Natural Gas Pipeline Research Workshop

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

Center for Information Technology Research in the Interest of Society

California Energy Commission
Hearing Room B

August 7, 2012

Agenda

- Introduction
- Goals
- PIER Approach
- Best Practices in Monitoring Technology (GTI)
- Innovative Monitoring Technologies (CITRIS)
- Lunch
- Recommended Areas of Emphasis for Solicitation Panel Discussions
- Workshop Conclusion and Next Steps
- Questions and Comments

Introduction – Who is here?

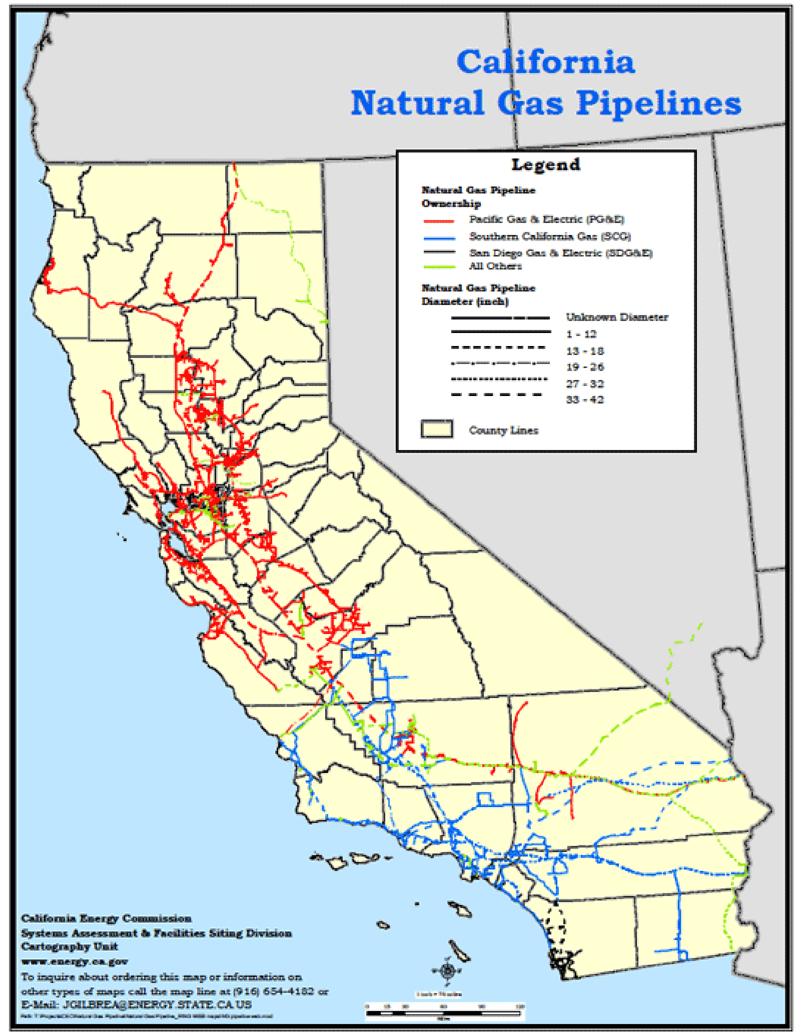
Mike Gravely – Deputy Division Chief
Fernando Piña – Energy Systems Integration Office (ESRO) Manager
Jamie Patterson – ESRO Team Lead
Johann Karkheck – Energy Technology Systems Integration Contract Manager

Paul Wright – Principal Investigator
Dick White – Principal Engineer
Gaymond Yee – Research Coordinator
Igor Paprotny – Technical Project Manager

James Marean – Principal Investigator (Teleconference)
Andrew Hammerschmidt – Project Manager (Teleconference)

Introduction – Why are we here?

- Approximately 85% of the natural gas used in California is imported.
- A vast network of pipelines is in place to transmit and distribute natural gas within the state.
- Many pipelines travel under high consequence areas (HCAs).
- Integrity management practices (IMPs) are essential to ensure the safety and reliability of the natural gas infrastructure.



Introduction – Why are we here?

- Various legislation has set standards for IMPs:
  - 49 CFR Part 192 Subpart O, Pipeline Safety Improvement Act of 2002, PIPES Act of 2006, National Pipeline Safety Act of 2011, etc.
- Research, Development and Demonstration are needed to provide tools to enhance operator's IMPs.
- In 2011, in consultation with the California Public Utilities Commission, the PIER program selected CITRIS and GTI to conduct research on natural gas pipeline inspection technology.

