault-tolerance (Interference and Noise)
- Wireless Industrial Networking Alliance (WINA) has accepted EMC² as its product testing and characterizing center to member companies
- Currently supports exhaustive modeling and simulation of the communication infrastructure for future electric grid
- Help develop or improve existing standards in industrial wireless networks to include measurement, verification and reliability of network and device parameters
- The center is being developed both as a user facility and an on-site testing provider using portable test equipment

Milestones, Deliverables, & Contact:

Key Milestones: Alliance with WINA and member companies for technology assessment and characterization; Provides modeling and simulation support for developing fault-tolerant electric-grid communication infrastructure

Deliverables: Standards-based report generation for different wireless devices and network layouts; Software development for characteristic network testing;

Contact Information:

Wayne Manges
mangesww@ornl.gov, 865-574-8529

Accelerating the adoption of wireless technologies in industry



WINA

WIRELESS INDUSTRIAL NETWORKING ALLIANCE

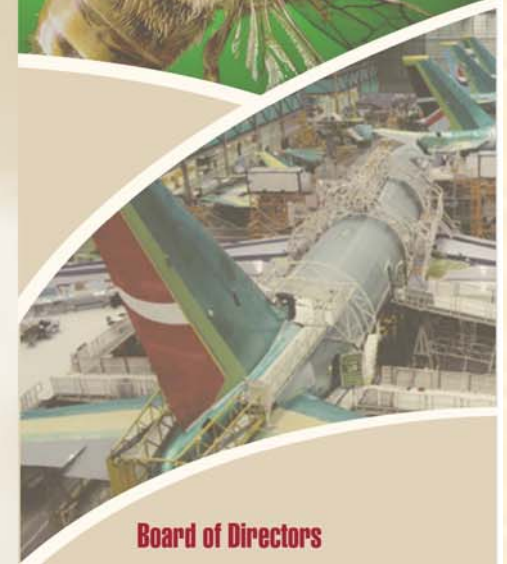
ISM frequencies

ZigBee™ 802.11 a/b/g
802.15.4
spread spectrum

1451-5
cyber-
security

Bluetooth®

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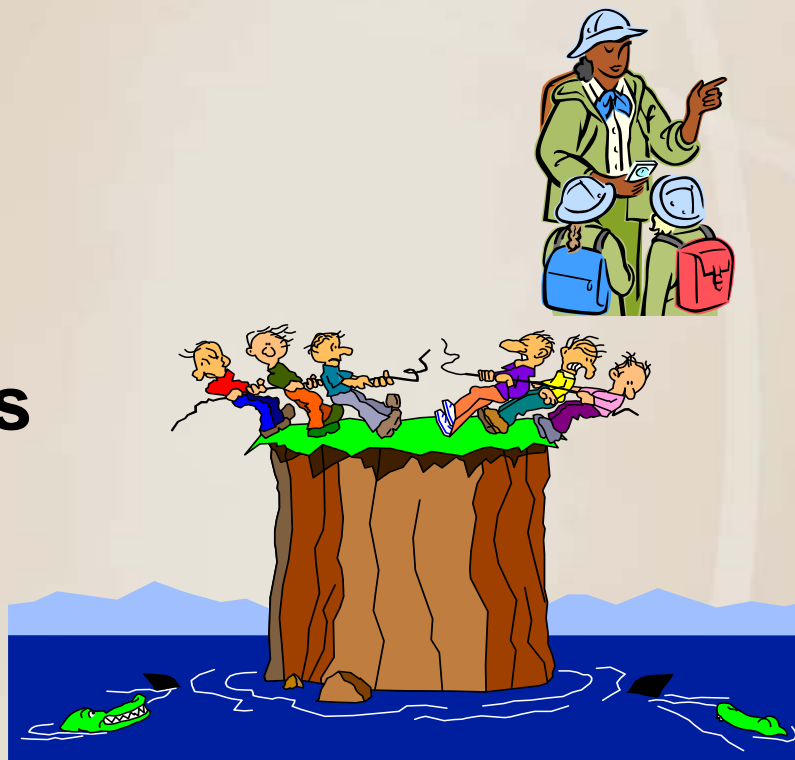
Board of Directors

- ◆ 3e Technologies International
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- ◆ Honeywell International
- ◆ Invensys
- ◆ Oak Ridge National Laboratory
- ◆ Omnex Controls
- ◆ RAE Systems
- ◆ ZigBee Alliance



Can We Get There From Here?

- **Standards – for industrial applications**
- **Markets - attractive**
- **Confidence - successes**
- **Tools – easy, handy**
- **Information – broad-based, clear to users**



Who Will Lead, Who Will Follow, Who Will Whine?