DOE Sensors & Automation 2005 Annual Portfolio Review

Distributed Wireless Multi-Sensor Technologies

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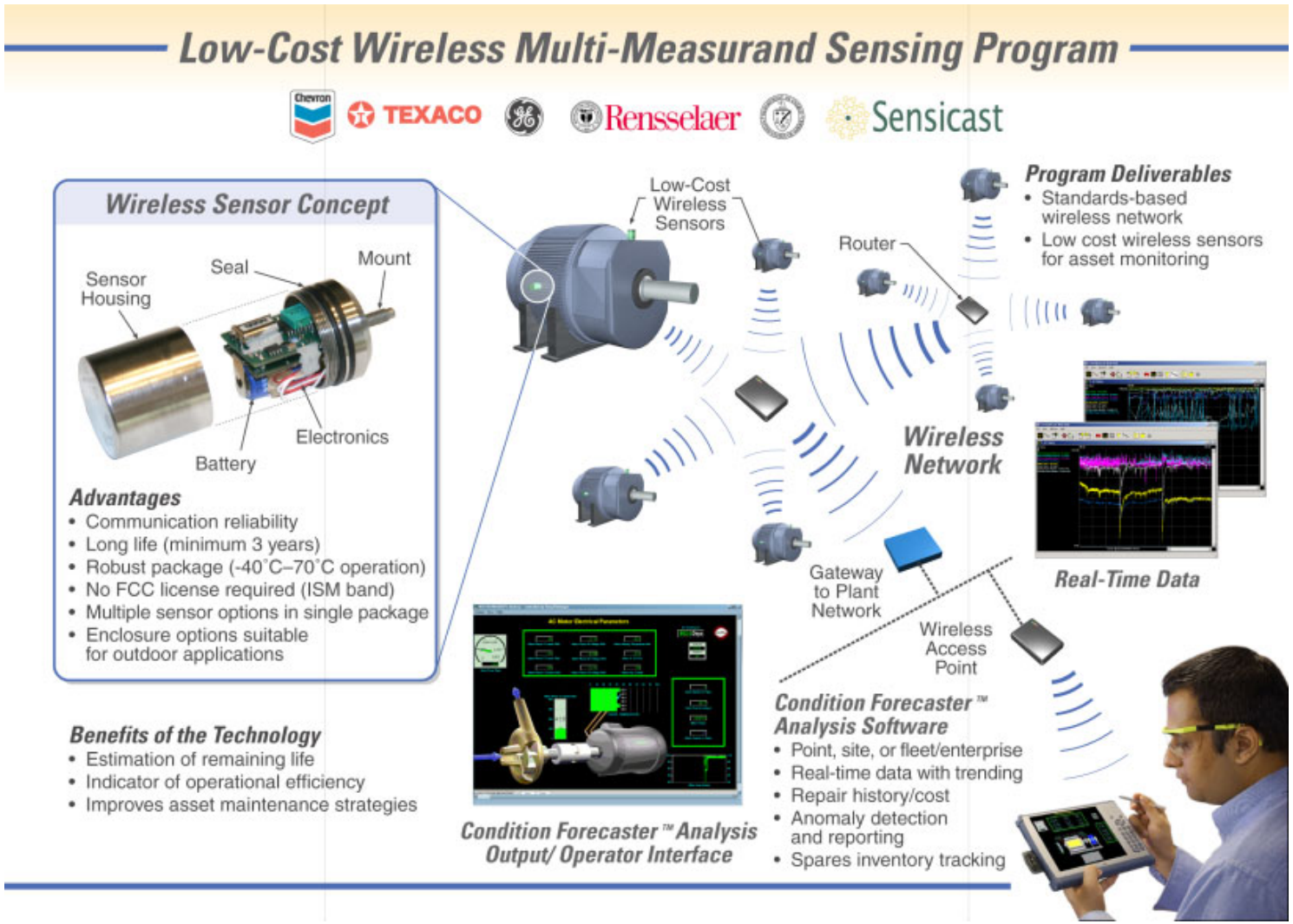
Project Description



Barriers and Pathways

Barrier-Pathway Approach

Barriers

- Noisy unreliable channel
- Short battery life
- Life cycle costs
- Network Security
- Standards
- Cultural

