

S&C FY02 ANNUAL REVIEW MEETING

Wireless Telemetry for Industrial Applications

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Project Description

Wireless Replaces and Augments Wired Systems for:

- **Rotating and Complex Machinery**
- **Sealed Compartments**
- **Geographically Distributed Sites**
- **Cluttered Work Areas**

Critical Issues Remain: EMI, battery life, legacy interfaces, security, robustness, etc.

Solutions Require New Approaches: Spread Spectrum, CDMA, Embedded Intelligence, Smaller Form Factor, power management, etc.

Project Objectives/Goal

- **IOF need(s) addressed by this technology**
 - Ubiquitous Sensing to reduce waste and emissions, improve efficiency, improve raw material utilization.

- **Objectives**
 - Demonstrate Reliable Wireless Telemetry
 - Integrate legacy sensors
 - Demonstrate new wireless sensor capability
 - Establish bounds on integrity - security and robustness

- **Overall goal**
 - Reduce the cost of deploying sensors in IOF facilities.

Technical Risks/Innovation

- **Technical risks**

- Reducing radio power while maintaining reliable communications in IOF facility harsh environments.

- **Innovation**

- Providing Direct Sequence (eventually hybrid), Spread Spectrum radio with 63-bit (or longer) spreading codes in robust configuration for reliable deployment with minimal operator intervention, no interference, and long battery life.

- **Advancement of state-of-the-art; over competition**

- Most commercial systems use frequency hopping which can interfere with plant electronics or use shorter spreading codes that are less robust. Other systems don't support legacy interfaces while providing a path to more advanced wireless networks. Embedded intelligence reduces bandwidth and power required.

Task Performance

Past Technical Milestones

Milestone	Due Date	Completion Date	Comments
Functional Description and Requirements Document	3/30/99	3/30/99	Evolved until 10/99
Architecture Specification	3/30/99	12/30/99	Funding arrived in 10/99
Field Prototype Demo	9/30/00	12/30/00	Funding arrived late
Industry Test bed started	9/30/01	9/30/01	Continue to work with Timken

Progress Toward Performance Goals

- **Highlighted in 1998 National Research Council Report describing goals for industrial wireless networks:**
 - Eliminating interference (assuring reliable communications);
 - Easing deployment of intelligent wireless sensors;
 - Developing reliable networks (robust architectures);
 - Developing remote power (long lasting and reliable);
 - Developing standardized communication protocols

Progress Toward Performance Goals

- **Functional Description and Requirements Document**
 - Numerous requests from IEEE 1451 committee and industry for our report on industry requirements
- **Architecture Specification**
 - Numerous requests for details on open, 1451 compliant, architecture for robust wireless telemetry
 - Open for others to duplicate using identical or functionally equivalent hardware and software
- **Commercial Viability - Now serving on IEEE 1451.5 committee for smart sensor, wireless telemetry**
 - proprietary systems being replaced
 - articles in numerous magazines and invited talks
 - ISA instructor and course developer for wireless course

Progress Toward Performance Goals

■ Demonstrations Highlight Performance

- USS The Sullivans - First Direct Sequence, Spread Spectrum, transmit only temperature sensor - 8/17/1998 - resulted in industrial partner (Aeptec) contract with Navy
- Bowater Paper Mill - Demonstrated bidirectional test bed hardware and software at 1/10,000 RF power density of previous technology that had disrupted operation. 12/27/2000
- Timken - Long-term installation of test bed provides data on failures in low-tech and hi-tech part of the system - 6/2001

We continue to get requests for test installations at industrial sites.