Goals

- Overarching
  - The general goal is to develop, and help bring to market, energy technologies that provide increased system awareness and reliability, lower system costs, and that provide tangible benefits to California utility customers.
- Today
  - Present the current research on technologies used for pipeline integrity and monitoring practices
  - Evaluate suggestions for technologies to pursue in the upcoming solicitation

PIER Approach

Device Development	System Development	System Demonstration

- 3 Phase Approach
  1. Develop & Improve Devices
  2. Integration of Devices into Systems
  3. Utility Scale Demonstrations
- Benefits
  - Pipelines more reliable, efficient, and secure
  - New technology approaches providing new options to assess the condition of pipelines

Focus: Determining the condition of natural gas pipelines the Energy to Lead

CALIFORNIA NATURAL GAS PIPELINE ASSESSMENT - CEC #500-10-050

PIPELINE INTEGRITY and MONITORING TECHNOLOGY ASSESSMENT

GTI Project Review

Natural Gas Pipeline Research Workshop

August 7, 2012

Project Goals - Summary

- Identify Quick "Wins" Commercial Technologies Not in Use That Could/Should Be
- Emerging Technologies That Could Be Moved to Commercial Availability Quicker
- Leverage and Optimize the Use of the Advanced Metering Infrastructure (AMI)
- Develop an Implementation Plan

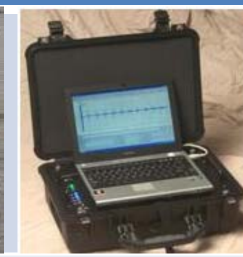
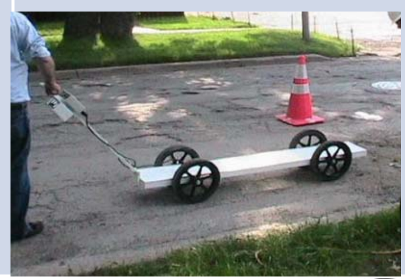
TASKS and DELIVERABLES

- Baseline Technology Assessment in the State of California
  - Review of current state of technologies being used
  - Completed – April 30, 2012
- Assessment of Currently Available Technology
  - Catalogue of available technologies
  - Gap analysis
  - Completed – July 31, 2012
- Evaluate Emerging Technology
  - Identify technologies that could be developed or enhanced in the next 2-4 years
  - Emphasis on integration with the AMI communications backbone
  - Scheduled Completion Date – October 31, 2012
- Implementation Plan
  - Recommend specific technologies to implement in a timely and cost effective manner
    - Testing and deployment currently available technologies
    - Development of select emerging technologies
    - Development of new technologies to meet outstanding gaps
  - Scheduled Completion Date – February 28, 2013

Task 2 – Baseline Assessment - Overview

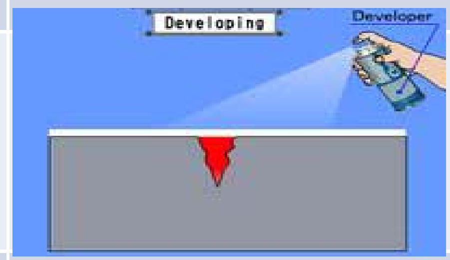
- Summarized the Natural Gas Pipeline System
- Interviewed Pipeline Operators to:
  - Identify all Pipeline Integrity Technologies in Use
  - Determine if:
    - There Were Any Technologies Used in the Past That Were No Longer in Use
    - Any Commercially Available Technologies Were Being Evaluated for Future Use
    - They Were Involved in the Development of New or Replacement Technologies
  - Asked for Their "Wish List"
- Technologies Placed in one of 11 Categories

Technology Categories and Examples

Category	Example(s)	
Internal & External Assessment and Inspection Methods	•Alternating Current Voltage Gradient •Guided Wave	  
Internal Inspection Methods	•Magnetic Flux Leakage •EMAT •Explorer II	 
Long Term Condition Monitoring	•Steel Coupons •Cathodic Protection Monitoring •Gas Chromotography	 
Risk Modeling and Incident Prediction Tools	•Real Time Transient Model •Digital Signal Analysis	
ROW Encroachment and Excavation Damage Prevention	•Pipe Locating – GPR, Acoustics, Magnetic, Current Mapping •Video Detection	 

