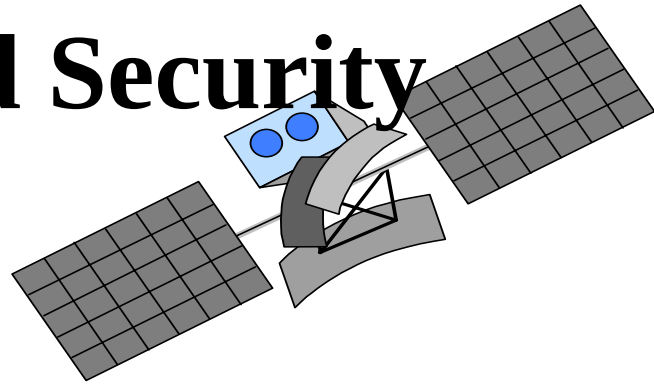
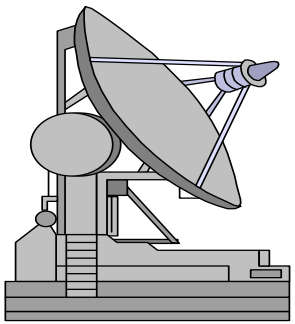
Industrial Wireless Technology: Agility, Mobility, and Security

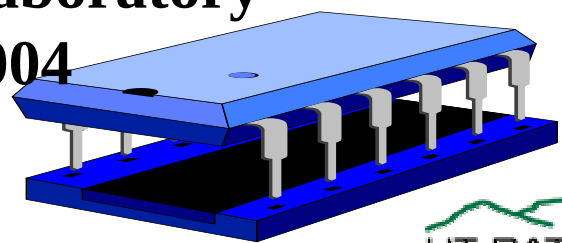


Lost Foam – Division 11



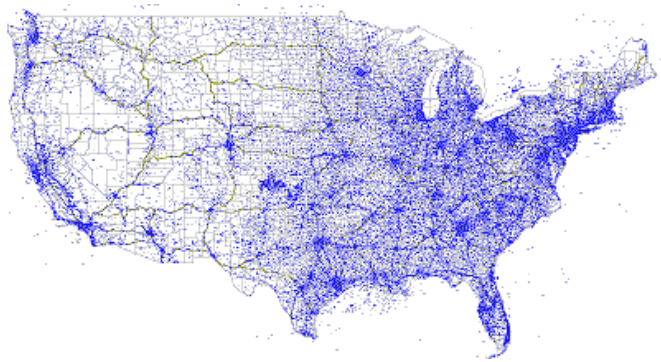
Wayne W. Manges (w/ Glenn Allgood)
Industrial Wireless Program Manager
Oak Ridge National Laboratory

February 17, 2004



Wireless Sensor Networking

…it's not cellular telephony



…it's not WiFi

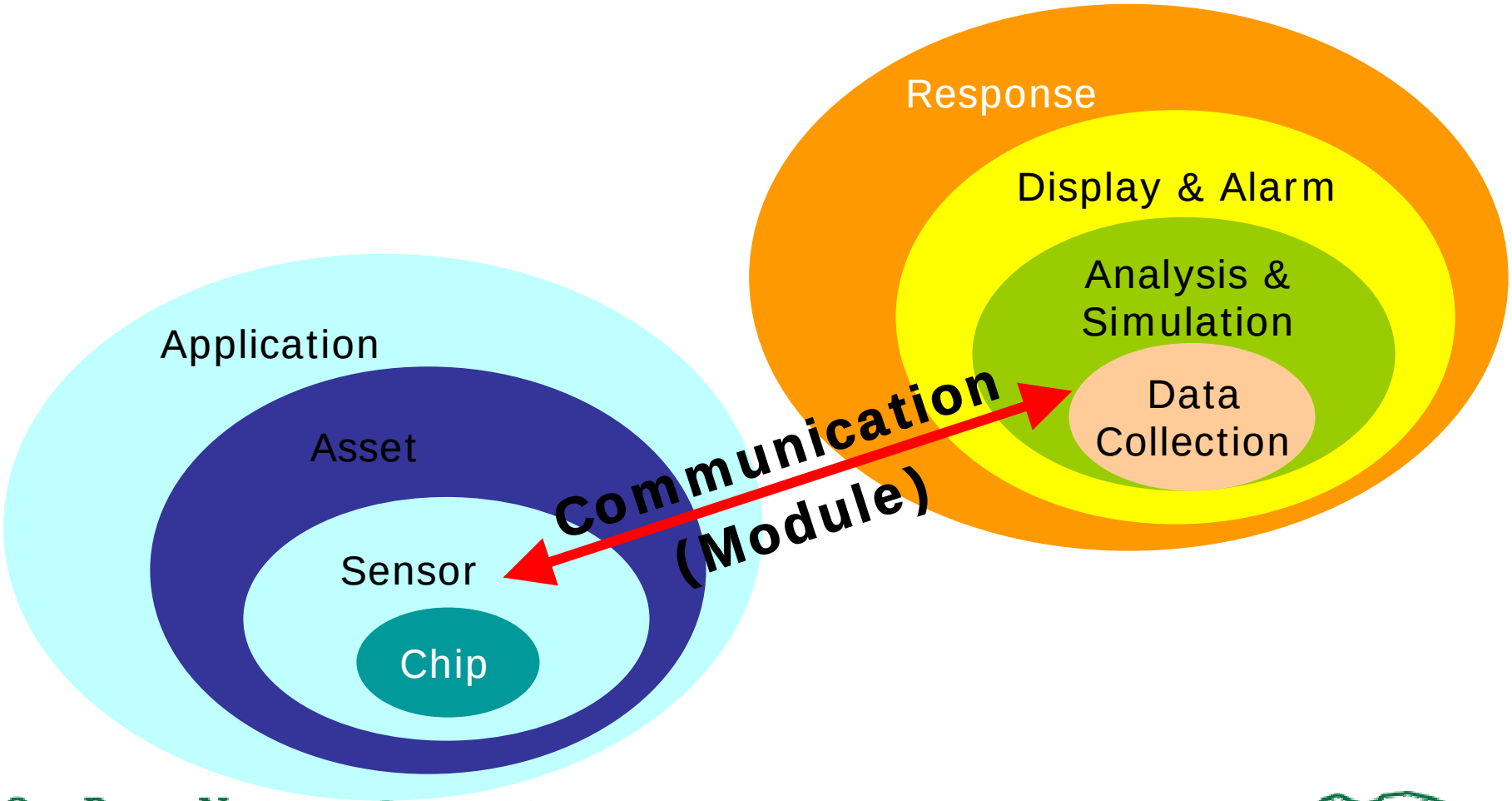
Each dot represents one cell phone tower.

…(and it just may be the next big thing)

Wireless devices circa 1930

RF Tags – expected to be >$2.6B by 2005

Wireless Ecosystem



Industrial Wireless – A Critical Enabler for Intelligent Process Automation

- How Did We Get Here? – history, perspective, focus on process analytical chemistry
- Can You Hear Me Now? - Technology basis for reliable communications
- Can You Afford it? - What's driving costs up and down.
- What's Holding Things Up? - Power?, IP Issues?, Standards?, Moore's Law?
- Future Shock – Intelligent Sensor Agents acting on our behalf

The Reason I'm Here!

- Revolutionary Patent
- Extraordinary Patriotism!
- Unparalleled Performer!

