International Electronic Machines Corporation

WISE Solutions for Transportation Safety & Security

IEM

STABILIZER LEVEL ACCURATE MEASUREMENT SYSTEM (SLAMS) WIRELESS MONITORING OF PROPELLANT STABILIZER

FOR SBIR TOPIC N111-010, CONTRACT N68335-12-C-0408

PREPARED FOR THE 11TH BIENNIAL CAD/PAD TECHNICAL EXCHANGE WORKSHOP, JOINT BASE ANDREWS

MAY 25, 2016

Presentation Overview

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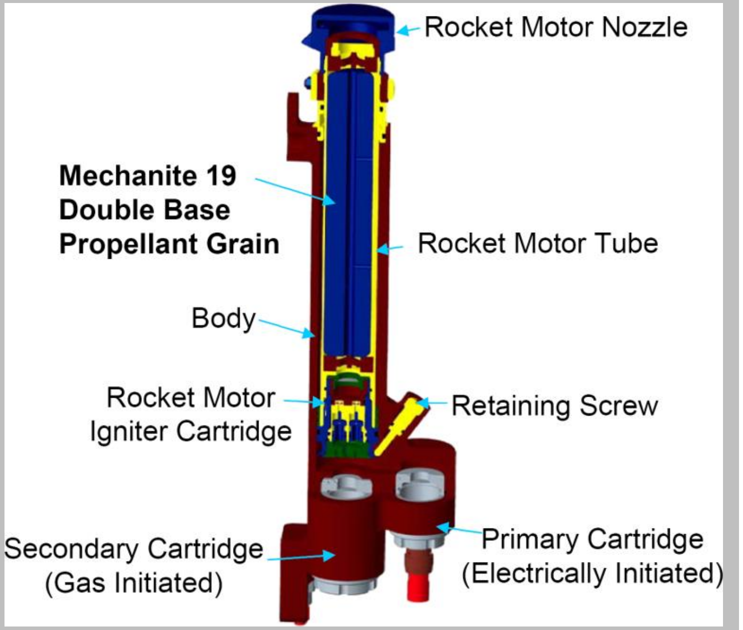
- PROBLEM AND CHALLENGES
- SOLUTION CONCEPT
- CURRENT DEVELOPMENT/RESULTS