Technology Categories and Examples

Category	Example(s)
Detection of Pipeline Leaks and Ruptures	•Foot, Mobile and Aerial Surveys •Pressure/Flow Monitoring
Remote Stress/Strain analysis of Pipeline	•Ring Expansion testing •Strain gauge
Tools, techniques and data Analysis Methods in IM P's	•FRASTA •MIC Testing
Non-destructive Examination & Testing	•External Crack detection •Metal Loss detection •X-Ray Analysis
Automated/Semi-Automated and manual Methods of Shutdown	•Remote Controlled Valve •SCADA and RTU's •System Modeling
Data Collection & Communications Techniques	•GIS •SCADA - Wired and Wireless •Human Machine Interface



“Wish List” - Technologies Needing Creation or Enhancement (1)

- Improved Leak Survey Technologies
- Fiber Optic Cabling for Monitoring Pipeline Right of Way (ROW) Intrusion
- Use AMI for:
  - Real-time methane detection, System Flow and Pressure Monitoring
  - Pipeline monitoring, and back-up (redundant path, emergency only) operation of selected valves
  - A low cost approach to move the data
- Enhancement to LiDAR
- Crack Sensor Detectors – on the 24 inch PIPETEL tool

“Wish List” - Technologies Needing Creation or Enhancement (2)

> Improve the Value of EMAT Technology - Use a Needs Assessment

> Automated Girth Weld Inspection Tool on a Tether

> Robotic ILI Tools for Medium and Large Diameter Pipelines that are Un-Piggable with Conventional Tools

> Alternative Acoustic Pipeline/ROW Intrusion Monitoring Technologies

> Real time modeling systems with an On-Line Analysis Tool
  - New ways to control the pipeline
  - Model the system
  - Use real-time data to gain intelligence
  - Identify risks as they develop

> Replacement Tool for the Existing GIS – Need a fundamental change to the data model and how the model is structured
  - Real-time monitoring
  - Analysis tools that integrate enterprise tools with GIS to know “what’s” “where”

"Wish List" - Technologies Needing Creation or Enhancement (3)

- Tool to Accurately Measure Crack Length and Depth in the Ditch
- Assessment of Long Seams and Girth Welds
- Industry Database Available to Others for Trend Analysis and Threat Identification
- Predictive Performance Based (Proactive) Modeling Tool
  - Integrate Company/Industry data
  - Improve effective decision making
  - Provide a programmatic decision method rather than a prescriptive (reactive) man-made method
  - Assist in identifying efficiency improvements
  - Supplement the man-made decision making method

"Wish List" - Technologies Needing Creation or Enhancement (4)

- Low Cost and Low Power Monitoring and Communicating Technology for Remote Applications to Expand the SCADA System
- Method to Integrate SCADA System with the GIS
  - Define Point Information Once and Populate with Field Data
- Mobile Technology - Field Tablets for Employees
  - Real time data to and from the field, eliminate paper and provide a single point of entry to the database

Task 2 Survey Results and Key Findings

- SME's Develop and Maintain IMP's Specific to the Needs of Each Operator
- Not Every Technology is Appropriate or Provides Value in Every Instance
- Technologies needed by some were in use by others
  - Crack Measurement in the Ditch
  - Hand-Held Field Data Collection Devices
- A Lessons Learned/Brainstorming Workshop Should Have Immediate Benefits
- Facilities Are Available for Testing and Verification

Task 3 – Currently Available Assessment – Overview (1)

- Catalogue of Technologies
  - Tools, Processes and Systems for Monitoring
    - 11 Categories
      - Description
      - Strengths
      - Weaknesses
      - Pictures – if Applicable
      - Provider - if Limited Number
      - Communications Capability
      - References
  - List of Acronyms
  - Glossary of Terms

Task 3 – Currently Available Assessment – Overview (2)

- Gap Analysis
  - Weaknesses
  - Communications Capability
  - From Interviews During Task 2
    - Previously Used
    - Being evaluated for Use
    - “Wish List”
  - Input from SME’s
  - Pipeline Assessment Technology Workshop

Task 3 - Pipeline Assessment Technology Workshop

- Purpose - to identify the needs and gaps in existing or emerging transmission pipeline assessment and monitoring technologies
- Conducted June 5-6, 2012
- Included
  - California Pipeline Operators
  - INGAA – Interstate Natural Gas Association of America
  - GTI – Gas Technology Institute
  - PRCI – Pipeline Research Council International