Hedy Lamarr -

Just Slightly Ahead of Her Time

- Spread Spectrum- A Wartime Innovation
- Very Secure - Low Detectability
- But Very Difficult to Implement - until now!

For audio track, go to www.oldcolo.com

farewell

Elegant Egghead

Hedy Lamarr, screen temptress, melded one part Dietrich, one part Edison

Hedy Lamarr was not a diva; she just played one in the movies. She was billed as "the most beautiful woman in the world" as she vamped her way from 1938's *Algiers* to 1949's *Samson and Delilah,* but her son Anthony Loder, 52, says that when he was a child, "the only reason I knew she was famous was once a police officer pulled us over, and instead of giving her a ticket, he recognized her and told her to take us out for ice cream."

Glamor queen was just a line on her résumé to Lamarr, who died in her sleep in an Orlando suburb on Jan. 19 at age 85. Police attribute her death to natural causes. Denise Loder-DeLuca, 54, Lamarr's other child by the third of her six husbands, actor John Loder (Lamarr and second husband Gene Markey also adopted a son, James, now 60 and a retired cop), says she talked to her mother often, and "she sounded like she was 38. She was totally hip and chic."

Born in Vienna, Lamarr first made a splash at age 19 by skinny-dipping in the racy 1933 Czech film *Ecstasy.* She set sail for America in 1937, and her ship came in even before her ship came in—MGM mogul Louis B. Mayer signed her on the liner to New York City.

If Lamarr looked bored onscreen, it's because she was. "Any girl can be glamorous," she once said. "All you have to do is stand still and look stupid." This was an actress for whom playing stupid was a stretch: In 1940 she invented an antijamming technique for radio signals that was largely ignored then but was employed by the U.S. military during the Cuban missile crisis and is still in use today.

Lamarr (ca. 1945) still got fan mail but wouldn't answer notes that had poor handwriting.

"If you have a cell phone, you are using her technology," says Loder. Unlike his mother, he profits from the idea: He owns a phone store in L.A.

In later years, Lamarr stayed feisty by suing everyone from the authors of her ghostwritten autobiography (the suit was dismissed) to Mel Brooks, who mocked her name in *Blazing Saddles* (they settled out of court). She was also arrested twice, but never convicted, for shoplifting. Perhaps it was absentmindedness; in one case she had checks totaling $14,000 in her purse. "Nobody," says Loder, "could tell her what to do." •

PEOPLE 2/7/00 107

The DOE OIT Wireless Program Focuses on Crosscutting Needs

- National Research Council – "advanced wireless sensors" identified as a critical research need.
- President's Committee of Advisors on Science and Technology – "wireless sensors can improve efficiency by 10% and cut emissions by more than 25%"
- Industrial Wireless Workshop – trade throughput for reliability

Wireless Enables Ubiquitous Sensing Needed in Process Analytical Chemistry!

National Research Council Identified 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

The Wireless Revolution Can Be Harnessed for Industrial Use

- **$4B per year projected sales**
- **New Paradigms - Not just wireless but truly wire-free**
- **New Companies - live and die**
- **Culture Change - biggest thing since the microprocessor**

Industrial Suppliers Are Leveraging Other Markets - Remember Ethernet?

- **IEEE 802.11b - Local Area Networks - Bill Gates says this may be the most important invention of the 20th century!!**
- **Cell Phones - batteries, chip sets, antennas**
- **PDAs - intelligence, interfaces, GUI**
- **Video Games – Wireless joystick**

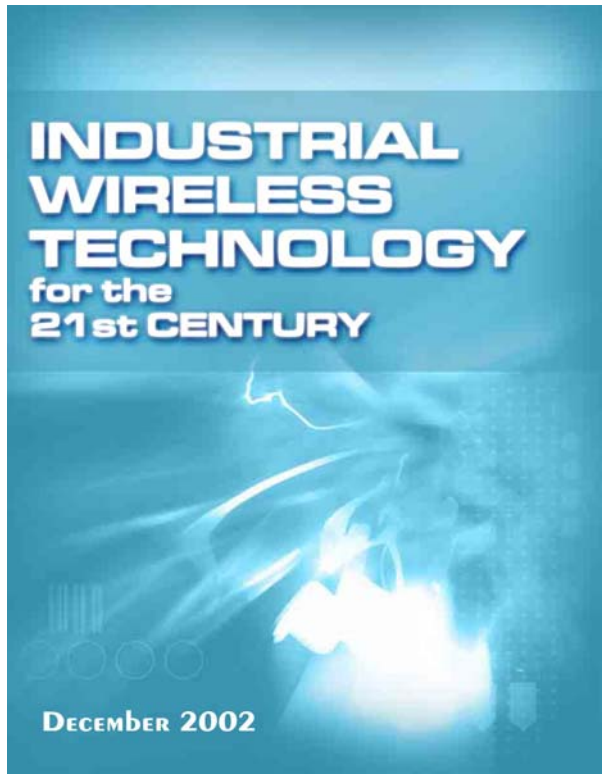
Can these technologies make the transition to the industrial marketplace?

"Anyone in the sensor business not delivering wireless sensors will be out of business in 5 years!" - CEO from major sensor company

- **ISA Chicago - Every sensor booth had a wireless offering**
- **Proprietary - standards lacking, business models are old school**
- **Unintegrated - radio attached to traditional sensor - problems with power, cost, packaging, EMI**
- **Few Manufacturers - Axonn, a few others**
- **Technology Driven - underlying technology determines connectivity, reliability, ease of deployment**

DOE's OIT Has Supported R&D at ORNL and Elsewhere

- Sponsored ORNL Demos at:
  - Navy's USS The Sullivans - metal walls, high EMI
  - Timken Steel - hard industry, rugged location
  - Bowater Paper - EMI sensitive process equipment
- Sponsored Workshop
  - San Francisco - 30 participants - publication available detailing needs, alternatives - http://www.oit.doe.gov/cfm/fullarticle.cfm/id=714
- Call for Proposals - Multidisciplinary, industry lead, multi-year, $12M, recently awarded – ORNL managed



Major Players - Some Old, Some New, Some Borrowed, Some Blue

- **Omnex - hard industrial packaging, robust wireless connectivity for 4-20ma sensors**
- **Robertshaw - Tank levels and others In their Centeron line**
- **Ember - out of MIT, uses 802.15.4 (ZigBee) in utilities monitoring**
- **3eTechnologies - Heavy in Defense**
- **Wilcoxon - old company making accelerometers and others**
- **Axonn - more radios in industry than anyone - millions!!**
- **Computational Systems, Inc - early player, now Emerson Electric**