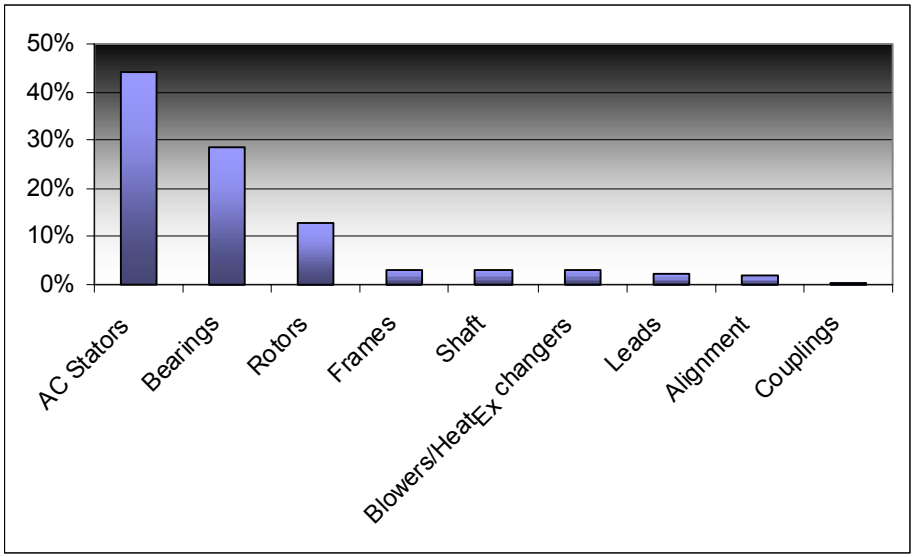
Pathways

- Characterize the channel, qualify a design approach.
- Low duty cycle operation, energy harvesting.
- Minimize device cost, maximize life and reduce installation expense
- Data Encryption/Authentication
- Utilize Standard Interfaces
- Demonstrations/Education

Critical Metrics

- Accurate early prediction of asset faults before they occur
- 5 year average unattended life
- Significant reduction in installed costs.
- Market Acceptance

Energy Savings Motor Failures



Pareto of 12,000 motor failures

Fault Condition \ Sensor	Overall Impact on Lost Energy	Vibration	Temperature	Motor Current	Stray Flux	Voltage/Partial Discharge
Cracked Rotor Bar	TBD	●	○	●	●	○
Bearings	◒	●	●	●	○	○
Insulation Breakdown	TBD	○	○	○	○	●
Clogged Ventilation	◒	○	●	○	○	○
Dirty End Windings	◒	○	●	○	○	○
Input Power	●	●	●	●	○	●
Shorts	TBD	●	○	●	●	○
System Mechanical	◒	●	●	●	○	○

Key: ● *High Impact,* ◒ *Some Impact,* ● *Effect,* ○ *No Effect.*

Sensor Requirements

Multiple Sensors are required to predict remaining life

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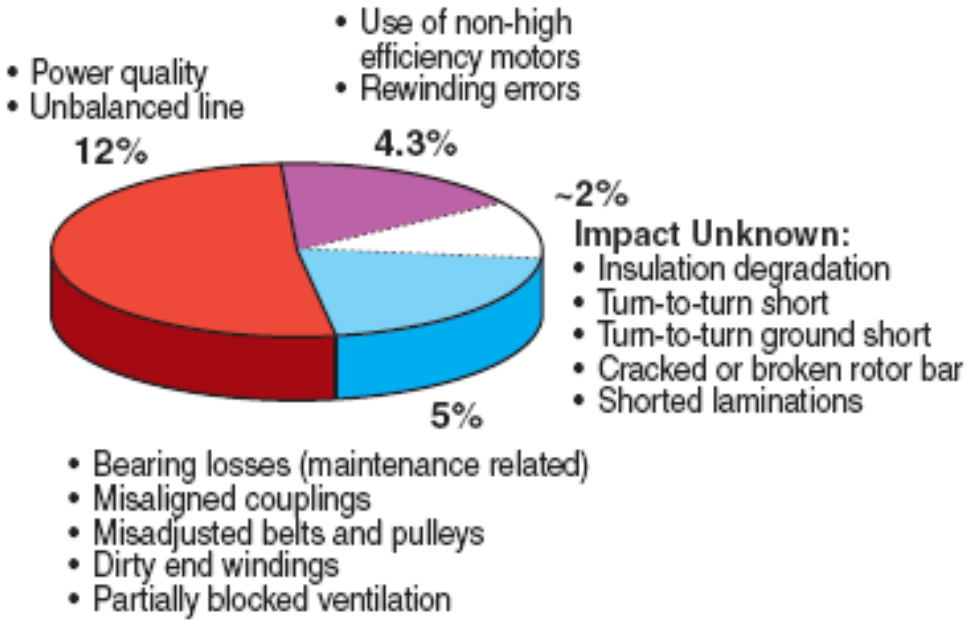
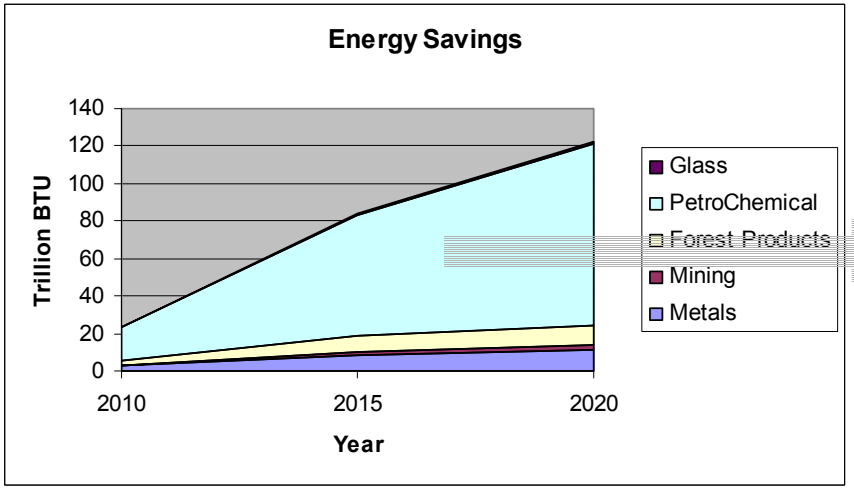
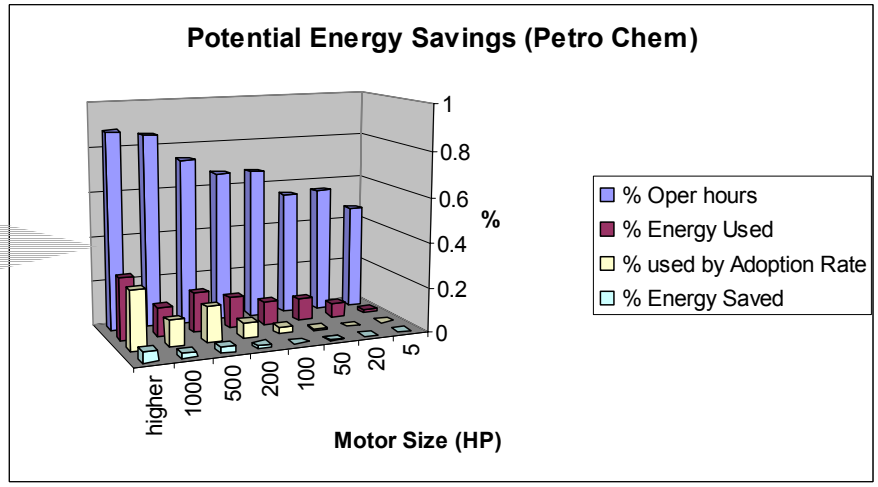
Motor Inefficiencies



