

Passive Wireless Sensor Technology(PWST) Workshop Vision and Summary of Past Workshops

NASA/JSC/George Studor

May 21, 2013

Passive Wireless Sensor Workshop 2013

Comment:

**The presentation is meant is meant to be used as Reference Material
to help understand the breadth of Technology and User needs**

Agenda

- 2012 PWST Workshop Presentation
 - “Fly-by-Wireless” motivation
 - 2012 PWST Workshop Presentation Summaries – p7
- Future Topics – p41
- 2011 PWST Workshop Summary/ Attendees – p43

Background/Motivation – Why a PWST Workshop?

“Fly-by-Wireless” Vision:

To Minimize Cables and Connectors and Increase Functionality across the aerospace industry by providing reliable, lower cost, modular, and higher performance alternatives to wired data connectivity to benefit the entire vehicle/program life-cycle.

Focus Areas:

1. System engineering & integration methods to reduce cables & connectors.
2. Vehicle provisions for modularity and accessibility.
3. A “tool box” of alternatives to wired connectivity.

What it is NOT:

- A vehicle with no wires.
- Wireless-only for all control systems.

Common Motivations

Systems and Vehicles:

- **Reduce Cost/Schedule of Wired Connectivity**
- **Increase Reliability/Maintainability**
- **Increase Safety**
- **Increase Security (some more than others)**
- **Increase System Functionality**
- **Changes in System Engineering & Integration, Vehicle Architecture and Technology Development/Awareness**
- **Decrease Size, Weight and Power**

Wireless Sensors:

- **Cost - No battery and no radio costs**
- **Manufacture In Quantity – Like RFID tags**
- **Life time power – no battery replacement**
- **Safety – little or no stored power**

What Is a Passive Wireless Sensor(PWS)?

Attributes:

- No battery
- No need for scavenging power over time
- No wired connection between sensor and data acquisition unit
- Provides a sensor reading along with a unique tag id
- Can provide range information for location/orientation
- Minimum electronics – can be fabricated for extreme temperature and other environments.
- Can be imbedded in/behind structure permanently or added after manufacturing
- Multiple industries have use cases – need to bring them together to generate demand.
- Compatible with high volume production – leading to low cost per measurement point:

Generation 1	Generation 2	Generation 3	Generation 4
Wired	Motes	Active Sensor Tags	PWST?
~\$10,000 per point	~\$1,000 per point	~\$100per point	~\$10 per point

Basic Types:

- EM-coupling: Simple – very short range
- RFID-based: Antenna for scavenge power for data return – med range
- NFC-based
- SAW-based: Surface Acoustic Wave reflection(s) + Antenna
 - Longer Range, Higher Sample Rate
 - Many tags interrogated at one time

2012 Passive Wireless Sensor Technology Workshop

Purpose:

To bring Passive Wireless Sensor-Tag(PWST) technology developers, manufacturers and potential industry end-users together to understand the larger market drivers that will drive costs down and applications up. We will also discuss logical next steps.

Objectives:

- Understand various PWST technologies, actual & potential uses, and maturity.
- Assess the future applications/advantages/limitations in various industries.
- Assess what is needed for high volume production, standardization & communication.
- Precipitate individual & group “next step” thinking to further develop/apply PWSTs.
- Accumulate contacts for potential partnering activities (start at 2011 PWST)

2012 PWST Workshop Summary

NASA/JSC/George Studor

Location: La Jolla, CA

Sponsor: ISA Comm Division

Full Presentations(2012/2011) at:

**[http://www.isa.org/MSTemplate.cfm?Section=Papers_Presentations&Site=Computer_Tech__Division
&Template=/ContentManagement/MSContentDisplay.cfm&ContentID=89830](http://www.isa.org/MSTemplate.cfm?Section=Papers_Presentations&Site=Computer_Tech__Division&Template=/ContentManagement/MSContentDisplay.cfm&ContentID=89830)**

2012 PWST Workshop Agenda

Session 1:

June 6th AM

- | | | | |
|---------|-----------------------------|----------------|---|
| 8:00am | NASA/JSC/Structures SHM | George Studor | - "Passive Wireless Sensor Technology(PWST) 2012 Workshop Plan" |
| 8:30am | GE Global Research | Daniel Sexton | - "ISA107.4: Wireless sensor for turbine instrumentation working group" |
| 9:00am | United Tech Research Center | Sanjay Bajekar | - "Wireless for Aerospace Applications" |
| 9:30am | NAWCWD China Lake | Rob Pritchard | - "Naval Applications of PWST from the End-user's Perspective" |
| 10:00am | Break | | |

Session 2:

- | | | | |
|--------------|----------------------------|----------------|--|
| 10:30am | BP/chief Technology Office | Dave Lafferty | - "Passive Sensor Needs at BP" |
| 11:00am | Shell | Ron Cramer | - "Oil and Gas Integrity Monitoring" |
| 11:30am | DOT/FHWA | Fred Faridazar | - "Wireless Sensors for Structural Monitoring During Extreme Events" |
| 12:00 - 1:00 | Lunch | | |

2012 PWST Workshop Agenda

June 6th PM

Session 3:

- | | | | |
|--------|---------------------------|-----------------|---|
| 1:00pm | Rockwell Automation | Cliff Whitehead | - “Machine-to-Machine Interfaces in Factory Automation” |
| 1:30pm | Arkansas Power & Electric | John Fraley | - “High Temperature Wireless Sensor Systems” |
| 2:00pm | Yokogawa | Penny Chen | - “PWST needs at Yokogawa” |
| 2:30pm | Break | | |

Session 4:

- | | | | |
|--------|--|------------------|---|
| 3:00pm | Savannah River Nuclear Solutions - Mike Mets | | - “PWST/RFID Technology for Material Control and Accountability at the Savannah River Site” |
| 3:30pm | On-Ramp Wireless | Jake Rasweiler | - “Ultra-Link High Capacity, Long Range Low Power Technology Applications” |
| 4:00pm | VTI Instruments | Chris Gibson | - “Integrating passive wireless sensors with existing data acquisition systems” |
| 4:30pm | AVSI Project AFE73 -WAIC | Radek Zakrzewski | - The Status of Wireless Avionics Intra-Aircraft Communications |

2012 PWST Workshop Agenda

June 7th AM

Session 5:

8:00am Syntonics	Bruce Montgomery	- "Passive Wireless Sensing in a High-Multipath, High-Doppler Environment"
8:30am Albido Corp	Fred Gnadinger	- "Wireless Passive Strain Sensors Based on Surface Acoustic Wave (SAW) Principles"
9:00am Environetix	Mauricio Pereira da Cunha	- "Harsh Environment Wireless Sensor System for Monitoring Static & Rotating Components in Turbine Engines and Other Industrial Applications"
9:30am nScript	Ken Church	- "Passive Direct-write Sensors"

10:00am Break

Session 6:

10:30am RF SAW	Paul Hartmann	- "Advances in SAW devices for Sensing and RFID Applications"
11:00am ASRDC	Jackie Hines	- "PWST SAW - Sensor System"
11:30am Univ of Cntl Florida	Don Malocha	- "SAW PWST: 915 Mhz Sensor System and Demonstrations"
12:00 - 1:00pm Lunch		

2012 PWST Workshop Agenda

June 7th PM

Session 7:

- | | | | |
|--------|--------------------------|-----------------|---|
| 1:00pm | Carinthian Tech Research | Heimo Mueller | - "SAW Sensors: Explore New Measurement Horizons" |
| 1:30pm | Vectron | Sabah Sabah | - "Vectron Wireless Temperature Monitoring Solutions" |
| 2:00pm | MIT Auto-ID Lab | Isaac Ehrenberg | - "RFID Tag Antenna-Based Sensing" |
| 2:30pm | Break | | |

Session 8:

- | | | | |
|--------|------------------------------|------------------|--|
| 3:00pm | Tag Array | Kourosh Pahlavan | - "Passive UWB: long range, low cost and precise location" |
| 3:30pm | MaXentric | Don Kimball | - "60 GHz Comm, RFID moving to PWST" |
| 4:00pm | Wireless Sensor Technologies | John Conkle | - "Wireless Sensors for Gas Turbine Engines" |
| 4:30 | Aerojet | Scott Hyde | "A System Engineering Simulation Tool and Data Base Proposal for Optimizing the Application of Wireless Sensors" |
| 5:00pm | Workshop Closing | George Studor | - Discussion, Conclusions |

Some History of Surface Acoustic Wave (SAW)

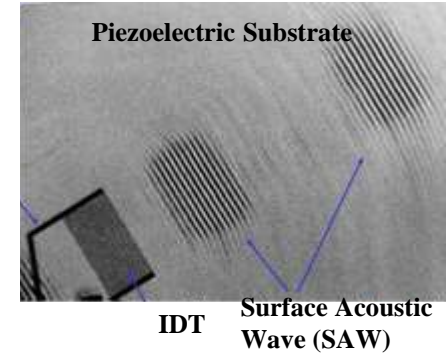
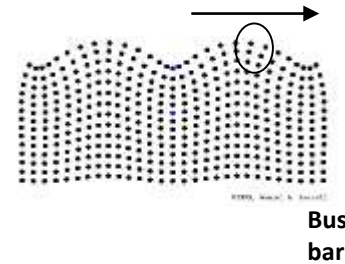
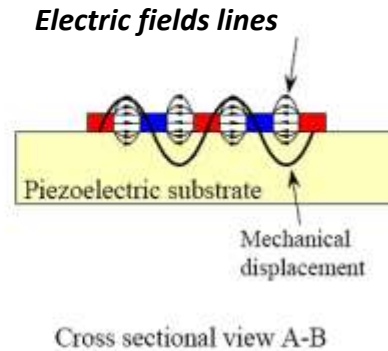
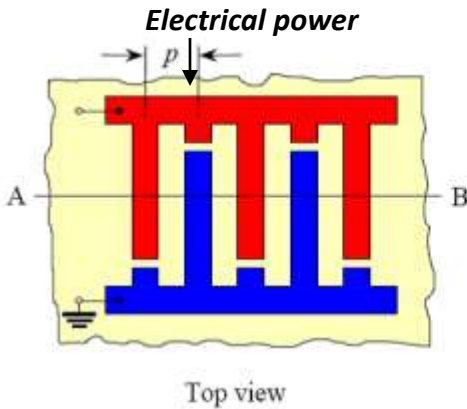
– courtesy Sabah Sabah, Vectron - Sengenuity

- 1880** Piezoelectricity, discovered by Jacques and Pierre Curie in quartz crystals`
- 1885** Lord Rayleigh characterizes Surface Acoustic Waves (earth quake)
- 1889** First interdigital electrode design, “Electric condenser” U.S. patent
Nikole Tesla
- 1965** First Interdigital Transducer (IDT’s) on a polished piezoelectric plate
(White / Voltmer)
- 1970** First applications: pulse expansion and compression in radar systems
- 1985** SAW filters replace LC filter in TVs and VCRs
- 1990** SAW filters allow for miniaturization of mobile phones
- 1990s** Passive Wireless SAW Sensors begin making their presence known.

Surface Acoustic Wave Technology Review

- Courtesy Sabah Sabah, Vectron-Sengenuity

Wave propagation ≈ 3000 [m/s]



Interdigital Transducer (IDT) as

- transmitter: converse piezoelectric effect \Rightarrow electric RF field generates SAW
 - receiver: piezoelectric effect \Rightarrow SAW generates electric RF field
- In both cases maximum coupling strength for $\lambda_{SAW} = v_{SAW} / f = 2 \cdot p$ ($\sim 1 \dots 10 \mu\text{m}$)

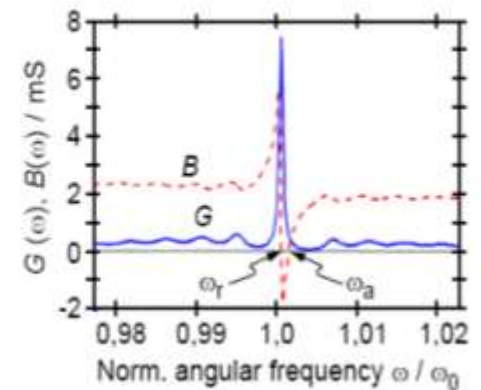
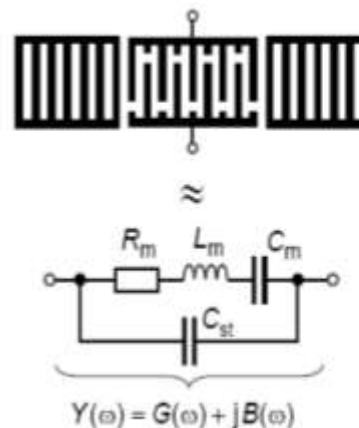
SAW - Rayleigh Wave propagation

$$v_{SAW} = f_{SAW} \times \lambda \longrightarrow f_{SAW}(T, Cut, \dots)$$

SAW Resonator as Temperature Sensor

First Fact: Surface wave velocities are temperature dependent and are determined by the orientation and type of crystalline material used to fabricate the sensor.

Second Fact: Very low power is required to excite the acoustic wave – Energy Harvesting (EM-Wave)



1.2 ISA107.4 Wireless Sensors for Turbine Instrumentation Working Group

Daniel Sexton - RF Instrumentation and Systems Laboratory
GE Global Research Niskayuna, NY - sextonda@ge.com

Scope: Wireless Instrumentation for Turbine Engine Test Cell :

Scalable architectures, system components, protocols, secure reliable wireless connectivity for test cell-based, multi-tier, active data transmission and passive wireless sensing, harsh environments

Basis for **future on-wing** engine health monitoring or control systems.

Purpose:

- Define Wireless interfaces, physical and RF environment
- Develop Multi-vendor interoperability support for various applications
- Develop co-existence support – possibly with other network standards

Future Activities:

- Technology Assessment and Gap Analysis
- Develop Needs Areas for Standards and Best Practices
- Users/Develop community develops Documents

Benefits of Creating a Standard:

1. System simplification
2. Compatibility between vendor equipment
3. Consistency in measurements
4. Reduced testing time and costs

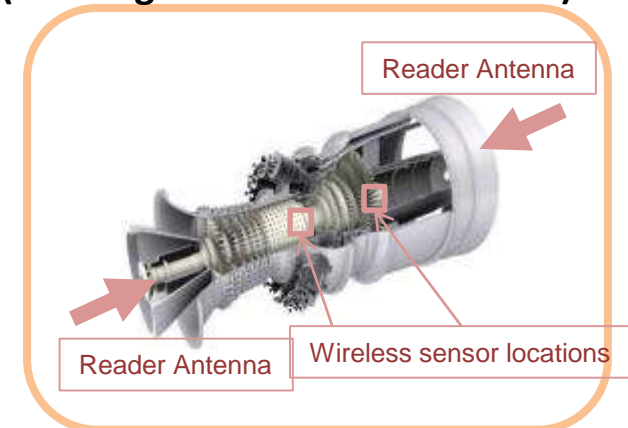


Wires are
a Common Problem

Level 0 - Engine (On/In-Engine – 1 ft)



Level 1 – Test Cell (Interrogators & Network – 50ft)



1.3 Wireless Technology for Aerospace Applications

Sanjay Bejekal – UTRC East Hartford, Conn. - BajekaS@utrc.utc.com

Wireless Needs:

- Long term health monitoring of the airframe and structures
- Short term health monitoring of targeted/specific issues using peel & stick sensors
- Security – resistance to intentional RF interference & protection from eavesdropping

Countermeasures:

- Frequency Hopping systems over large frequency bands (>500 MHz)
- Antenna Gain pattern (fixed and adaptive phased arrays)
- Adaptive Tx power control (burn through)
- Coding
- Novel Technologies (Magnetic comm, Free space optics, Higher freq > 40 GHz)
 - Mag comm can have 3 orders of magnitude less susceptibility to eavesdropping vs RF

Energy Harvesting:

- Combine sources – PV, Mechanical, Remote RF
- Power Storage – Ultra Capacitors or thin film rechargeable – Printed Zinc batteries

System Integration:

- Communication Range
- Protocols: Physical and Software Stacks

Passive Wireless Potential: Low Cost - Short & Long Term Health Monitoring, Security

1.4 Naval Applications of PWST from the End-user's Perspective

Robert Pritchard – Navair, NAWCWD China Lake robert.w.pritchard@navy.mil

Potential Uses of PWST:

- **Condition-based Maintenance**
 - Energy Autonomy – e.g. thermal scavenging for external skin sensors
 - Event Monitoring – e.g. munitions comm link integrity –voltage drop at umbilical
 - Energy Harvesting – e.g. helicopter blade damage, pitch link dynamic loads
- **Health Management/Monitoring and Inventory Management**
 - Ext Environment where munitions have been -Temp, Humidity, Vib, Shock, Chem, etc
 - Internal Conditions – Temp, Press, Humid, Stress/Strain, Chem, Corrosion, Leak, etc.
 - Detection, Identification, Location, Remote Sensing(Encryption for Security)
- **Anti-Tampering(DOD and DHS)**
 - disable LIVE/DUD munitions – remotely commanded or self-destruct
 - sense tampering
- **Power Systems:** Improve Isp, Mass Fraction, Cost, Uncertainty, Reliability
 - Novel Ocean(Thermal) Powered Underwater Vehicle – NASA/JPL
 - Energy Mgmt/System Control: Press, Temp, Power, RPM, Fuel Flow, Vol, Haz Gas
- **JANNAF sponsored Space and Military Wireless Sensor Systems Workshops**
 - Co-chairs: Pritchard and Dr. Tim Miller/AFRL - EAFB
- **OPNAV Ordnance RFID Implementation Policy(Aug 2008)**
- **List of Challenges, Approaches, Critical Measurements, “Low Hanging Fruit”**
- **Desirable Wireless Sensor Features and Approaches**

2.1 Passive Sensor Needs at BP

Dave Lafferty – Chief Technology Office - david.lafferty@bp.com

BP: Worldwide – Down-hole, Transport, Refine, Market – 80,000 employees

Fundamentals of Sensing: Deploy > Measure > Communicate > Take Action

PWST Applications that work/should work:

- Rotational Equip/ Shafts, Flames, Cement, Turbine Tips, Gas Detection,

Specific PWST Use Cases needing solutions:

- Corrosion Under Insulation (Indicators – Moisture, Humidity, Ph)
- Down-hole Cement between casing and rock(level, temp, strain)

Potential PWST Use Cases:

- Difficult to inspect locations
- Operating in hostile environments
- Extend the service life of assets beyond their designed life
- Reducing and managing risk via measuring the environment

2.2 Oil and Gas Asset Integrity Monitoring: the Needs and Challenges

Ron Cramer - Ronald.Cramer@shell.com

- Safety, Sustainability, Security, Ubiquitous Sensors
- Remote Sensing
- Health Care
- MEMS: versatile, powerful, reliable, cheap
- Measure any variable under multiple conditions
- Bring Cost Down, Performance Up
- Sub-Sea Integrity and Leak Detection

Approach

- Prior applications in other industries
- Conversion to O&G – Algorithms to convert signal to info
- Integration into a functional system
- Partnership with technology suppliers: industry & academia
- Quick route to failure – Game-changer

Sensor Elements

- MEMS for Vibration, acoustic detection, temperature
- SONAR, RADAR
- Magnetic detectors
- Ultrasonic

Common Systems

- Existing and emerging sensors
- Power generation and storage
- Signal conditioning and transmission
- Networking
- System architecture
- Data analysis

Systems

- Autonomous underwater vehicle
- Fixed subsea sensor networks
- Fixed acoustic/temperature/chemical/US sensors network onshore
- Versatile and expandable framework

2.3 Wireless Sensor Monitoring of Structures During Extreme Events

Fred Faridazar - Turner-Fairbank Highway Research Center (TFHRC) McLean, VA fred.faridazar@dot.gov
<http://www.fhwa.dot.gov/advancedresearch/index.cfm>

Exploratory Advanced Research Programs

David.Kuehn@dot.gov; terry.halkyard@dot.gov

- **Integrated Highway System Concepts**
 - International approaches: vehicle automation
- **Nano-scale Research**
 - Measurement of dispersion
- **Human Behavior and Travel Choices**
 - Dynamic ridesharing
 - Vision assisted technologies
- **Energy and Resource Conservation**
 - Sustainable underground structures
 - Electric vehicle commercialization
- **Information Sciences**
 - Video decoding, feature extraction
 - Probabilistic record linkage (data mining)
- **Breakthroughs in Materials Science**
 - “Self-healing” materials
 - Cement hydration kinetics
- **Technology for Assessing Performance**
 - “Smart balls” for autonomous culvert inspection
 - Pressure sensitive paints for aerodynamic testing
 - Remote sensing for environmental processes

Infrastructure

- Pavement Materials
- Pavement Design and Construction
- Long Term Pavement Performance
- Bridge and Foundation Engineering
- Hazard Mitigation
 - Flood, Seismic, etc.
- Infrastructure Management

Operations and Safety - david.yang@dot.gov

www.fhwa.dot.gov/research/tfhrc/programs/safety

- Human Factors
- Intersections
- Pedestrian & Bicycles
- Roadway Departure
- Speed Management
- Comprehensive Safety – Predicting Societal and
 - Complex Natural Systems



3.1 Machine-to-Machine Interfaces in Factory Automation

Cliff Whitehead – Rockwell Automation - cjwhiteheadjr@ra.rockwell.com

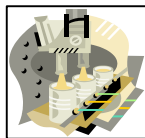
What if machines could report: their “health”?



- vibration of rotating equipment
- motor winding temperature
- oil or lubricant temperature or quality

their production?

- good parts or batches
- substandard parts or batches
- scrap or waste
- consumable materials used
- energy or utilities consumed



their “inventory”?

mechanical components
electrical components – including those
inside control cabinets
changeover parts
spare part requirements



their “location”?

work cell name
work cell unique identity
physical location inside the plant
operational status
safety status
upstream and downstream interfaces



Wireless in Automation Today:

Most prevalent in higher latency, non-deterministic monitoring applications

- Temperature, Flow, Vibration

Attractiveness stems from:

- Standard interfaces to well-established industrial network protocols (e.g., EtherNet/IP)
- Field-based devices for wireless interrogation and data translation

Challenges arise when speed is important

Summary:

Passive wireless sensing has promise for Factory Automation applications

The challenge is competing for mindshare with other wired and wireless technologies, and “the way it’s always been done”

Standards play a role by exposing user and technical requirements that can challenge our industry to advance our efforts to meet those requirements that are currently unmet is important

3.2 High Temperature Wireless Systems

John R. Fraley/Byron Western – Arkansas Power Electronics - jfraley@APEI.net

Why High Temperature Wireless?

- Data Collection from Rotating Components
- Increased SNR from Sensors
- Reduced Weight from Cabling
- Distributed Systems
- Improved Process Controls

Technical:

Enabling Technologies:

HTSOL: rated 225 °C and operable to 300 °C.

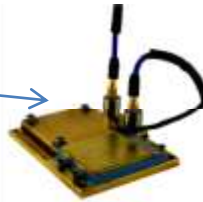
Wide Band Gap semiconductors up to 600 °C

Low Temp Co-fired Ceramic – multi-layer circuit

Energy harvesting Vibr, RF, TEG

Bearing Sensor Design

Blade Sensor Design

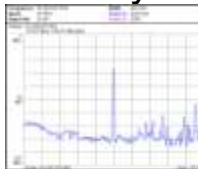


Testing Facilities:

Bearing Tests-AFRL



Spin Tests-Aerodyne



Overview:

Motivation

Applications:

Aerospace: HM for Bearings & Gearbox
Distributed Engine Controls

Geological Exploration: Temp, Press, Flow
Wireless Drill Head Control

Power Generation: Turbine Blades, Condition-
based maintenance, Smart Turbine Control

Industrial Processes: Manufacturing and
Chemical Process Monitoring



What's Next?

- Energy Harvester & Transmitter in Single Package
- HTSOL and SiC ASICs
- Integrated Sensors
- Improved Power Conditioning



3.3 PWST Needs At Yokogawa

Penny Chen – Yokogawa Corporation of America -
penny.chen@us.yokogawa.com

Future PWST Measurement Needs:

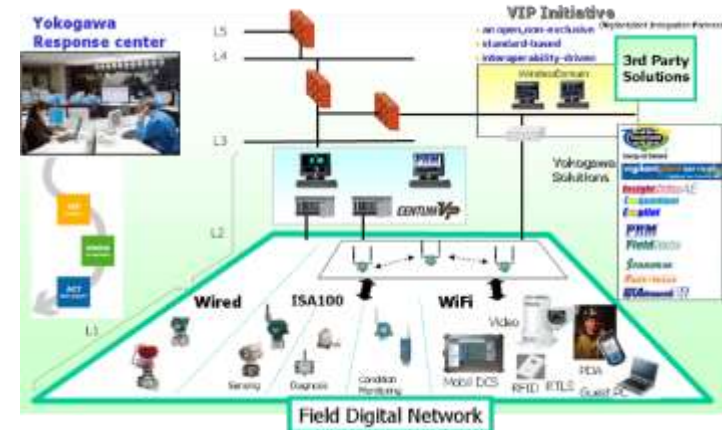
Corrosion
 Humidity
 Optical, Infrared
 Pressure, Tension
 Gas, CO2, Smell
 Vibration
 Acoustic Emission
 Temperature
 PH, Liquid Level, Flow
 Location, Proximity
 Valve position

PWST Challenges:

- Industrial environment :
- Life reliability & stability
- System scalability
- Robust, secure wireless
- Large Data Volume
- Low initial entry cost
- Variety of sensor types
- Coexistence w/wireless
- Open standards

Vigilantplant:

See Clearly
 Know in Advance,
 Act with Agility



	Requirements	Key technologies	Our Solutions
4:Application	<ul style="list-style-type: none"> -Full Automation -Full Navigation -Opt. Performance 	<ul style="list-style-type: none"> -Simulation -Advanced HMI (3D, MM, VR) -Production Traceability 	<ul style="list-style-type: none"> - Scenario-based Operation - Augmented Reality - Predictive Navigation - Advanced Optimization
3:Control	<ul style="list-style-type: none"> - Robustness - Integrity - Flexibility 	<ul style="list-style-type: none"> - Asynchronous Control Algorithm - Predictive control 	<ul style="list-style-type: none"> -palc-PID for continues control block -Shadow function block -APC, Opt. controller
2:Connection	<ul style="list-style-type: none"> - Reliability, Robust - Deterministic - Min. Latency, Jitter - Scalability - Interoperability 	<ul style="list-style-type: none"> -Full Redundancy (Duo cast, Gateway) - TDMA scheduling - FB communication 	<ul style="list-style-type: none"> - Redundant Gateway - Star topology by Duo cast / dual BBR -MM comm. On BBR - Reliable/long range Radio Comm.
1:Device	<ul style="list-style-type: none"> - Long Battery life - Growing Intelligent - Function block 	<ul style="list-style-type: none"> - Higher battery Capacity - Low power consumption -Energy Harvesting -Diagnostics -Intelligent Application 	<ul style="list-style-type: none"> -Standard battery case/pack with long life -Zone1 replaceable battery -Extending antenna cable -High gain antenna

4.1 Passive Wireless Sensor Technology for SRS Material Storage

Michael Mets - Process Controls and Automation Technology,
Savannah River Nuclear Solutions, LLC - michael.mets@srs.gov

**SRNS: M&O Contractor, DOE Savannah River Site, Aiken SC Nuclear
Materials Storage Mission:**

- Handling, Storage & Surveillance of Plutonium and other NM

Challenges for RF Systems:

Regulatory Environment

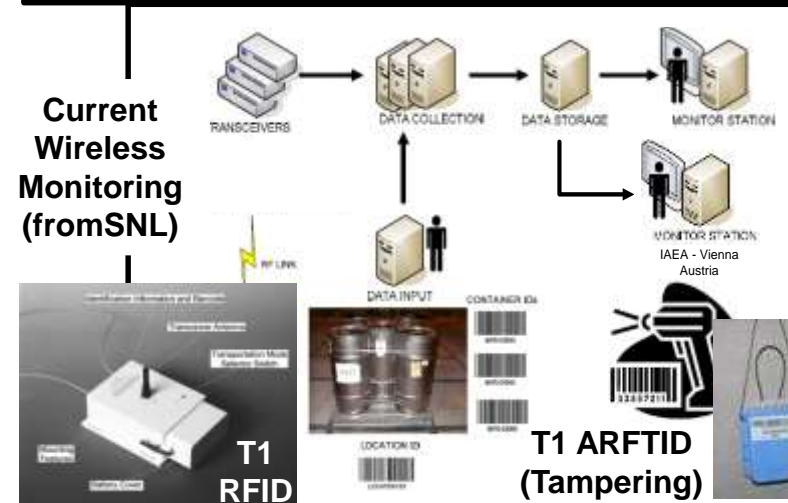
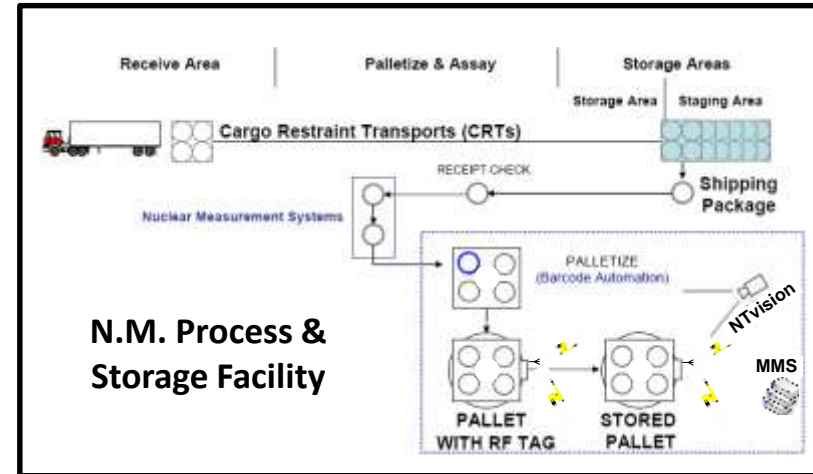
Spectrum Supportability Auth.
Procurement Authorization
Risk Assessment
Security and Test Plans

Physical Environment

Reflective & Attenuating Surfaces
Various Sources of EMI
Coexistence with Legacy Equip.
Harsh Environmental Conditions
Significant Radiation Levels

Passive Wireless Sensor Wish List

- Low cost <\$500
- -40° to +85° C ambient ops
- RF low power
- Security (AES 128-bit encryption) - NIST
- Authentication (AES 128-bit CMAC) - NIST
- Store messages locally
- Fiber optic loop (up to 50m)
- Remote data collection
- Real time clock
- Tamper detection
- Radiation Monitoring and Reporting
- Temperature & Humidity Monitoring



NEW: Remotely Monitored Seal Array(RMSA)
- 902MHz - Sandia N. Lab



ARG-US RFID
- Argonne N Lab



4.2 Introduction to On-Ramp Wireless

Jake Rasweiler – On-Ramp Wireless - jake.rasweiler@onrampwireless.com

“Ultra-Link” Technology

Applications:

- Utilities, Smart Grid
- Process Industries
- Personnel and Asset Tracking
- Critical Infrastructure

System Goals:

- Lowest Total Cost of Ownership
- Best Coverage in Industry
- Connectivity in Hardest to Reach Areas
- Immense Capacity
- Seamless Support for Battery Devices
- Robust Operation in Noisy ISM Band

Performance Metrics:

Coverage
Capacity
Coexistence
Power
Security
Cost
Deploy Schedule?