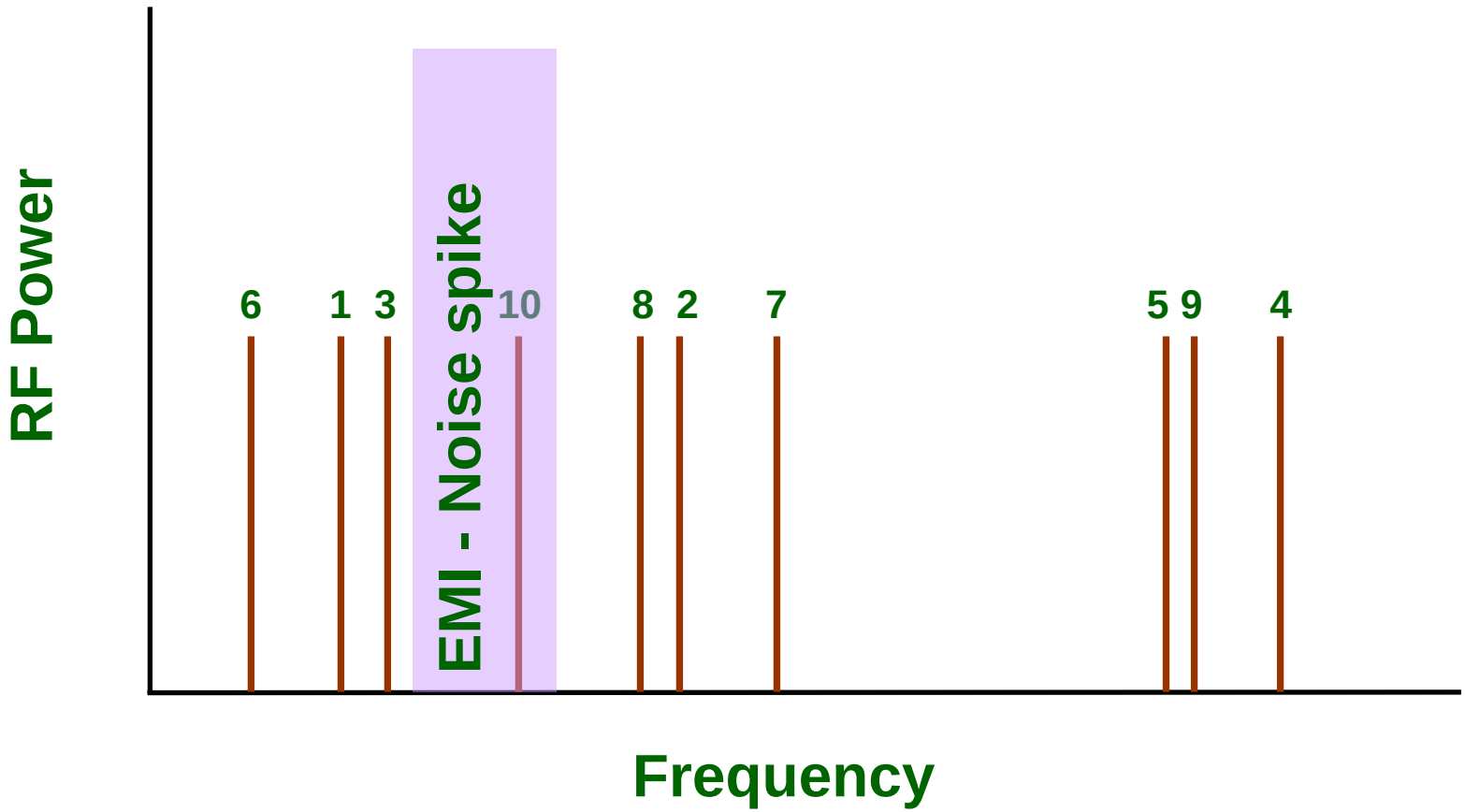
So What's Driving This Market?

- **Cost - Wiring can cost from $100 per foot in the open field to $2000 per foot in nuclear power plant**
- **Ease of Installation - reduces need for highly skilled installers**
- **Impossible Locations - Impenetrable walls, moving equipment, insurmountable obstacles (roads, rivers), no infrastructure in place**
- **FCC - allocation of Industry, Science, Medicine (ISM) bands permits license-free radios (but still type-accepted)**

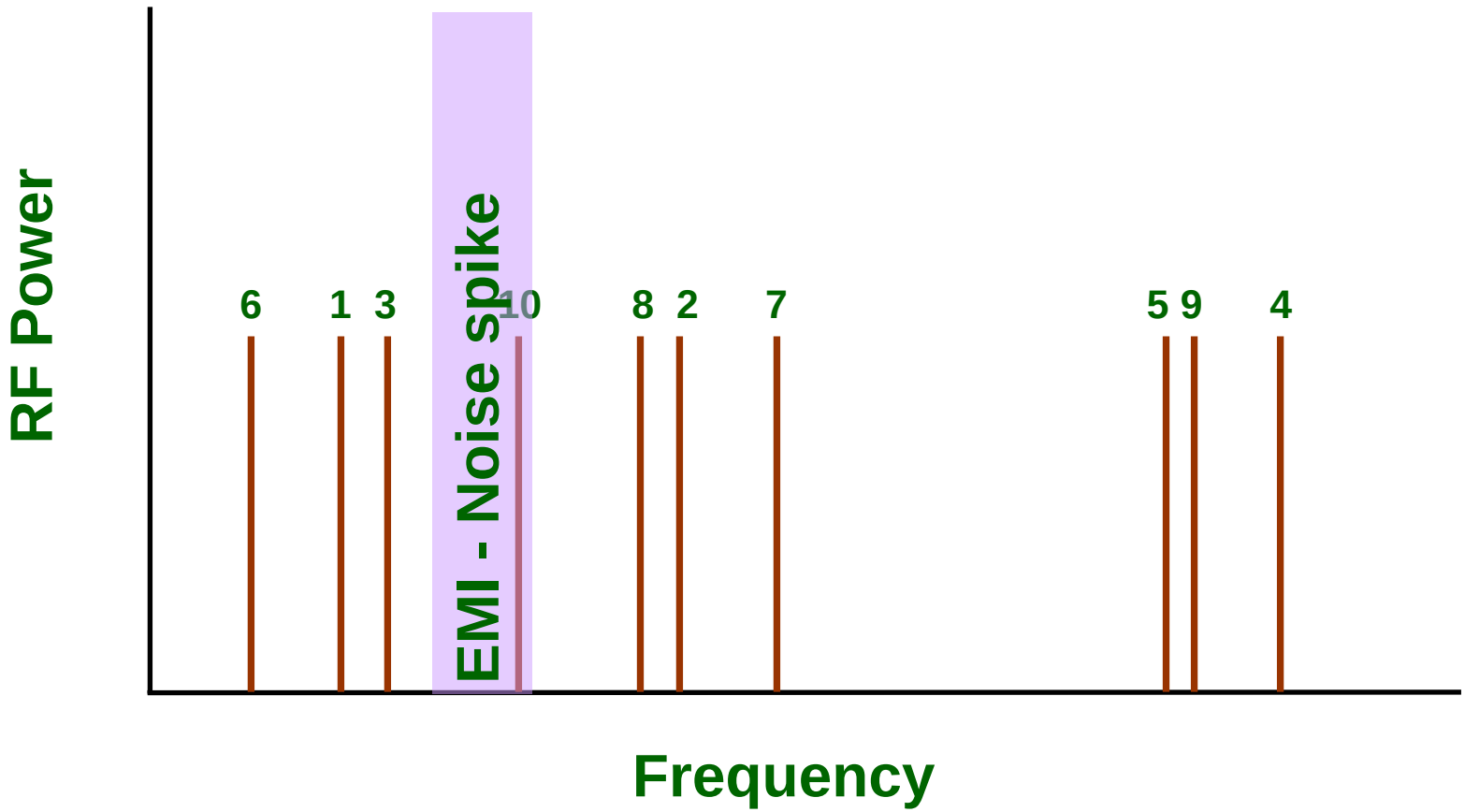
Opening ISM Bands Started the Ball Rolling - It Hasn't Stopped Since