Food For Thought - 1

- Top Three Needs, Gaps, Concerns
- No Technology with the Capability of Interest
- Used in Another Industry But Not in Natural Gas
- Short Comings:
  - Detection Limits
  - Missing Parameters of Interest/Concern
  - Cumbersome or Difficult to Use
- Information Technology Requirements
- Database Issues
  - SCADA with GIS, GIS with Stoner

Food For Thought - 2

> Communications Limitations
  - Proprietary vs. Interoperable
  - Different Generations
  - Varying Ability – How Much, How Frequent, What Language, Level of Sensitivity, Accuracy vs Precision, Storage is too Small, Timeliness of Data Refresh – “What is Real Now?” “10,000 Versions of the Truth!”
  - None Available for Device of Interest
  - One-Way vs. Two-Way
  - Limited Availability – Cellular, RF, Satellite

Pipeline Assessment Technology Workshop - Outcome

- Ensure Goals/Roadmaps of the 3 Industry R&D Groups are Aligned
- Commercially Available Not Useful Due to Operational or Regulatory Barriers – "Prove it, Get it Accepted"
    - Need the Three Legs of the Stool – Industry, Regulators and Manufacturers
    - What's Missing
    - Standard of Acceptance – Operator, Regulator
- Three Areas of Focus For Rapid Deployment
    1. ROW Encroachment and Excavation Damage Prevention
    2. Alternate Inspection Technologies
    3. Education

ROW Encroachment & Excavation Damage Prevention (1)

- Know When Someone is on the ROW
- Cost Effective Retrofit for Existing ROW
  - Focus on HCA’s
  - Fence Post Approach
- New Installations
- Visual or Vibration
- Date/Time Stamped
- Record Events for Download

ROW Encroachment & Excavation Damage Prevention (2)

- Below or at Ground Level
  - Wet or Dry
  - Acoustics
  - Fiber
  - Other
    - Pressure Sensor as a Microphone
    - Visual Recognition
- Aerial
  - Fixed Wing
  - Helicopter
  - Unmanned
- Satellite

Alternate Inspection Technologies

- Focus on Alternative to Hydro Test – Piggable and Non-Piggable
  - No Water
  - Leak/Rupture Boundary - Threat/Risk, Likely failure – Probability/Severity
  - Virtual Records - Industry Database – Common Threads
  - Guided Wave – Address PHMSA's 18 Points
    - http://primis.phmsa.dot.gov/gasimp/docs/GuidedWaveCheckList110107.pdf
  - Non-Piggable Assessment Tools
    - Robotics
    - Non-Invasive Data Collection Techniques
  - ILI Decision Matrix/Assessment Tool Guidelines
    - 30+ ILI Vendors
    - Multiple Tool(s)/Pig

Education

> Needs
  - Primer on Integrity Management – Non-Industry Author
  - Situational Awareness – Emergency Responders and Public
  - Real Time Knowledge to the Situation – Video Link to Advisor
  - Training and Retention of Workforce
    - Need a Larger Pool – Education System with Degree Programs
    - Documented Process, Training Matrix, Improved Delivery Format – New Generation of Learning Styles

> Audience
  - Emergency Responders
  - Public
  - Regulators
  - Employees

Additional Opportunities – 12 Months to Deploy

- Hand-held devices for field use
- Integration of field data immediately into a GIS
- Survey grade GPS w/o post-processing immediately into a GIS
- Bar coding to optimize and automate field data collection
- Radio Frequency Identification (RFID) tags to locate facilities and collect and store field data for later processing
- A lessons learned and technology demonstration workshop
- An industry database as the first step toward the development of a predictive performance based (proactive) modeling tool

Additional Opportunities – 12 - 24 Months to Deploy (1)

- Upgraded and integrated GIS with enterprise software available to the field "**Make My Pipeline Like My House – Where is my stuff, I want to control it**"
- Accurate measurement of crack length and depth in the ditch with transmittal to the back office
- Predictive performance based modeling tool integrated with an industry database to supplement man-made decision making
- Remote, low cost methane detectors in the 100 to 200 ppm range and providing an alarm
- Tracking and work management software for HCA's as accurate and reliable as "boots on the ground"

Additional Opportunities – 12 - 24 Months to Deploy (2)

- Low cost, low power technologies at smaller intervals - an accurate “picture” in real-time
- Requires verification of the AMI and sensor capabilities:
  - AMI has redundancy and security in the areas of sensor deployment
  - Full access to and inter-operability of the AMI system
  - Cost advantage of sensors under development
  - Full inter-operability of the all sensors

Additional Opportunities – 12 - 24 Months to Deploy (3)

- Once verified use the AMI system to provide:
  - Redundant two-way communications for data flow
  - Data collection, monitoring and system control as new technologies are developed – Ex. Right-of-Way (ROW) encroachment and excavation damage prevention, leak detection
  - Improved real-time monitoring of flow and pressure
  - Improved operation of selected valves
  - Instantaneous identification of an issue or failure requiring pipeline shutdown

the Energy to Lead

QUESTIONS???