Application Type	Data/Day	#Nodes per AP*
Electric AMI Meter	2.4 KB	20,000+
Hazardous Alarms	100 bytes	100,000+
Pressure Sensor	100 bytes	100,000+
Cathodic Protection	100 bytes	100,000+

Installations: stationary during RF Ops, underground, in containers or Indoors, wide area coverage

AP Simultaneous Up & Down-link

AP Up-Link of User Data:

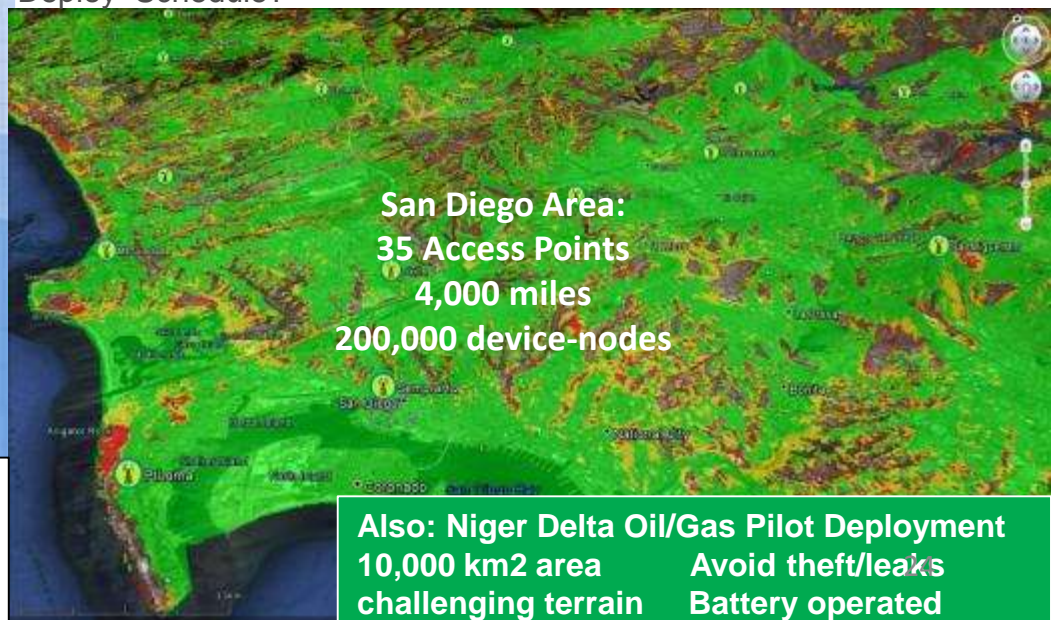
- 100 Mbytes/day
- 2,000 Nodes simultaneously

AP Down-link of User Data:

- Unicast: 72 MBytes/day
- Multi-cast: 144 kBytes/day
- Broadcast: 72 kBytes/day

Device Nodes:

-90 kBytes/day - 2.7% throughput for Electric meter – DSSS works fine



Also: Niger Delta Oil/Gas Pilot Deployment
10,000 km2 area Avoid theft/leaks
challenging terrain Battery operated

DSSS: Spreading factors up to 8192 chips/symbol
gets up to **39 dB of processing gain**
Receiver sensitivity is -133 dBm on downlink
-142 dBm on uplink

4.3 Integrating Wireless Sensors with Existing Data Acquisition Systems

Chris Gibson –VTI Instruments, Irvine CA - cgibson@vtiinstruments.com

What is important to End Users?

(Wireless Opportunities in Red - Bold)

Gen Purpose/High Speed Data Acquisition

- Cost/channel
- Accuracy
- **Ease of Use**
- **Quick test setup and teardown**
- Ability to distribute across large area
- Turnkey software, or min development effort
- Software tools to roll their own application
- Data processing done post test
- Continuous sampling important (no gaps)

Modal Ground Vibration Testing

- Distribute the measurements close to the structure
- **Cables add mass and damping, I need to manage this**
- Simultaneous sampling -eliminate channel/channel phase skew
- The ability to move lots of data is very important
- Turnkey software is historically required
- Data is analyzed in the frequency domain
- Move raw data and have the PC do the analysis/processing

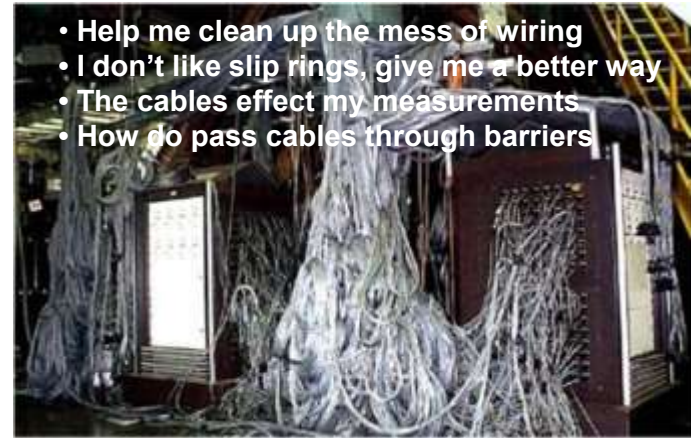
Rotational Machinery and Order Analysis

(Turbine Generators, Drive Train, Transmissions, Windmills)

- Repeatability of measurements is a must
- High performance Tachometer inputs simply setup
- **I need to measure rotating mass**
- Data will be re-sampled for order domain analysis
- Phase angle/sampling , Tach accuracy important for balance ops
- Turn key software solutions are desired
- Distributed Sensing
- Software tools that they can use to roll their own application

Typical VTI Test Sites

- Jet engine Test Cells
- Rocket engine Test Cells
- White Good Manufacturers
- General Automotive Testing
- Battery/Solar Cell Testing



- Help me clean up the mess of wiring
- I don't like slip rings, give me a better way
- The cables effect my measurements
- How do pass cables through barriers

Static Structural and Fatigue:

- **The ability to place the instruments close to the structure to minimize cable lengths**
- Synchronization for improved data understanding in the event of a failure
- Front end configuration flexibility, support multiple transducer types (load, strain, pressure, displacement)
- **Scalability is critical - these can become very large tests**
- Turnkey software is preferred, ease of use
- **Help me manage channels for large test configurations**

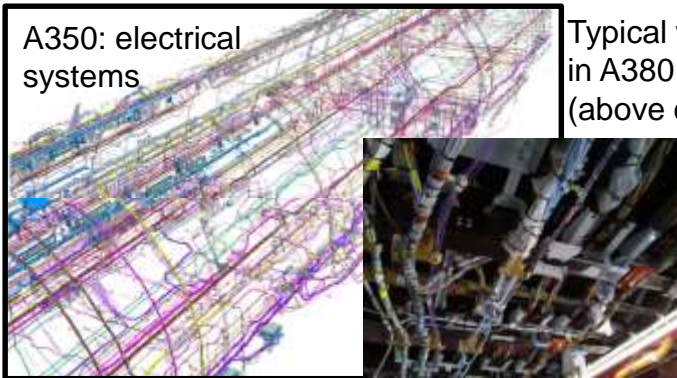
Temperature Testing/Test Cells

- Repeatability of measurements is a premium
- Temperature accuracy
- **Easy connectivity, mini-TC simplifies setup**
- OTD shows failed channels before critical testing
- Measurement stability, some tests last for a long time
- Distributed measurements ease setup and reduce noise
- Real time limit checking with alarm or shutdown capability
- Software tools that they can use to roll their own application

4.4 Protected Spectrum for Wireless Avionics Intra-Communications

Radek Zakrzewski – AVSI Project AFE73 Chair - radek.zakrzewski@goodrich.com

A350: electrical systems



Typical wiring installation in A380 crown area (above ceiling panels)

About 30% of wiring can be potentially substituted by wireless

A380-800 wiring:

- Total wire count: ~100 000
- Total wire length: 470 km
- Total weight of wires: 5 700 kg
- Add 30% more for **wire mounting**

Motivation:

Reconfigurability: Efficient cabin or other changes/upgrades(e.g. Wireless – relocatable-Oxygen Supply Unit)

Safety: Dissimilar or Added redundancy, Fewer mechanical failures

Efficiency/Environmental: Less fuel burned due to reduced weight

Reliability: reduce aging wiring, data for aging aircraft

Challenge: Obtain Protected RF Spectrum World-wide needed for aircraft OEMs to install RF systems
(License-free – ISM – bands not suitable for safety-critical uses)

Aerospace Vehicle System Institute(AVSI) Consortium – www.avsi.aero – David Redman

WAIC – Wireless Avionics Intra-Communications – On-board, not air-to-ground, air-to-air, air-to-space

Project AFE73 – began in 2008 – **Members:** Airbus, BAE Systems, Boeing, Bombardier, Embraer, Goodrich, **Goals:** Gulfstream, GE Aviation, Honeywell, NASA, Sikorsky

- Develop Technical justification and broad support for Protected Spectrum request - ITU-R
- Receive Protected Frequency for WAIC systems world-wide at World Radiocommunications Conference

Progress: **WRC-12 (Feb 2012) adopted and Agenda Item for WAIC, WRC-15 will vote on proposal in 2015**

ITU-R M.2197 Report: http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2197-2010-PDF-E.pdf

WRC15 Agenda Item: http://legacy.icao.int/anb/panels/acp/wg/f/wgf26/ACP-WGF26-WP13_WAIC%20AI%201.17%20draft.doc

Next: Detailed Sharing Studies must be accomplished in preparation for 2015.

5.1 “Passive Wireless Sensing in a High-Multipath, High-Doppler Environment”

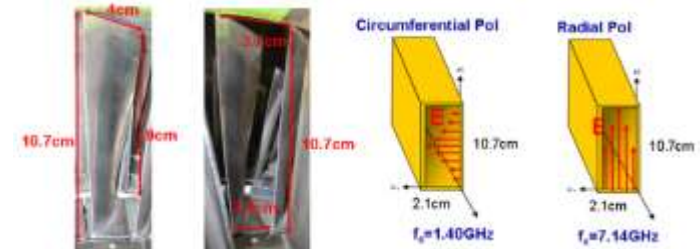
Bruce Montgomery – Pres. Syntonics Corp - Bruce.Montgomery@syntonicscorp.com

RF Propagation in Jet Engines:



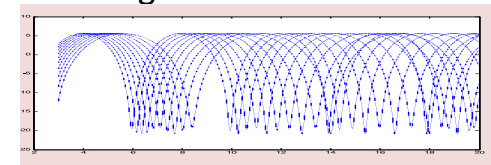
RF Transmission Testing:

- GE CF6-50 at WPAFB
- Small: GD F-16 engine, Large Boeing 747 engine
- Circular Polarization and Radial Polarization
- Signal loss can be less than in free space's $1 \div R^2$
- Signal Energy is spread out in time: initial and reflections
- Investigated EM “Windows”
- Multiple reflection time corresponds to 3x compressor size
- Time domain: Discerned Individual stages, not blades
- Internal compressor propagation is axial, not circumferential or spiral
- “Cutoff” frequency – for F16, 30db losses below 5.2 GHz



RF Modeling:

- Inserted “scatterers” at several points between transmitter-receiver
- Added waveguides to Model

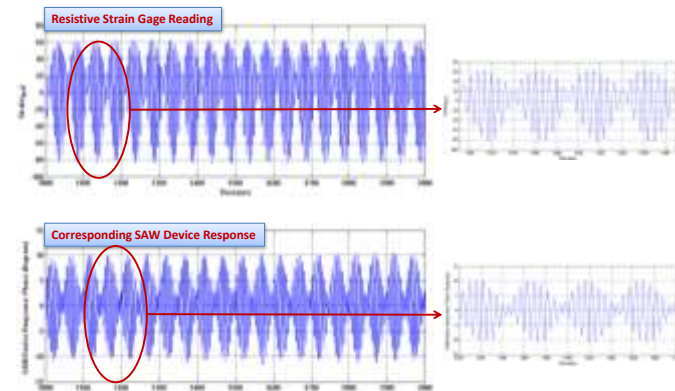
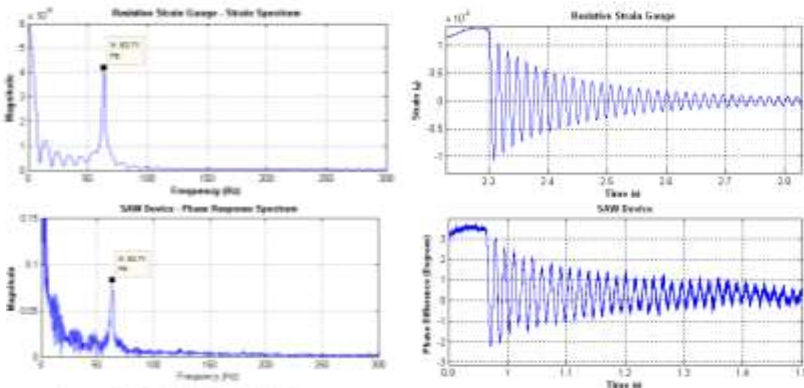


RF Passive Sensor Testing:

SAW device and resistive strain gauge Measurements the same

- Cantilever Strain Measurements

- Harmonically Driven



5.2 “Wireless Passive Strain Sensors Based on Surface Acoustic Wave (SAW) Principles”

Fred Gnadinger – Pres&CEO Albido Corp - fred@gnadinger.com; www.albido.com

Navy STTR Program
ONR COTR – Scott Coombes

Albido Passive Wireless SAW Sensors

Coded

Large bandwidth, high speed

Large read range

Small, rugged, cheap

Noise tolerant, no cross sensitivity

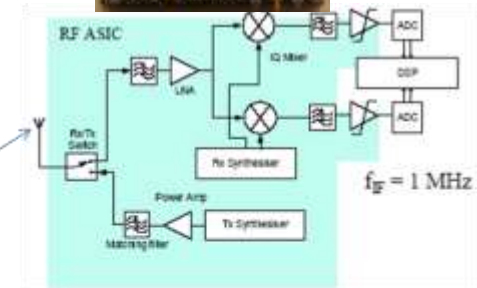
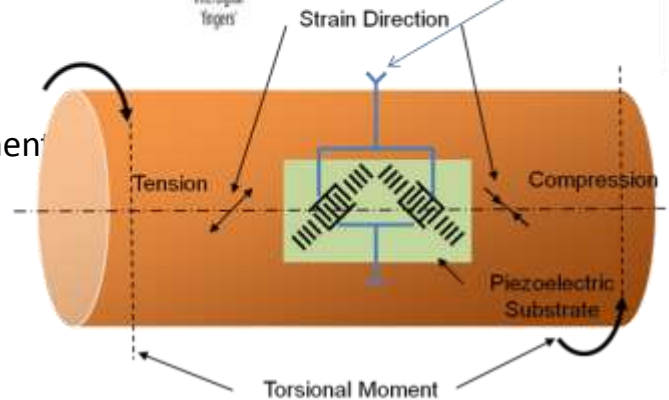
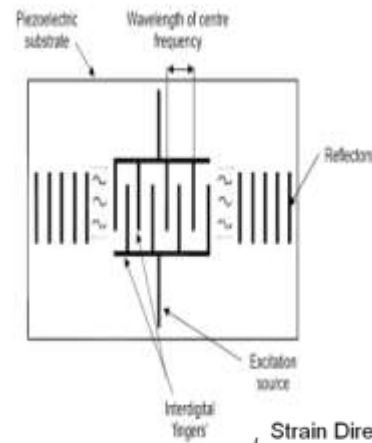
Low loss and variable frequency

Radiation hard for space applications

Physical, chemical and biological parameters

Wide temperature range and harsh environment

- new temp compensation method

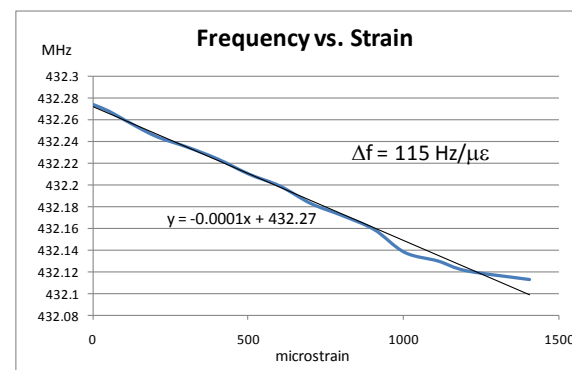
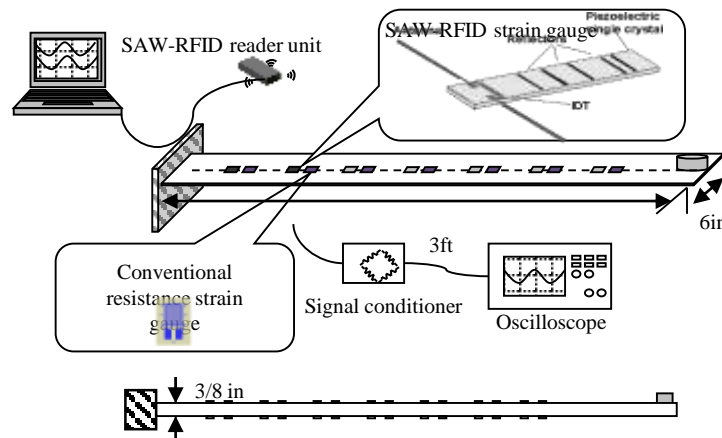


Reader



1cm x 1cm
Strain Sensor

Cantilever Strain Test:



5.3 “Wireless Microwave Acoustic Sensor Systems for Harsh Environments”

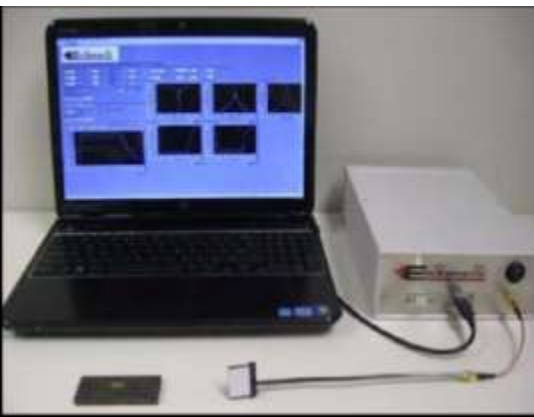
Mauricio Pierera da Cunha –Environetx- mdacunha@environetix.com www.environetix.com

Environetix Passive Wireless SAW Sensors

- Stable and reliable operation up to 900oC (1650oF)
- Wireless RF interrogator electronics
- Custom installation on rotating or static parts
- User-friendly data output on laptop PC
- Proprietary sensor packaging and attachment
- Multiple strain and temp sensors - integrated RF antennas
- Dyn Strain, pressure, corrosion , pressure sensors in work
- RF Frequency: 100MHz to 1GHz depending on need
- LANGASITE LA3GA5SIO14 Piezoelectric crystal
 - Stable up to 1400oC - Thermal shock resistant

Demo s at Power Plants, Furnaces, Engine Exhausts
- up to 1200oC (2200oF)

EVHT-100 for multiple
Temperature Sensors



temperature range:
accuracy:
resolution:
long term drift:
operating life:
insensitivity to press:
operating frequency:
sampling rate:
rotation:

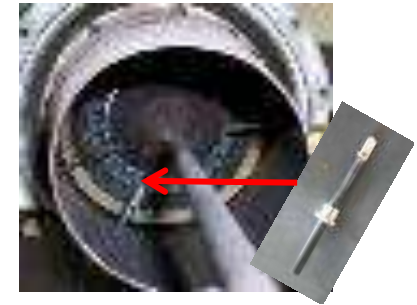
150oC (300oF) to 900oC (1650oF)
±10oC over full range
within ± 5oC
< 1oC / 150 hours
> 500 hours
0 to 750 psi with < 1oC error
100 MHz to 1 GHz
1 Hz to 100 kHz
up to 53,000g's



90,000rpm
53,000 G



TMC85-1



ARMFIELD CM-4



GE CT7 / T700



JETCAT P-70 & P-80



5.4 “Passive Direct-write Sensors”

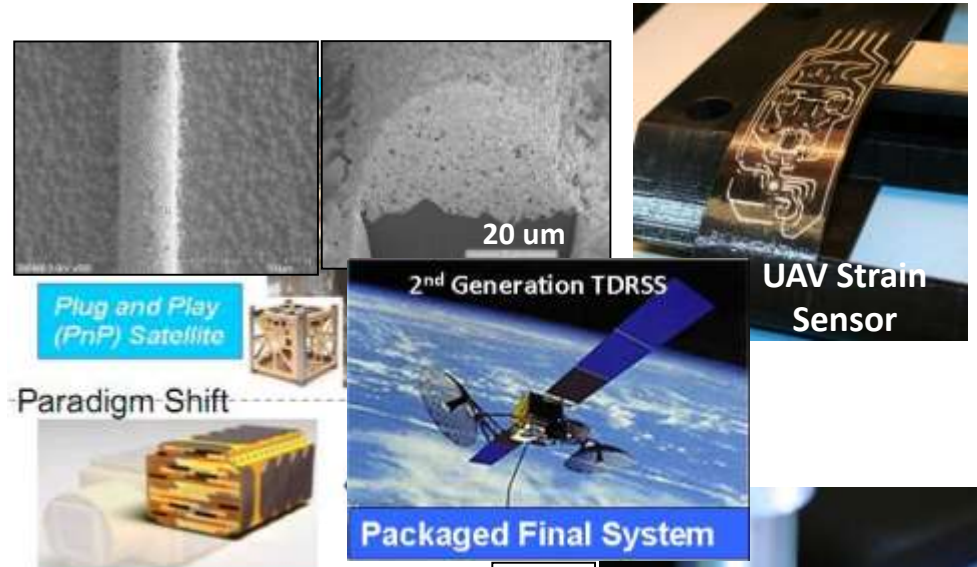
Mike Newton – nScript- mNewton@nscriptinc.com - www.nscriptinc.com

Printed Electronics + 3D Additive Manufacturing = Direct Print Additive Manufacturing

Print what you can....place what you can't.

Micro-Dispensing/direct printing:

- High speed
- As fast as 500mm/sec.
- Wide range of material choice:
- Viscosity from 1cps to >1 million cps.
- Many Types of materials
- Capability of high resolution and accuracy
- Pico-liter level column control
- Line as small as 20um, dot as small as 75um.



Applications:

- 2nd Generation TDRSS
- Print and Play Monolithic Satellite
- UAV monolithic strain sensor
- Magnetometer
- Vibration Sensor
- Electronic Circuits
- Solar Cell Mfg
- Metal loaded silicone
- **Passive Wireless Sensors??**

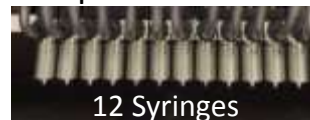
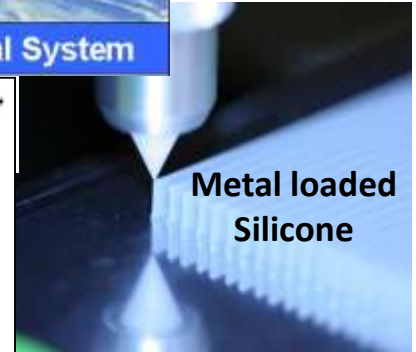
3D Print n Play Monolithic Satellite

Mixture, by volume:
25% DSM Somos 11122
75% Ceramic powder

Syringe for
Loading,
mixing,
storing,
dispensing



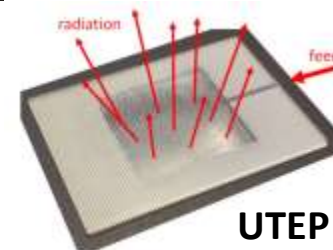
Metal loaded
Silicone



12 Syringes



Solar Cells



UTEP
Antenna



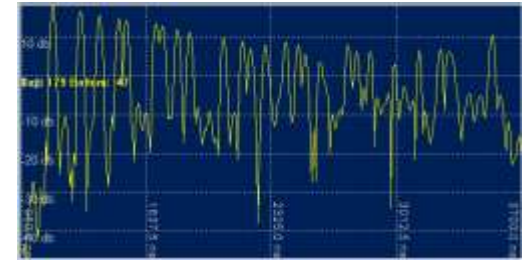
USF
30

6.1 “Advances in SAW Devices for Sensing and RFID Applications”

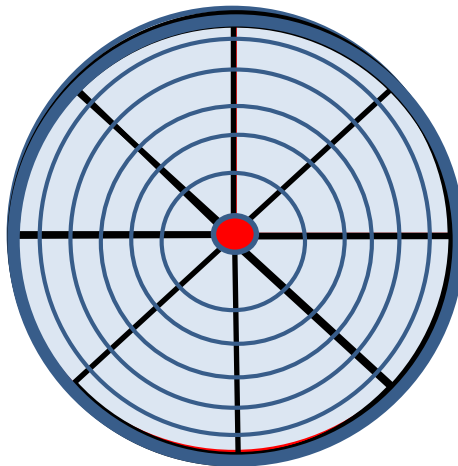
Paul Hartman – RFSAW Inc. -phartmann@rfsaw.com - www.rfsaw.com

Global SAW Tag (GST) - SAW-based passive RFID – 2.44GHz

- Longest passive sensor reading range
- HERO certified for safe use on munitions
- Anti-Collision Matched Filter Processing
- Temperature tolerant Codes with Cross-correlation (i.e. anti-collision)
- Range-dependent zones – group similar tag response magnitudes using times of arrival



Actual 96-Bit Wireless Tag Waveform



Potentially 240 SAW Temperature Tags:

- 5 Codes
- 6 Ranges
- 8 Directions(Antennas)
- Reader switches from one antenna to the next
-



8 Port Reader

6.2 “PWST SAW - Sensor System”

Jackie Hines – VP ASRDC Corp. jhines@asrdcorp.com - www.asrdcorp.com/
Applied Sensor Research & Development Corporation

Wireless SAW Sensor Advantages:

- Operate wirelessly RFID capable
- RF signal activates sensor,
- Require no batteries Sensitive/accurate
- Perform multiple real-time measurements
- Last a long time (decades)
- Survive & operate in extreme environments
- Cryo to 1,000°C RadHard to > 10 MRad
- Low cost
- Established technology
- High Volume - Billions of devices sold/year for cell phones

=> **Enable low cost distributed sensing**

SAW Sensors under development @ ASRDC

- Coded sensor-tag wireless interface devices
 - use variable impedance input from Std sensors
- Humidity - Today's Focus
- Hydrogen
- Temperature
- Methane
- Hypergol leak detection(MMH, DMH, NTO)
- (Cryogenic) liquid (level)
- Concrete maturity monitor
- Biosensor for infectious agents (CT)

Passive Wireless SAW Humidity Sensor System



- Temple developed quick response sensor from Nanoparticle PVP/LiCl-doped TiO₂ films

DSSS codes with time, frequency diversity – 32 T sensors

Discrete Frequency Coding (DFC) – 8 good codes

Time Diversity - Re-used each code at eight distinct time delays

Orthogonal chips at each freq. have different delays to produce codes

Similar to OFC, but with code “chips” in frequency bands that do not overlap

Relative Humidity measured, need to add temperature compensation

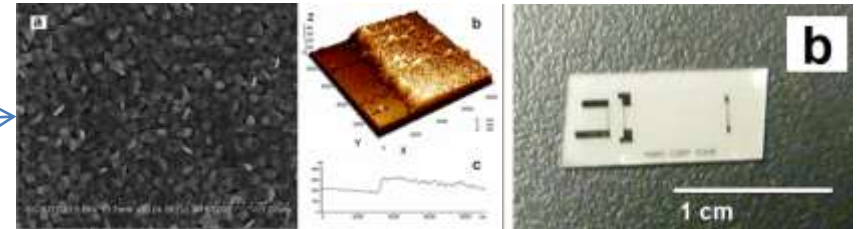
System Delivered to NASA KSC, making improvements – deliver Nov 2012

Advances in Sensor-tag Coding

13-bit Barker code with time & frequency diversity – 100 sensor-tags

DSSS codes with time, frequency diversity – 32 T sensors

SBIR Phase 2 Temperature Sensor System(32) to NASA/MSFC – 2013



-Time integrating correlator-based Transceiver
-Power spectral density of response measured
half-passband integrated energy 32

6.3 "SAW PWST: 915 Mhz Sensor System and Demonstrations"

Don Malocha – Univ of Central Florida - malocha@mail.ucf.edu

UCF Progress:			2 dBi antenna Isotropic Range (m)	Data Transfer Rate (sec)	Post Processing Rate (msec)/sensor	Plotting and Overhead (sec)
Year	Hardware	# Sensors				
2008	UCF	1-2	< 1	5	>1000	2
2009	UCF	1-2	1-3	2	>1000	2
2010	UCF & MNI	1-4	1-4	0.5	500	2
2011	MNI	1-6	1-5	0.5	100	2
2012	MNI	1-8	1-7	0.5	10	2
2013	MNI and ?	1-16	1-10	0.5	5	?
2014	MNI and ?	1-32	1-50	0.001	1	?