Efficient Motor Operation and Motor Failures are related

Energy Savings Calculation





~US DOE December 2002 United States Electric Motor Systems Market Opportunity Assessment

Savings from:

- System Maintenance
- Motor Maintenance
- Motor Application Practices

36% Captured Savings

Benefits (est.)	2020
Energy Savings	**122 trillion Btu**
Cost Savings	
Carbon Reduction	**2.13 MMTCe**

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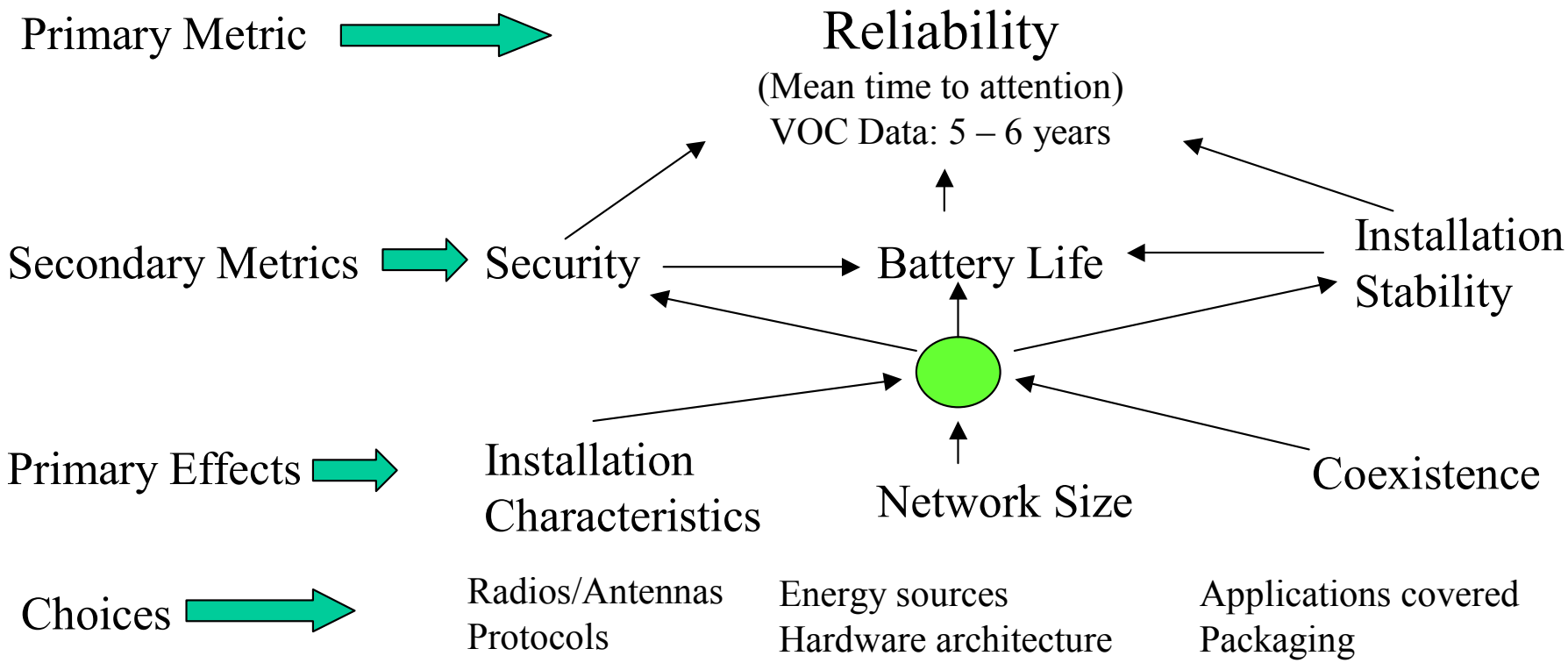
Other Important Metrics