Nature of the Problem

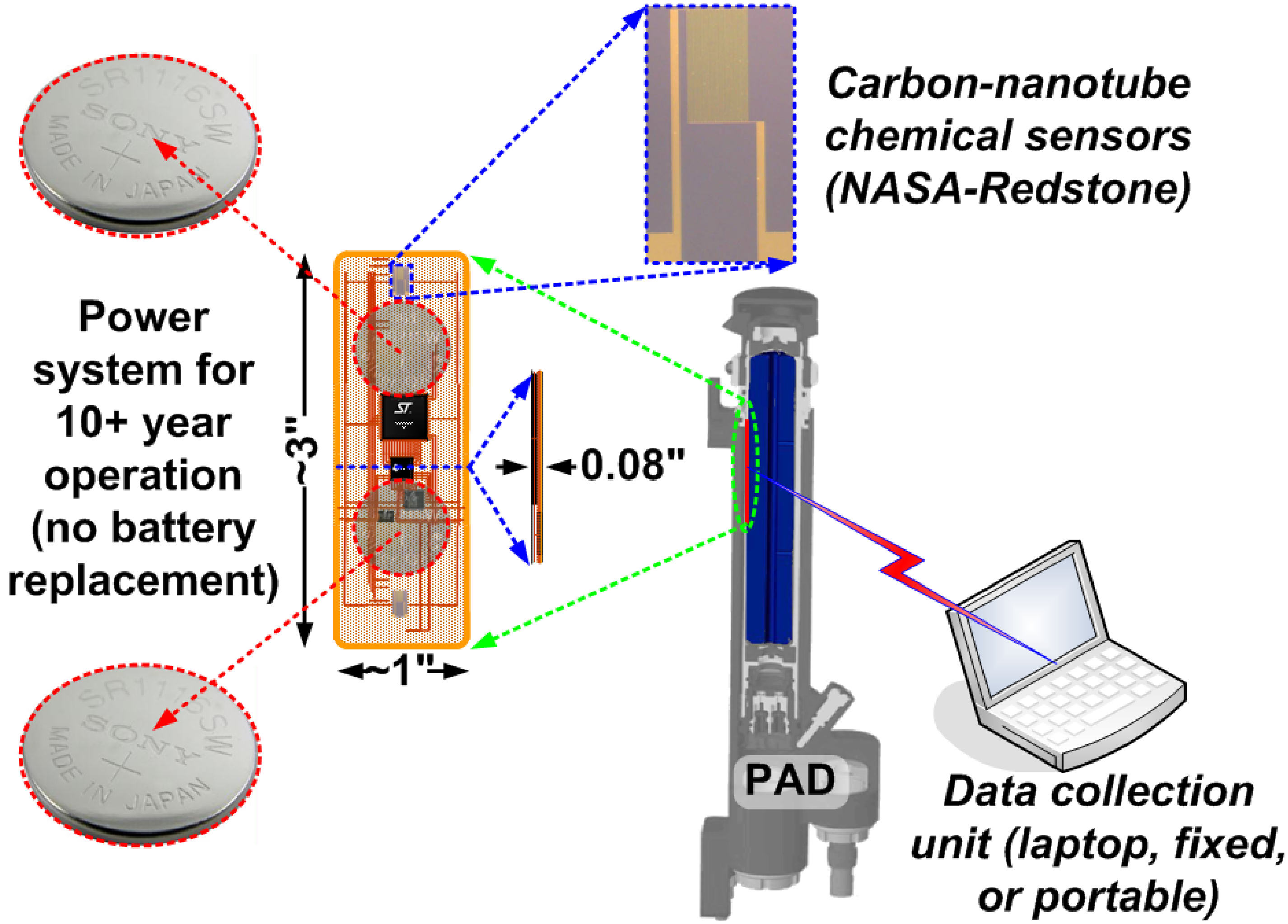
- PADs and CADs use highly energetic materials
  - Decomposition to NO_X can lead to runaway reaction
  - Stabilizers added to prevent NO_X buildup
  - Eventually stabilizer (and stabilizing daughter products) may be depleted
  - Cannot predict how long “eventually” is (temperature variations which produce complex changes in total stabilizer consumption rate)
- No technology currently exists to detect this *in situ*
  - Size, power, accessibility, and safety exclude all potential COTS candidates



Challenges

- Size is one of the primary constraints
  - Maximum 3″ L x 1.15″ W x 0.08″ H (2mm thick)
  - Thickness limitation due to installation (cylindrical charge in close-fitting tube)
- Accuracy and reliability
- Intrinsic safety (no possibility of ignition)
- Data transmission assurance
- Ruggedness
- Zero Maintenance over decade-scale emplacement
- EMI

Solution Concept: SLAMS



Key Elements

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Overview

- Long-term maintenance-free operation
  - No battery replacement or recharging
  - Severely space constrained
- Transmit/Receive data even from within enclosure
  - Many enclosures fully-sealed metallic – screen out RF transmissions
- Sensor Development
  - Customize for target stabilizers
  - Determine sensitivity, accuracy, reliability
  - Originally FSCRs from Sandia National Laboratory
  - Now carbon nanotube sensors from Redstone based on NASA research

Project Results

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Low-power Node Operation Design

- Operation of sensor node divided into two sections
  - Hibernation: Ultra-low power mode (~0.1μA) waking up periodically to sample and listen for download requests
  - Active mode: Data collection draws ~20mA for ~5ms (1/200th of a second); transmission comparable, time interval proportional to amount of stored data
- Total power consumption over 10 years estimated to be 9.64mA-h; 8.77mA-h consumed in hibernation mode and 0.87mA-h by the active mode.