Sensors: temperature, range, strain, hydrogen, magnetic, liquid, cryogenic

Environments: isotropic, hallways (60m), faraday cage (.5x.5 m), anechoic

UCF Fast Prototyping <1 week from idea to device prototype

RF Transciever – more parts are making it faster and cheaper to develop

UCF Correlator Synchronous Transceiver- Software Radio (2004-2010)

- Pulse Interrogation: Chirp or RF burst
- Integration of multiple "pings" OFC processing gain
- 915 MHz sync transceiver(Mnemonics, Inc) to NASA/KSC – STTR

Dual Track Gas Sensor: (On-board Sensor) Ref to left and thin film sensor to right)

Magnetic Puck for Closure switch sensor (On-board)

Antenna used as Closure sensors (Off-board)

Matched Filters to reduce noise, Correlator Time Delay Extraction(CTDE)

- S/N determines the precision and accuracy

Adaptive Temperature Correlator

Range: Current: 5meters; Future: 250m – 800m

High Temperature SAW devices on Langatate (LGT) - stable up to ~1450°C

- Platinum thin/thick films under investigation

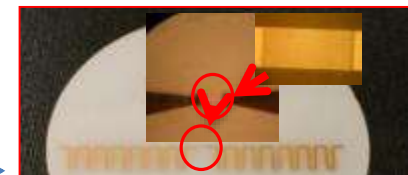
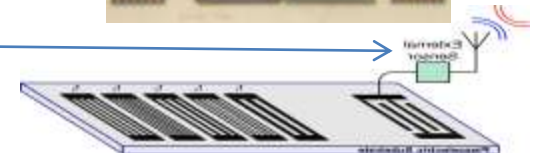
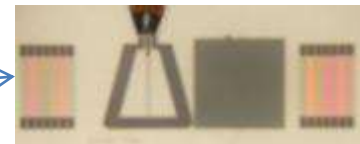
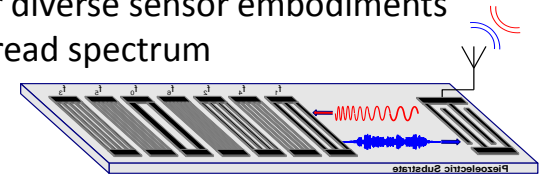
Sawtenna development

Acknowledgements

NASA/KSC Dr. Bob Youngquist
Florida High Tech Corridor Council
Florida Space Institute
Mnemonics(MNI)

Orthogonal SAW Frequency Coding(OFC):

- Frequency & time offer great coding diversity
- Single communication platform for diverse sensor embodiments
- Spread spectrum

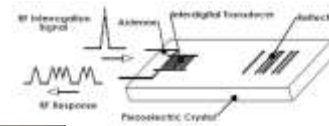


7.1 “SAW Sensors: Explore New Measurement Horizons”

Heimo Mueller – CTR Carinthian Tech Research, Villach, Austria - heimo.mueller@CTR.at – www.ctr.at

Wireless SAW Sensor Symposium, Villach, Sep 20 & 21, 2012 www.saw-symposium.com

CTR SAW System Sensor-Tags



Temp	C	F
Range	-55°C to +400°C	-67°F to +752°F
Accuracy	±2°C	±3.6°F
Resolution	0.1°C	0.18°F
Read range	Meters	Feet
9 dBi antenna	up to 2m	up to 6.6ft
18 dBi antenna	up to 4.5m	up to 14.8ft



19.2 mm

SAW Applications

- Automotive: Pressure, Varnish lines
- Food: Baking Plates – ID, Temp & Pressure
- Oil: Drill Pipe – ID - www.hmenergyllc.com
- Steel – Slag Vessels, Slide Gate Plates – ID
 - Refrac Drying & Mold Temps
- Energy – Transmission Line Temps



Rotating Machine Elements – Temps



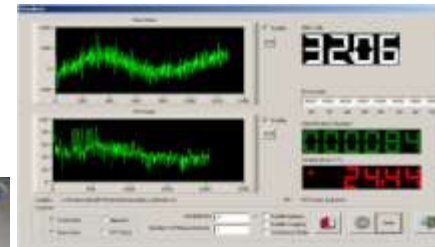
Trying:
Al Nitride thin
film on
Sapphire
1100°C
(2012°F)

Readers



	Standard	Fast	Handheld
Read Time	300msec	100µsec	100msec
Channels	4	1	1
Frequency Bandwidth	2,45 GHz 80 MHz	2,45 GHz 80 MHz	2,45 GHz 80 MHz
Interface	LAN	LAN	Bluetooth
Power Source	EN 300440, FFC Part 15, JP	EN 300440	Battery life > 10.000 reads

Software: Visualizer



Panel



CTR SAW R & D

Beam-based 7 Membrane-based pressure
Strain - Tensile & Lateral strain
- Temperature compensation

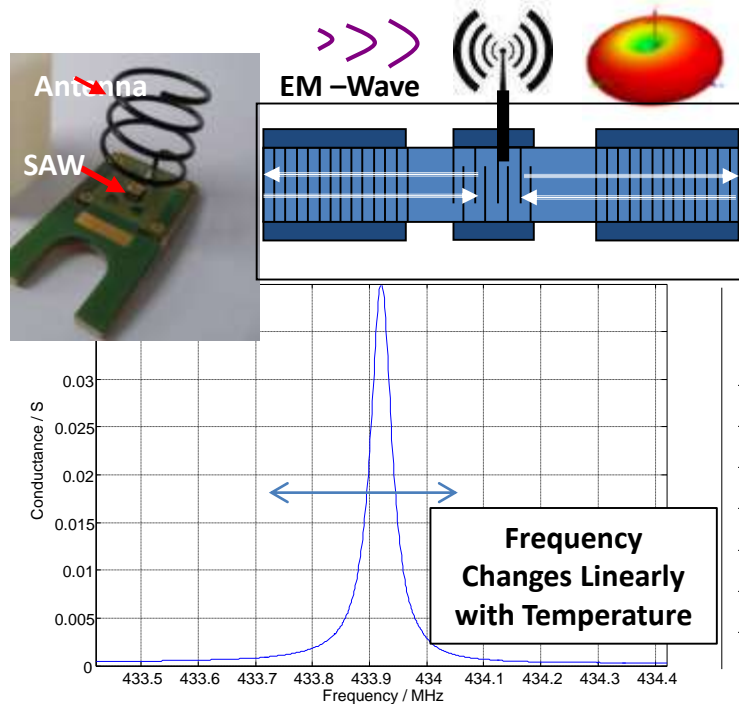
High Temp - 600°C (1112°F) working temp
- 800°C (1472°F) short term

Housings: Ceramic & Metal housing needs

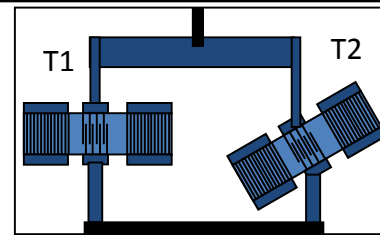
7.2 “Vectron Wireless Temperature Monitoring Solutions

Sabah Sabah – Vectron-Sengenuity - sabah@sengenuity.com – www.sengenuity.com

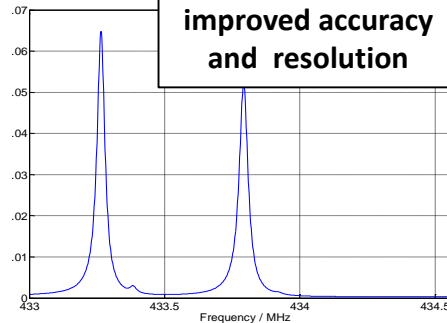
Single SAW Resonator: Absolute Measurement



Double SAW Resonator: Differential Measurement



Differential Meas
improved accuracy
and resolution



Temp
Trackr™



Six Temperature Measurements
At 6 Frequencies 428 to 439 MHz



Applications:

Switching Temps for Smart Grid
Food Thermometer
Rotating Equipment Temps
Tire pressure
Fluid Viscosity

Food Thermometer

Antenna

SAW Temperature
Sensor



- **Passive** and **Wireless**, non-invasive and no active electronic circuits
 - Save 20%-80% of industrial wire installation costs (est. US \$130 – \$650 /m)
- **Medium & High** temperature operating ranges: -20°C to 120°C & up to +260°C
- **Reading Distance:** 0.1 to 3 Meters (depend on the antenna and RF environment)
- **System accuracy:** $\pm 2^\circ\text{C}$ (temperature operating range -20°C to 120°C)
- **Robust, reliable, stable and suitable for harsh**, hazard and inaccessible hot-spots
- **Multi- Communication Protocol:** RS485, RS232, USB, CAN. Analog-Output, MODBUS
- **User Friendly**, ease of installation, simple to use Interfaces and data logging
- **Real-Time** and Continuously Thermal Monitoring – 24/7/365
- **Miniature:** small and light, low cost
- **Low Maintenances**
- **Low ageing degradations** ($\pm 2^\circ\text{C}$ <12 years)
- **Environmental** and green technology – no recycling of battery

7.3 “RFID Tag Antenna-Based Sensing”

Isaac Ehrenberg – MIT Auto-ID Labs - yitzi@mit.edu; Rahul Bhattacharyya - rahul_b@mit.edu
Prof Sanjay Sarma



KSW semi-passive RFID temperature logger (>\$3)
www.variosens.com

➤ Keeping Tabs on Things:

➤ Why RFID?

- Proven track record of pervasive deployment
- Low cost RFID tag manufacturing
- Standardized reader-tag communication
- Free adoption in RFID-enabled processes

➤ 2 Concepts:

Use Reader-Tag Signal Parameters for Sensing

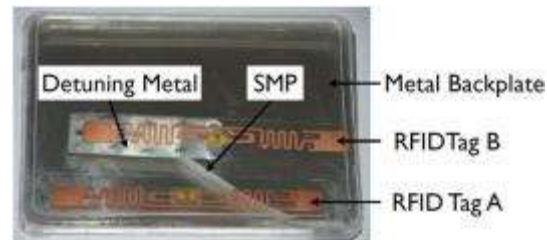
AM: Use Reader Power or Tag Backscatter

FM: Use Freq shift in Tag Response

Applications:

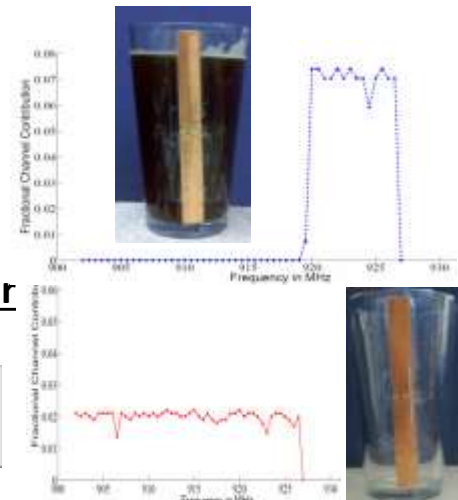
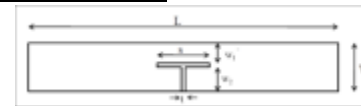
Temperature: perishables in cold chain

Temperature, Humidity and Shock on large scale



- Temperature Threshold Sensor

- Fluid Level Sensor



Low-cost, non-electric Memory

Normally, Passive RFID Tags can't record events when unpowered

- Permanent Change to Antenna(e.g. damage) = memory - Temp Threshold Sensor

- Temporary Change: Shape Memory Polymers – Glass Transition Temp – flexible vs rigid
Diaphragm or Antenna Detuning metal – changes Tag Backscatter (AM)
Fluid in a glass(Deavors 2010)

Note: Other Inventions Potyrailo 2010, Siden 2007, Caizzone 2011

8.1 “Passive UWB: Long Range, Low Cost and Precise Location”

Kourosh Pahlavan – TagArray - kourosh@tagarray.com www.tagarray.com

Motivation:

- Cost Effective: Total cost of ownership 100x less than GEN2 or active RTLS
- Zero Watt Passive Transceiver: Tag consumes < 2 μ W when communicating
- Accurate Location and Long Range: 2-3 inch resolution from 100 meters away

How it Works:

1. Beacon is a Narrowband UHF Transmitter
2. Narrowband signal powers Tag, initiates query session - 4W EIRP: 10m range
3. Receiver harvests RF power and wakes up
4. Tag transmits UWB impulses - 6dBm: 50-100m range
5. UWB Receiver(Single Chip/ Very Low Cost) uses Digital Antenna

Advantages:

- Small Cost & Size: UWB Readers are 100x and 20 times smaller than Gen2
- Read Range: 50-100 meters
- Resolution: 2-3 inches
- Sample Rate: 1000s of reads per second per reader
- Multi-path Immunity:
 - Robust tag detection/location determination
 - Signal propagates through openings and cracks
- Low Power: Tag chip consumes ave of 2 μ W (memory incl)
 - Alt power options: micro solar cell, MEMS harvesters, etc.

Status:

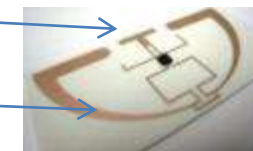
- Available: Tag, Reader and Software
- Next: Increase DA sensitivity to achieve 100m range
- Tag Antenna, Reader, Software for many tags, FCC cert

Applications:

- RTLS & Indoor tracking
- RFID
- Sensors
- Surveillance

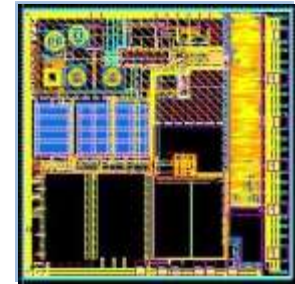


Tag 1mm x 1mm

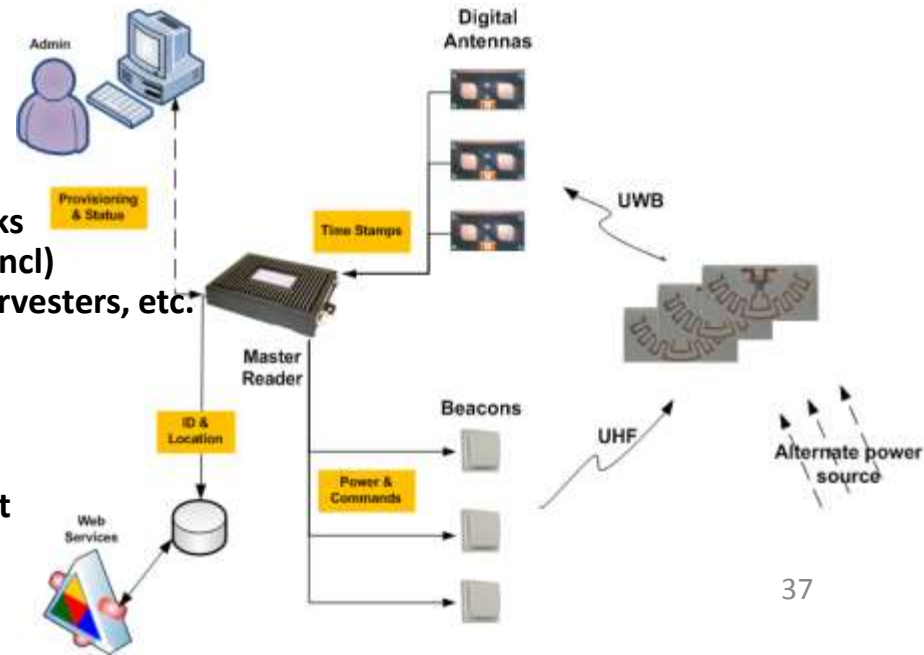


UWB Ant

UHF Ant



Reader 1mm x 1mm



8.2 “60 GHz Comm, RFID - moving to Passive Sensors”

Don Kimball – Maxentric - dkimball@maxentric.com www.maxentric.com

ViFi- V-band wireless Fixed and Mesh Network

Unlicensed at 59-64 GHz in many countries

Low SWaP at high freq

Directional Antenna



- Highly Reflective inside metallic enclosures like spacecraft

Order of magnitude better than 2.4GHz in satisfying HERO

(Hazards of Electromagnetic Radiation to Ordnance)

atmospheric resonance attenuates signal beyond 100-300 ft

Mesh Network: Ad-hoc Mesh, High Data Rate(>Gbps), Delay Tolerant
(Memory-based), Ethernet Compliant

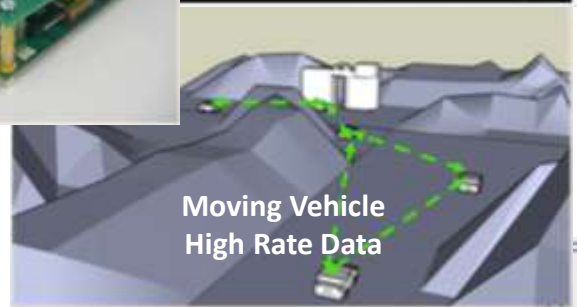
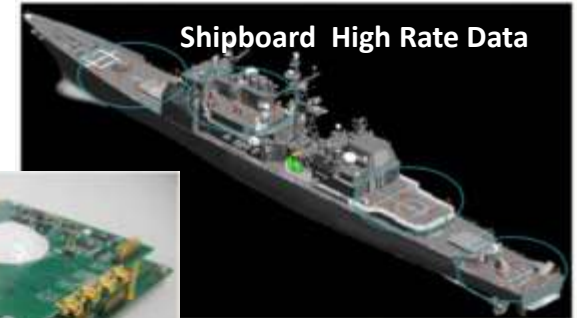
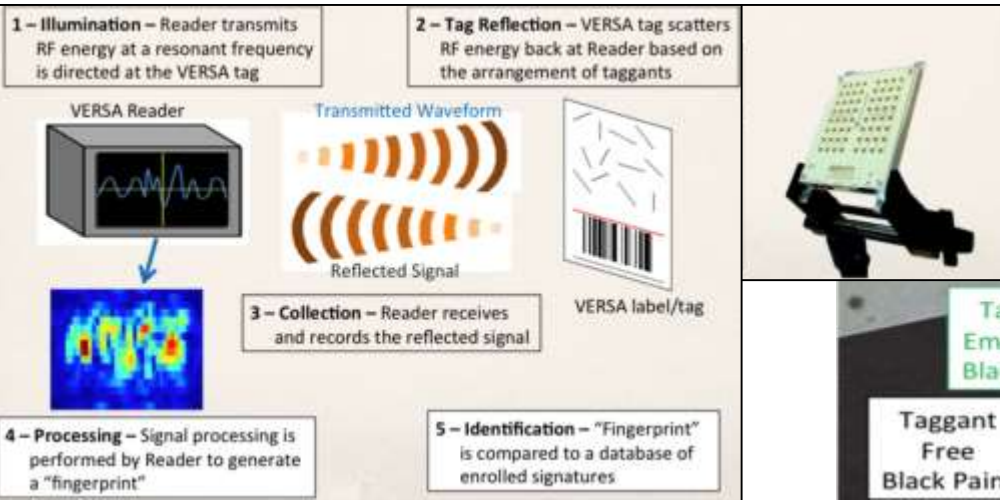
Gbps and adjustable to 10 Mbps

VERSA - V-band Enhanced RFID/Sensing

metal dipoles called Taggants – tiny for high freq

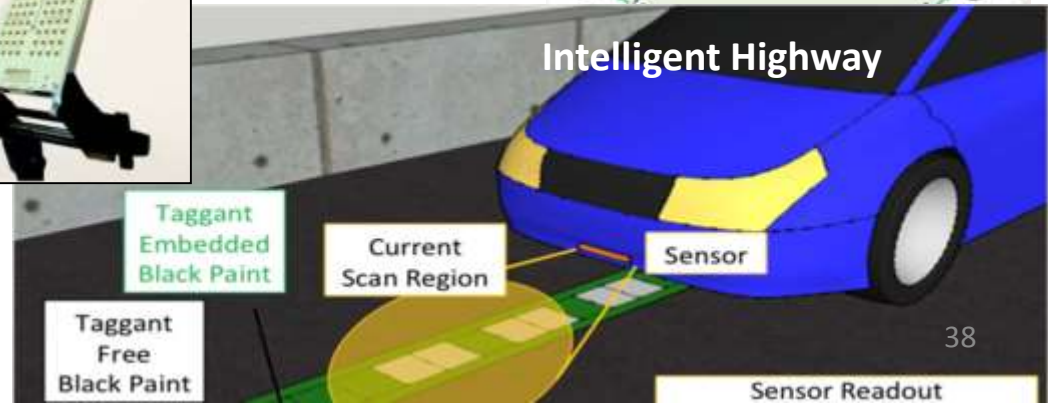
- Tag-response based on: Taggant orientation & Relative positions

Temperature, Pressure, Voltage, Location & Orientation



- 1.3

- Thin



8.3 “Wireless Temperature Sensors for Gas Turbine Engines”

John Conkle - Wireless Sensor Technologies - jrconkle@att.net

Problem:

- Catastrophic Failure caused by degradation and damage to hot section components
- Poor characterization of degradation process affects the development of durable components

Users:

Jet Engine Developers, Users, Maintenance
Other harsh environment applications - control and CBM applications in carbon, steam, or nuclear-fueled power plants.

Requirements:

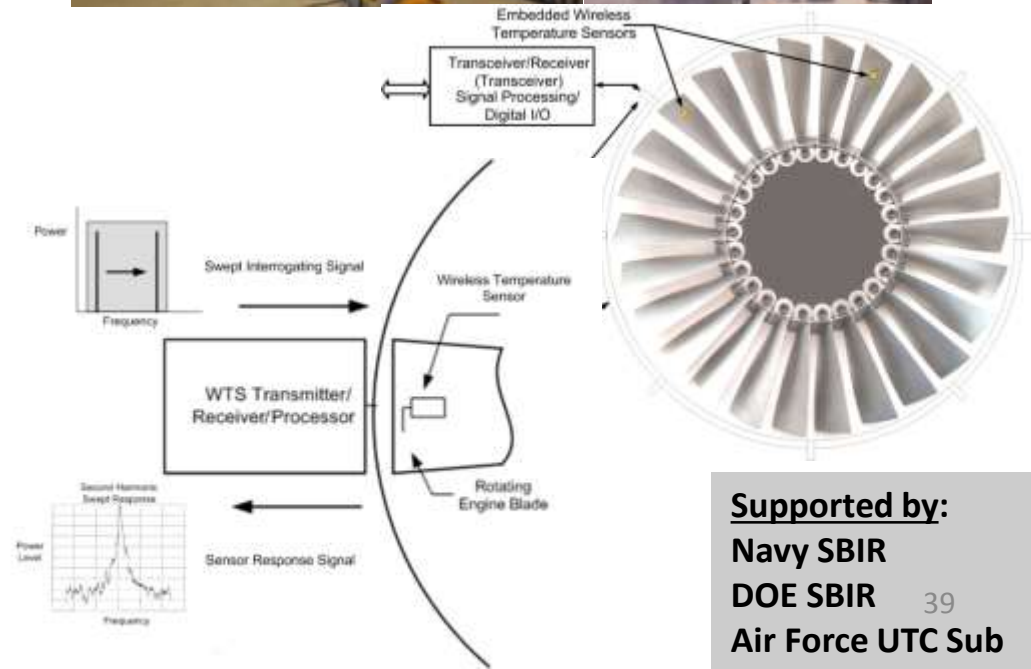
- Accurate temperature measurement
 - 10° C accuracy, Range of -60 to 1300C
- Long-term reliability
 - ‘00’s of hours for developmental testing
 - “000’s of hours for PHM and CBM application
- Easily mount on turbine blade or target surface
 - Not alter the blade dynamics (weight, gas flow)
 - “Massless” and “Zero” height

WST Solution:

- Sensor Printed like an IC out of Alumina
- Antenna,
- Ceramic Dielectric, AZO Schottky Diode
- TRL5 in Fall 2012

In-Engine temperature surface data critical for:

- Propulsion Health Monitoring (PHM)
- Condition-based Maintenance (CBM) that has been mandated for use by the DoD
- Developmental testing of new engine designs



Supported by:

Navy SBIR
DOE SBIR
Air Force UTC Sub

8.4 “A System Engineering Simulation Tool and Data Base Proposal for Optimizing the Application of Wireless Sensors”

Scott Hyde – Aerojet - Scott.Hyde@Aerojet.com www.aerojet.com

Machine-to-Machine (M2M) Market Lesson’s Learned

- M2M communications consists of using a device to capture an “event” relayed through a network to an application, translating the captured event into meaningful information.

- Similar problems to Aerospace: too much to communicate, systems are inflexible, system cost

<http://www.machinetomachinemagazine.com>

Power of Simulation and its Role with Wireless Sensing

Simulation Reduces Upfront Costs and Pays Off Through the Systems Life-Cycle by Facilitating Assessment of Change Requirements, Impacts Due to Obsolescence and Software/Hardware Upgrades

Elements of a System Architecture can be Simulated with High Fidelity Enabling Management of System Complexity and Communication Congestion – Physical Level, Logical Level, System Level

CPIAC Sensor Database :

- Chemical Propulsion Information Analysis Center (CPIAC) is developing a secure, online, portal for the collaborative collection and dissemination of sensor related information.

- Access has ITAR restrictions (U.S. Citizens only)

- Sponsors: NASA , US Air Force and US Department of Energy

- CPIAC to Design, Implement and Host/Maintain an Online Tool for JANNAF to:

- Allow the secure exchange and collection of information on sensors
- Wiki-like functionality: Users create new entries based on standard forms
- Documents can be attached as references for each sensor
- Search capability based on keywords or filtering by criteria
- Data reviewed prior to posting by an approving authority
- CPIAC to perform initial data population using NASA sensors database

Include
Active and Passive
Wireless Sensors?

Add an ISA or other
External database to
complement it?

Potential Future Areas of Emphasis

Next Workshop 2013?

Technology Developers

- **Progress in Technology and Applications since 2011/2012 Workshops**
- **Near Field Communications**
- **RFID Sensors**
- Mechanical Sensing
- Manufacturing Advances
- Embedded sensing and Nano-materials
- **Hybrid Systems**
- Systems Integration
- **International Developers**

End User/Stakeholder Needs

- **Consumer Products**
- Aerospace
- DOD and Security
- **Energy, Efficiency and Environments**
- **Automation and Machine-to-Machine Interfaces**
- **Health Monitoring**
- Test Instrumentation
- Facility and Vehicle Architecture Changes

Coordination:

- Communication
- Research and Education
- Community of Practice
- **System and User Needs Data Base**

Comments – Questions?