"In most industrial applications, reliability is far more important than throughput."

DOE Document: Industrial Wireless Technology for the 21st Century, December 2002

Accomplishments to Date

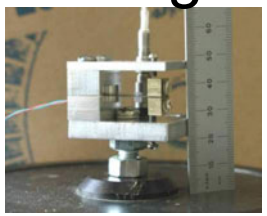
- **Industrial Wireless Channel Capability Analysis**
  - Multipath/Interference/Coexistence
  - Field data collection/analysis
- **Sensor Platform Design**
  - Battery Life/Energy Harvesting
  - Low power operation
  - Hybrid Spread Spectrum
  - Power Amplification
- **Reliable Network Operation**
  - Networking protocols
  - Diversity Modeling
- **Demonstration Hardware Platform**
  - Real Hardware experience
  - Network Reliability Testing and Monitoring tools

Accomplishments to Date

Channel Capability Analysis

- Over 240 data sets collected
- Radio, channel and interference models built
  - Verifications in progress
- Actual radio performance tests performed
- Data processing algorithms in place

Sensor Platform Longevity

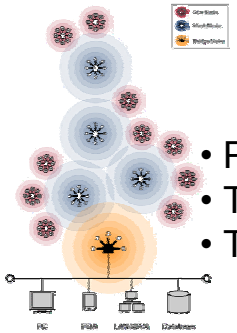


- Energy Harvesting circuit
  - GE Testing complete
  - KCF Technologies powered GE Node
- Battery accelerated life testing
- Sensor life measurement based model

Demonstration Hardware Platform

- 110 units built (Sensors, routers, gateways)
- Initial testing in process
- Demonstration planning for '05

Reliable Network Operation



- Protocols ported to new platform
- Test and Verification in process
- Tools to analyze performance

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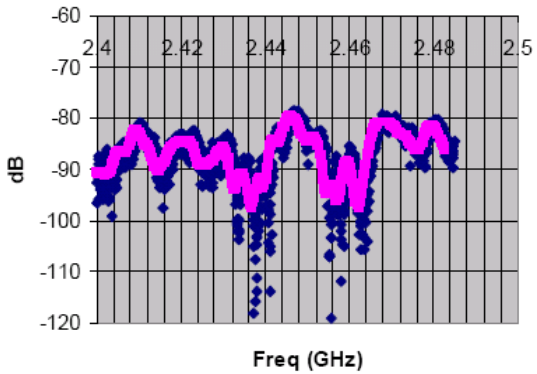
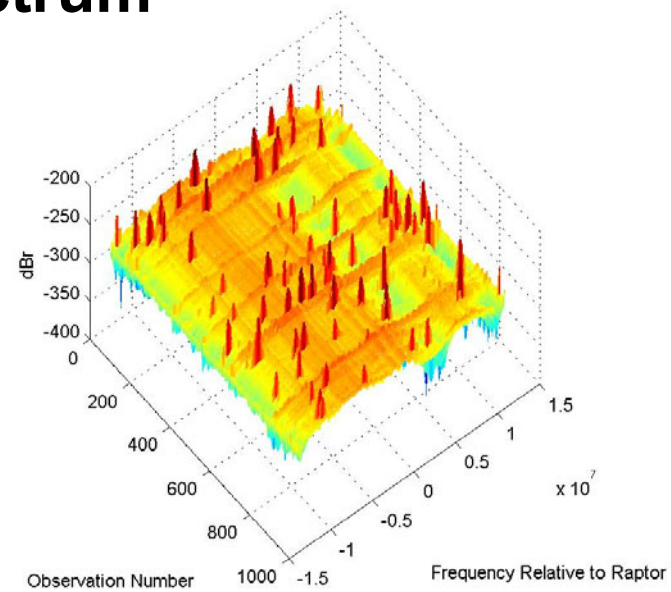
Accomplishments to Date