Project Results

Low-power Node Operation Design

- Two separate modes of power consumption
  - Constant draw at very low current
  - Short-term periodic draw at high current.
- Select silver-oxide primary batteries
  - Can be very small, high-capacity, very low self-discharge, and inexpensive
- Accumulator Subsystem for high draw
  - Capacitor-based storage recharges between transmission/datalogging events
  - Tested and proven

Silver Oxide cell: 1.6x11mm, 33mAh, 10+year lifetime

Project Results

Low-Power Node Operation Design

- Low-power subsystem performs periodic wakeup
  - Adjustable time interval
  - Clock independent of main system – ultra low power
- External wakeup for download
  - Interrogation ping from outside triggers wakeup with no need for high-power sleep-wake cycles
- Automatically powers down after data gathering or completed download

Project Results

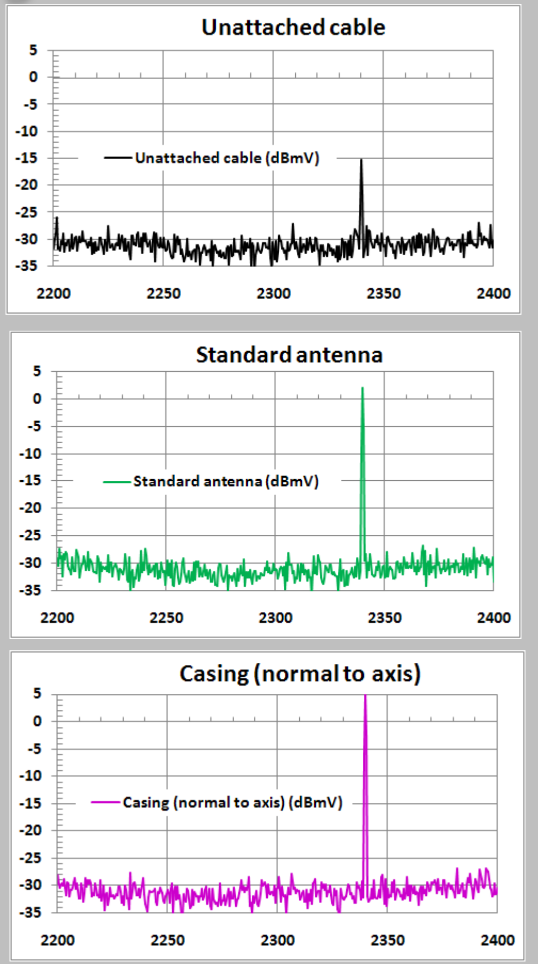
Transmission Through Casing

- Major challenge is to transmit through casing
  - Known to be sealed metal container
  - Prevents transmission of RF at reasonable frequencies and power levels
- Need method to transmit data from sensor unit inside casing
  - Conductive metallic composition is key
  - Implies that enclosure itself may be used as antenna
    - Dependent on sufficient size for wavelength
    - Impedance match will be required for best performance
- Tested enclosure as antenna compared to bare lead (no antenna) and commercial antenna in selected 2.4GHz ISM band

Project Results

Transmission Through Casing

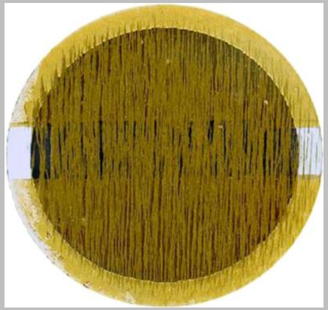
- Testing successful
  - Transmission strength only moderately affected by orientation (+3.9dB vs +5.0 dB)
  - Significantly outperforms standard WiFi 2.4GHz antenna (at 2.0dB)
  - Verified by unattached lead (-15dB) (noise floor ~30dB)
  - Performs across entire ISM band (minimum of +13.5dB over cable)
  - Verified in later testing of through-case transmission
- Extending this approach addresses issue of larger enclosure around casing
  - Use second enclosure as receiving antenna for "relay"
- Patent Pending: Application 14/695,628