**George Studor
NASA/Johnson Space Center
Structural Engineering Division
(763) 208-9283
George.F.Studor@nasa.gov**

2011 PWST Workshop Summary

Background/Motivation – Why a PWST Workshop?

“Fly-by-Wireless” Vision:

To Minimize Cables and Connectors and Increase Functionality across the aerospace industry by providing reliable, lower cost, modular, and higher performance alternatives to wired data connectivity to benefit the entire vehicle/program life-cycle.

Focus Areas:

- 1. System engineering & integration methods to reduce cables & connectors.**
- 2. Vehicle provisions for modularity and accessibility.**
- 3. A “tool box” of alternatives to wired connectivity.**

What it is NOT:

- A vehicle with no wires.**
- Wireless-only for all control systems.**

“Fly-by-Wireless” Focus Areas

(1) System engineering and integration to reduce cables and connectors,

- Capture the true program effects for cabling from launch & manned vehicles.
- Requirements that enable and integrate alternatives to wires.
- Metrics that best monitor progress or lack of progress toward goals. (# cables, length, # of connectors/pins, # of penetrations, overall weight/connectivity, total data moved/lb).
- Design Approach that doesn't assume a wires-only approach, but optimizes all practical options, providing for the inevitable growth in alternatives to wired connectivity.

(2) Provisions for modularity and accessibility in the vehicle architecture.

- Vehicle Zone Accessibility – Considers standalone sensors along with system assembly, inspections, failure modes/trouble-shooting, system/environment monitoring, remove & repair.
- Vehicle Zone Modularity – Vehicle wired buses provide power, two-way data/commanding, grounding and time in a plug-and-play fashion. Wireless networks are standardized by function and are also plug-and-play.
- Centralized & De-centralized approaches are available for measurement & control.
- Entire life-cycle considered in addition to schedule, performance, weight & volume.

(3) Develop Alternatives to wired connectivity for the system designers and operators.

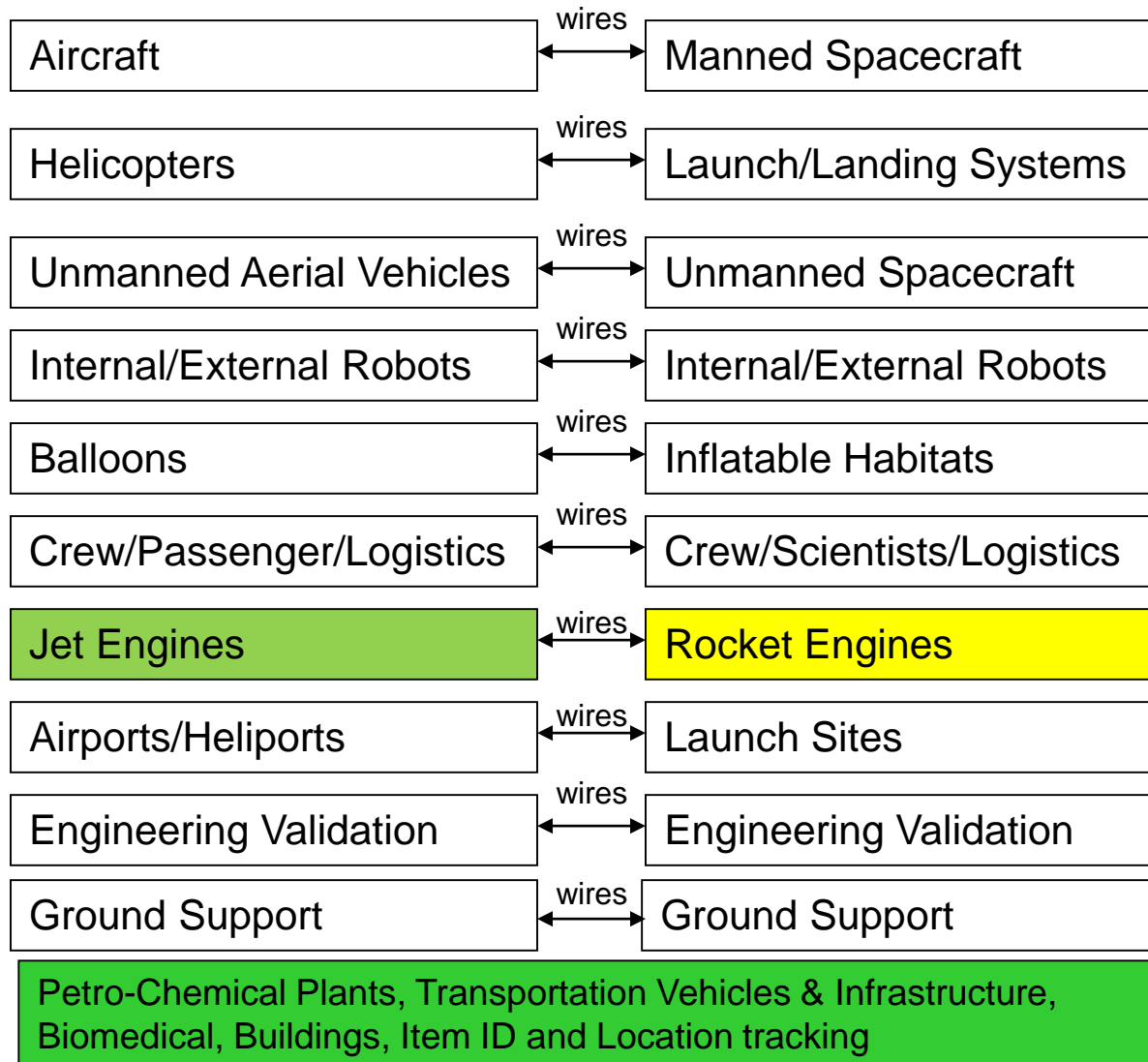
- Plug-n-Play wireless devices
- Wireless no-power sensors/sensor-tags
- Standalone wireless smart data acquisition
- Standardized I/Fs, networks & operability
- Wireless controls – back-up or low criticality
- Robust high speed wireless avionics comm.
- Data on power lines, light, structure, liquids
- No connectors for bulkheads, avionics power
- Robust software programmable radios
- Light wt coatings, shielding, connectors
- **RFID for ID, position, data, & sensing.**
- Inductive coupling for rechargeable batteries

What Do the 2 sides of Aerospace Have in Common?

Wires!!

Aviation

Space



What do these have in common?

1. Data, Power, Grounding Wires and Connectors for: Avionics, Flight Control, Data Distribution, IVHM and Instrumentation.
2. Mobility & accessibility needs that restrict use of wires.
3. Performance issues that depend on weight.
4. Harsh environments.
5. Limited flexibility in the central avionics and data systems.
6. Limited accessibility.
7. Need to finalize the avionics architecture early in the lifecycle.
8. Manufacturing, pre and post delivery testing.
9. Schedule pressure, resource issues, security and reliability.
10. Operations and aging problems.
11. Civilian, military, academic & international institutions.
12. Life-cycle costs due to wired infrastructure.
13. Need for Wireless Alternatives!!

Common Motivations

Systems and Vehicles:

- **Reduce Cost/Schedule of Wired Connectivity**
- **Increase Reliability/Maintainability**
- **Increase Safety**
- **Increase Security (some more than others)**
- **Increase System Functionality**
- **Changes in System Engineering & Integration, Vehicle Architecture and Technology Development/Awareness**
- **Decrease Size, Weight and Power**

Wireless Sensors:

- **Cost - No battery and no radio costs**
- **Manufacture In Quantity – Like RFID tags**
- **Life time power – no battery replacement**
- **Safety – little or no stored power**

What Is a Passive Wireless Sensor(PWS)?

Attributes:

- No battery
- No need for scavenging power over time
- No wired connection between sensor and data acquisition unit
- Provides a sensor reading along with a unique tag id
- Can provide range information for location/orientation
- Minimum electronics – can be fabricated for extreme temperature and other environments.
- Can be imbedded in/behind structure permanently or added after manufacturing
- Multiple industries have use cases – need to bring them together to generate demand.
- Compatible with high volume production – leading to low cost per measurement point:

Generation 1	Generation 2	Generation 3	Generation 4
Wired	Motes	Active Sensor Tags	PWST?
~\$10,000 per point	~\$1,000 per point	~\$100per point	~\$10 per point

Basic Types:

- EM-coupling: Simple – very short range
- RFID-based: Antenna for scavenge power for data return – med range
- SAW-based: Surface Acoustic Wave reflection(s) + Antenna
 - Longer Range, Higher Sample Rate
 - Many tags interrogated at one time

2012 Passive Wireless Sensor Technology Workshop

Purpose:

To bring Passive Wireless Sensor-Tag(PWST) technology developers, manufacturers and potential industry end-users together to understand the larger market drivers that will drive costs down and applications up. We will also discuss logical next steps.

Objectives:

- Understand various PWST technologies, actual & potential uses, and maturity.
- Assess the future applications/advantages/limitations in various industries.
- Assess what is needed for high volume production, standardization & communication.
- Precipitate individual & group “next step” thinking to further develop/apply PWSTs.
- Accumulate contacts for potential partnering activities (start at 2011 PWST)

Methods for growing the Technology **without “doing it all myself”**

- Make more organizations aware of the technology and its uses
 - Briefings available to Public – who do I talk to?
 - Opportunities from Private Discussions - details
- Stimulate other organizations to fund and use the technology.
- Identify use cases—technology areas of potentially large volume
 - as well as combined use cases.
- Facilitate private “one-on-one” discussions for partnering.
- Facilitate next step discussions between members.
- Invite Government and University observers to stimulate thinking and opportunities.
- Follow-up with public availability of the briefings.
- Make the interested community aware of new opportunities

Common Interests that make this format productive

- Understand how to take advantage of new PWST technology.
- Efficient ways to keep up with new technologies at all levels.
- Discover others that are developing/using PWST technology similar to what we need.
- Technology developers need to know what problems need solving.
- “Out of the Box” thinking at System Engineering level.
- Cross “barriers” between Industries, Government Orgs and Countries.
- Combined Business Cases in multiple industries for larger scale production.
- Communication is the key - let's work at it!

2012 PWST Workshop

June 6 & 7, 2012

- Presentations should complement 2011 PWST Workshop
 - Maximize the Synergy with co-located IIS Symposium
 - Networking Opportunities during Breaks after each set of Presenters - will be at prescribed locations at each break
 - I will be available during breaks, lunch and after the workshop each day to discuss feedback and forward actions
 - Recommend One-on-Ones happen at Lunch and Dinner (you make it happen)
 - Discuss Outcomes of 2011 PWST Workshop and what to do.
-
- Presentations, Brochure and Updated PWST Summary will be made available on the ISA Comm Division Website
 - List of Presenters and Attendees will be available to attendees

2012 PWST Workshop Agenda

June 6th AM

- | | | | |
|--------------|-----------------------------|----------------|---|
| 8:00am | NASA/JSC/Structures SHM | George Studor | - "Passive Wireless Sensor Technology 2012 Workshop Plan" |
| 8:30am | GE Global Research | Daniel Sexton | - "ISA107.4: Wireless sensor for turbine instrumentation working group" |
| 9:00am | United Tech Research Center | Sanjay Bajekar | - Wireless for Aerospace Applications |
| 9:30am | NAWCWD China Lake | Rob Pritchard | - "Naval Applications of PWST from the End-user's Perspective" |
| 10:00am | Break | | |
| 10:30am | BP/chief Technology Office | Dave Lafferty | - "Passive Sensor Needs at BP" |
| 11:00am | Shell | Ron Cramer | - "Oil and Gas Integrity Monitoring" |
| 11:30am | DOT/FHWA | Fred Faridazar | - "Wireless Sensors for Structural Monitoring During Extreme Events" |
| 12:00 - 1:00 | Lunch | | |

2012 PWST Workshop Agenda

June 6th PM

- | | | | |
|--------|--|------------------|---|
| 1:00pm | Rockwell Automation | Cliff Whitehead | - “Machine-to-Machine Interfaces in Factory Automation” |
| 1:30pm | Arkansas Power & Electric | John Fraley | - “High Temperature Wireless Sensor Systems” |
| 2:00pm | Yokogawa | Penny Chen | - PWST needs at Yokogawa |
| 2:30pm | Break | | |
| 3:00pm | Savannah River Nuclear Solutions - Mike Mets - “PWST/RFID Technology for Material Control and Accountability at the Savannah River Site” | | |
| 3:30pm | DOE/Electrical Grid | James Briones* | - PWST for the Electrical Power Grid |
| 4:00pm | On-Ramp Wireless | Jake Rasweiler | - Ultra-Link High Capacity, Long Range, Low Power Technology Applications |
| 4:30pm | AVSI Project AFE73 -WAIC | Radek Zakrzewski | - The Status of Wireless Avionics Intra-Aircraft Communications |

2012 PWST Workshop Agenda

June 7th AM

8:00am Syntonics	Bruce Montgomery	- "Passive Wireless Sensing in a High-Multipath, High-Doppler Environment"
8:30am Albido Corp	Fred Gnadinger	- "Wireless Passive Strain Sensors Based on Surface Acoustic Wave (SAW) Principles"
9:00am Environetix	Mauricio Pereira da Cunha	- "Harsh Environment Wireless Sensor System for Monitoring Static & Rotating Components in Turbine Engines and Other Industrial Applications"
9:30am nScript	Ken Church	- "Passive Direct-write Sensors"
10:00am Break		
10:30am RF SAW	Paul Hartmann	- "Advances in SAW devices for Sensing and RFID Applications"
11:00am ASRDC	Jackie Hines	- PWST SAW - Sensor System
11:30am Univ of Cntl Florida	Don Malocha	- SAW Sensor Technology
12:00 - 1:00pm Lunch		

2012 PWST Workshop Agenda

June 7th PM

1:00pm	Carinthian Tech Research	Heimo Mueller	- “SAW Sensors: Explore New Measurement Horizons”
1:30pm	Vectron	Sabah Sabah	- “Vectron Wireless Temperature Monitoring Solutions”
2:00pm	MIT	Isaac Ehrenberg	- “RFID Tag Antenna-Based Sensing”
2:30pm	Break		
3:00pm	Tag Array	Kourosh Pahlavan	- Passive UWB Location
3:30pm	VTI Instruments	Chris Gibson	- Adding PWST to standard test instrumentation
4:00pm	MaXentric	Don Kimball	- 60 GHz Comm, RFID moving to PWST
4:30pm	Wireless Sensor Technologies	John Conkle	- Wireless Sensors for Gas Turbine Engines
5:00pm	Workshop Closing	George Studor	- Discussion, Conclusions

2012 PWST Workshop Presenters

#	Name	Organization	Role	Location	Phone	Email	Title/Technology/Interest
1.1	George Studor	NASA JSC	Project Engineer	Minneapolis, MN	(763) 208-9283 (281) 415-3986(c)	george.f.studor@nasa.gov	"Passive Wireless Sensor Technology(PWST) 2012 Workshop Plan"
1.2	Daniel Sexton	GE-Global Research	Project Engineer	Niskayuna, NY	518-387-4121; 518-424-5728	sextonda@ge.com	"ISA107.4: Wireless sensor for turbine instrumentation working group"
1.3	Sanjay Bajekal	UTRC		East Hartford, CT	(860) 610-7700	BajekaS@utrc.utrc.com	"Wireless for Aerospace Applications"
1.4	Robert Pritchard	Naval Air Warfare Center/WD	Senior Scientist	China Lake, CA	760-939-7504	robert.w.pritchard@navy.mil	"Naval Applications of PWST from the End-user's Perspective"
2.1	Dave Lafferty	BP	BP - Chief Tech Office	Houston, TX	(281) 504-8852 (630) 853-7625(m)	david.lafferty@bp.com	"Passive Sensor Needs at BP"
2.2	Ron Cramer	Shell	PACO Americas	Houston, TX	281-544-4411 713 894 9141(m)	Ronald.Cramer@shell.com	"Oil and Gas Integrity Monitoring"
2.3	Fred Faridazar	DOT/FHWA	Research Engineer (Highway)	McLean, VA	(202) 493-3076	fred.faridazar@dot.gov	"Wireless Sensors for structural monitoring during extreme events"
3.1	Cliff Whitehead	Rockwell Automation	Manager, Business Development	Mayfield Heights, OH	440.646.3779 216.288.9269(m)	cjwhiteheadjr@ra.rockwell.com	"Machine-to-Machine Interfaces in Factory Automation"
3.2	John Fraley	Arkansas Power & Electric	Lead Wireless Engineer	Fayetteville, AR	(479) 443-5759	jfraley@APEI.net	"High Temperature Wireless Sensor Systems"
3.3	Penny Chen	Yokagawa Industry Automation	Princ. Systems Arch, IA Global Marketing	San Jose, CA	(408) 636-8544	penny.chen@us.yokogawa.com	"PWST needs at Yokogawa"
4.1	Michael Mets	Savannah River Nuclear Systems	Nuclear Materials Org. & Eng Support	Aiken, SC	(803) 952-9578	michael.mets@srs.gov	"PWST/RFID Technology for Material Control and Accountability at the Savannah River Site"
4.2	Jake Rasweiler	On-Ramp Wireless	Chief Strategic Officer	San Diego, CA	858 312-8397 516 761-2235(cell)	jake.rasweiler@onrampwireless.com	"Ultra-Link" High Capacity, Long Range, Low Power Technology/Applications
4.3	Chris Gibson	VTI Instruments	Mgr Mktg & Business Development	Irvine, CA	949-955-1894 425-508-0887	cgibson@vtiinstruments.com	"Integrating passive wireless sensors with existing data acquisition systems"
4.4	Radek Zakrzewski	WAIC - Goodrich	AVSI-WAIC Project Lead	NH	802-877-4757	Radek.Zakrzewski@goodrich.com	"Protected Spectrum for Wireless Avionics Intra-Communications"
5.1	Bruce Montgomery	Syntonics Corp	President	Columbia, MD	410-884-0500 x201 410-913-2907(c)	Bruce.Montgomery@syntonicscorp.com	"Passive Wireless Sensing in a High-Multipath, High-Doppler Environment"
5.2	Fred Gnadinger	Albido Corp	President & CEO	Colorado Springs, CO	719-337-4318	fred@gnadinger.com	"Wireless Passive Strain Sensors Based on Surface Acoustic Wave (SAW) Principles"
5.3	Mauricio Pereira da Cunha	Environetix	Vice President and CEO	Orono, ME	207-581-2384	mdacunha@environetix.com	"Harsh Environment Wireless Sensor System for Monitoring Static & Rotating Components in Turbine Engines and Other Industrial Applications"
5.4	Mike Newton	nScript	Dir. Strategic Tech	Orlando, FL	407-275-4720	mNewton@nscriptinc.com	"Passive Direct-write Sensors"
6.1	Paul Hartmann	RFSAW	Vice Pres. for Engineering	Richardson, TX	(469) 227-0322	phartmann@rfsaw.com	"Advances in SAW devices for Sensing and RFID Applications"
6.2	Jackie Hines	ASRDC	President	Arnold, MD	(410) 544-4664	jhines@asrdcorp.com	"PWST SAW - Sensor System"
6.3	Don Malocha	UCF - Univ Ctl FL	Professor	Orlando, FL	(407) 823-2414	malocha@mail.ucf.edu	"SAW PWST: 915 Mhz Sensor System and Demonstrations"
7.1	Heimo Mueller	Carinthian (CTR)	Sr Acct Mgr R&D	Villach, Austria	43 (0)4242 56300 213	heimo.mueller@CTR.at	"SAW Sensors: Explore New Measurement Horizons"
7.2	Sabah Sabah	Vectron	Product Mktg Mgr	Hudson, NH	(603) 577-6751	sabah@sengenuity.com	"Vectron Wireless Temperature Monitoring Solutions"
7.3	Isaac Ehrenberg	MIT Auto ID Labs	Research Assistant	Cambridge, MA	201-390-6168	iytzi@MIT.EDU	"RFID Tag Antenna-Based Sensing"
8.1	Kourosh Pahlavan	TagArray	CEO & CTO	Palo Alto, CA	(650)251-4400 x 202	kourosh@tagarray.com	"Passive UWB: long range, low cost and precise location"
8.2	Don Kimball	MaXentric		LaJolla, CA	858-272-8800	dkimball@maxentric.com	"60 GHz Comm, RFID - moving to Passive Sensors"
8.3	John Conkle	Wireless Sensor Tech	President	Encinitas, CA	(408) 234-3741	jconkle@att.net	"Wireless Temperature Sensors for Gas Turbine Engines"
8.4	Scott Hyde	Aerojet	Mktg Manager for Strategic Propulsion	Clearfield, Utah	801-774-2474 801-745-7449	Scott.Hyde@Aerojet.com	"A System Engineering Simulation Tool and Data Base Proposal for Optimizing the Application of Wireless Sensors"

2012 PWST Workshop other Attendees

Name	Company	Role	Location	Phone	Email
Doyle Carr	ATA		Arnold AFB		doyle.carr@arnold.af.mil
Elizabeth Adams	BP		Munster, IN	(219) 218-2375	adamseg@bp.com
Scott Marston	Boeing	Wireless Cabin Systems	Bellevue, WA	(425) 256-0991	scott.e.marston@boeing.com
Bob Lad	Environetix	President	Orono, ME		rlad@environetix.com
Kirk Galier	GE				kirk.gallier@ge.com
Nilesh Tralshawala	GE Global Research		Shenectady, NY	518-385-1928	nilesh.tralshawala@ge.com
Raj Singh	Honeywell		Golden Valley, MN	763-954-6341	rajan.singh@honeywell.com
Rama Budampati	Honeywell		Golden Vallley, MN		ramakrishna.budampati@honeywell.com
Aaron Trott	Invocon		Conroe, TX	281-292-9903	atrott@invocon.com
Chuck McConaghy	Lawrence Livermore Nat Lab				mccconaghy1@llnl.gov
Mark Cmar	NASA	Plumbrook			mark.d.cmar@nasa.gov
Nekheel Gajjar	Panduit Corp		Tinkley Park, IL		nsg@panduit.com
Kevin Thompson	Perpetua Power				KT@perpetuapower.com
Peter Flanagan	Rosemount - Emmerson		Chanhassen, MN		peter.flanagan@emerson.com
Thanh Vu	Savannah River Nuclear Solutions		Aiken, SC		thanh.vu@srs.gov
Joshua McConkey	Seimens	Seimens	Orlando, FL		Joshua.McConkey@siemens.com
Brian Schaible	Sporian				brian@sporian.com
Farokh Eskafi	Tagarray				farokh@tagarray.com
Paul Fortier	Univ of Massechusetts				pfortier@umass.edu
Haydn Thompson	Univ of Sheffield		Sheffield, UK		h.thompson@sheffield.ac.uk
Tom Birnbaum	Wireless Sensor Technologies				tbirnbaum@att.net
Steve Noro	Yokogawa				shuichiro.noro@us.yokogawa.com

2011 PWST Workshop Objectives

- **Understand various PWST technologies, actual & potential uses, and maturity.**
- **Assess the future applications/advantages/limitations in various industries.**
- **Assess what is needed for high volume production, standardization & communication.**
- **Precipitate individual and group “next step” thinking to further develop/apply PWSTs.**
- **Incrementally develop A PWST COMMUNITY**

2011 PWST Workshop Approach

Day 1:

- **Session 1 & 2: Set Landscape/Vision Of PWST
Introduction To PWST Technology**
- **Session 3 & 4: Technology Presentations and Demonstrations**
- **Dinner in small groups**

Day 2:

- **Session 5 & 6: End-User Presentations**
- **Session 7: Related enabling technologies and activities**
- **Session 8: Forward Planning Splinter Sessions/Reports**

**Note: One On One Sessions facilitated through-out both days.
Hardware Demonstrations Encouraged**

2011 PWST Workshop Statistics

- Time from 1st Announcement to Workshop: 3 months
- 34 Presenters: 18 on Day 1 + 16 on day 2
- 52 attendees: 25 + 27
- 13 Technology Demonstrations
- 13 One-on-One Tables
- Overseas: 1 from Germany, 1 Holland, 1 UK, 2 Japan, 2 Canada
- 6 University
- 18 Government
- 4 from JSC besides me – EV(2) and ES and EC
- 6 Forward Planning **Splinter Groups**:
 - Next Workshop - ISA/DOE-ORNL/Peter Fuhr
 - Business Case Development – Radiant360/Jeffrey Smith
 - Standards & Inter-operability - RFSAW/Clinton Hartmann(SAW tag-side)
 - Testing And Evaluation - NASA/LaRC/Cy Wilson, with KSC, JSC, MSFC, GRC
 - Communication - RFID Network/Louis Sirico - see first product already posted at <http://RFID.net>~~<~~<http://rfid.net/>
 - University Participation - MaXentric/UC SanDiego/Don Kimball

2011 PWST Workshop Speakers: Day 1

1-1	Lafferty	Dave	Welcome from BP - Interest, Facilities, Safety, etc	BP - Tech Office - host	Houston, TX	Chief Technology Office - Technology Advisor
1-2	Studor	George	"Fly-by-Wireless and the Passive Wireless Sensor Workshop"	NASA/Workshop Vision	Houston, TX	Staff, Strategic Planning and Partnership Opportunities Office
1-3	Malocha	Don	"Wireless Passive SAW Sensors using Coded Spread Spectrum Techniques"	Univ of Central Florida	Orlando, FL	Prof, Dep Electrical & Computer Eng, Harris Engineering Center (HEC 346)
1-3	Belkerdid	Madjid	Joint Presentation - Demonstration	Mnemonics	Melbourne, FL	Principal Systems Engineer
2-1	Surman	Cheryl	"Multivariable passive RFID sensors: From detailed laboratory evaluations to pilot-scale manufacturing"	GE Global Research Center	Niskayuna, New York	Bioanalytical Chemist- Chemical Sensor Laboratory
2-1	Bloch	Peter	Joint Presentation - Demonstration with GE	Avery Dennison	Madison, WI	Sr. Mgr of Strategic Alliances, RFID Div
2-2	Matthews	Robert Dr.	"Compliance Independence-- is this the passive revolution?"	West Wireless Health Institute	La Jolla, CA	Chief Technology Officer
Lunch Spkr	Reindl	Leonhard	"History, Applications, and Market Overview of Passive Wireless Sensors"	Imtek, Institute for Microsystem Tech	Freiburg, Germany	Head, Dept of Electrical Instrumentation, Imtek
3-1	Hartmann	Clinton	"Advanced SAW Devices for RFID and Sensing Applications"	RFSAW	Richardson, TX	Founder and President
3-2	Hines	Jackie	"SAW Sensor and Sensor-tag Developments at ASR&D"	ASRDC	Arnold, MD	President
3-3	Woods	Brian	"VERSA: V-band Enhanced RFID/Sensing Architecture"	MaXentric	LaJolla, CA	R & D Engineer - Note: Also accompanied by the Chief Technology Office Don Kimball
3-4	Brown	Jeffrey K.	"Seeing Through the Fog: Collecting PWST Data in a Harsh Environment"	Radiant360	St. John's, Newfoundland	Executive Vice President
3-5	Abedi	Ali	"Location and Temperature Passive Wireless Sensor Tags"	Univ of Maine/CANEUS	Orono, ME	Associate Professor Electrical and Computer Eng.
4-1	Trelewicz	Jason	"Integrated Diagnostics Using Direct Write Sensors"	Mesoscribe	St. James, NY	Program Manager
4-2	Conkle	John	"Wireless Sensors for Gas Turbine Engines"	Wireless Sensor Technologies	Encinitas, CA	Founder and President
4-3	Krawczewicz	Mark	"A New Class of Passive Secure ID Display Card"	Tocreo Labs	Annapolis, MD	Founder and CEO
4-4	Kalinin	Victor	"Wireless Resonant SAW Sensors for Automotive Applications"	Transense	Upper Heyford, Oxfordshire, UK	Chief Scientist
4-5	Ostafte	Harry	"High-Function, Long-Range PWST"	Powercast	Pittsburgh, PA	Vice President of Marketing & Business Devel