IEEE 802.15.4 2.4GHz Physical Layer with Hybrid Spread Spectrum



- DSSS reduces Frequency Selective Fading
- DSSS spreads narrowband noise power while enhancing desired signal
- FHSS Hops around interference
- FHSS Hops around multipath
- Collision Avoidance waits for clear channel – reduces interference to others/avoids interference from others



Field data – showing time and frequency dependent interference and multipath

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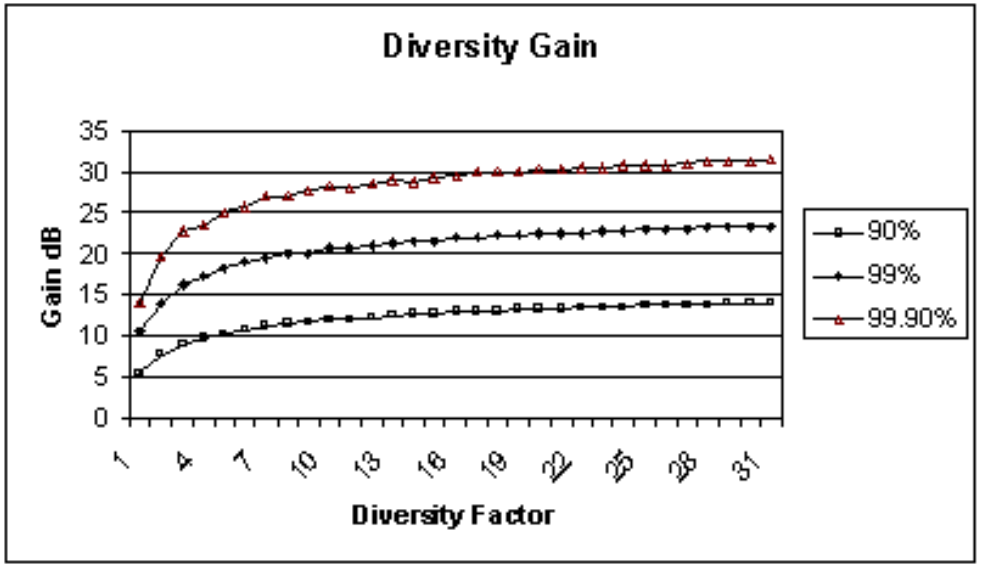
Accomplishments to Date



NLOS Channel
Rayleigh Faded

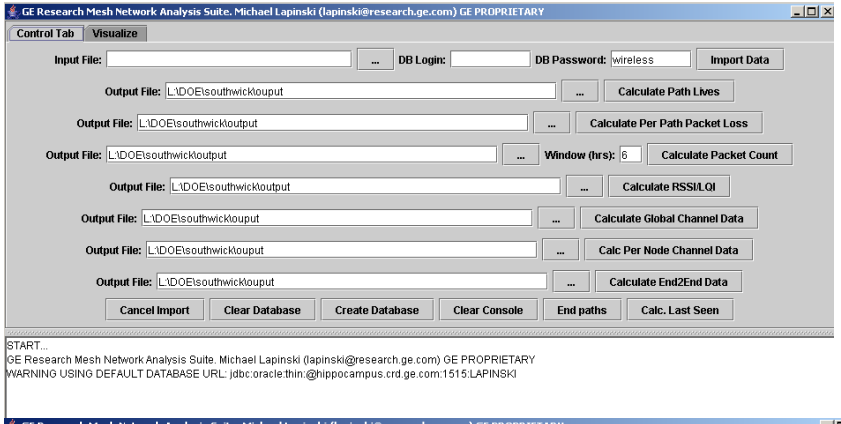
Methods to Obtain Diversity Gain (Small Scale)