Frequency Band	Characteristics	Products Using It
914 MHz (902-928 MHz)	Lower Throughput, better wall penetration and range. US, Canada, Australia only	ZigBee, Axonn, Proprietary
2.4 GHz (2.400 – 2.4835 GHz)	Frequency slots available worldwide	Bluetooth, 802.11b, industrial heaters
5.8 GHz (5.725 – 5.850 GHz)	Highest throughput, better noise immunity, stricter line-of-sight constraints, smaller antennae	802.11a; greater technical challenges at higher frequencies; higher cost

Frequency Hopping is More Intuitive Than Direct Sequence Spread Spectrum



Frequency Hopping is More Intuitive Than Direct Sequence Spread Spectrum



Vendors Offer Solutions in Various Flavors

Spread-Spectrum Encoding Techniques

Technique	Approach	Characteristics
Frequency Hopping Spread Spectrum (FHSS)	Transmission jumps from frequency to frequency at a predefined rate and pseudo-random sequence	Reduces interference
Direct Sequence Spread Spectrum (DSSS)	Signal is sent over a range of frequencies by sub-sampling each bit in the data stream with a high-rate, pseudo-random spreading code	Implementations with a 64-bit spreading code provide a robust interface and process gain (power savings)
Ultra-Wideband (UWB)	Spreads signal over a very large frequency range at low power	High throughput; good in areas with physical obstacles; used for live video feeds

Each technique offers advantages and disadvantages under the various conditions that might be encountered in a typical sensor application.

BlueTooth Key Features

- Royalty free operation
- Embed tiny short-range (< 20 ft) transceivers into any mobile device
- Data throughput at 721 kbps plus three voice channels
- Transceivers use unlicensed 2.45 GHz band with 0.1 W transmit power (8-30 milliamps)
- Standby power consumption less than 100 microwatts
- Target audience: cameras, palm computers, pocket phones, PDAs,… - NOT SENSORS!!!

Bluetooth vs. the Rest

Parameter	802.11b	HomeRF	Bluetooth	ZigBee
Technology	2.4 GHz, DSSS 11 chips/bit	2.4GHz, FHSS 50 hops/s	2.4 GHz, FHSS 1000+hops/s	2.4 GHz,DSSS (+900) 15 chips/bit
Data Rate	11Mbps	1 Mbps	1Mbps	40 kbits/s
Power	+20 dBm	+20 dBm	0, +20dBm	0dBm
Range	50m	50m	1-10m, 50m	100m
Topology	128 devices CSMA/CA	128 devices CSMA/CA	8 devices, Piconet	100s devices, CSMA/CA
Security	Optional WEP	Optional	Encryption	Not yet
Voice Channel	Optional	Optional	Yes	No

Bluetooth – aka IEEE 802.15.1

ZigBee – aka IEEE 802.15.4

What About the Licensed Radios in Industry?

- Defacto Standard for Crane controls – mission critical?
- Allocated to Specific Manufacturer who obtains FCC license for each unit – not “type accepted” like ISM
- User must maintain FCC paper work on-site.
- Fully Proprietary – single source for application, support strong for established vendors

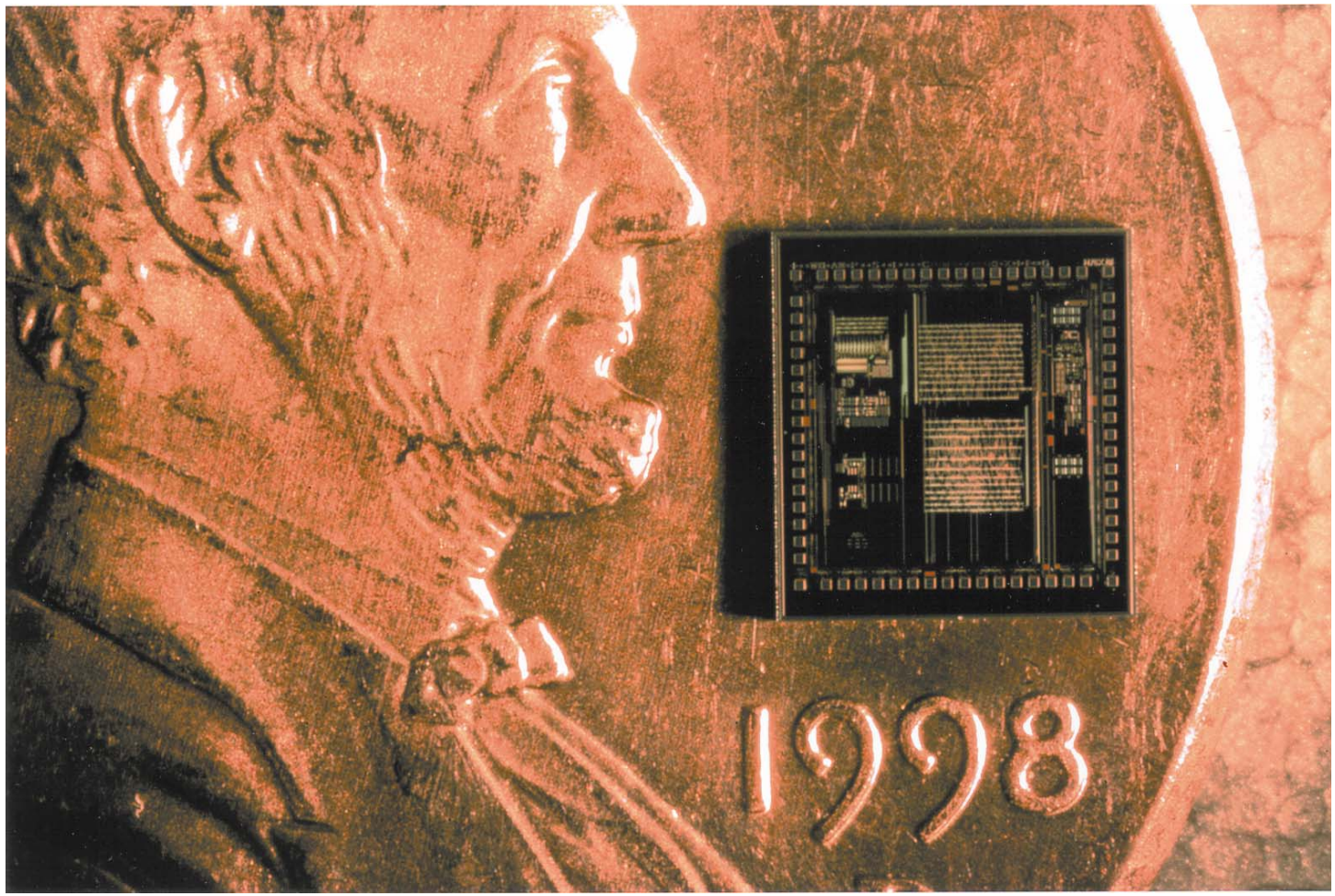
More About the Licensed Radios in Industry!