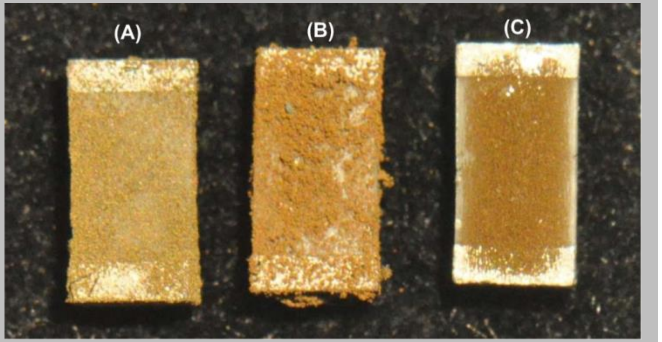


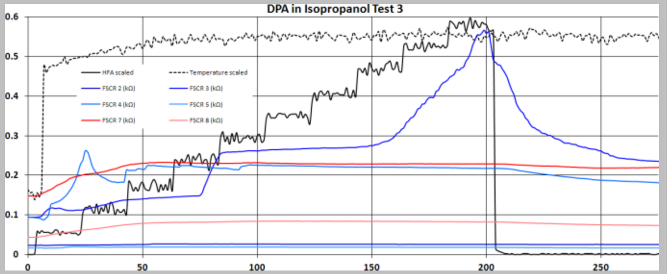
Project Results

Sensors and Sensor array

- Original: Field-Structured Chemiresistors
  - Licensable Sandia technology
  - Extremely small: Millimeter scale
  - Ultra-low power: Microwatts
- Developed new sensors
  - Tailored polymers and redesigns
  - Improved sensitivity and response time
- Reached current limits of technology
  - Could not reduce size/thickness sufficiently
  - Remaining nanoscale path would require significant additional research



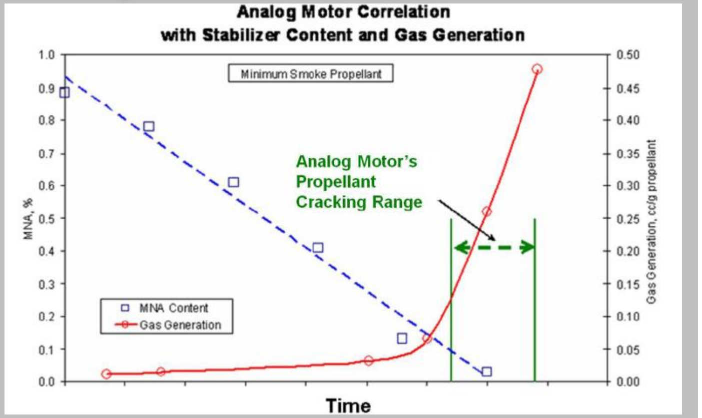


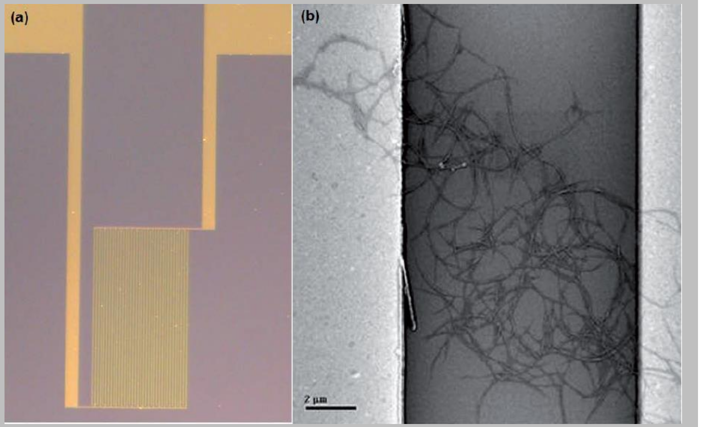


Project Results

Sensors and Sensor array

- New approach: Sense NO_X
  - Nitrogen oxide production inversely related to stabilizer
  - Study showed feasible method of detecting stabilizer loss
- Redstone-NASA Carbon Nanotube sensors
  - Small and low power (resistive sensors)
  - Inexpensive to produce
  - Sense target analyte directly
  - Single-analyte target means no "electronic nose" array needed





Current Conclusions/Moving Forward

Current Conclusions

- Overall functionality and practicality of SLAMS sensor node complete and proven
  - Ability to gather data at selectable and adjustable intervals; automatic wakeup/sleep for ultra-low average power; external wakeup for download or software updates
  - Solved problem of transmission through sealed casing
    - Applicable to multiple-enclosure situations
    - Limited only by size and ability to characterize enclosures
- Revised and updated sensing approach
  - NO_X sensing approach reduces size, complexity, power demand
  - Direct measurement less dependent on complex analyte interactions

Discussion/Q&A