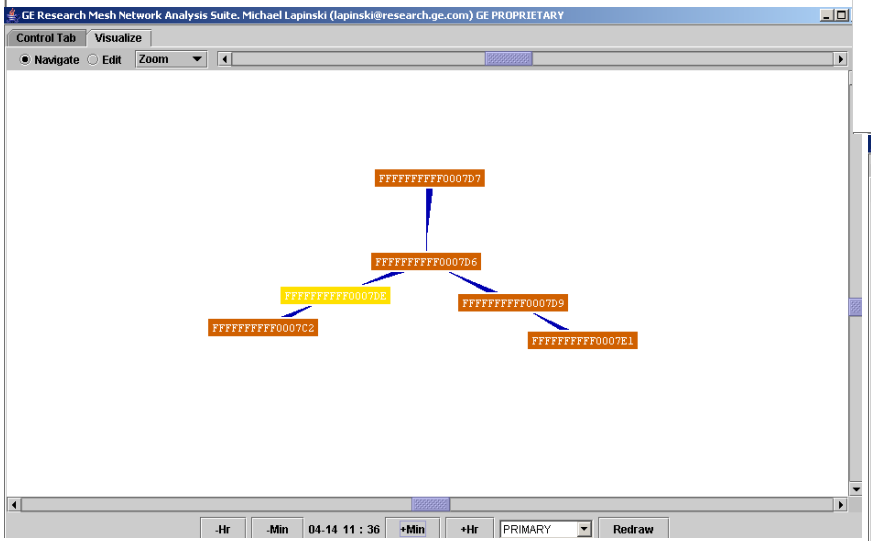
- **Frequency Diversity** (> Coherence Bandwidth)
  - Good Margin for fading and interference
- **Path Diversity** (> 1 wave length)
  - Good Margin for fading, some for interference
- **Time Diversity** (> Coherence Time)
  - Good Margin for interference, some for fading
- **15 dBm output power**