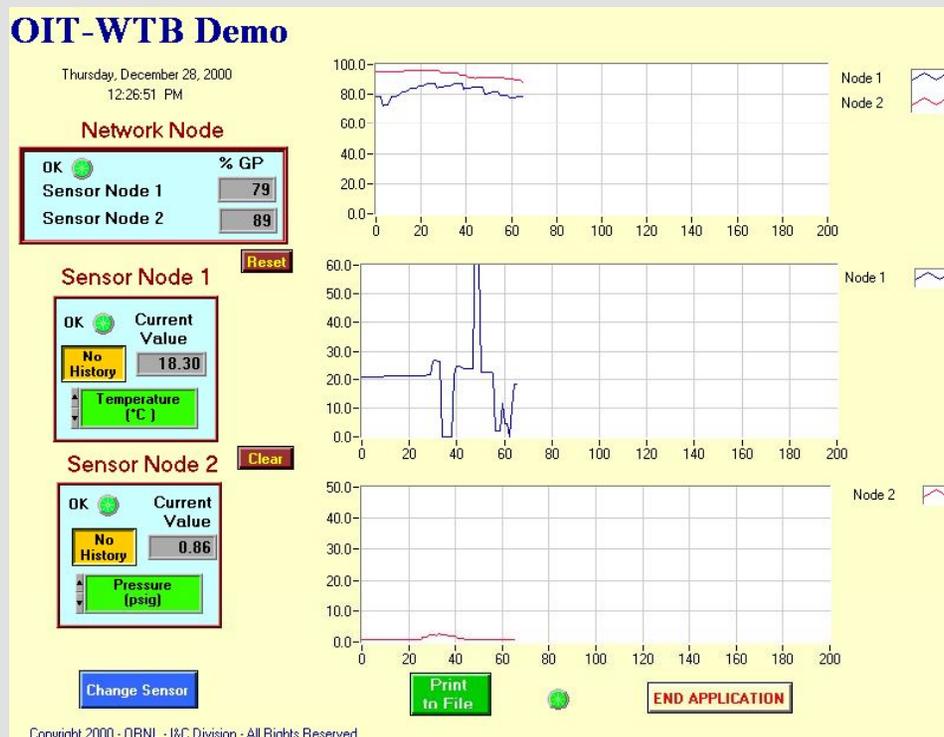
Progress Toward Performance Goals

- **Demo on USS The Sullivans Showed Potential:**
 - **Highly Reflective - multi-path potential failed to compromise connectivity - recorded temperature over 3 decks as well as control room, engine room, generator room.**
 - **Other interferors - IEEE 802.11b wireless network gave no trouble.**
 - **Throughput tracks Bit-error-rate as expected**



Progress Toward Performance Goals

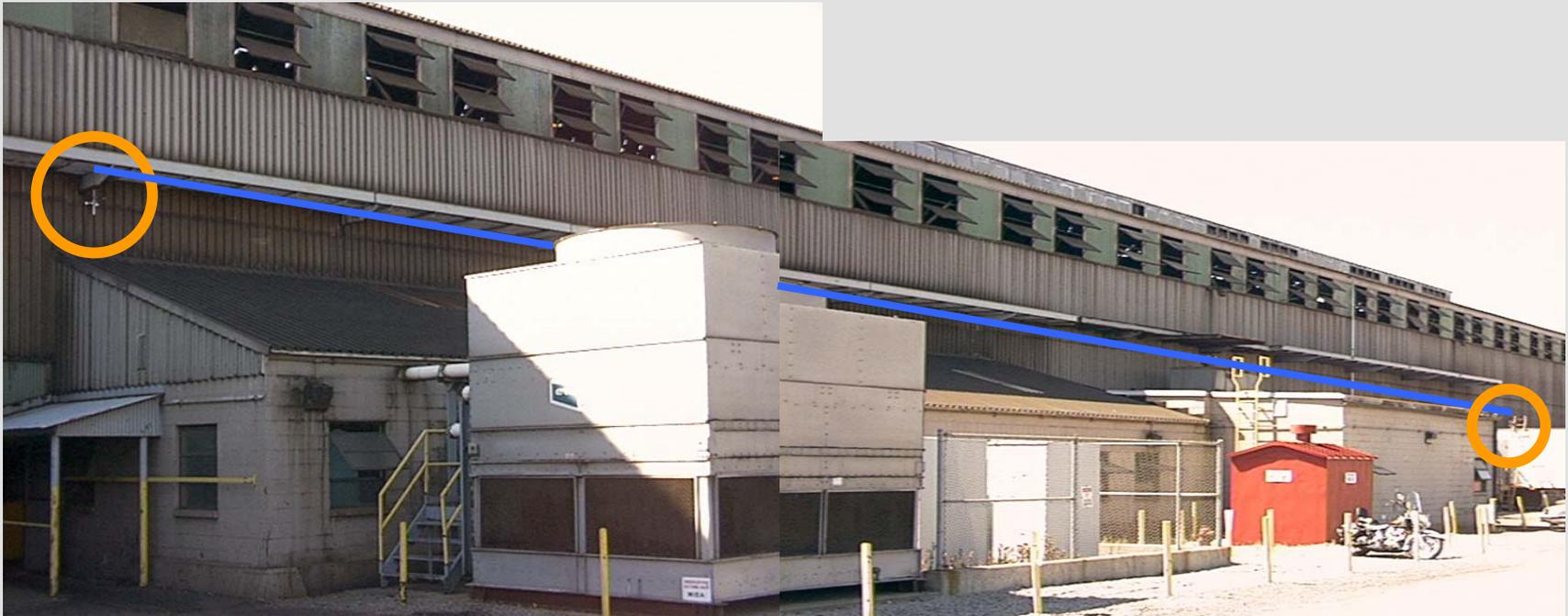
- **Bowater Test Showed Bidirectional Capability**
 - 140 foot connectivity with acceptable BER and throughput
 - saw some storage temperature sensitivity from overnight