- Interference Better Controlled – ISM requires that receiver "tolerate" others, licenses grant "exclusive" use
- Low data rates – unsophisticated, older technology
- Proven – used in industry for 20 years or more
- Better Coverage – frequencies used (27MHz and others) have better penetration properties for industrial structures
- Some Support in Industrial LANs – LONworks, others

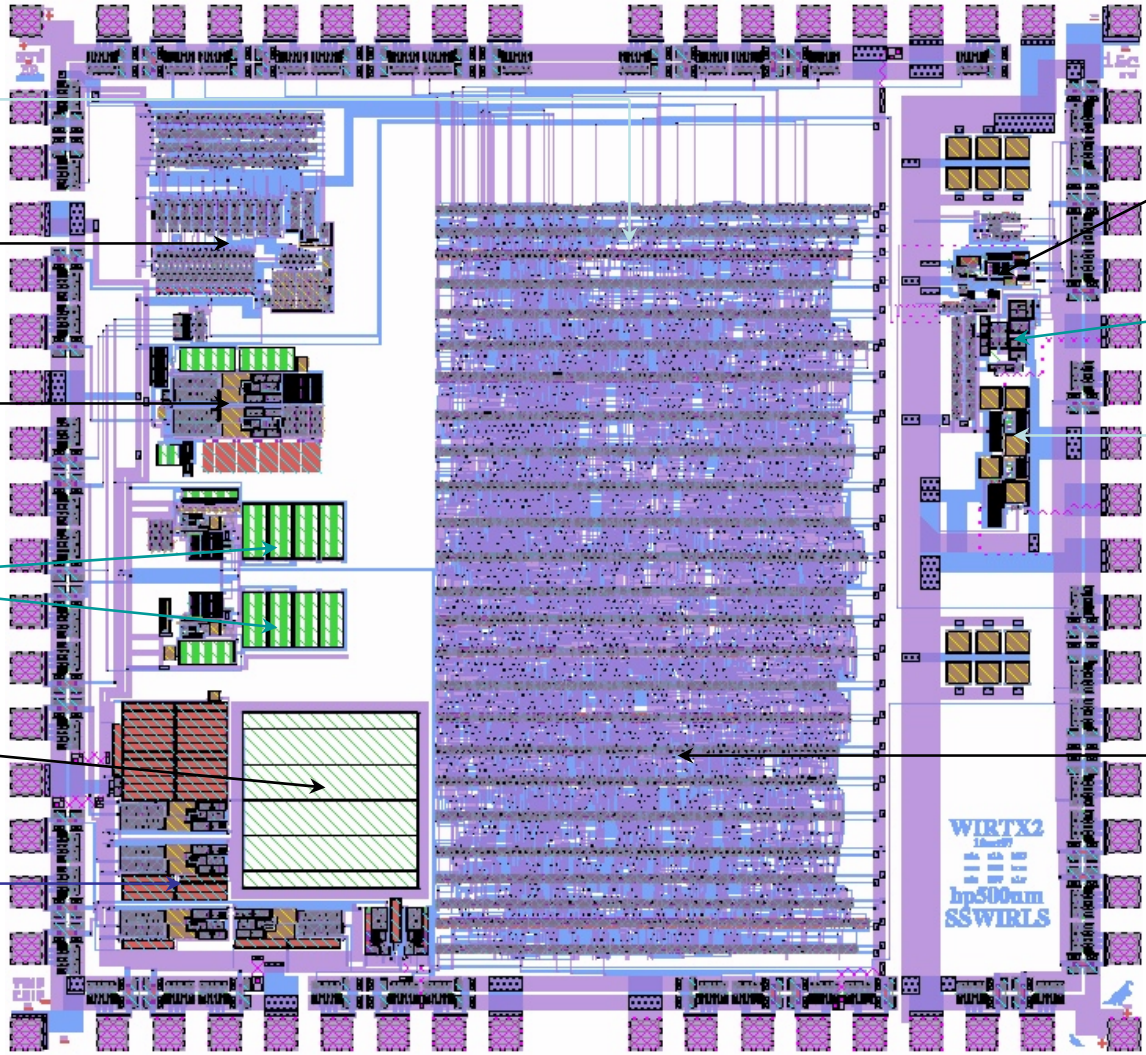
How About a Vendor Comparison?

Vendor	***Tech.***	***Cost***	***Maturity***	***Volume***
Axonn	DSSS- 63 chips/b	Low	High	High
3e Tech.	Bluetooth	Low	Low	Low
Xtreme Spectrum	UWB	Medium	Lowest	Lowest
Omnex	FHSS	high	high	Medium

MULTI-CHANNEL INTEGRATED SPREAD-SPECTRUM TELESENSOR



Advanced Wireless Telesensor Chip



Spread-Spectrum Gen.

ADC

Voltage Ref.

Temp. Sensors

Optical Detector

Optical Data Interface

Size:
3.3 mm sq.

VCO/PLL

Mixer

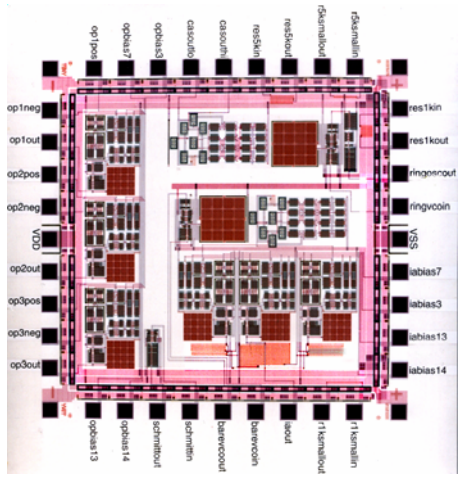
RF Amp

Control Logic

Process:
0.5-μ H-P

Examples Illustrate Emerging Technology

- Health Sensor
- Thin Film Battery
- Bee chip
- Microcantilever

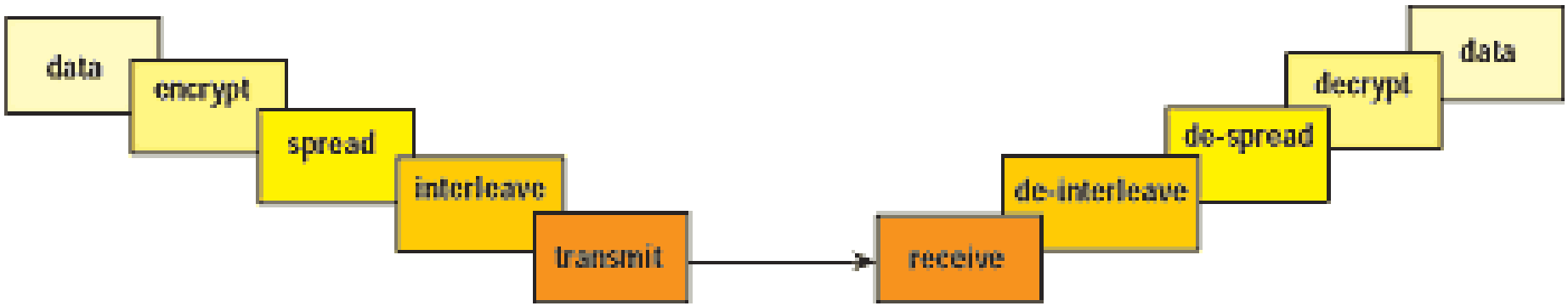


Reliability and Security Drive Acceptance

- **Wireless as good as wire – or better!**
- **Robust security technology available in hardware and software layers of communications protocol!**
- **New M&S facilities for 10,000 node networks!**

"Can you hear me now?" is not an engineered solution!