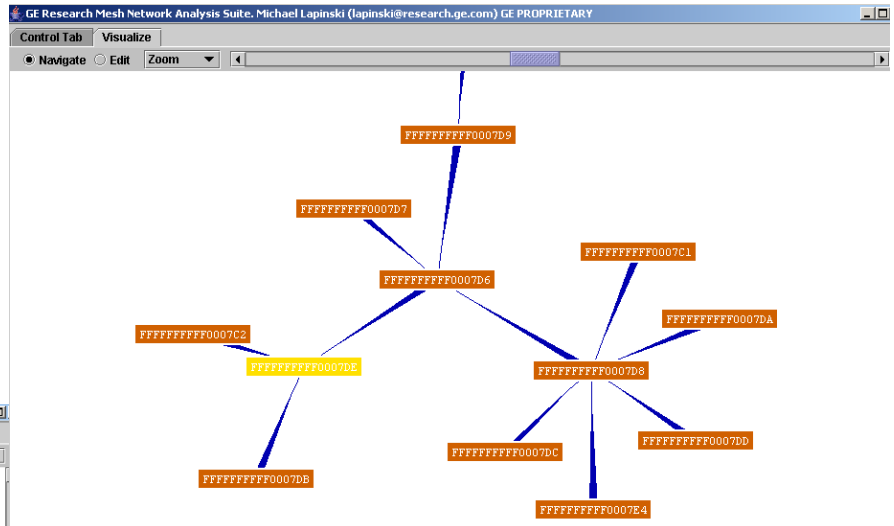
10^3 Margin Improvement

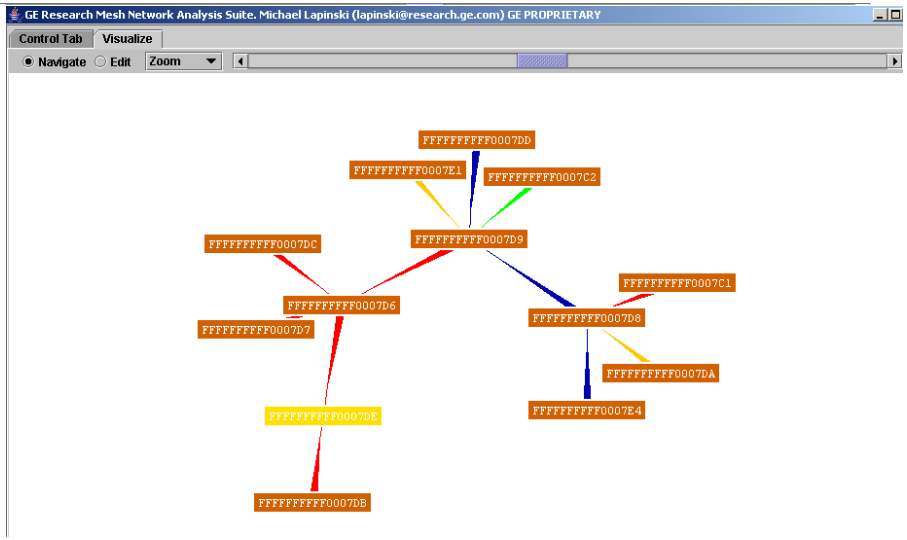
Accomplishments to Date

Network Visualization Tools









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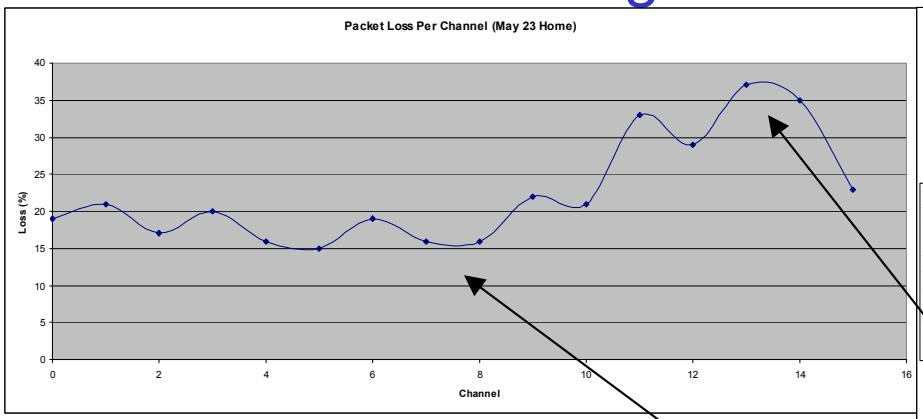
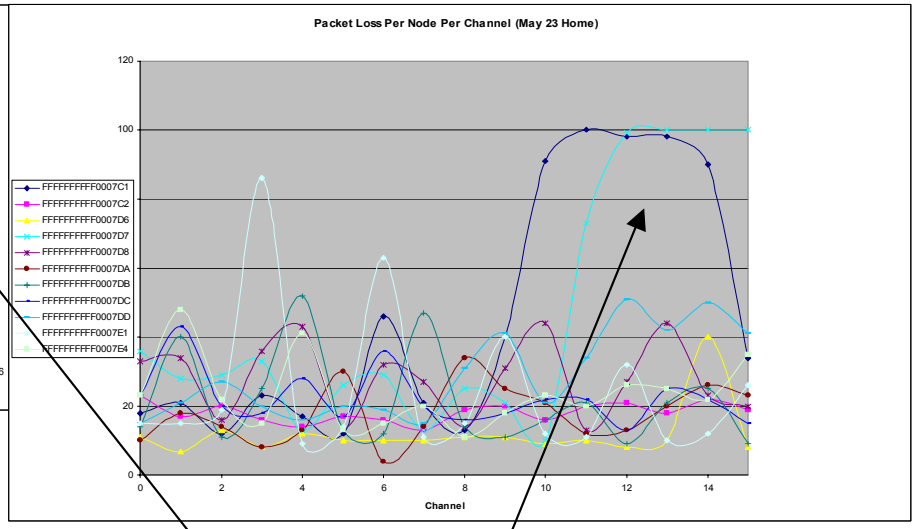
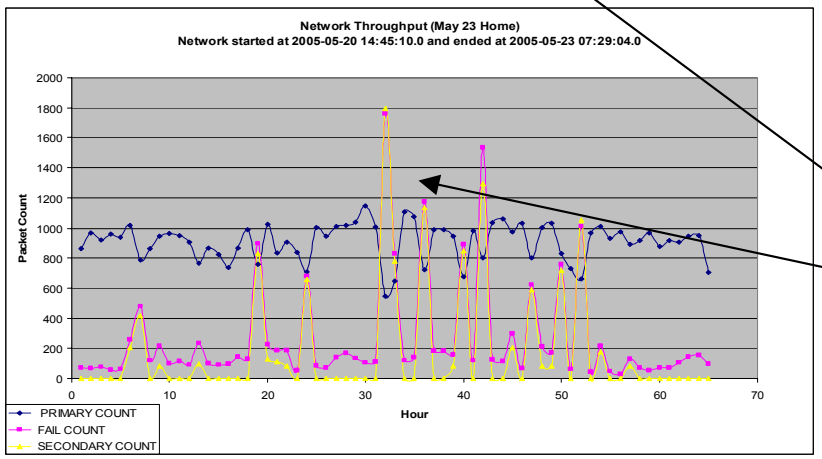
Accomplishments to Date

Network Diagnostics and Performance Tools







Effect of Bad Transmitters

Effect of Gateway Synchronization Problem

Data collected and gathered without a back channel

Network Still Performing the Mission

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Next Project Steps

- **System level simulation based on primary reliability factors**
- **Continue network testing and improvements – bug fixes**
- **Monitor performance and feedback into models.**
- **Refining channel models**
- **Deploy at customer site – gather field experience.**
- **Network Security Design Implementation**
- **Support standards efforts.**
- **Improve hardware platform design**
- **Major Field Demo**