Natural Gas Pipeline Sensors

CEC R&D Roadmap Workshop

Tuesday August 7th, 2012

Prof. Paul Wright (ME/CITRIS)
Gaymond Yee (CIEE)
Fabien Chimrai (EECS/BSAC)

Prof. Dick White (EECS/BSAC)
Yiping Zhu (EECS/BSAC)
Prof. Kris Pister (EECS/BSAC)

Dr. Igor Paprotny (EECS/BSAC)
Adam Tornheim (MSME)

Agenda

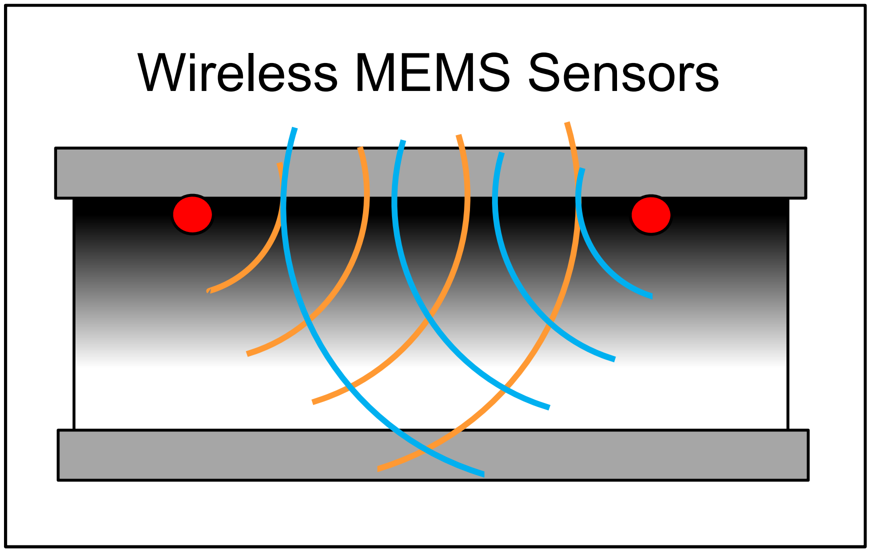
- Overview
- Timeline
- Progress/Status:
  - MEMS Wireless Sensor Modules
  - Laser Ultrasonic Testing (LUT) and other ultrasonic diagnostic methods

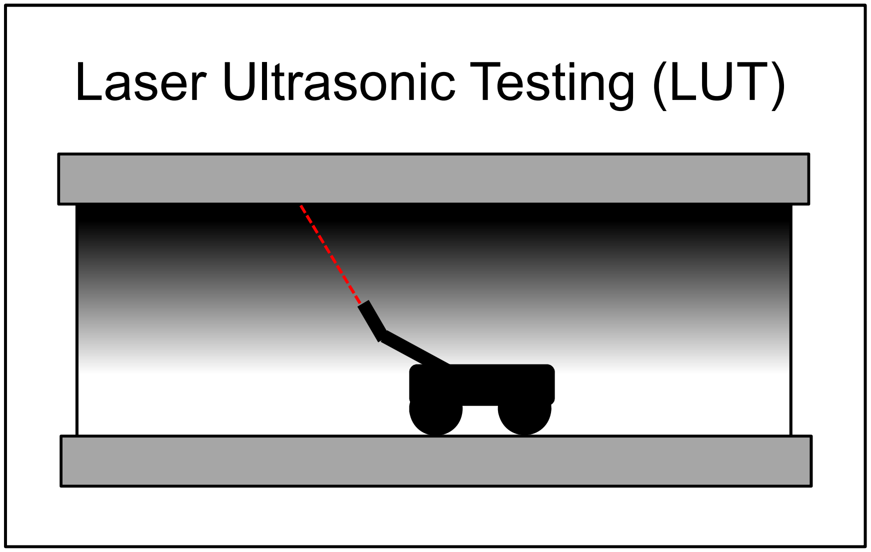
UC Berkeley Nat. Gas Sensors

- Project kick-off: November 2011

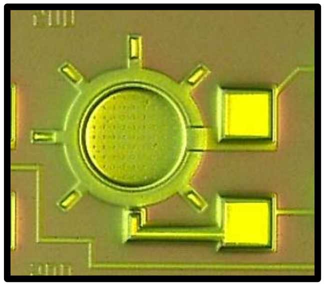
Project objective:

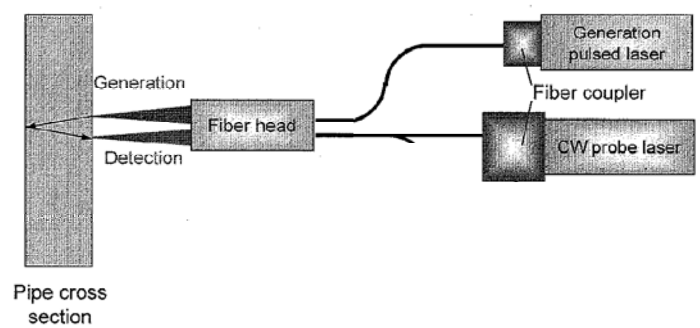
- **design, fabrication, lab testing, and field testing of next generation low-cost sensors and methods for use in natural gas pipelines.**

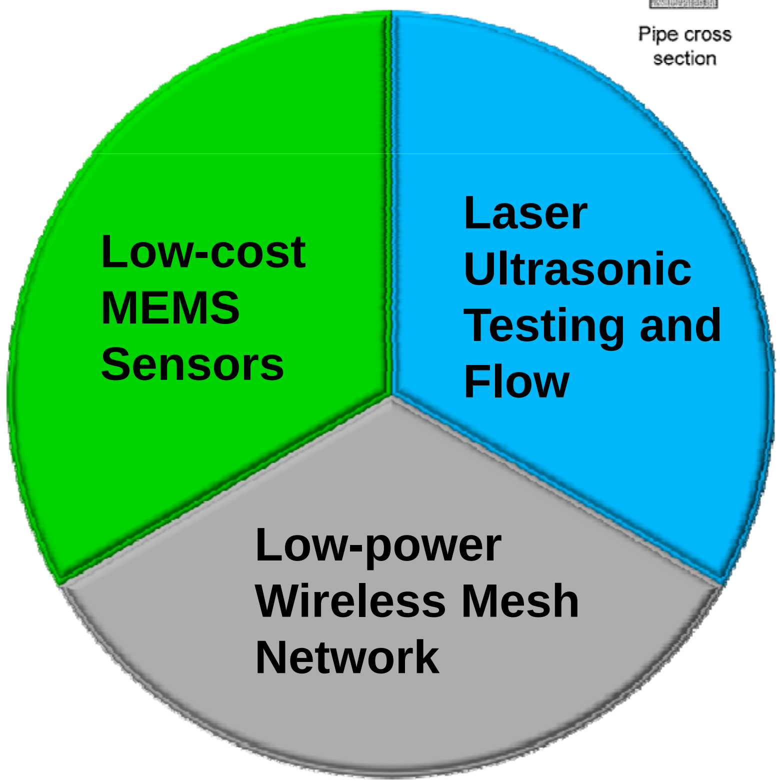




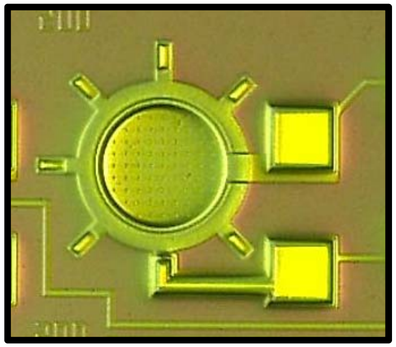
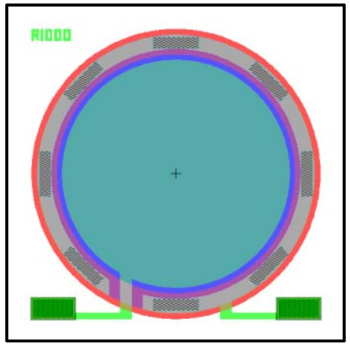
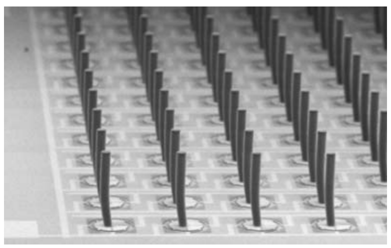
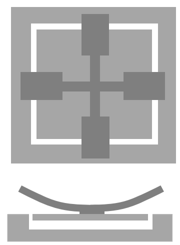
Per the 2005 Integrated Energy Policy Report, this project will assist in expanding the analytical ability to determine the adequacy of the State's natural gas infrastructure and likelihood of potentially destructive peak demand spikes, and also ensure that the State's natural gas infrastructure can both convey and store supplies.