2011 PWST Workshop Speakers: Day 2

5-1	Lafferty	Dave	"Potential Passive Wireless Sensor Tag Applications"	BP - Tech Office - host	Houston, TX	Chief Technology Office - Advisor
5-2	Chow	Ivan	"Proceed with Caution with Disaster Recovery Applications Nuclear Power Plant Control System"	Doosan/HF Controls	Plano, TX	V&V Manager at Doosan HF Controls
5-3	Stieger	Ron	"RFID Sensors in Transportation"	Zonar Systems	Seattle, WA	Director of Engineering
5-4	Faridazar	Fred	"Intelligent Multi-Sensor Measurements to Enhance Pavement Monitoring and Safety"	DOT-FHWA - Turner-Fairbank Admin	McLean, VA	Office of Infrastructure Research and Development - Pavement Design and Construction Team
5-4	Lajnef	Nizar	"A Sub-Microwatt Long-term Monitoring Sensor"	Michigan State Univ	East Lansing, MI	Ass. Prof, Dir. Comp Sensors Lab/Civil&Env. Eng
5-5	Mrad	Nezih	"Potential Applications of PWST"	Department of National Defence (DND)	Ottawa, CA	Defence Scientist,Air Vehicles Research Section (AVRS)
6-1	Gemdjian	Ed	"Passive Wireless SAW Temperature Sensors"	Kongsberg Maritime	Northvale, NJ	Mechanical Engineer
6-2	Hernandez	George	"Sensors and Controls Enabled Solutions"	DOE/PNNL - Building Sensors	Richland, WA/Wash DC	Staff Engineer - detailed to DOE HQ
6-3	Salour	Al	"Use of Passive RFID and Networking Technology in Aerospace Manufacturing"	Boeing – Aerospace Manufacturing Sensors	St. Louis, MO	Enterprise Leader for the Boeing Research & Technology's Network Enabled Manufacturing (NEM) initiatives
6-4	Safa-baksh	Robab	"Passive Wireless Sensors, Vehicle Health Management Applications"	Boeing Research and Technology	Philadelphia, PA	Asso. Tech Fellow for VHM & SHM
Lunch Spkr	Sirico	Louis	"What Works in the World of Wireless Sensors"	The RFID Network	Campbell, CA	Host of The RFID Network, a TV video series dedicated to RFID and wireless sensor technologies
7-1	Vega	Victor	"Interactive Gen2 Bridging the Gap between Passive RFID, Sensors and Electronics"	NXP Semiconductors	San Jose, CA	Business Development Manager, Marketing Director, RFID Solutions
7-2	Plourde	Rich	"Aerosol Jet Direct Write Technology – A Tool for Printed Electronics"	Optomec - Headquarters	Albuquerque, NM	Aerospace & Defense Business Liaison
7-3	Wilson	William C.	"NASA Testing of PWST"	NASA-LaRC	Langley, VA	LaRC-SAW Device Design, COTR
7-4	Fisher	Fred	"AVSI Cooperative Research in Intra-Aircraft Spectrum Usage"	AVSI - Assist Dir; TEES -Dir Eng& Comp	College Station, TX	Assistant Director, AVSI
7-5	Pimprikar	Milind	"Bridging the Mid TRL Gap through Coordinated Technology Development"	CANEUS	Montreal, CA	Founder and Chairman
Intro	Fuhr	Peter	Motivation and Explanation of Splinter Sessions	DOE/ORNL	Knoxville, TN	Future ISA Comm Chair
Mtg	Splinter Sessions Meet in Separate Locations					
Sum	Splinter Spokesperson		5 minute Report from Each of 7 Splinter Groups			

2011 PWST Workshop Attendees

Last	First	Position	Organization	Location	Type
Adams	Elizabeth	Technology Project Leader - Wireless	BP	Naperville, IL	Ind
Adkins	Andrea	Assist Dir. Commercialization: Tech Transfer	UCF	Orlando, FL	Univ
Bachtel	Russel	Engineer	NASA-JSC - EC	Houston, TX	Gov
Bain	Mark	Systems Engineering Electrical	Space Systems Loral	Palo Alto, CA	Ind
Barton	Rick	Wireless Communication Engineer	NASA- JSC/EV4	Houston, TX	Gov
Baumann	Wolfgang	Sales Engineer	R. STAHL INC	Houston, TX	Ind
Bonneau	Walt Jr.	President & General Manager	Cubic Security Systems, Inc	San Diego, CA	Ind
Chen	Penny	Principal Systems Architect	Yokagawa	Palo Alto, CA	Ind
Citrano	Joseph	Global Product Marketing Manager	Honeywell	Golden Valley, MN	Ind
Cote	Andrea	Chief Technology Officer and VP of PM	Omni-ID	Rochester, NY	Ind
Cramer	Ronald	Senior Advisor	Shell	Houston, TX	Ind
Cuartas	Wilson	Engineer	AW ELECTRONICA	Houston, TX	Ind
Daniel	Alan	Sr. Research Engineer	Southwire Company	Carrollton, GA	Ind
Dodds	Kevin	Land Geological Integrity`	BP	Houston, TX	Ind
Drobshoff	Alex	Engineer	Lawrence Livermore National Lab	Livermore, CA	Gov
Ferguson	Dana	Business Development	Ventyx	Houston, TX	Ind
Goodenow	Debra	Instr. for Heavy Lift Launch Vehicles	NASA - GRC	Cleveland, OH	Gov
Griggs	Steve	Engineer	Weatherford	Houston, TX	Ind
Haines	Mark	Director of Engineering	Mnemonics	Melbourne, FL	Ind
Hartmann	Tom	Director Brand Security & Electronics	Topflight	Glenn rock, PA	Ind
Hartmann	Paul	Vice President, Engineering	RFSAW	Richardson, TX	Ind
Hedtke	Bob	Director of Technology	Rosemount Inc	Chanhassen, MN	Ind
Hines	Andy	Technician	ASRDC	Arnold, Maryland US	Ind
Hines	Jackie	President	ASR&D	Arnold, Maryland US	Ind
Ho	Stephen	Research Scientist	MIT Auto-ID Labs	Cambridge, MA	Univ

2011 PWST Workshop Attendees

Hyde	Scott	Marketing Manager for Strategic Propulsion	Aerojet	Clearfield, Utah	Ind
Kimball	Don	Chief Technology Officer	MaXentric	LaJolla, CA	Ind
Krisel	Robert	Engineering Manager	Panduit Corp	Tinkley Park, IL	Ind
McIntyre	Timothy	Leader, Sensors and Controls Research Grp	DOE/ORNL - Sensors & Controls	Knoxville, TN	Gov
Montgomery	Bruce	President	Syntonics LLC	Columbia, MD	Ind
Nadler	Gerry	President	Wihart systems	Acton, MA	Ind
Oberle	Larry	Instr. For Heavy Lift Launch Vehicles	NASA - GRC	Cleveland, OH	Gov
Oeste	Tom	Technician	ASRDC	Arnold, Maryland US	ind
Ogai	Takashi	Mgr, Gr. Space Dev., Aero Eng & Space Ops	IHI Corporation	Japan	Ind
Oluwatosin	Adedeji	Shell Global Solutions International B.V.	Shell	Rijswijk,S.Holland NL	Ind
Pahlavan	Kourosh	CEO & CTO	TagArray	Palo Alto, CA	Ind
Patterson	Mark	Propulsion Dir., Turbine EngResearch Center	AFRL /RZTE	WPAFB, OH	Gov
Saito	Hiroki	Staff Member - Aero Engines & Space Ops	IHI Corporation	Japan	Ind
Schoenborn	Renee	Senior Instrument Engineer	Shell Global Solutions(US)	Houston, TX	Ind
Scoggins	Doyle	STPNOC Metrology Supervisor	STP Nuclear Operating Company	Wadsworth, TX	Ind
Scott	Jeffrey	Technologist - RFID	Pacific Northwest National Labs	Richland, WA	Gov
Smith	William	Project Engineer	Mesoscribe	Huntington Beach, CA	Ind
Smith	Richard	Shell SEIP	Shell	Houston, TX	Ind
Solie	Leland	Senior Scientist	ASRDC	Arnold, Maryland US	Ind
Song	Gangbing	Director, Smart Materials/Structures Lab	Univ of Houston	Houston, TX	Univ
Struble	Ed	Vice Pres Avionics, Weapons & Sensor Sys	Mnemonics	Melbourne, FL	Ind
Tran	Thanh	NMO Process Engineer	Savannah River Nuclear Solutions	Aiken, SC	Gov
Trott	Aaron	Program Director	Invocon	Conroe, TX	Ind
Wagner	Raymond	Sr. Research Development Scientist	NASA - JSC	Houston, TX	Gov
Ward	Justin	Sr Business Systems Associate	EOG Resources	Fort Worth, TX	Ind
Willoner	Terry	Engineer	Savannah River Nuclear Solutions	Aiken, South Carolina	Ind
Zipay	John	Structural Engineer	NASA/JSC - ES	Houston, TX	Gov

Passive Wireless Sensor Technology

Workshop Web-links

ISA Communication Division

Workshop Program:

http://www.isa.org/Content/Microsites530/Computer_Tech_Division/Home528/Passive_Wireless_Sensor_Workshop/Final2011Program.pdf

Workshop Summary:

http://www.isa.org/MSTemplate.cfm?Section=Passive_Wireless_Sensor_Workshop&Site=Computer_Tech_Division&Template=/ContentManagement/MSCoContentDisplay.cfm&ContentID=86981

Workshop Presentations:

http://www.isa.org/MSTemplate.cfm?Section=Papers_Presentations&Site=Computer_Tech_Division&Template=/ContentManagement/MSCoContentDisplay.cfm&ContentID=86991

Communications:

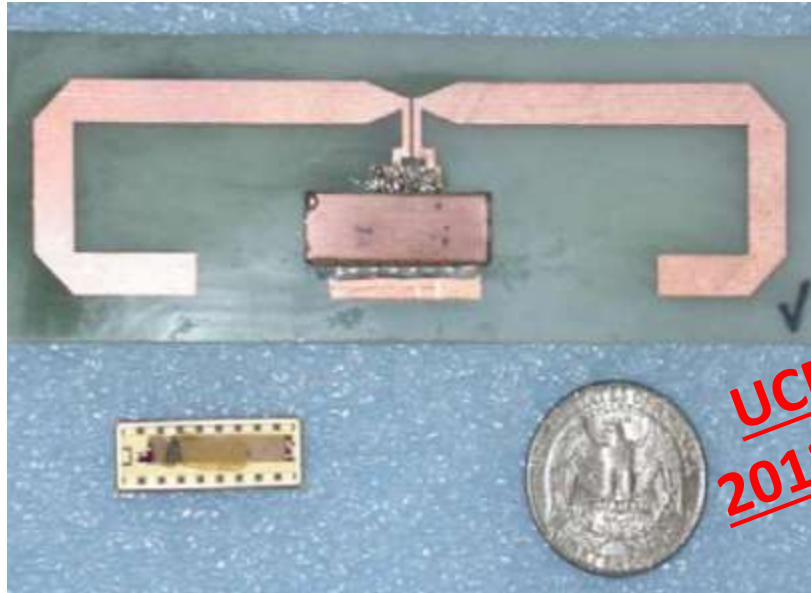
<http://rfid.net/applications/energy/289-passive-wireless-sensor-tags-benefit-energy-aerospace-transportation-a-industry>

Briefing Summaries

Wireless Passive SAW Sensors using Coded Spread Spectrum Techniques

Univ of Central Florida/Mnemonics

Don Malocha <http://caat.engr.ucf.edu/> - Madjid Belkerdid <http://mnemonics-esd.com>



**915 MHz Wideband
Folded Dipole Antenna**

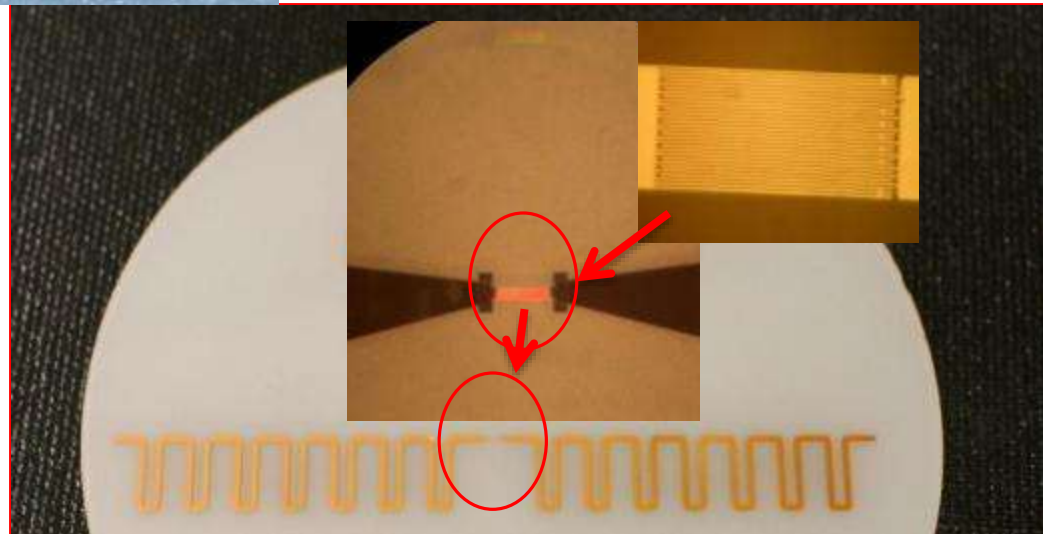
**UCF will Present at
2012 PWST Workshop**



**Miniature 915MHz Integrated
OFC SAW-Patch Antenna**

***OFC=Orthogonal Frequency Coded
SAW=Surface Acoustic Wave***

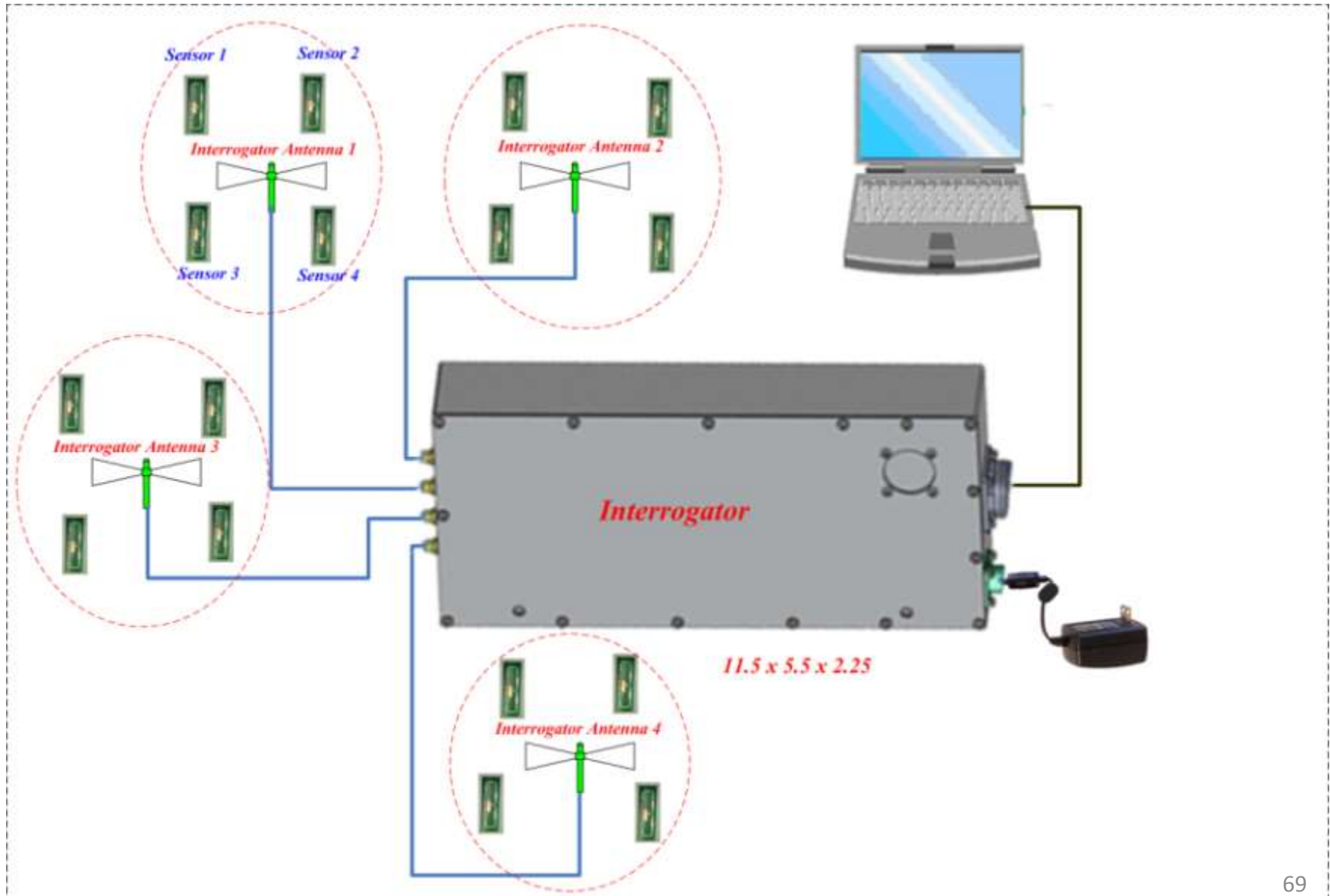
**Fully integrated
on-wafer SAW OFC
sensor and antenna**



Wireless Passive SAW Sensors using Coded Spread Spectrum Techniques

Univ of Central Florida/Mnemonics

Don Malocha <http://caat.engr.ucf.edu/> - Madjid Belkerdid <http://mnemonics-esd.com>



NASA Phase 2 STTR Award

UCF & Mnemonics

10-2 T7.01-9980

Wireless SAW Sensor Strain Gauge & Integrated Interrogator Design

Awarded – Apr 27, 2012

TECHNICAL ABSTRACT

The proposed Wireless, passive, SAW sensor system operates in a multi-sensor environment with a range in excess of 45 feet. This proposed system offers unique features in two (2) important areas. The first is in the development of a new sensor type, a strain gauge that is based on OFC techniques and implemented with the low loss characteristics of SAW Unidirectional transducers. The second is in the design of an integrated interrogator system that has DSP-based embedded signal processing. Interrogator will also be capable of rapidly performing multiple interrogations which can then be used to make vibration measurements or averaged to extend the operational range of the system. This proposal extends the Phase I and previous work in two major areas; developing a SAW strain sensor, and dramatically increasing interrogation range, which is applicable to both the new strain sensors and the previously developed temperature sensors. In order to increase SAW sensor range, sensitivity and accuracy, the most important device parameters were identified and initial investigation begun in Phase I and will be put into practice in Phase II. To reduce SAW sensor loss and minimize multi-transit acoustic echoes, low loss unidirectional studies were initiated. Phase I produced three alternative low-loss approaches that will be evaluated in the Phase II work. Success will lower the insertion loss by approximately 15 dB, and multi-transit echoes are predicted to be less than -40 dB from the main signal; doubling the system range and reducing the sensors self-noise. Advanced coding techniques were investigated in Phase I that have led to longer delay path lengths, and shorter codes with less inter-sensor interference.

During Phase II, the interrogator will improve the following critical capabilities: onboard-fully-integrated DSP, extended connectivity options to customer's computer, and rapid interrogation capabilities. This will allow vibration sensing and signal integration.

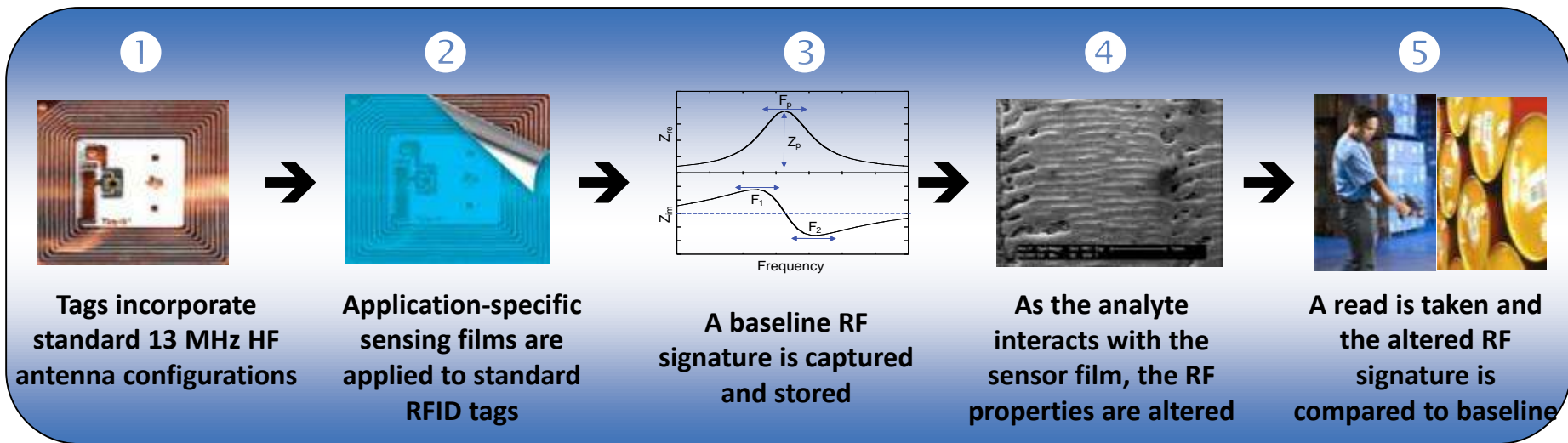
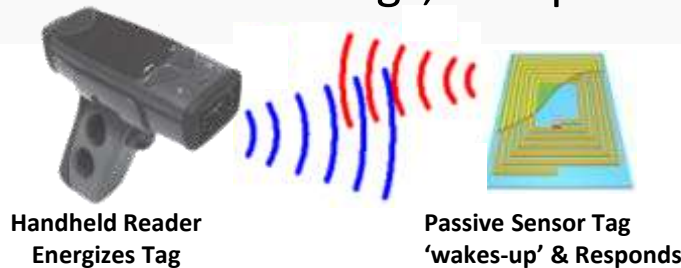
Multivariable passive RFID sensors: From detailed laboratory evaluations to pilot-scale manufacturing

GE Global Research/Cheryl Surman(surman@ge.com)

Avery Denison/Peter Bloch(peter.bloch@averydennison.com) - <http://ge.geglobalresearch.com>

How it works:

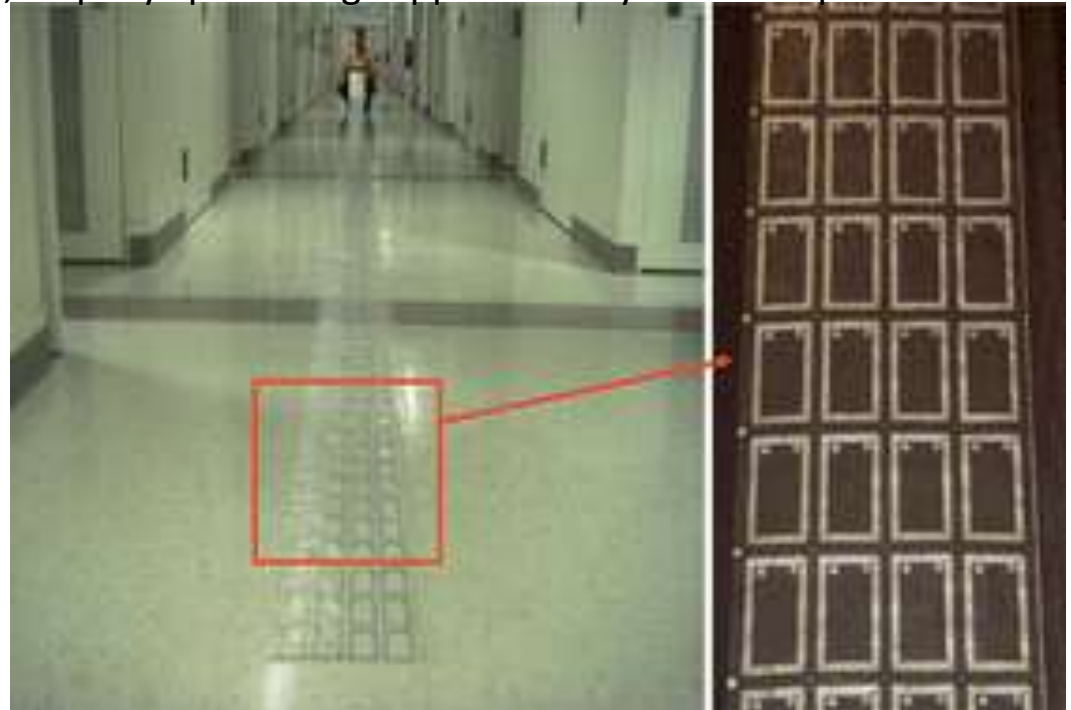
- GE RF Sensing utilizes the complex waveform of an existing high-frequency (HF) RFID technology as a signal transport.
- The reader interrogates the sensor tags, interprets the waveform, and determines measurement value.



Feb 2012 Analyst: “Multivariable passive RFID vapor sensors: roll-to-roll fabrication on a flexible substrate” Radislav Potyrailo, Andrew Burns, Cherly Surman, D.J. Lee, Edward McGinniss

We demonstrate roll-to-roll (R2R) fabrication of highly selective, battery-free radio frequency identification (RFID) sensors on a flexible polyethylene terephthalate (PET) polymeric substrate. Selectivity of our developed RFID sensors is provided by measurements of their resonance impedance spectra, followed by the multivariate analysis of spectral features, and correlation of these spectral features to the concentrations of vapors of interest. The multivariate analysis of spectral features also provides the ability for the rejection of ambient interferences. As a demonstration of our R2R fabrication process, we employed polyetherurethane (PEUT) as a “classic” sensing material, extruded this sensing material as 25, 75, and 125- μm thick films, and thermally laminated the films onto RFID inlays, rapidly producing approximately 5000 vapor sensors.

We further tested these RFID vapor sensors for their response selectivity toward several model vapors such as toluene, acetone, and ethanol as well as water vapor as an abundant interferent. Our RFID sensing concept features 16-bit resolution provided by the sensor reader, granting a highly desired independence from costly proprietary RFID memory chips with a low-resolution analog input. Future steps are being planned for field-testing of these sensors in numerous conditions.



Compliance Independence– is this the passive revolution?

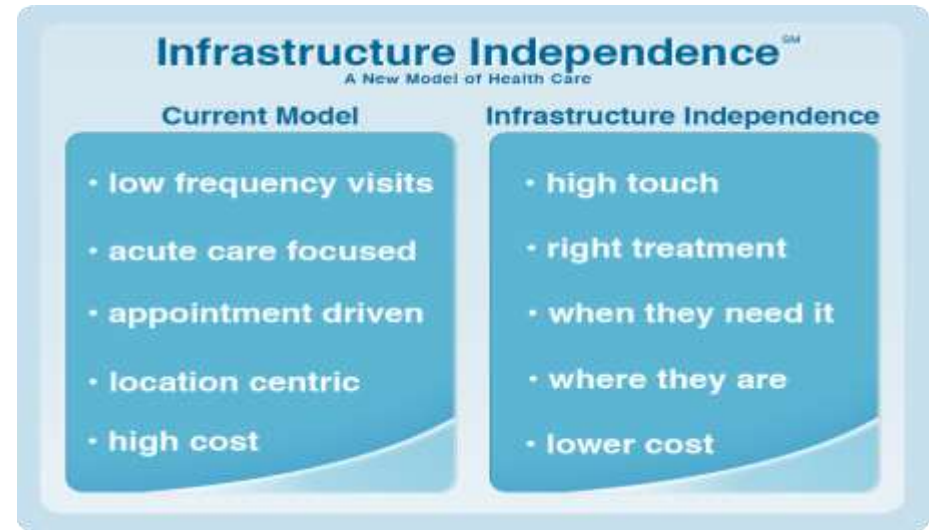
West Wireless Health Institute/Robert Matthews - CTO

<http://www.westwirelesshealth.org/rmatthews@gmwhi.org>

■ Primary Mission: Lower Health Care Costs

PWST Application Areas:

- Smart patient ID
- In home/office sensors
- On body sensors
- Medication compliance



Sensors in the bed:

Pressure – management of bed sores
Weight – identify weight gain (fluids)
Heart rate – various diseases
Motion -- various diseases
Wetness – need to change bedding

Patient ID – Once a day, some patient is mis-identified.