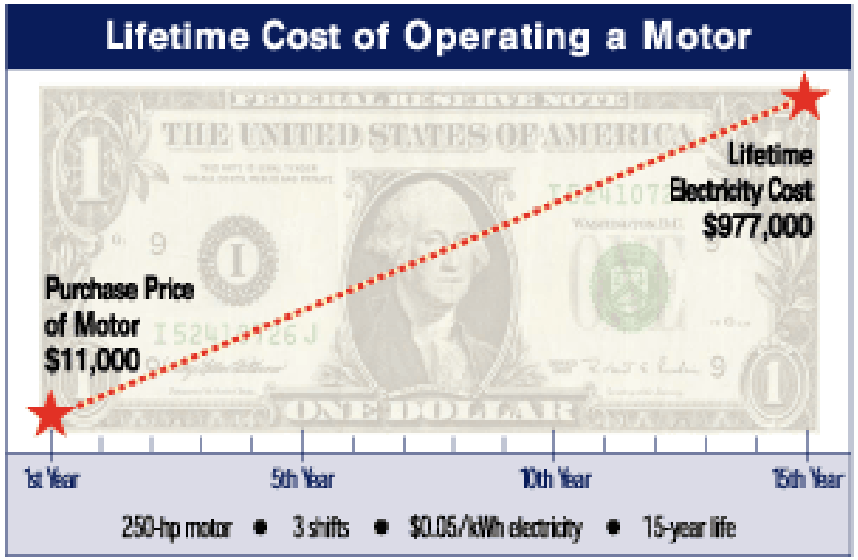
Future Milestones

- **Improvements in Scalability**
- **Adaptive/Cognitive behavior added to Network**
- **Authentication and trust**
- **Improved Battery Life**
- **Transition to product**
- **Standards**

Continuation after ITP-Sponsored Project

- **Market pressure very high – technology needed before it is ready**
- **This technology will transition straight to market**
  - Product design efforts anticipated to start this year
- **Additional R&D required over the next 24 months as follows:**
  - Defining standards covering a range of applications
  - Optimizations dealing with coexistence issues
  - Increased performance to widen range of applications
  - Adaptive/Cognitive techniques to improve radio performance over time.

Value Proposition for End User



Source: Electric League of the Pacific Northwest

"Unscheduled downtime is the largest single factor eroding plant performance. Over $20 Billion, or almost 5 percent of total production, is lost each year in North America alone due to unscheduled downtime."
~ ARC 2002

- **Electric motors systems consume approximately 60% of all electricity generated in the United States.**
- **Motors Systems represent about 70% of total power costs for most process industries.**

~US DOE December 2002 United States Electric Motor Systems Market Opportunity Assessment

Commercialization Plan
GE Infrastructure – Wireless

- **Sensor Networks for Condition Monitoring & Telematics Services**
- **Factory Automation Systems**
- **Residential Security & Automation**
- **Enterprise Security & Building Automation**
- **Cargo Security**
- **Property Management**
- **Video Distribution**

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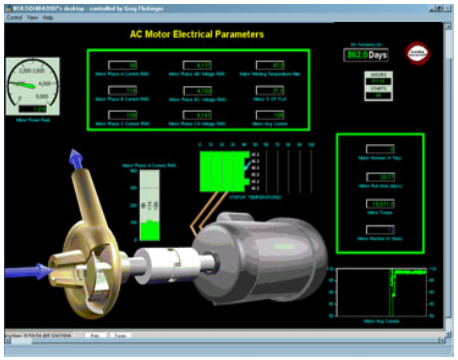
Commercialization Plan
GE Energy – Services



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Commercialization Plan
GE Consumer and Industrial

Plant Network – Distributed Protection

802.11 wireless
802.3 wired
Industrial Ethernet Protocols

M60 Motor Management Relay

Sensors included with motors
Built to customer specs

Large Motors

- Wireless Interface
- Samples Line current and voltage directly

Commercialization Plan
Sensicast

Currently selling 900MHz version
DOE Developed path to market
2.4GHz DOE sponsored platform offered – Summer 2005

http://www.bb-elec.com/wireless_mesh_networks.asp

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Wireless Mesh Networks-
New freedom from power wiring and data cabling

Sensicast Systems Wireless Mesh Networks

No power wires, no data cabling needed for

- Temperature / Humidity Monitoring
- Industrial Monitoring
- Building Automation
- Data Centers
- Refrigeration Monitoring
- Facility Monitoring
- Perimeter Security
- and many other applications

Would you like to place sensors just about anywhere you want, without wiring for power or cabling for data? To move them as needed? To add or reduce the number of nodes easily? These are some of the benefits of wireless mesh network systems from B&B Electronics and Sensicast Systems.

Off-the shelf models & OEM versions

Features and benefits
Models and prices
How wireless mesh networking works
Applications
Success stories
Custom and OEM products
VAR and SI programs

Commercial/Technical Risks Remaining

- **Technical Risks**
  - Ability to accurately predict installation requirements without a site survey.
  - Outdoor installations may pose special problems where no significant multipath exists.
  - Automatic learning, adaptation and system warnings based on changing environment – eliminate the need for frequent user interventions.
- **Commercial Risks**
  - Multiple non-standard options, marketplace confusion.
  - Systems that don't perform well can spoil the market.