Generation
Detection
Fiber head
Generation pulsed laser
Fiber coupler
CW probe laser
Pipe cross section


Low-cost MEMS Sensors
Laser Ultrasonic Testing and Flow
Low-power Wireless Mesh Network

Microfabricated (MEMS) Nat. Gas Sensors

Objectives

- Develop and fabricate low-cost/low-power pressure and flow sensors which can be used for ubiquitous monitoring of natural gas pipelines to increase their safety and reliability
- Extend the fabrication process to enable wafer-level assembly of complete system, enabling low-cost deployable sensing solution

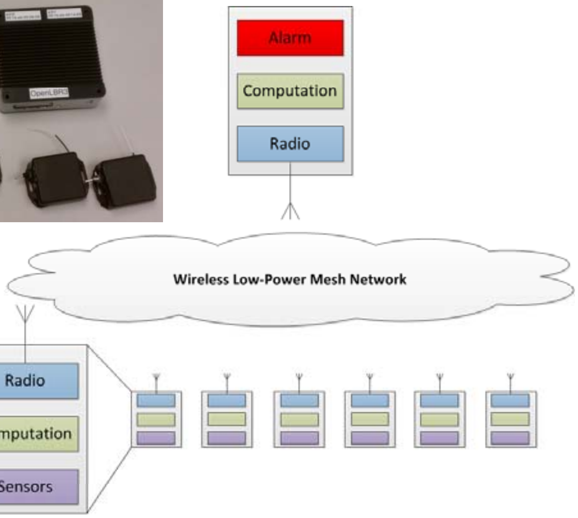
Accomplishments

- Fabricated first pass MEMS pressure sensor design using MEMS foundry service
- Designed and fabricated masks for in-house pressure sensor fabrication
- Modeling of non-thermopile flow sensor designs ongoing.

Expected Results

- Design and fabrication of MEMS pressure and non-thermopile flow sensors
- Integration of the sensors with a low-power radio wireless mesh network
- Pilot test the sensor concept in field in collaboration with the utilities

Low-power Wireless Infrastructure



Objectives

- Create a reliable low-power wireless backbone for sensor data communication
  - Provide interface with existing communication backbone, such as AMI network
- Extend the mesh network to support wafer-level integration of a deployable sensing solution

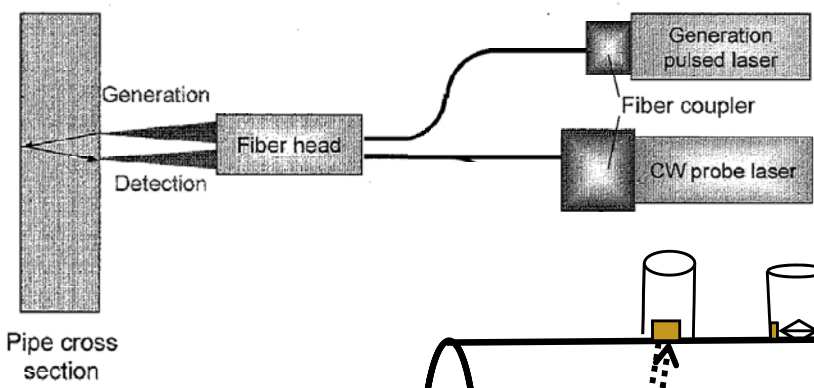
Accomplishments

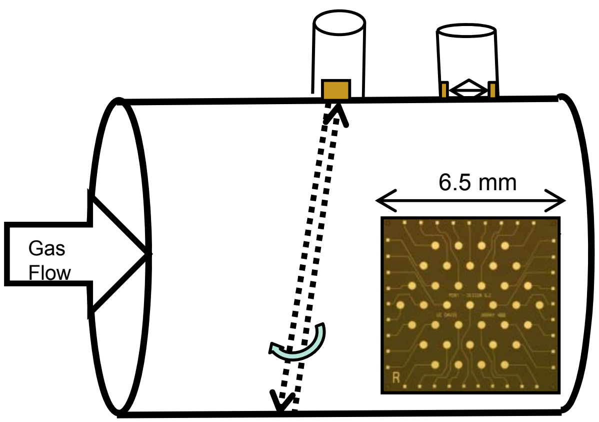
- Designed the wireless mesh network based on Dust® WirelessHart.
- Implemented a local network architecture based on legacy GINA design.