Patient Info: Who, what, when

- Allergies, genetic information
- What and when medications were take
- What batch of blood etc

Desired PWST Attributes:

Very Cheap -- cents (disposable)
Long range (100's ft)
Non-trivial power for sensors without risk to patients
Buffer power for use whilst not being illuminated
Store significant amounts of data (both read and write)

HIPPA compliant
Very small, Mechanically flexible
Reliable/Robust
Configurable
Easy to integrate

West Wireless Health Institute 2012 Update(from website)

West Wireless Health Council

SAN DIEGO – February 15, 2012

A new coalition of hospital and health system leaders to create a standard approach to installing wireless infrastructure in health care settings and develop innovative solutions that will enable the full potential of wireless health technology to be realized in health care delivery settings, and ultimately lower health care costs.

https://s3.amazonaws.com/wwhi.org/WWHC_Release-02142012.pdf

Sense4Baby:

Late Term Home Monitor connects to medical experts via Smartphone tablet Bluetooth and internet. Other functions



<http://www.westwirelesshealth.org/index.php/sense4baby>

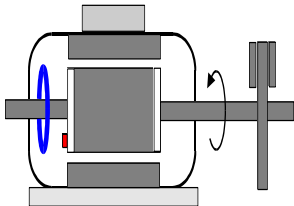
History, Applications, and Market Overview of Passive Wireless Sensors

IMTEK - Leo Reindle – Dept Head, Electrical Instrumentation

reindl@imtek.uni-freiburg.de - <http://www.imtek.de>

- 1st Passive Wireless Sensors: Wolf-Eckhard Bulst
- 1st Chirped Wireless Sensors: Franz Seifert
- 1st Phase Information Basis: Valentin Magori
- 1st Interrogator(Siemens): Patric Heide, Frank Schmid
433 MHz by Univ. Vienna
- Tollway Application in Norway – 500,000 tags
- 1st Pulse Position Coding: Victor Plessky
- SOFIS on SIEMENS rail – Munich Subway (2.45GHz)
- Temperature Sensors:

Motor Rotor HV Surge Arresters Train Brakes



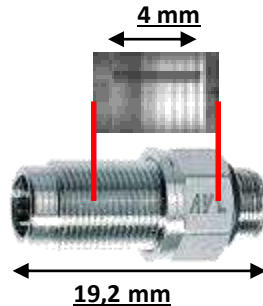
- High Temp SAW Sensors with Platinum Electrodes on Langasite
 - Tire Pressure Sensor(Siemens): G. Schimetta
 - SAW Sensor for Tire Friction Control(Siemens +)
 - Torque – **Sensor Technology's** Torquense System
- SEIMENS** Got out of SAW busyness due to assignment of it to EPCOSS
- SAW Accelerometer – Dart Demo
 - SAW Current Sensor
 - SAW Water Content Sensor - Alexander Kiermayer



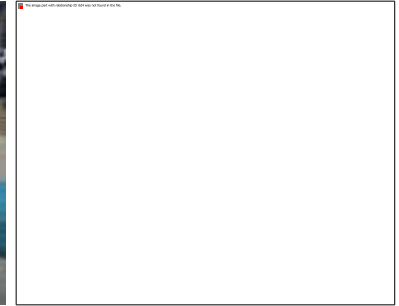
IMTEK - Leo Reindle: European Company Products

Mobile Readers:

AVL – Pressure Sensor with Integrated ID:



RSSI GmbH & Carinthian Technologies



http://www.ctr.at/carinthian_tech_research_english

RHI - RFID and Sensing in a Steel Plant(+1400C)



CTR - Doble Lemke -Temperature Monitoring of Power Transmission Lines

***CTR will Present at
2012 PWST Workshop***



**CTR – Temperature Monitoring of Rotating Machine Elements
Up to 15,000 RPM**



IMTEK – Leo Reindle: European Companies

SENSeOR - Unique Features for High Value Applications

Revolutionary sensors

- **Wireless**
- **Passive**
- **Robust**



➔ Enabling measurements

- On moving and rotating parts
- In confined or inaccessible spaces
- Where cabling costs too much or is impossible
- In harsh environments – like: strong fields, explosive, corrosive

➔➔ For measurable benefits

- **Improved productivity**
- **Performance optimization**
- **Security enhancements**

• Pressure in pipes
• Oven temperature
• Stress in structures

• Instrumented industrial valves
• Stress in concrete

GREENTECH

• Tire pressure
• Motor temperature
• Oil pressure

Condition Monitoring - Structural Health Monitoring
Process Control - Precision Metrology

IMTEK – Leo Reindle: European Companies



SAW Temperature Evaluation
Kit EVAL KIT T01

**SENSeOR offers to partner with anyone
such as to industrialize such applications
and to make the technology known.**

**Once we find strong applications and/or
partners in the US then SENSeOR will
establish an office in the USA.**



Pressure
sensor chip



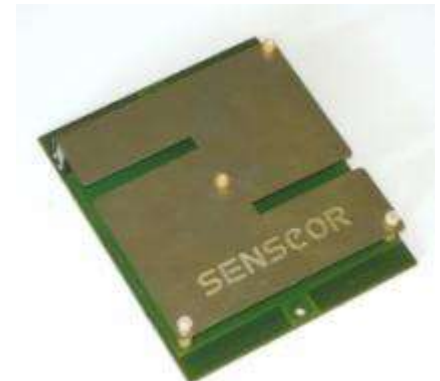
Packaged
temperature sensor
TSE AS10



Fixture mounted temperature
sensor with antenna
TSA D031



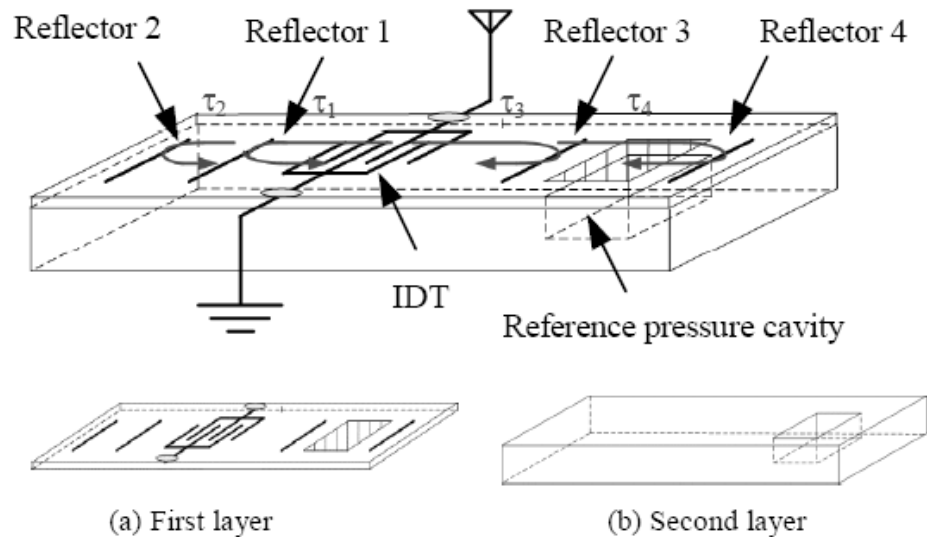
Thermowell packaged
temperature sensor
TSM D100



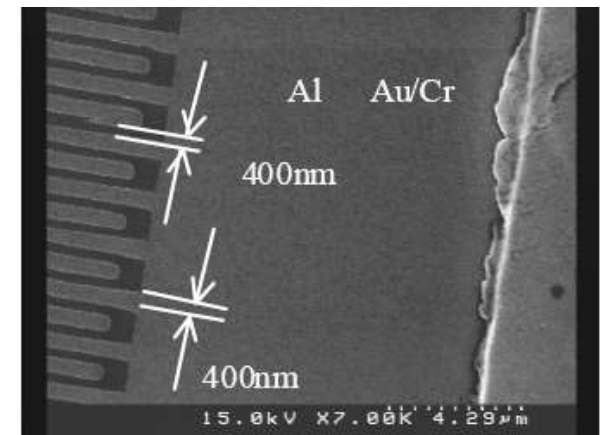
PIFA antenna mounted
temperature sensor
TSA D003

IMTEK – Leo Reindle: Other Offerings

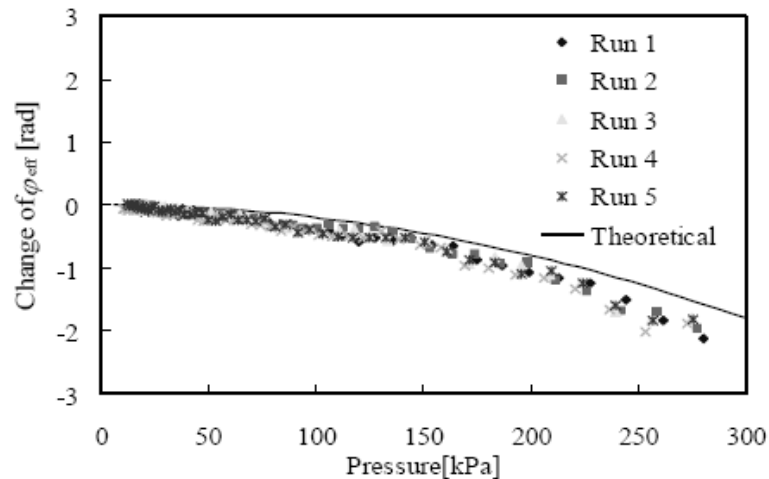
Nissan pressure sensor



Schematic structure of the SAW delay line pressure sensor



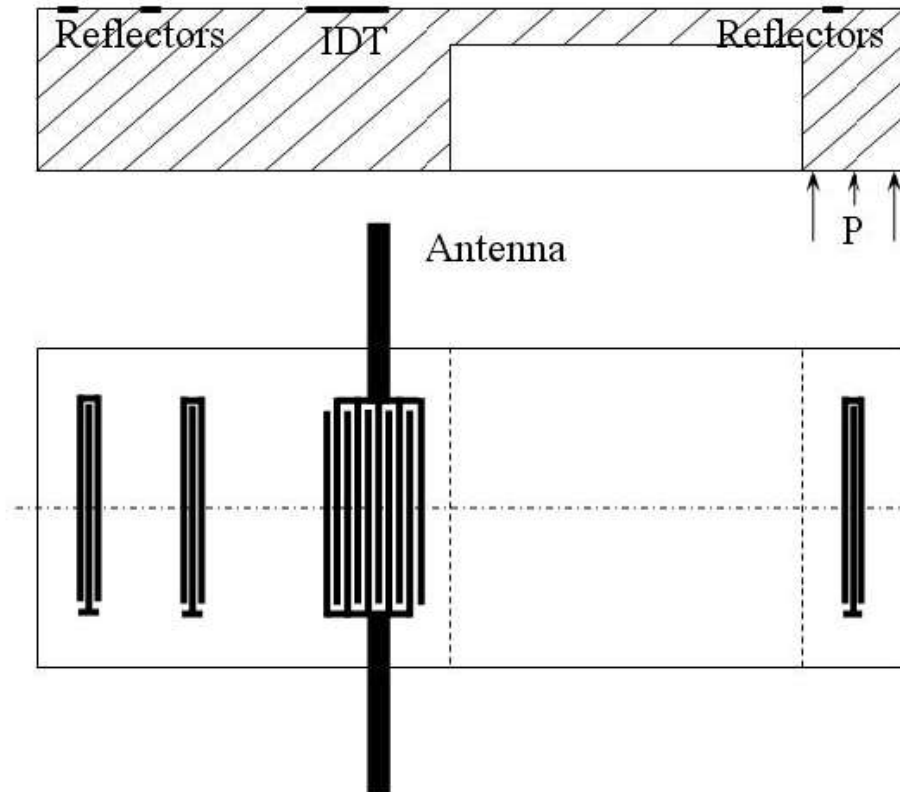
Fabricated interdigital transducer



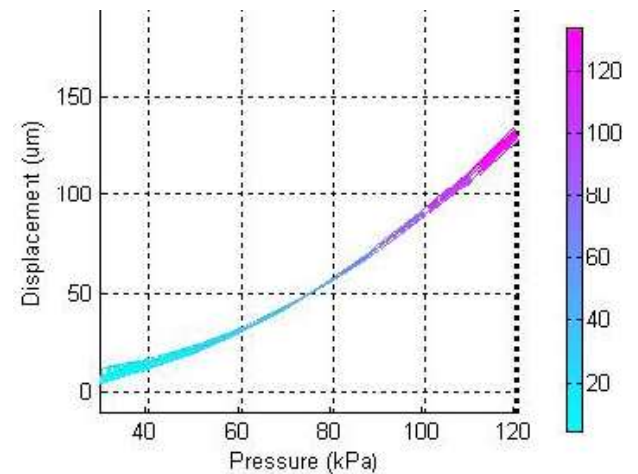
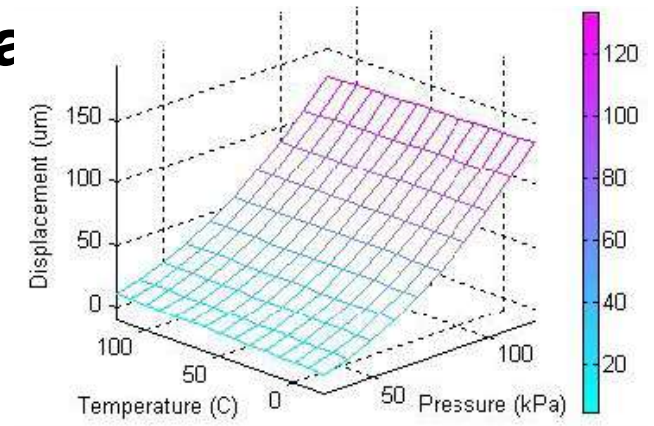
Change of the effective phase φ_{eff} by pressure change

IMTEK – Leo Reindle: Other Offerings

Harbin Institute of Technology, China



The structure of the wireless passive SAW sensor

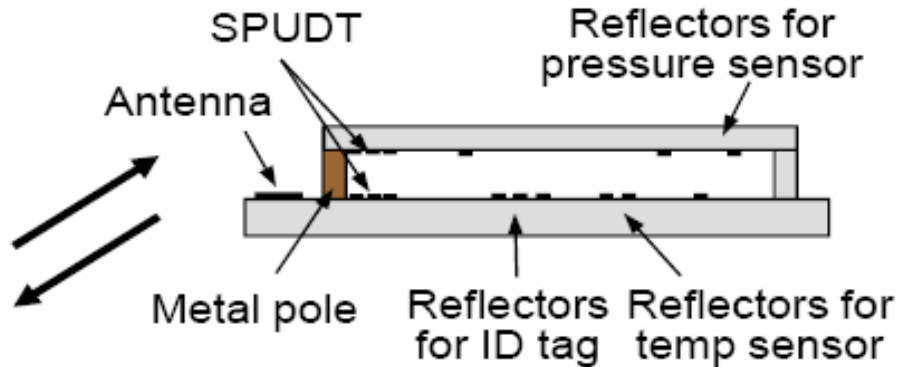


Displacement affected by the temperature and pressure after data processing.

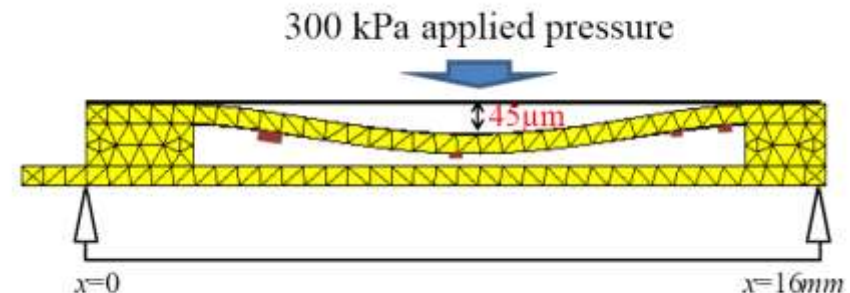
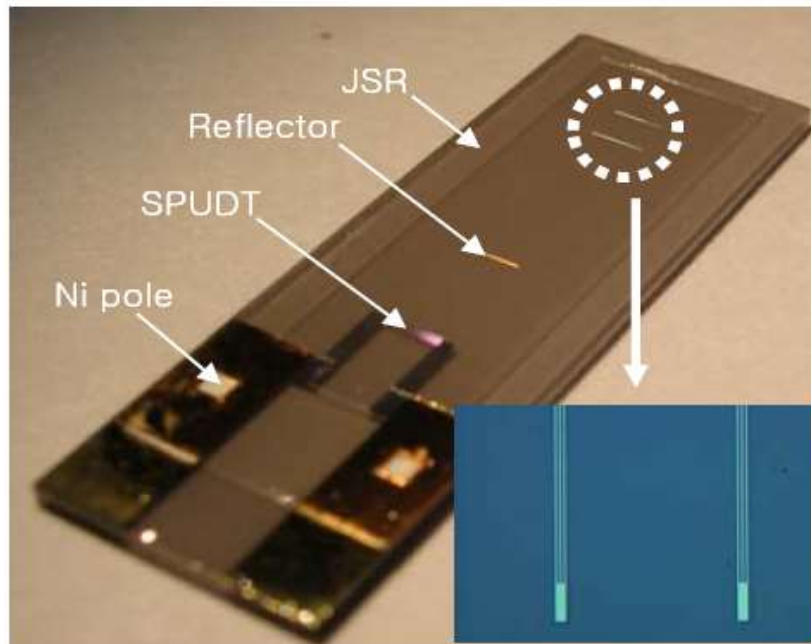
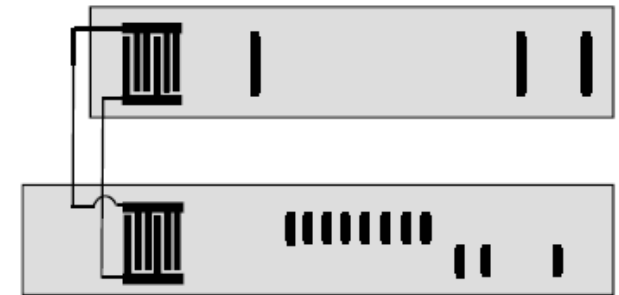
IMTEK – Leo Reindle: Other Offerings

Anyun University, Korea, wireless SAW sensor for simultaneous measurement of pressure, temperature & ID

Cross-sectional view of the fabricated microsensor



views of the top and bottom devices



Calculated diaphragm bending under applied pressure of 350kPa using FEM analysis

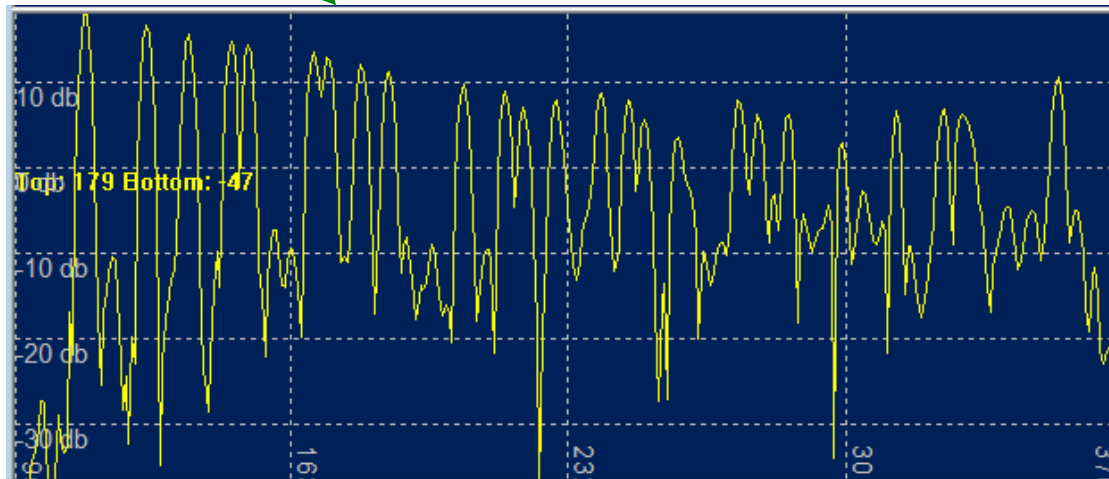
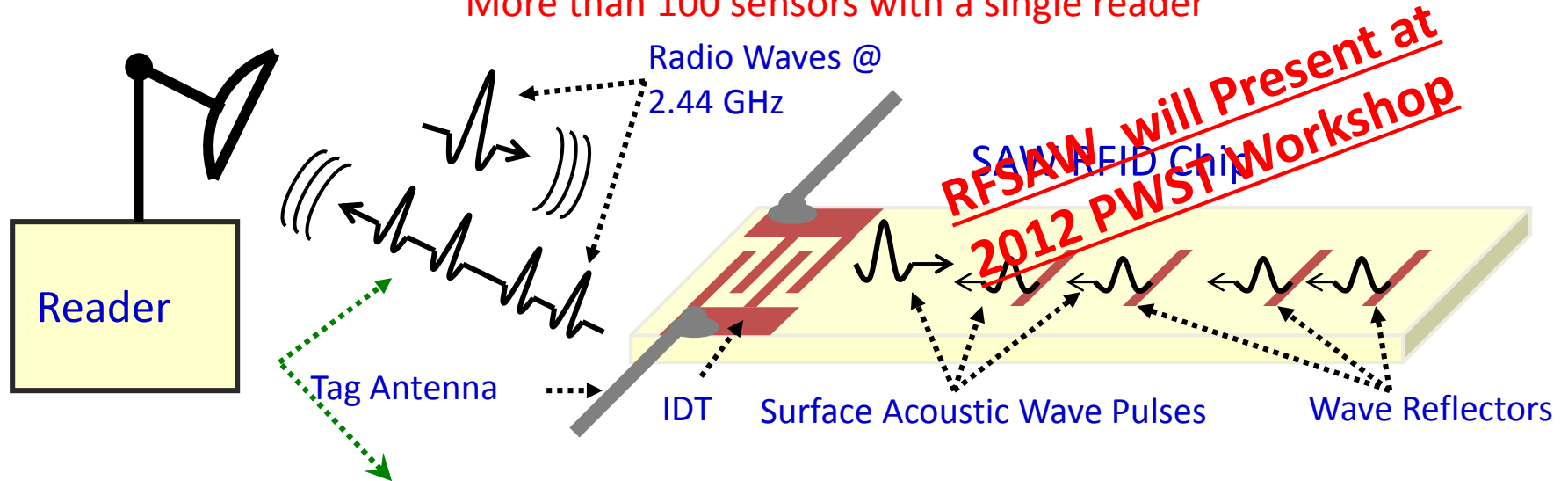
Leo Reindle: Rack-up of Sensor Sources

Company	Temp	Pressure	Stress	Torque	Bio/Chem
Applied Sensor R&D (USA)	☺		☺		☺
Avianamolecular (USA)					☺
Bürkert (D)					☺
CTR (A)	☺				
Doble Lemke (D, CH)	☺				
Electronic Sensor Technology					☺
GVR Trade (CH)	☺				
Heinz (D)	☺	☺	☺		
Honeywell (USA)	☺	☺			
Promicron (D)	☺		☺	(☺)	
SAW Instruments (D)					☺
Sengenuity (USA)	☺		(☺)	(☺)	
sensAction (D)					☺
SENSeOR (D,F)	☺	☺	☺	(☺)	☺
Siemens / GE / NG / Honeywell	(☺)	(☺)	(☺)	(☺)	(☺)
Transense (UK)		☺	☺	☺	
	10	4	5	3	8

RF SAW's Global SAW Tag System

Clinton Hartman/RFSAW - CHartmann@RFSAW.com - www.rfsaw.com

More than 100 sensors with a single reader



Actual 96-Bit Wireless Tag Waveform

GST Features

- Trillions of Trillions of ID Numbers
- Inherent Temperature Sensing
- Inherent Tag Localization

SAW Sensor and Sensor-tag Developments at ASR&D

Jackie Hines/ASRDC

jhines@asrdcorp.com - www.asrdcorp.com

Demonstrated sensor devices for:

- ◆ Temperature ◆ Liquid (level) ◆ Humidity
- ◆ Hydrogen ◆ Sensor-tags (strain, T, V, etc.)

Products under development:

- Coded sensor-tag wireless interface devices
- Humidity sensors
- Hydrogen sensors
- Temperature sensors
- Methane sensors
- Hypergol leak detection sensors (MMH, DMH, NTO)
- Cryogenic Liquid (level) sensors
- Concrete maturity monitor
- Biosensor for infectious agents (CT)

Systems:

- 32 tag humidity sensor to KSC Sept 29, 2011
- 32 tag temperature sensor system SBIR Phase 2 – begun June 2011 to MSFC



***ASRDC will Present at
2012 PWST Workshop
SBIR Phase 2 System***

“VERSA” Resonant Passive Tags

MaXentric – Brian Woods

bwoods@maxentric.com - www.MaXentric.com

V-band Enhanced RFID Sensing Architecture(VERSA) Tags: 24 or 60 GHz

- VERSA tags are completely **passive**
- **Potentially** 1-2cents increase in label/tag production cost
- VERSA tags are embedded with **thin metal dipoles called taggants**
 - Length of the taggant and type of material determine resonant frequency (60GHz=2.5mm), several micrometers wide, and hundreds of nanometers thick
- Can be **manufactured on a variety of materials**: paper, wood, plastic
- At 60GHz ISM Band, system uses 7GHz of freq band
- **60GHz is in the Oxygen absorption region** – allowing natural security
- **Unique RF signature** depends on many parameters and pattern
 - Taggant orientation



**MaXentric (local)
will Present at
2012 PWST Workshop**



Business/Use Case Assessments

Jeff Brown/Radient360

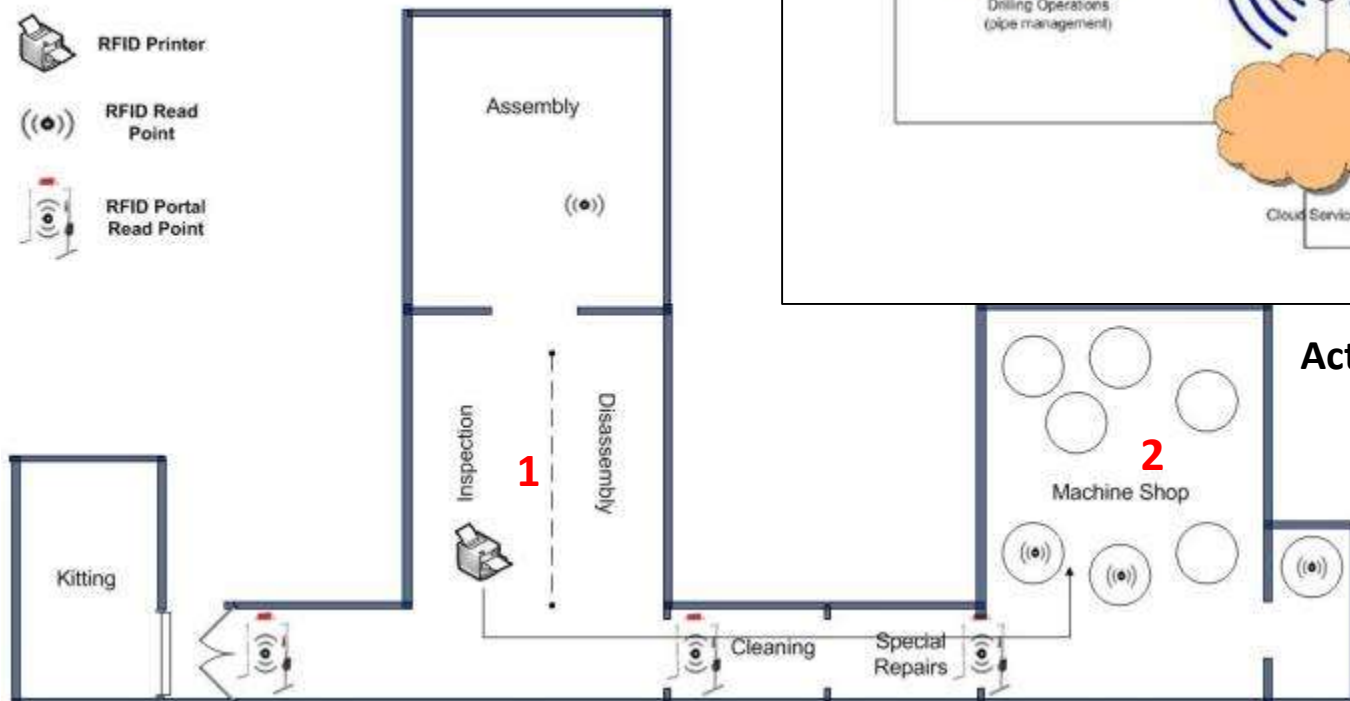
jeff.brown@radient360.com - www.radient360.com