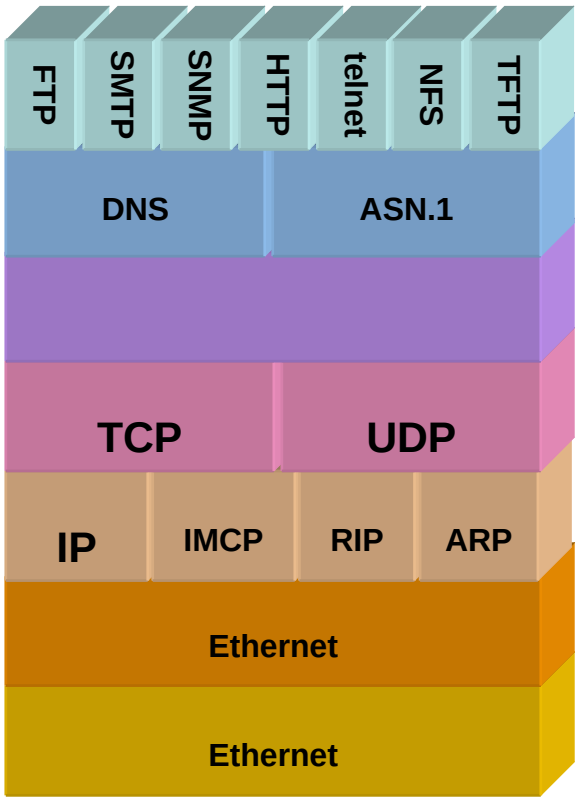
Wireless Data Security: Encryption, Spreading, Interleaving



Wireless networks use a variety of techniques to enhance security, such as spreading and interleaving. These techniques can make the signal virtually undetectable without prior knowledge about the network. This can improve the security of the network by orders of magnitude.

Hi-Fidelity, Distributed, Extensible Models Require Advances in M&S Technology

Internet



Application: Standards to transfer files, send emails, etc.

Presentation: deals format conversion, encryption and security

Session: manages series of messages for a complete a session

Transport: Responsible for end to end connectivity

Network: Message routing in complex networks

Data Link: Media Access Control, Framing, Error Checking, Addressing

Physical: Standards for cabling, signaling, voltage levels, modulation

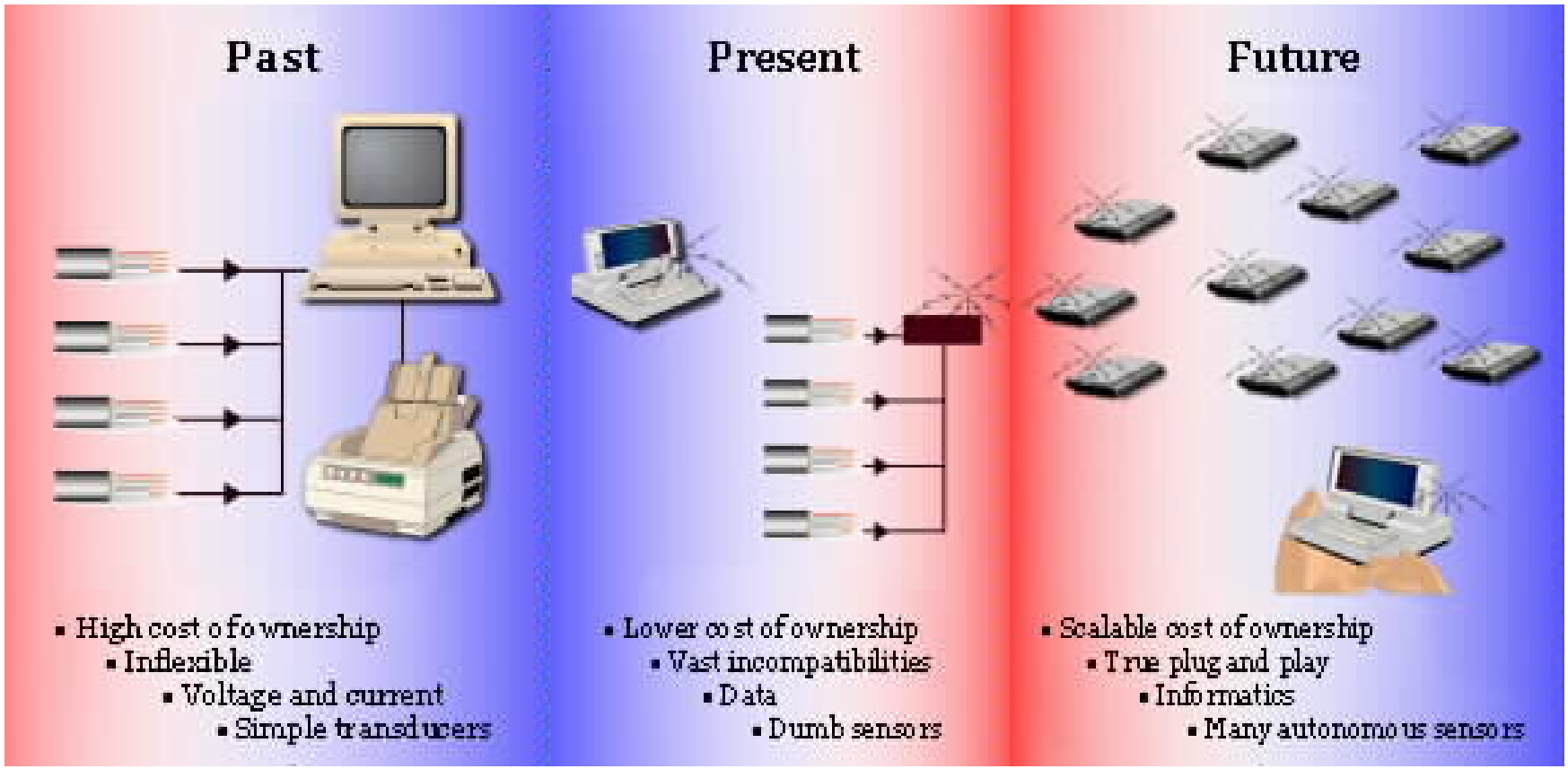
What Pushes Us to the Next Generation?

The next generation measurement system will change the world's view of how measurements are defined, made, and used.

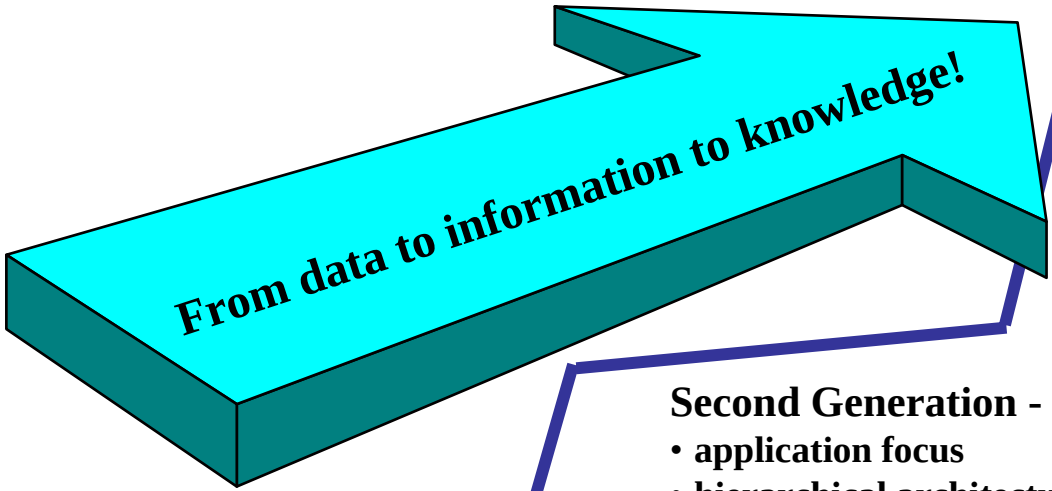
<u>Even the latest systems being deployed:</u>

- are limited in their scope and ability to measure complex systems.
- are rigid in their construction requiring excessive costs for incremental expansion.
- lack agility to respond to problems.
- defined by its components and not its requirements or needs.
- are hardware dependent.