Progress Toward Performance Goals

- **Timken Tests Implemented First Repeater Technology**
 - *Bidirectional, small footprint, Direct Sequence Spread Spectrum*
 - *Robust packaging, upgraded firmware*
 - *saw problems with interference from 800-number pager tower*
 - *seeing problems with micro-controller but no more with radio telemetry*

Long-Term Testing Provides Valuable Information



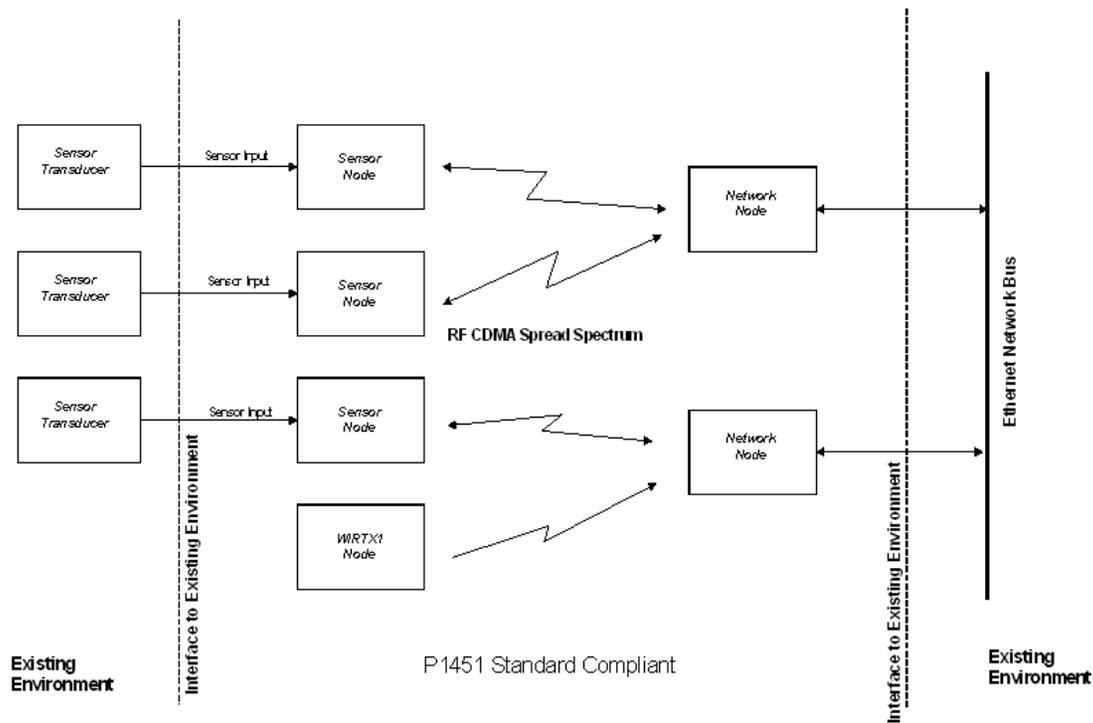
Outside transmitter

**Line of Sight
to LUT Cabin**