Tracking Aircraft Engine Parts

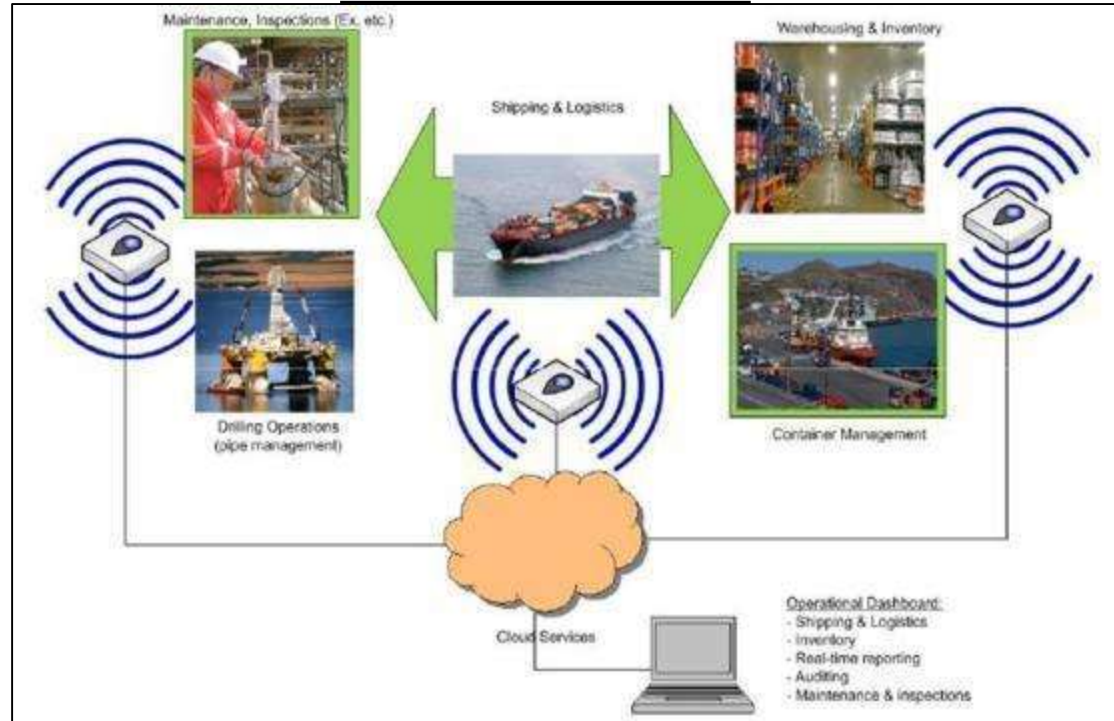
Aircraft Engine Parts Repair Process:

1. Tag applied to work order at Inspection (based on activity performed 'business as usual')
2. Part is 'read' instantaneously as it moves through out the facility

LEGEND



Offshore Oil and Gas

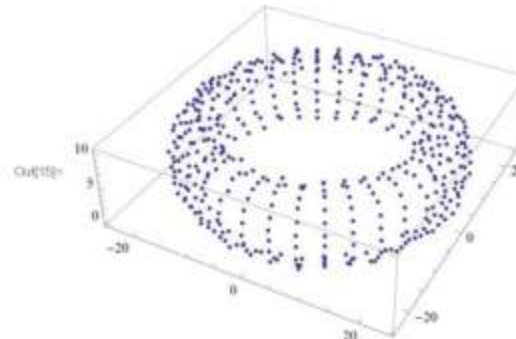


Active and Passive RFID & GPS In Harsh Environments

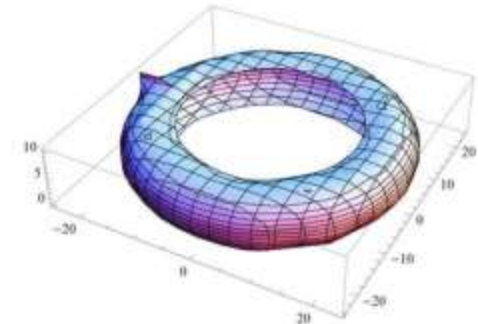


Location and Temperature Passive Wireless Sensor-Tags

Univ of Maine/Ali Abedi <http://www.wisenet.eece.maine.edu> - ali.abedi@maine.edu



2D Shape Reconstruction



3D Shape Reconstruction

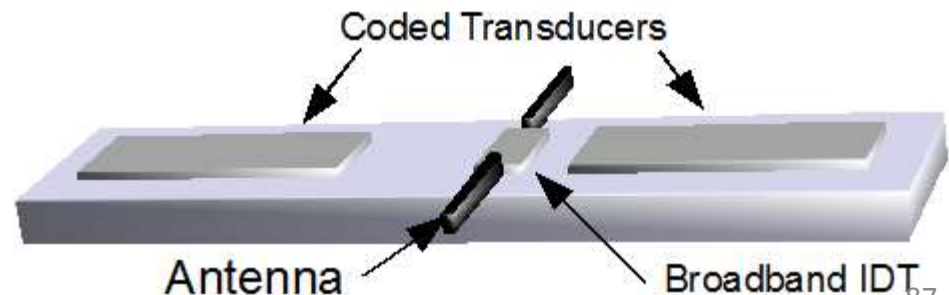
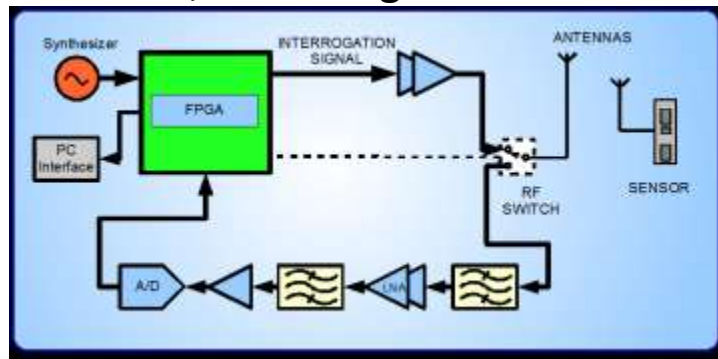
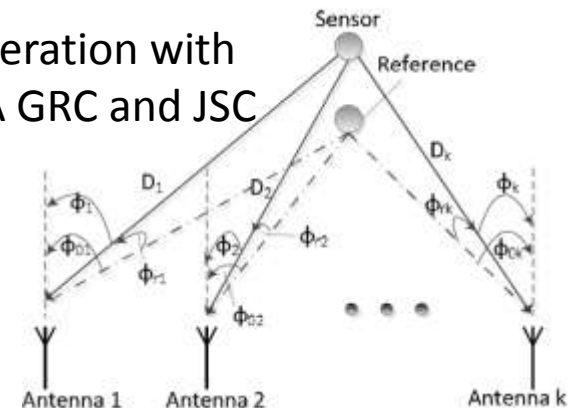
Passive SAW Tag for Location/Shape

- 860-960 MHz -10 ft read range
- Passive – no battery
- EPC Global Gen 2 / ISO 18000-6C Standard
- Motorola Reader with 70 degree field of view

Passive SAW Temperature Tag

- Designed and built at Umaine/Prof Mauricio Pierra da Cunha
- 107 MHz, 18 ft range

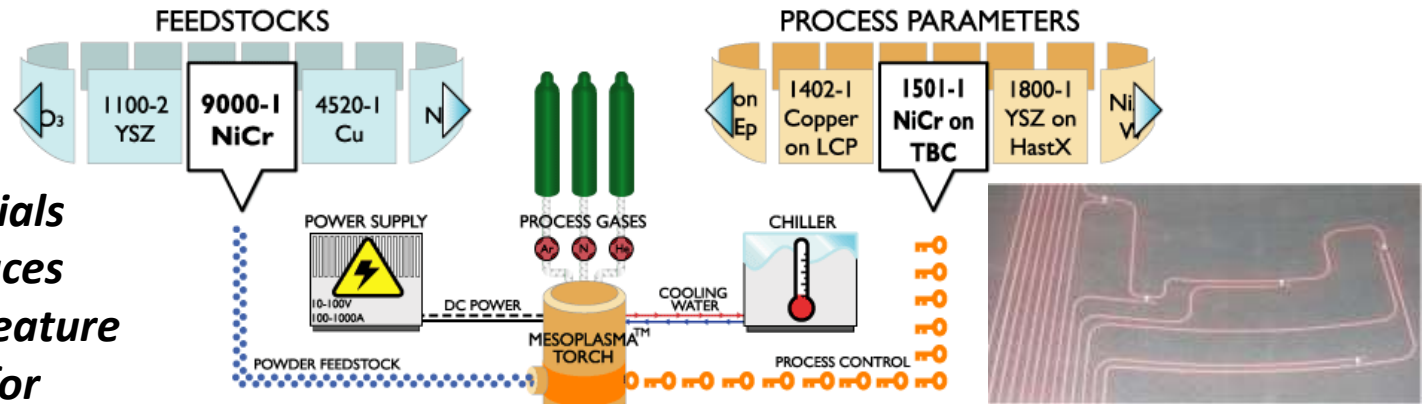
Cooperation with
NASA GRC and JSC



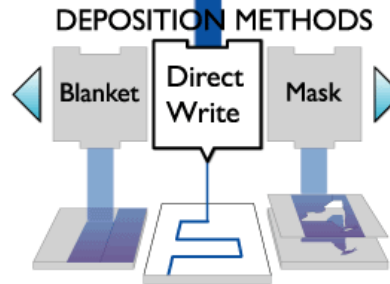
MesoPlasma™ Direct Write Fabrication of Conformal, Harsh Environment Sensors

Mesoscribe/Jasen Trelewicz www.mesoscribe.com - JTrelewicz@mesoscribe.com

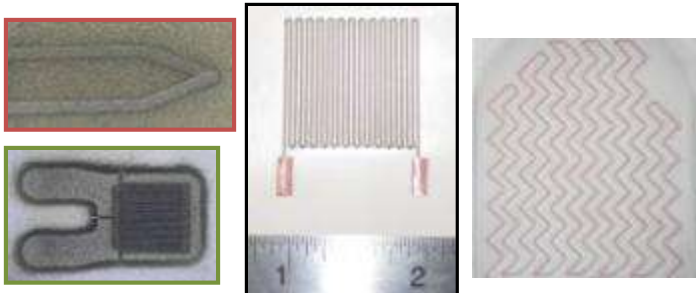
Direct Write:
“print”
functional materials
on complex surfaces
to produce fine feature
sensor patterns for
integrated diagnostics



- ☐ **Dynamic trace control**
 - ✓ Trace geometry can be actively tailored for complex patterns
- ☐ **Trace width**
 - ✓ Direct Write trace $\geq 0.01''$ ($\geq 250\mu\text{m}$)
 - ✓ Laser Scribed trace $\geq 0.001''$ ($\geq 25\mu\text{m}$)
- ☐ **Trace thickness**
 - ✓ Generally $\geq 0.001''$ ($\geq 25\mu\text{m}$)

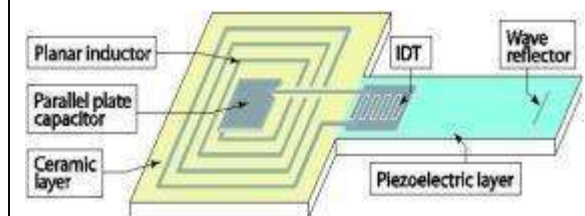


- ☐ **Conductors**
 - ✓ Cu, Ni, Pt, Pd, Ag
- ☐ **Sensor Alloys**
 - ✓ NiCr, NiAl, NiSi, NiCrSi, CuNi
 - ✓ NiCrAlY, FeNi, PdAg
- ☐ **Advanced Sensor Materials**
 - ✓ ITO and other ceramic TE oxides
- ☐ **Dielectrics**
 - ✓ YSZ, MgAl_2O_4 ... proprietary matls



- ☐ Component Health Monitoring
- ☐ Integrated Wiring
- ☐ Structural Energy Storage
- ☐ Damage Detection
- ☐ Antennas
- ☐ Active Control and SHM

Phs 2 SBIR PWST – NASA LaRC



Wireless Temperature Sensor for Gas Turbine Engine Applications

Wireless Sensor Technologies/John Conkle jconkle@wisen-tech.com

Close Proximity Interrogation – Rotating Turbine Blades

Components of Wireless Temperature Sensor - RLC Circuit + Diode Frequency Multiplier – Resonance varies with Temperature

1. Antenna

- Enables the interrogating signal to be received
- Sets the frequency of operation of the sensor
- Enables the return signal to be transmitted back to the Tx/Rx/Signal Processing

2. Diode

- Causes the generation of RF harmonics of the interrogating signal(as filtered by the antenna) which allow the return signal to be easily separated from the interrogating signal by the Tx/Rx/Signal Processing

3. Alumina or TBC Dielectric

- possesses temperature-dependent electrical properties(DK, dielectric constant) which alters the antenna center frequency as the temperature changes

Also Developed Wireless Heat Flux Sensor

Supported by SBIRs in Navy, DOE and Air Force

Thin Film Secure Display Inlay: A Revolutionary new Class of ID card

Tocreo Labs/Mark Krawczewicz

mark.kraz@tocreo.com - www.tocreo.com

Simple technology: On-card display – Extraordinary Security - Chain-of-Trust – batteryless

Applications: Physical & Logical Access Control, Remote log-in, & Mobile Device Unlock

Huge Market: need strategic partners for system integration in Aviation, Transit, National & Commercial network

Applications for Passive Wireless Sensors used with Near Field Communications???

Capabilites:

Dynamic Bi-State Display

- Users Access -**day / hour / privileges / remaining balance** can be written to the display defining role or access period by access control station
- Display can also show pending **authentication, cryptographic, transactional , or other security process**
- **Visual passport** – user carries auditing trail

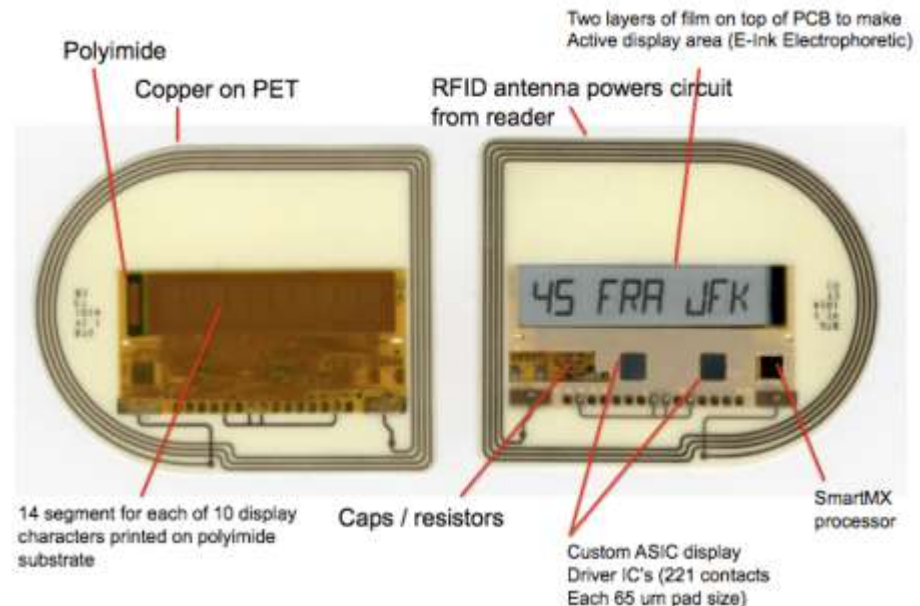
Both an visual ID credential and a secure “Container” for data like photo, ID number, name, medical certificate, biometric, audit file, etc. .

Extraordinarily secure – same security processor as in 250 million passports

Uses only reader power – will last indefinitely

Maintains the Chain of Trust - (Users can verify at one terminal and then at a later time, facility, or secured area, prove it) – **Virtual Fence**

Single card bridges physical & network access worlds

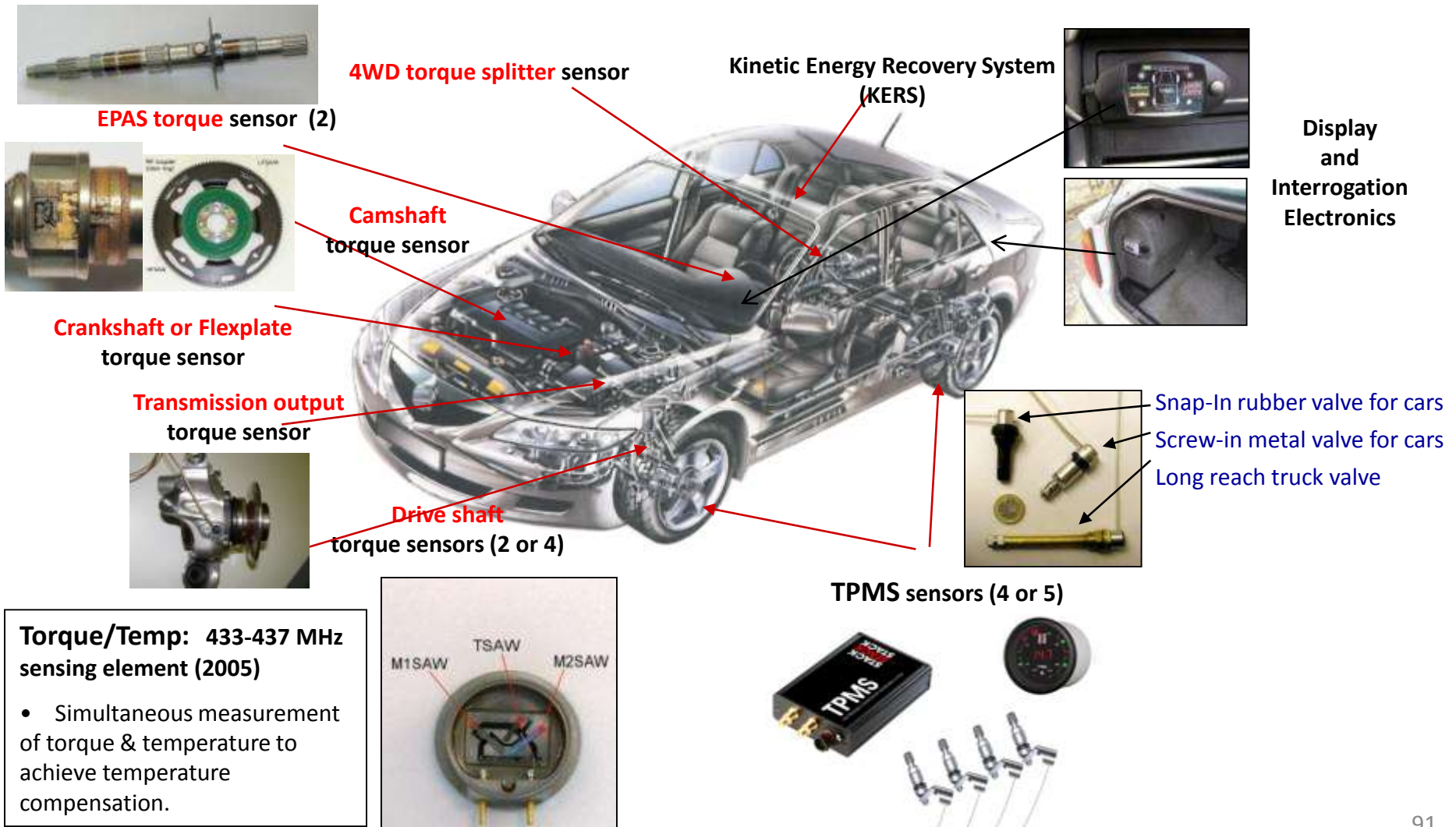


SAW Resonant Passive Wireless Sensors for Automotive and Industrial Applications

Over 8 SAW
systems per
vehicle

Transense/Victor Kalinin

victor.kalinin@transense.co.uk - www.transense.co.uk



Transense – GM Flexplate Project

Announcement Sep 26, 2011

<http://www.transense.co.uk/news/235-gm-transense-flexplate-project>

The Torque drive-line 'flexplate' sensor was “ originally developed for eight-cylinder engines and is now being adapted for 4 and 6 cylinder engines.

“ As part of this process Transense has successfully negotiated a variation of the otherwise exclusive licence to Honeywell, permitting Transense to deal directly with various named companies including GM preferred Tier 1 suppliers. Since then discussions about the technology have commenced between Transense and a Tier 1 supplier permitted under the Honeywell variation agreement.

The flexplate is an integral part of the vehicle powertrain control system and has the potential to improve vehicle driveability, reduce fuel consumption and improve transmission shift quality. This will be the first time a propulsion system has been able to measure engine torque 'live', enabling optimal control to be maintained throughout a vehicle's life. Current torque management systems rely on simulated models derived from production engine testing which can differ from the actual engine torque output over time. The new flexplate technology provides continuous real-time torque measurement allowing actual torque measurement on a per-vehicle basis for maximisation of engine efficiency.

GM is currently evaluating further applications of the technology for real-time vehicle control.”

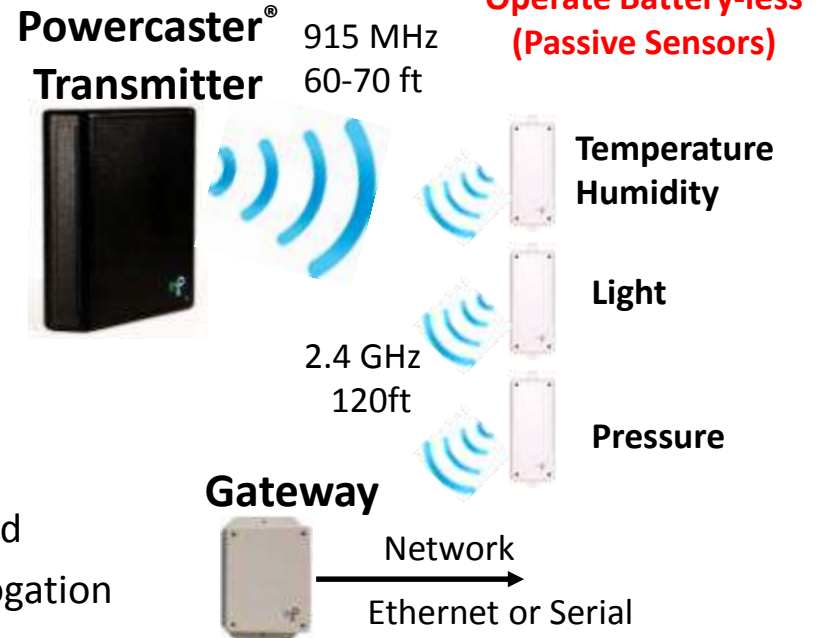
High Function, Long Range Passive Wireless Sensor Tags

Powercast – Harry Ostaffe

hostaffe@powercastco.com - www.powercastco.com

Scavenge Power alternatives:

- Light / solar energy not always sufficient and rechargeable batteries are required
- Temperature requires large ΔT 915 MHz
- Vibration has narrow bandwidth, moving parts
- **RF-based wireless power**
 - Send power over distance - μW , low mW
 - One-to-many, any-to-any topologies
 - Overcomes lack of light, temp diff., or vibration
 - Controllable: continuous, scheduled, on-demand
- **Future:** Smart Phone-based wireless power - interrogation



P1110

Continuous Power Output

- RF range: -5.0dBm to 20dBm
- Output voltage: 1.8V to 4.2V (configurable)
- Range of at least 3 meters



P2110

Pulsed Power Output

- RF range: -11.5dBm to 15dBm
- Output voltage: 1.8V to 5.25V (configurable and regulated)
- Range of at least 10 meters



Proceed With Caution: Disaster Recovery (PWST)

Applications in Nuclear Control Systems

Ivan Chow - Doosan, HFControls - ivan.chow@doosan.com

www.HFControls.com

Worldwide Nuclear Power Plants

Measurement Types

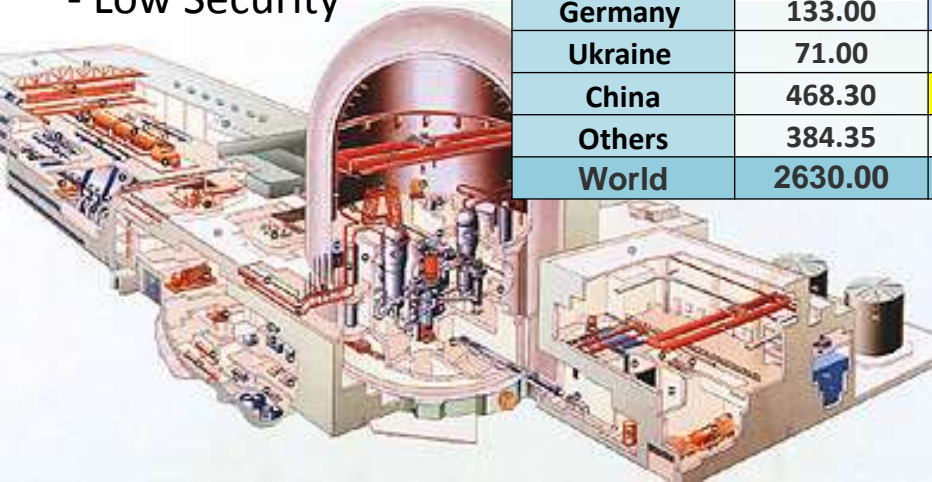
- Temperature
- Radiation
- Others TBD

Use Cases:

- After “Shutdown” sequences initiated
- With or without main power source
- Cover All plant units
- Low Security

COUNTRY	Nuclear Electricity 2010 billion kWh	Reactors							
		Operable 1 July 2011		Under Construction 1 July 2011		Planned July 2011		Proposed July 2011	
		No.	MWe net	No.	MWe gross	No.	MWe gross	No.	MWe gross
USA	807.10	104	101421	1	1218	6	7200	28	38600
France	410.10	58	63130	1	1720	1	1720	1	1100
Japan	280.30	51	44642	2	2756	10	13772	5	6760
Russia	155.40	32	23084	10	8960	14	16000	30	28000
South Korea	141.90	21	18716	5	5800	6	8400	0	0
India	20.50	20	4385	5	3900	18	15700	40	49000
Canada	85.50	18	12679	2	1500	3	3300	3	3800
United Kingdom	56.90	18	10745	0	0	4	6680	9	12000
Germany	133.00	17	20339	0	0	0	0	0	0
Ukraine	71.00	15	13168	0	0	2	1900	20	22800
China	468.30	14	11271	26	28710	52	59990	120	123000
Others	384.35	72	52842	9	8770	38	36783	87	106295
World	2630.00	440	376422	61	63334	154	171445	343	391355

Data from World Nuclear Association as of July 1, 2011



RFID Sensors in Transportation

Ron Stieger – Zonar - Director of Engineering ron.stieger@zonarsystems.com

www.zonarsystems.com

Truck Inspection Integrity



Tag placed at
inspection locations
- add sensors

Odometer from
Tire Rotations
needs calibration



Payload Weight



Trash Pick-up
Management

Battery Voltage on Trailers



Temps in Refrigerated Truck



Engine Temperature

Brake Stroke



Fluid Levels: Fuel, Oil, Others

Intelligent Multi-Sensor Measurements to Enhance Pavement Monitoring and Safety

Fred Faridazar - Federal Highway Administration

Turner-Fairbank Highway Research Center

<http://www.fhwa.dot.gov/research/>; <http://www.tfhr.gov>

fred.faridazar@dot.gov

1. Exploratory Advanced Research

2. Pavement Sensors

- Pavement Monitoring
- Self-powered Pavement Monitoring Sensor
- Carbon Nanotube Based Self-sensing Concrete for Pavement Materials Tracking
- Applications of RFID Technology to Asphalt Paving

3. Roadway Renewable Energy

4. Stay-in Lane

5. Additional Application Need

**DOT will Present at
2012 PWST Workshop**

Turner-Fairbank Highway Research Center Radio Frequency Identification (RFID)

The Solution?



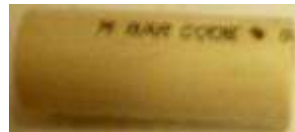
HMA from Plant



Haul Truck



Paver



Encapsulated
RFID Tag

Add PWST Temperature?



Compaction

Identifying where loads of material
end up in the pavement

Tags scanned when
convenient after
construction



Finished Pavement



Federal Highway Administration

Turner-Fairbank Highway Research Center

Corrosion of Post-Tensioned Bridge Tendons



Staying in Lane - Intelligent Fusion of Vehicle Sensor Data



Long Term Pavement Monitoring

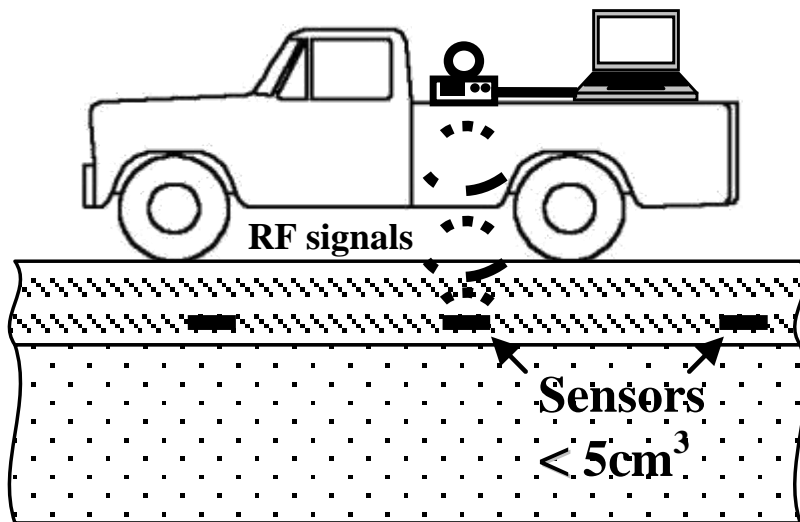
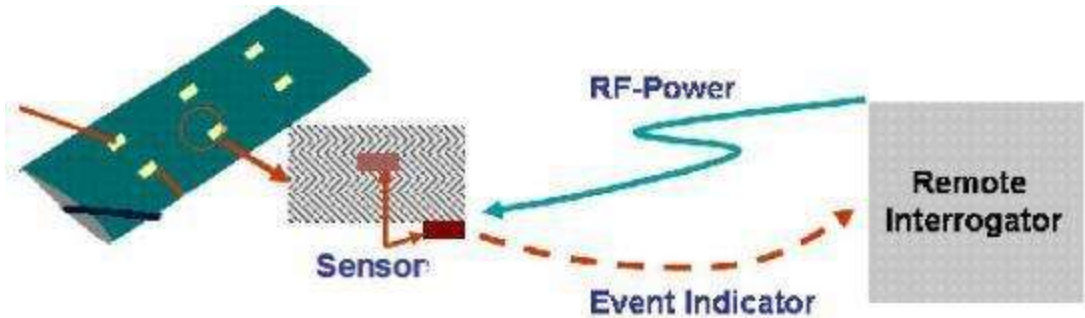
- UMD Pavement Monitoring - RFID and active Intelligent Automation Inc. Sensors
- Kinetic to Electric Energy Conversion (KEEC) – VPI/VSU
- Univ of Minn
 - Carbon Nanotube (CNTs) Based Self-Sensing Concrete



A Sub-microwatt Long-term Monitoring Sensor

Nizar Lajnef, Ph.D., Michigan State Univ. for FHWA

lajnefni@egr.msu.edu - <http://www.egr.msu.edu/cee/people/lajnef.html>



Potential Applications of PWST

Nezih Mrad, Ph.D.