The Future:
The Sensor IS the Network



What Is The Next Generation Sensor System?



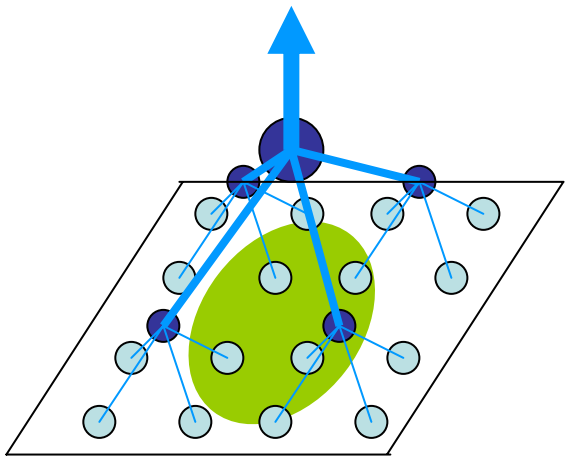
Third Generation - Sensor Agents
- goal focus
- dynamic architecture
- network intelligence

Second Generation - Smart Sensors
- application focus
- hierarchical architecture
- local intelligence

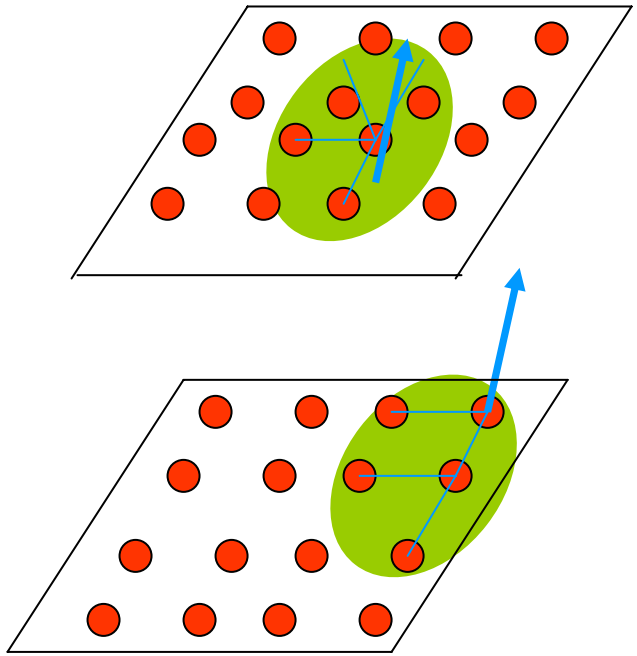
First Generation - Dumb Sensors
- data focus
- flat architecture
- no intelligence

What is the Next Generation Measurement System? How Will You Know It When You See It?

Present-day systems have fixed hierarchy



Next generation network will self-organize in response to specific events



Recent Trends in Portable Phones Point to Wireless Infrastructure for Manufacturing

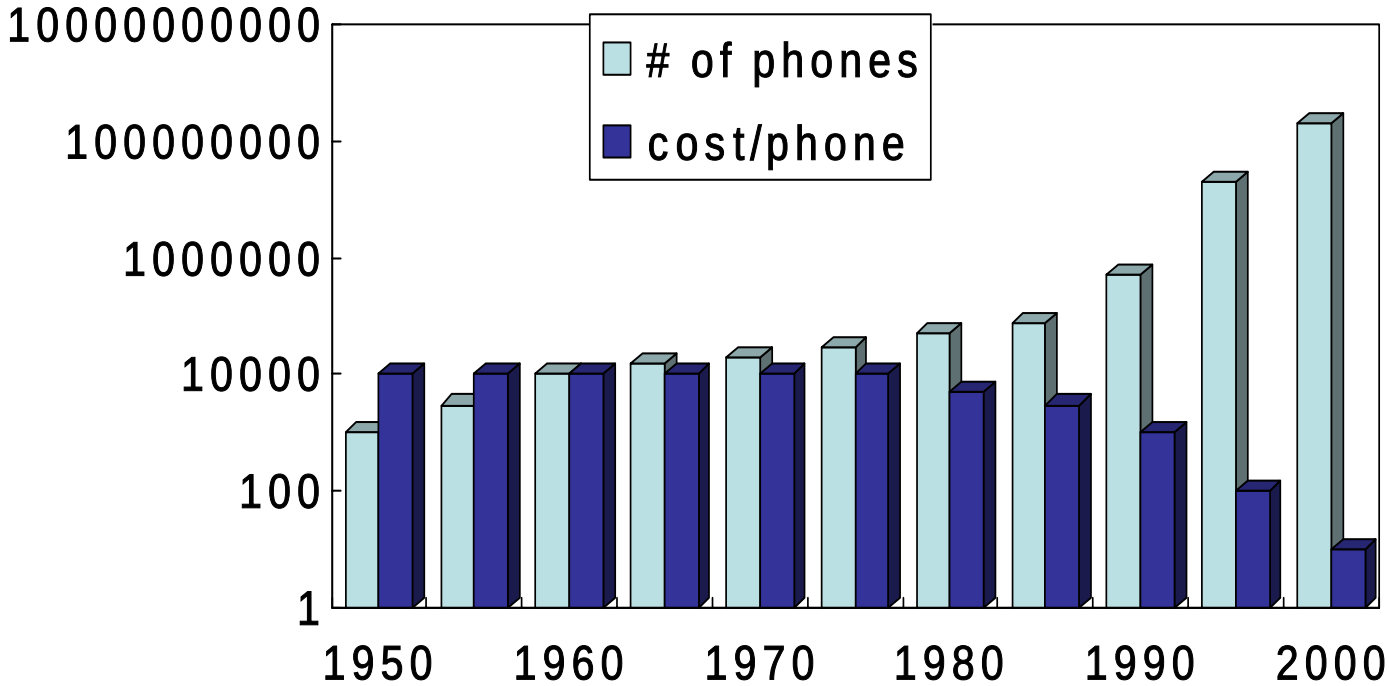
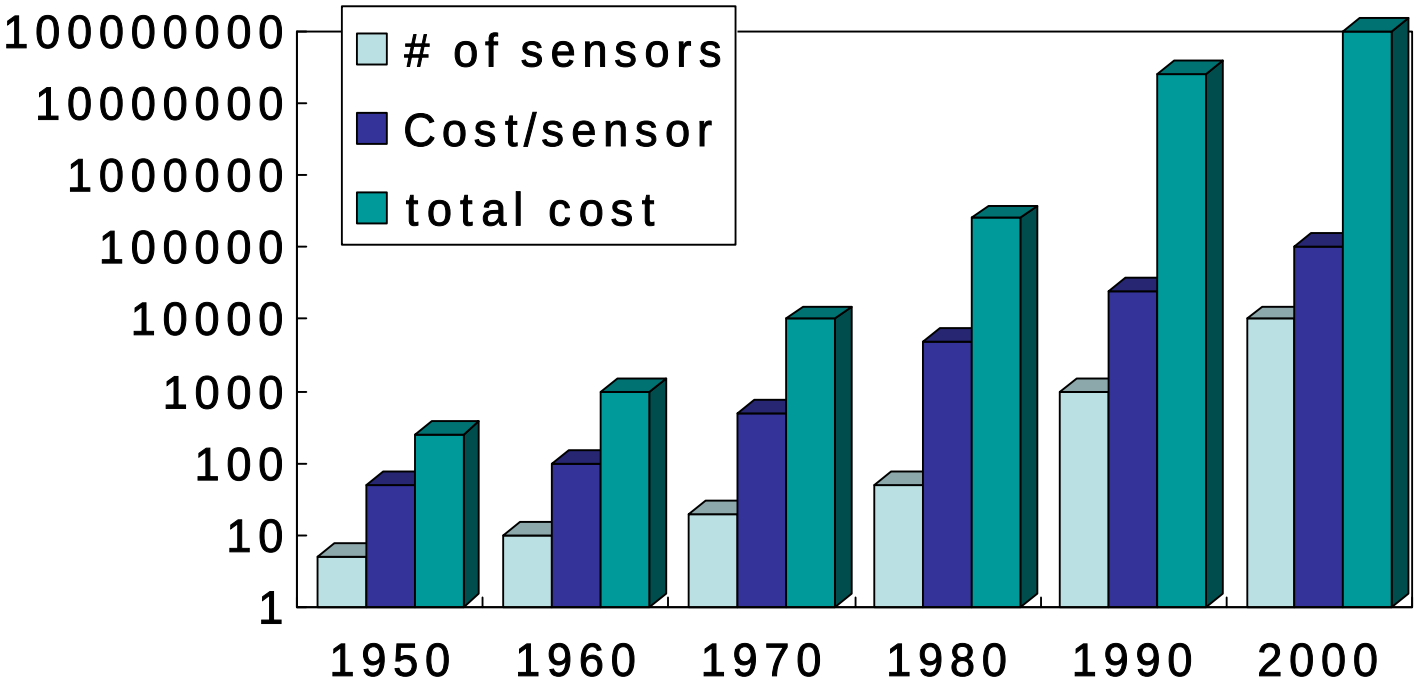