Simple Architecture Supports Legacy Sensors

DOE/OIT Board Level Wireless Test Bed

Overall System Block Diagram



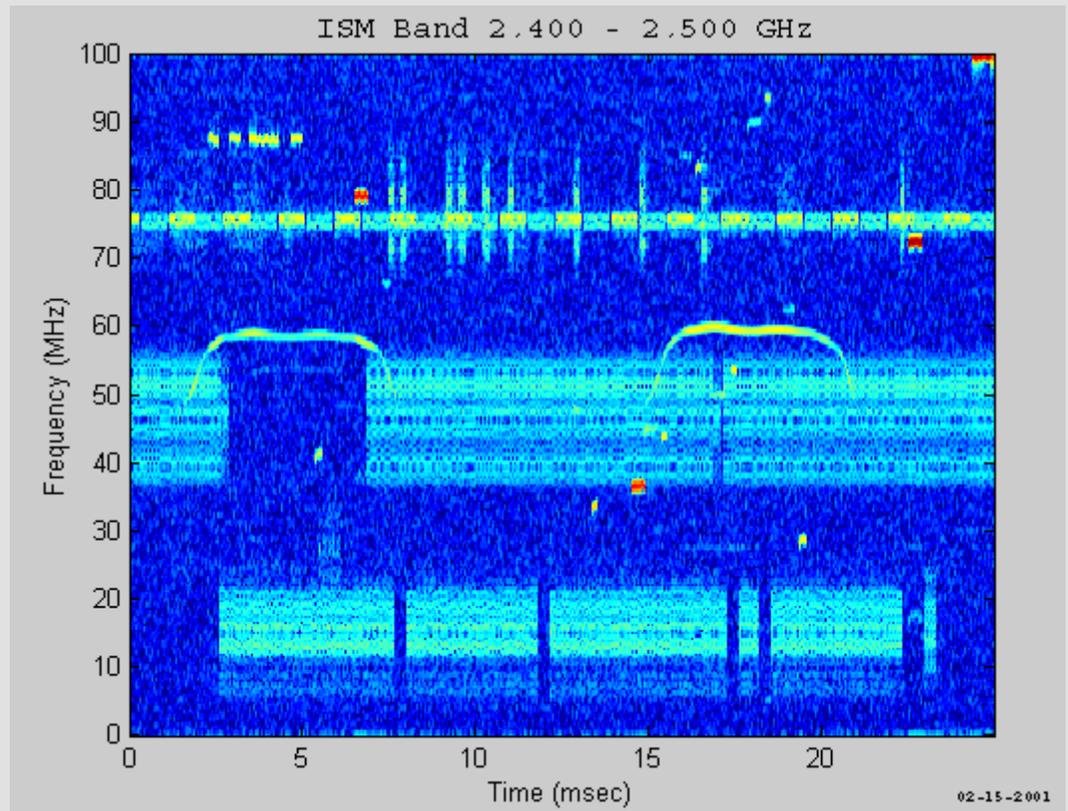
Roberto Lenarduzzi 04-14-1999

Current Generation Hardware Designed for Testing



Who/What is in the ISM band?

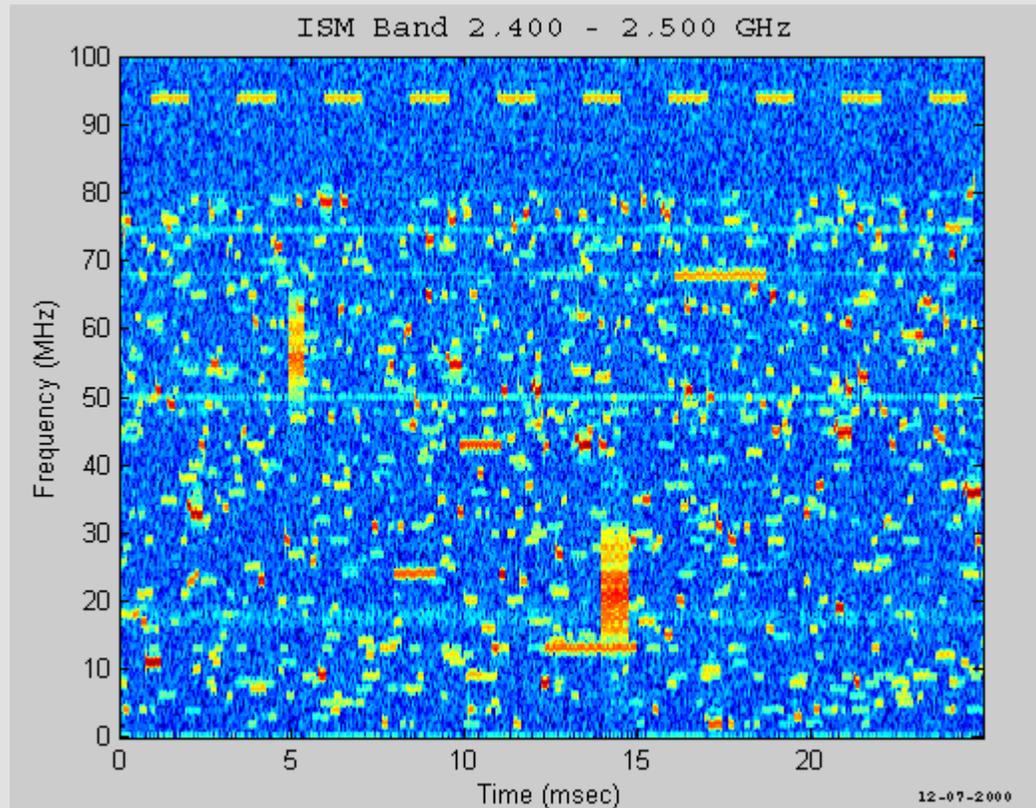
- **WLANs**
- **WPANsTM**
- **Industrial**
- **Medical**
- **Scientific**



Both IEEE 802.11b and Bluetooth operate in the same 2.4 GHz ISM Band

What is the WLAN ISM Environment?