Defence R&D Canada (DRDC), Air Vehicles Research Section (AVRS)

<http://www.drdc-rddc.gc.ca> - Nezih.Mrad@drdc-rddc.gc.ca

Mission:

To ensure the Canadian Forces are technologically prepared and operationally relevant.

- ◆ Advise on Science & Technology
- ◆ Conduct Defence research, development and analysis
- ◆ Assess technology trends, threats, and opportunities
- ◆ Engage industrial, academic and international partners in the commercialization of technology
- ◆ Conduct S&T projects for non-DND clients



PWST Interest Areas:

- Advanced Health Monitoring Capability Development and Demonstration
 - Sensors development, evaluation and demonstration (strain, load, corrosion, chemical, damage, cracking, etc.)
 - Modeling, simulation and analysis
 - Experimental capability development
- Engine PHM Capability Development and Demonstration
 - Sensors development, evaluation and demonstration (H/L Temp blade strain and temperature, blade damage and erosion, oil quality/debris monitoring and leak)
 - Data fusion and mining, etc.
- Asset monitoring and tracking
 - Materials visibility and condition assessment (e.g. ration, fuel, spare parts, etc.)



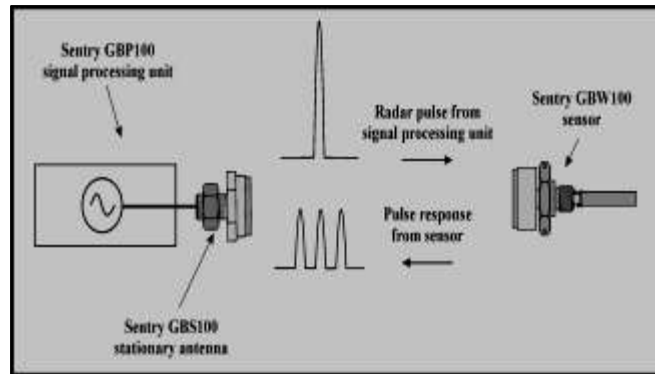
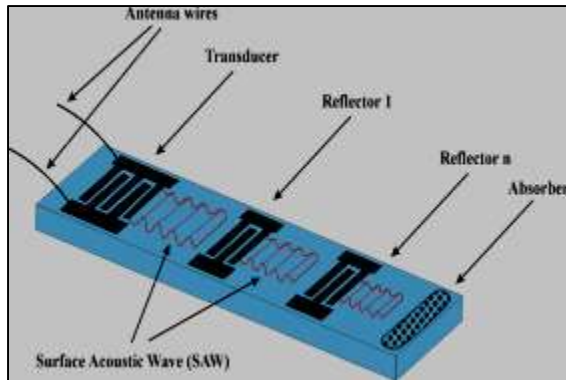
Passive Wireless SAW Temperature Sensors

Kongsberg Maritime NJ (Sensors) - Ed. Gemdjian

www.kongsberg.com - KongsbergNJ@verizon.net

SENTRY Wireless Temperature Monitoring – Technology – in use for a decade!

- Fast and reliable temperature monitoring of moving or rotating bearings
- Improved overall operational safety for crew and machinery



SENTRY Applications: "Radar Sensor" Temperature Monitoring of Large Rotating Machinery

- **Diesel Engines and Reciprocating Compressors** – new and retrofit
 - main, wrist/cross pin, crank pin, connecting rod(small end, big end, crosshead) bearings
- **Wind Turbine Gears** - the roller bearings in the planetary unit of the gearbox
- **Paper Machines' Drum** – paper roll shell temps – 6 read by 1 antenna - ID by rpm counter
- **Electric Motors & Generators** – rotor windings
- **High Voltage Power Transformers**
- **Hydraulic Clutches** – Oil temps

Sensors and Controls Enabled Solutions

George Hernandez – DOE/Energy Efficiency and Renewable Energy

Pacific Northwest National Laboratory

eere.energy.gov; George.Hernandez@ee.doe.gov

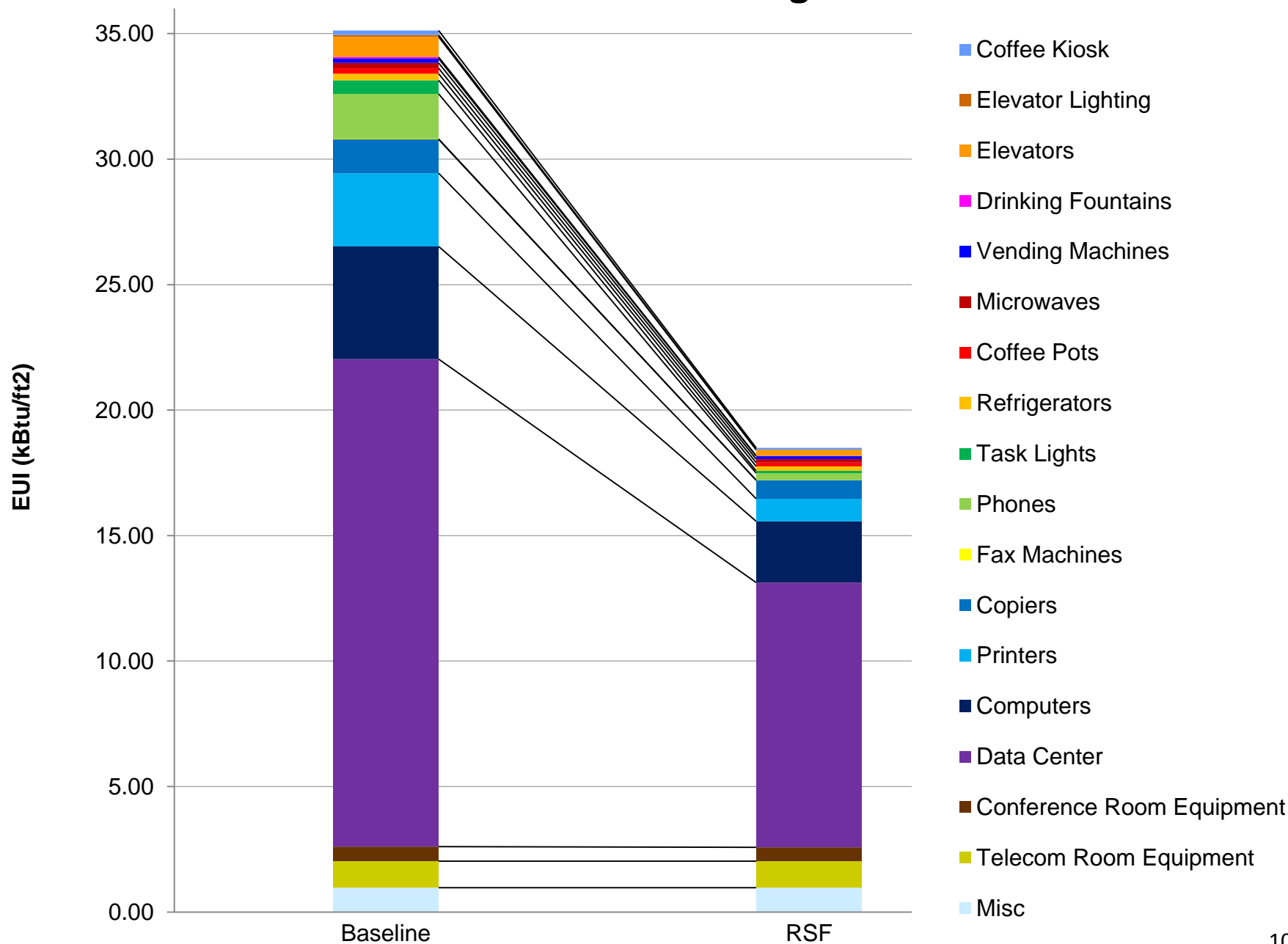
Target Applications:

- **Advanced Controls and Diagnostic Packages for Packaged Air Conditioners**
- **Self-Correcting and Self-Configuring HVAC Controls**
- **Proactive Building Energy Management – automation and occupant participation**
- **MEL(Miscellaneous Equipment Loads) Management**

Attributes Needed:

- **Temperature, Relative Humidity, CO2, Flow (air and liquid), Pressure, Power, Light**
- **Occupancy Sensors - Image Processing-Based – motions sensors don't work well**
- **Inexpensive – much less than \$100 typical per measurement location**
 - **Cost is the main deterrent for commercial buildings not installing Efficiency Monitoring/Control sensors**
- **Accurate (+/- 1 deg C is not good enough for diagnostics) - minimum drift**
- **Common interfaces**
- **Relocatable**
- **Location provided**

Baseline vs RSF Annual Plug Load EUI



Network Enabled Manufacturing(NEM) & Passive Wireless Technologies

Al Salour, Ph.D. – Technical Fellow

Boeing Research & Technology

al.salour@boeing.com 314-232-1743

NEM Considerations:

- Multi-disciplined technical skills development team
- Serve the customer needs in changing environment
- Emphasis in Composites materials and processes
- In-house fabrication core competencies “Metallic and non-Metallic”
- Supplier management “Increases in the third party material suppliers”
- Wireless secured networks
- Multi-site manufacturing & replication opportunities
- Latest advancements in real time plug & play autonomous systems

NEM Technology Needs:

- **Sensors:** Location, illumination, temperature, humidity, pressure, flow, vibration, proximity, etc.
- **RTLS:** Chokepoint, Presence, Location
 - Battery powered,
 - \$40 per sensor -> apply to high value assets
 - UWB indoor & outdoor system for Tool Kits
- **pRFID (passive RFID): Material Management**
 - Commonly used on high volume items
 - No power source (*No batteries*)
 - Inexpensive (\$0.50 or less)
 - Minimal data storage
 - EPCGlobal Standard Passive RFID Tag Inlay
 - Gen 2 Class 1 – WMRM

(Write Many-Read Many)



pRFID Applications:

Time & Temperature Sensitive Material - Sealants inventory
-Walk in freezer composite material out time / inventory
Paint - Paint mix room
Receiving - Incoming materials
Shipping - UID Bar codes on selected shipments
Work in process – Tube shop
Tool number, serial number, shelf location
Handheld reader for localization and ID – Biomark tag test

Passive Wireless Sensors Vehicle Health Management Applications

Robab Safa-Bakhsh - robab.safa-bakhsh@boeing.com

Associate Technical Fellow , Boeing Research and Technology

Customers: Boeing Commercial Aircraft, Military Fixed and Rotary Wing aircraft

Objectives: Life-Cycle Cost, Mission Reliability, Availability, Operational Plans, Supply Chain

Life Cycle Applications: Design & Development; Manufacturing, Operation & Sustainment

Sensors:

Flight Control: Electro-Mechanical Actuators, Hydraulic Actuators, Linkage, Hydraulic System

Electrical System: Generators, Converters, Contactors, APU, Batteries, Cooling System

Propulsion: Blades, Bearing, Gas path, valves

Avionic: Power Supply, Electronics

Rotor System: Rotor blades, Rotor hub, Tie bar, Rotor shaft

Fuel System: Fuel Pumps, Motors, Valves

Structures: Airframe Structure, Dynamic Components

Drive System: Gears, Bearings, Shafts, Lubrication, Housing

Electrical Wiring: Wiring insulation, Pins connections

Under Carriage: Landing Gear, Tires, Wheels, Brakes



Challenges: Reliable Comm/cross-talk, EMI, Reliable installations, Harsh environments, Sensor accuracy, life Stability

Passive Wireless Sensor Tag Research Focus:

- Meet min requirements for resolution, accuracy, repeatability & durability of traditional sensors
- System expandability & communication quality as the number of interrogated sensors increases
- EMI for long range interrogation
- Out of sight sensors implementation
- Synchronization of multiple sensors
- Synchronization of multiple interrogators
- Minimize size, weight and power of the interrogators
- Reliable installation and operation over the life of monitored component



What Works in the World of Wireless Sensors

Louis Sirico (Louis@RFID.net), Host & CTO of The RFID Network, Campbell, CA

<http://RFID.net> and www.Rfidwikipedia.org

- **Responsible RFID Benchmarking in a web-based TV Video Series & info source for Wikipedia**
“We don't publish what people tell us, we make them prove it”
<http://rfid.net/applications/energy/289-passive-wireless-sensor-tags-benefit-energy-aerospace-transportation-a-industry>
- **We show you** how Radio Frequency Identification and wireless RF sensors can improve your business. We provide information, tools, and advice that help you decide what to buy and how to get the most out of RFID.
 - Install, Implement and Integrate RFID
- **Durable RFID Tag Benchmarking:**
 - [Defining 'Durability' and the RFID Tags Evaluated](#)
 - [Vibration Survival Tests](#)[Supply Chain Logistics Operations Tests](#): *Mixed Pallets with an RFID Enabled Portal & Handheld RFID Reader*
 - [Asset Tracking Tests](#): *Maximum Read Range Outdoors with a GPS enabled Handheld RFID Reader*
 - [Manufacturing Work-In-Progress Tests](#): *Maximum Read Range Indoors with a Fixed Position RFID Reader*
 - [Overall Benchmark Test Analysis](#)
 - [Important Considerations When Selecting RFID Tags](#)

RFID Net Website:

1. Use
2. Benefit
3. Compare / Evaluate / Buy
4. Install / Implement / Integrate
5. Back to #1 – Repeat

RFIDWikipedia Website:

1. Define
2. Explain
3. Educate

- **Call for Content: RFID Network is Looking for Subject Matter Experts(SME's) for RFIDWikipedia.org**

- ✓ **SAW**
- ✓ **Wireless Sensors**
- ✓ **RFID**

NXP Interactive Gen2

“Bridging the Gap between Passive RFID, Sensors and Electronics”

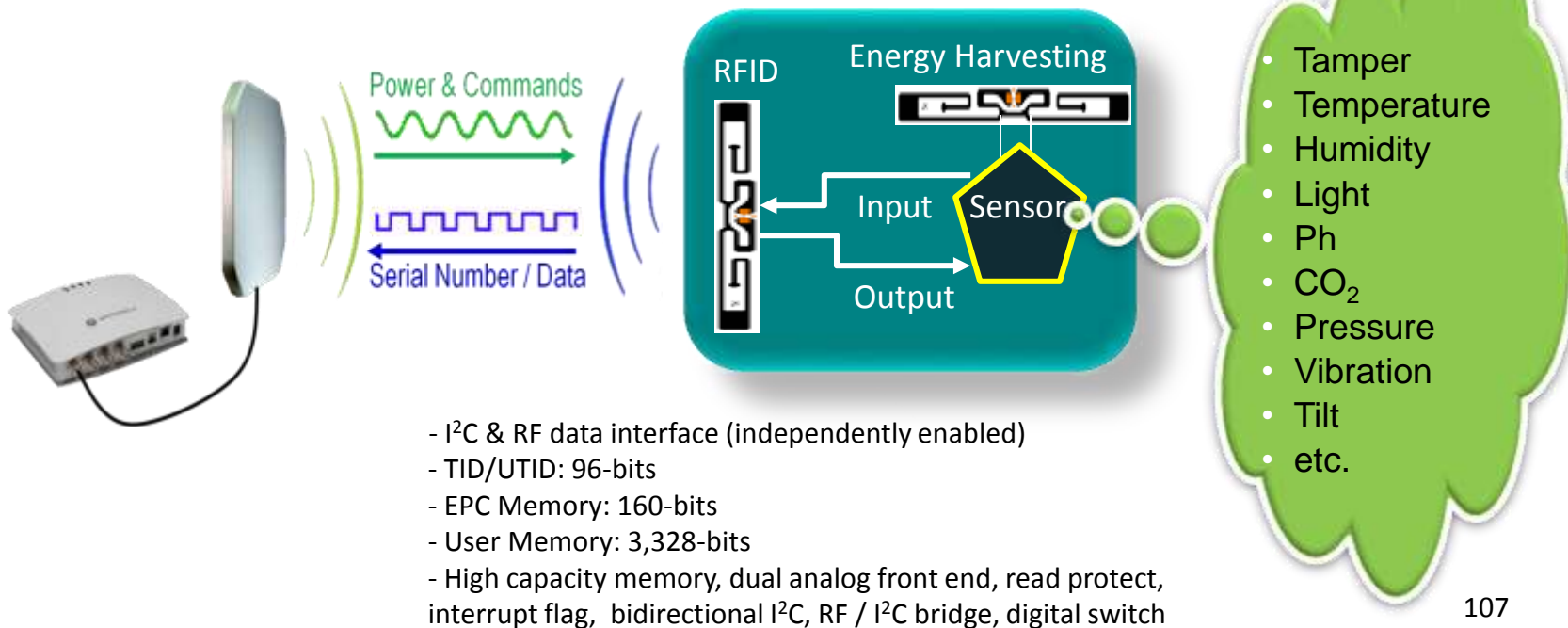
Victor Vega - Marketing Director, RFID Solutions

www.NXP-RFID.com

UCODE G2iL+ & G2iM+ series ICs add a digital input / output to RFID



- Input enables tamper or level detection for simple digital sensors
- State change is transmitted via RF to reader, along with device's unique s/n
- Output may be used as digital switch to assert a remote action
- Use cases may include alerts – for example, if bearing temperature threshold is exceeded



Aerosol Jet® (AJ) Direct Write Technology

A Manufacturing Tool for Printed Electronics

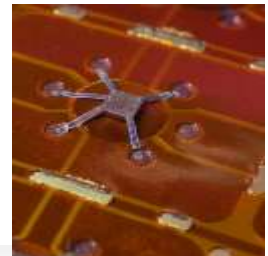
Optomec - Rich Plourde

rplourde@optomec.com

Note: Optomec does not design SAW, RFID, Antennas or Circuits

Contract Mfg: Quest Integrated Inc., Jonathan Kniss, <http://www.qi2.com>

- **Patented Material Deposition Kernel (atomizers, PCMs, print modules)**
 - Configurable for wide range of Feature Sizes & Multiplexing for volume production
- **Development Platforms Successfully Fielded**
 - for **material, process & application development / prototyping**
 - Configurable Atomizers, Heads, Motion, etc.
- **High Throughput Multiplexed Heads for Production**
 - ie: 40 nozzle head prints 2400 silicon solar wafers / hour
- **Platform Independent Modular Print Engines**
 - for **high volume manufacturing**
 - Standardized communications protocols & interfaces
 - Easily integrated with 3rd Party Manufacturing Systems
 - Manz Automation: print 80 solar collector lines on silicon wafers in 2.5 seconds
 - Speedline Technologies: print 20+ die stack interconnects / second



Die Attach



1cm GPS
Antenna



3D

Interconnects

NASA Testing of PWST

NASA LaRC/William C. Wilson william.c.wilson@nasa.gov

with support from KSC/Emilio Valencia, JSC/Richard Barton, LaRC/Jay Ely

NASA has the capability for most forms of testing!

Transducer characterization

Cryostat



Strain Characterization – COPV



RF Testing



Functional testing



Compliance Testing

Industry, MIL Spec, Space Qual



Flight Testing



- MLAS
- 747&A320 Cargo Bays
- 747 Landing Gear
- Intl. Space Station



Aerospace Vehicle Systems Institute

On-Aircraft Wireless Communications Research at AVSI

A part of the Texas Engineering Experiment Station at Texas A&M

Dr. Fred Fisher, Asst. Director, AVSI www.avsi.aero; Ffisher@avsi.aero

Full Members

- Airbus
- BAE Systems
- Boeing
- DoD
- Embraer
- GE Aviation
- Goodrich
- Honeywell
- Lockheed Martin
- Rockwell Collins
- UTC

Liaison Members

- FAA
- NASA

Associate Members

- Bombardier
- Gulfstream

Common problem-Cooperative solution-Immediate need

RFID Relevant Research Projects:

- AFE41 - Wireless Communications for Aircraft Systems
- AFE41 - Mitigating the Impact of RF Emissions from PEDs to Airplane Systems through Aircraft Hardening
- AFE50 - Energy Harvesting Potential Assessment
- AFE 56: Feasibility of Intra-Aircraft Wireless Sensors
- AFE54 - RFID Study
- AFE56s1 - Feasibility of Intra Aircraft Wireless Sensors + Supplement
- AFE73 - Wireless Avionics Intra-Communications (WAIC)

**WAIC Project Status
will be presented at
2012 PWST Workshop**

AVSI - RFID Relevant Research Projects

AFE 14: Wireless Communication for Aircraft Systems

- Develop and validate a performance model of wireless comm. within aircraft environment.
- Determine viability of using wireless comm for essential or critical aircraft systems.
- Validate model using a ground based aircraft
- Evaluate the impact of passive and active components within the aircraft (structural components, engines, and existing electronic and electro-hydraulic subsystems) at both physical and protocol layers.

AFE 41: Mitigating the Impact of RF Emissions from PEDs to Airplane Systems thru A/C Hardening

- Determine practical aircraft hardening techniques for mitigation of airplane system susceptibility to RF energy from portable electronic devices .
- Use results of this effort may be to support protective regulatory requirements .
- Select approaches for mitigating the impact of PEDs and experimentally evaluate effectiveness of the approaches.

AFE 50: Energy Harvesting Potential Assessment

- _Quantify available energy on aircraft for potential energy harvesting.
- Survey one or two types of aircraft to determine the type and amount of energy that is available for harvest.
- Look at vibration/strain, thermal & RF energy levels.
- Assess energy levels for all status of the aircraft i.e. storage, docked, taxi, climb, cruise, decent, etc., to produce an available energy profile.

•AFE 56: Feasibility of IntraAircraft Wireless Sensors

- Evaluate Current aircraft RF certification process
- Evaluate RTCA SC 202 working group and draft DO-294 T-PEDS status as extensible to wireless sensors.
- Evaluate European work in this area.
- Determine Suitability of the ISM band, Possible alternative bands,
- Determine need for encryption.
- Define next steps and or work needed to fill holes/gaps - in coordination with the FAA
- Collect & evaluate existing Channel Modeling work

AVSI - RFID Relevant Research Projects

AFE 54: RFID Study

Deliver: A quantitative model of tag & interrogator emissions

Activities:

- Select representative tags /interrogators for analysis
- Survey existing work (NASA & others)
- Develop catalog of quantitative tag & interrogator models
- Install tags & interrogators in and around selected aircraft
- Measure tag and interrogator performance on the aircraft at selected locations and correlate with previously developed models
- Develop an avionics interference model for the tag/interrogator emissions
- Measure and quantify levels of interference with aircraft avionics

AFE 56s1: Feasibility of Intra Aircraft Wireless Sensors/Supplement

Prepare an info package to start formal frequency allocation process:

- Perform economic analysis on different band classifications
- Characterize potential usage profile envelope for wireless sensors: bandwidths, data rates, power levels, modulation techniques
- Down select frequency candidates from the already identified list.
- Cost and availability of commercial radio devices that operate in the candidate frequency band shall be included as factors in down-selection.
- Establish on-going contact with FAA spectrum office, FCC WTB and OET, NTIA. Contacts with any regulatory agencies/Washington DC offices shall be coordinated in advance w/AVSI PMC member companies' reg. offices.
- Evaluate pros and cons of the RTCA route
- Involve NASA, European contacts, other industry members (possibly as additional members of this PMC)
- Define and prepare a suitable information package including detailed roadmaps for each of the different band classifications (licensed dedicated, licensed shared, unlicensed dedicated portion) use by a third party to lobby the appropriate authorities (e.g. for licensed dedicated, the FCC and NTIA)

Prepare a specific certification strategy for information assurance:

- Determine actual impact of DoD Directive 8500.1
- Study and recommend strategies to certify security approaches that use randomized techniques
- Study and recommend approaches to facilitate upgrade-able encryption/security solutions with minimal FAA re-certification effort
- Study likely characteristics of jamming and denial of service attacks
- Study likely decrypting capabilities of an information interceptor
- Define a reasonable threat model for information assurance requirements

AFE 73: Wireless Avionics Intra-Communications (WAIC) - <http://waic.avsi.aero/>

- Use of wireless communication technology in safety-critical systems requires that appropriate frequency bands will be available with sufficient regulatory protection against unwanted interference.
- Interact with ITU-R through its Working Party 5B to get their recommendation for an allocation proposal.
- Perform technical studies and analyses necessary to formulate and justify a proposal.
- Formalize previous industry working group / ITU-R interactions.
- Establish a WRC 2015 Agenda Item relative to protected spectrum during the World Radio Conference in 2011.
- Perform all necessary follow-up activities to support allocation of the protected spectrum through regulatory organizations.
- The project serves as an important stepping-stone on the road towards allocation of protected spectrum for wireless avionics system.

- Pending project topics
 - WAIC band sharing studies
 - WAIC/PED/RFID/WiFi coexistence
 - WAIC protocol standard
 - Active/Passive Sensor Networks
 - System architecture virtual integration
 - Integrated reliability processes
 - Certification of RFID applications

Bridging the Mid TRL Gap through Coordinated Technology Development

Milind Pimprikar, Founder & Chairman, CANEUS International

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CANEUS' Sole Purpose: Enable Productive Public-Private Partnerships

CANEUS Proven Capabilities:

- **CANEUS brings together** technology developers, End-users, Governmental policymakers and investors from across the world.
- **CANEUS provides** a public/ private platform of transitioning emergent technologies rapidly and efficiently from concepts to the aerospace systems / products / missions.

CANEUS' Public/Private Consortia:

1. **Fly-by-Wireless (FBW)**
2. **Small (Nano/Pico/Micro) Satellites** for Civilian and Defence Applications
3. **Reliability Testing**
4. **Devices-** Harsh Environment Sensors,
5. **Nanomaterials** for Aerospace Applications including **Micro-energetic** for power generation, energy conversion, and micro-rockets

Benefits from joining the CANEUS FBW Consortium:

1. Cost/Risk Mitigation: Access to jointly developed pre-competitive technology & proprietary product development.
2. Participation in a collaborative technology, product and business development environments.
3. Licensing access to a fair and equitable IP-brokering service.
4. Reduced time-to-market and rapid system-level product deployment through supply chain collaboration.
5. Participate in the development of global standards in cooperation with leading aerospace corporations & agencies.
6. CANEUS will “harmonize” various National Policies controlling collaborative international technology development and frequency band allocations.
7. Access to CANEUS forums/conferences as key networking platforms for Fly-by-Wireless project members to address the relevant issues.
8. Access to CANEUS' global “technology portal” that identifies state-of-the-art and the technology developers and suppliers.

Industry Canada – Opportunities for Collaboration

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- **Industry Canada** - Mandate is to help make Canadian industry more productive and competitive in the global economy, thus improving the economic and social well-being of Canadians.

Website: http://www.ic.gc.ca/eic/site/ic1.nsf/eng/h_00000.html?OpenDocument

- **Strategic Aerospace & Defence Initiative (SADI)**: http://ito.ic.gc.ca/eic/site/ito-oti.nsf/eng/h_00023.html
 - To encourage strategic research and development (R&D) that will result in innovation and excellence in new products and services;
 - To enhance the competitiveness of Canadian A&D companies;
 - To foster collaboration between research institutes, universities, colleges & the private sector.

Note: A US company could be treated as a subcontractor under a SADI agreement with a Canadian company but it is difficult to justify.

- **Industrial and Regional Benefits (IRB's)**: <http://www.ic.gc.ca/eic/site/042.nsf/eng/00029.html>
 - Obligates Prime Contractors who have successfully won defence contracts to place economic activities in Canada
- **Defence Development Sharing Agreement (DDSA)**:
 - IC Industrial Technology Office is the contact point for DDSA projects - www.ito.ca