Chart Your Own Industry (flow sensor illustrated)



costs include purchase, installation, maintenance, configuration management

Moore's Law Holds the Key - Better AND Cheaper Every Year, Just Like Your Office Computer

- High Volume - can be mass produced
- Low Cost - modular, scalable components
- Renewed Markets - The same people buy over and over
- A New Market Strategy - Who will survive - DEC, IBM, Compaq

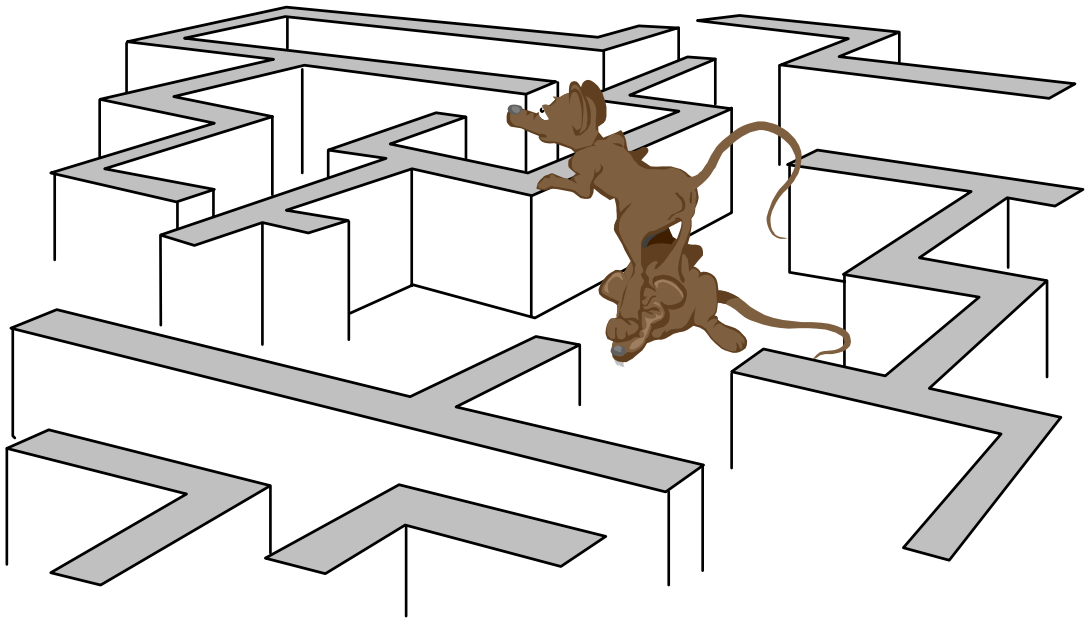
Without Renewed Markets, Volume not Sustainable

Who’s Leading the Way?

- Government? - not anymore
- Big Guys? - “We’ll wait for some small company to invent it and then we’ll buy the company.”
- Small, Agile Companies -seize the opportunity, start with niche markets, find partners

Exploiting the Coming Revolution Requires Strategic Partnerships

Merging science, technology, standards, and marketing



OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

UT-BATTELLE

Wireless Industrial Networking Alliance

You too can be a WINA!

- Directed by Dr. Robert Poor – Ember
- Members about one-third end users
- Focus on Impact not technology
- Realization and Extension of DOE-sponsored vision for industry

WINA Formation

WIRELESS
INDUSTRIAL
NETWORKING
ALLIANCE

WINA

In the spring of 2003, the Wireless Industrial Networking Alliance (WINA) was formed to promote the adoption of wireless networking technologies and practices that will help increase industrial productivity and efficiency.

Come join us – www.wina.org

WINA Charter

Charter

Wireless technology and wireless networking systems hold great promise to help U.S. (and international) industry use energy and materials more efficiently, lower systems and infrastructure costs, lower production costs, and increase productivity. Although major advances in both price and performance have occurred in wireless networking, its acceptance in the industrial sectors has been slow. WINA focuses on activities to accelerate the adoption of wireless technologies in the industrial sector.

Decisions, Decisions …

WINA

What about Zigbee?

What about 802.11/a/b/g/x?

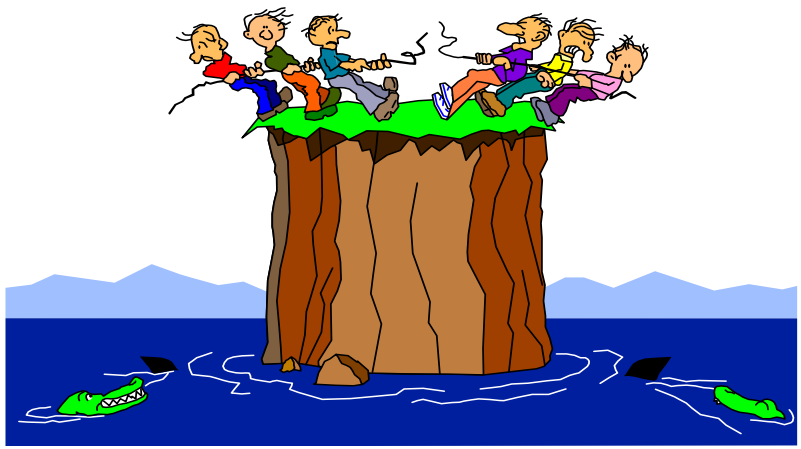
What about 802.15.4?

What about Bluetooth?

What about 1451.1/2/3/4/5?

What about UWB?

What about …?

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

- Technology is ready - driven by cellular personal/business communications
- Market is ready - $2000/ft for wires in some plants
- Are we ready? - partnerships, consortia, standards, and collaborations