- Pico-nets
- Scatter-nets
- Proprietary communication and control
- 802.11b
- 802.11g



Communication of devices within a Personal Operating Space

Commercialization

- **Proposed plant tests/deployments, and planned use in IOF manufacturing plant(s)**
 - Timken Steel - long term testbed and beneficial use installation
 - Bowater Paper - next generation planned
- **Commercialization path & partners**
 - Graviton - \$M CRADA just ended
 - Tarallax - \$M CRADA just starting
 - Robertshaw - long term relationship
 - Aeptec (3e Technologies, Inc) - long term relationship

Nine related patents attract interest from commercial sector.

Performance Merits

■ Improving energy efficiency

- How will energy be saved?
 - Maintenance, performance monitoring - reduce unscheduled downtime which reduces scrap
 - Asset Tracking - reduces energy wasted waiting for material, maintenance
 - Process Improvements - lower cost sensing raises process efficiencies in production, in depth view of process - mining the process - not the data base.
- What are the energy savings (per installed unit and nationwide)?
 - In 1997, the President's advisors on science and technology asserted that wireless sensors could improve efficiency by 10% and reduce emissions by more than 25%.

Performance Merits

- **Reducing emissions**

- How will emissions be reduced?
 - Process efficiencies - improvements reduce emissions
 - Emission monitoring - early warnings reduce emissions
 - Maintenance - reduces risk of failures
- What are the reduction levels?
 - S&T advisors to the President estimate 25%

Performance Merits

- **Improving product quality**

- How will product quality be improved?
 - Process Monitoring and Control - previously unmeasurable (too costly because of motion, distance, clutter, regulations) parameters can now be measured
 - Enabling Technology - provides cheaper, faster, better interfaces for new instrumentation - like LUT at Timken
- How will this improvement be quantified?
 - Yield improvements - identify quality improvements, waste reduction, reduced cost allows more measurements
 - Value-Chain - compare with potentials available

Performance Merits

- **Improving productivity**

- How will productivity be improved?
 - Process Monitoring and Control - previously unmeasurable or sampled rather than on-line
 - Reduced downtime - improved maintenance, extended operating life
 - Anticipating needs rather than reacting
- How will this improvement be quantified?
 - Life tests, operating costs on instrumented lines, uptime measurements.

Performance Merits

■ Reducing costs

- How will costs be reduced?
 - Wiring costs - as high as \$2000/ft in nuclear power plant and \$200/ft (nominal) in chemical plant.
 - Wiring errors - self identifying sensors reduces wiring errors so connectivity is assured
 - Maintenance costs - \$4T/yr (worldwide) spent on unneeded replacement of components because no viable measure of status, expected life.
- What are the cost savings?
 - Depends on process being instrumented

Performance Merits

- **Minimizing waste**

- How will waste be minimized?
 - Process Monitoring - reduces waste through improved controls, use as trigger (like LUT) improves equipment life
 - Higher Product Yield - fewer rejects
 - Better Customer Satisfaction - fewer returns
- How will waste minimization be quantified?
 - Equipment life, improved yields

Path Forward

Future Technical Milestones

Milestone	Due Date	Completion Date	Comments
Interim Report	9/30/02		
5.8 GHz components tested	9/30/02		New SiGe technology
Timken Test bed provides reliable connectivity, on-line reports	9/30/02		
Sensor Agent Architecture defined, verified	9/30/02		Embedded intelligence

Path Forward

■ Next steps

- SiGe Components Tested - improves bandwidth and reduces interference
- Timken Testbed - remoted, verified
- Sensor Agent - architecture defined and verified - reduces bandwidth, battery requirements, increased knowledge/bit transmitted, and improves reliability
- Hybrid Spread Spectrum - advantages of frequency hopping and direct sequence spread spectrum - patents pending

■ Go/no-go consideration(s)

- Timken - robust connectivity demonstration required
- SiGe - move to 5.8GHz important but not necessary - research!