Expected Results

- Develop a reliable low-power wireless network to support communication with the distributed MEMS sensors.
- Integration of the sensors with a low-power radio wireless mesh network
- Pilot test the sensor concept in field in collaboration with the utilities

Ultrasonic Diagnostic and Test Devices for Natural Gas Pipelines





Customer Problems to be Solved

- Evaluate non-contacting laser-based ultrasonic tool for inspecting pipeline welds, locating cracks, detecting pipe offsets and measuring pipe wall thinning due to internal or external corrosion
- Engineer wirelessly enabled low-power scanning ultrasonic gas flow sensor for unobtrusive installation in legacy and new natural gas transmission pipelines

Innovation goals

Laser Ultrasonic Test System

- Non-contact laser ultrasonic tool for determining pipe integrity when used on utility's "crawler

Microfabricated Ultrasonic Gas Flow Sensor

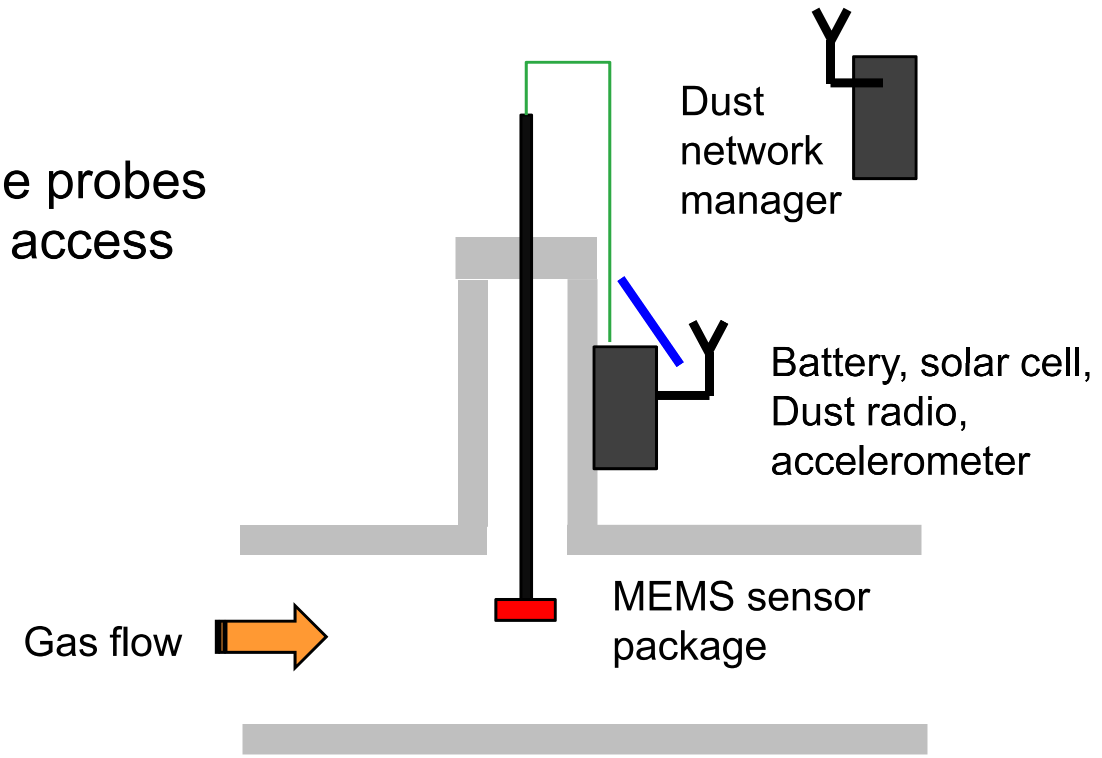
- Novel low-power approach to wirelessly enabled non-intrusive gas flow sensing

Project Plan

- Continue interaction with laser ultrasonic test manufacturer and utility to evaluate compatibility with existing pipeline crawler
- Complete analysis of operation of ultrasonic flow sensor based on existing prototype microfabricated scanning ultrasonic arrays
- Test array flow sensor in our air-flow tube setup
- Design for realistic incorporation of flow sensor in operating gas transmission pipes

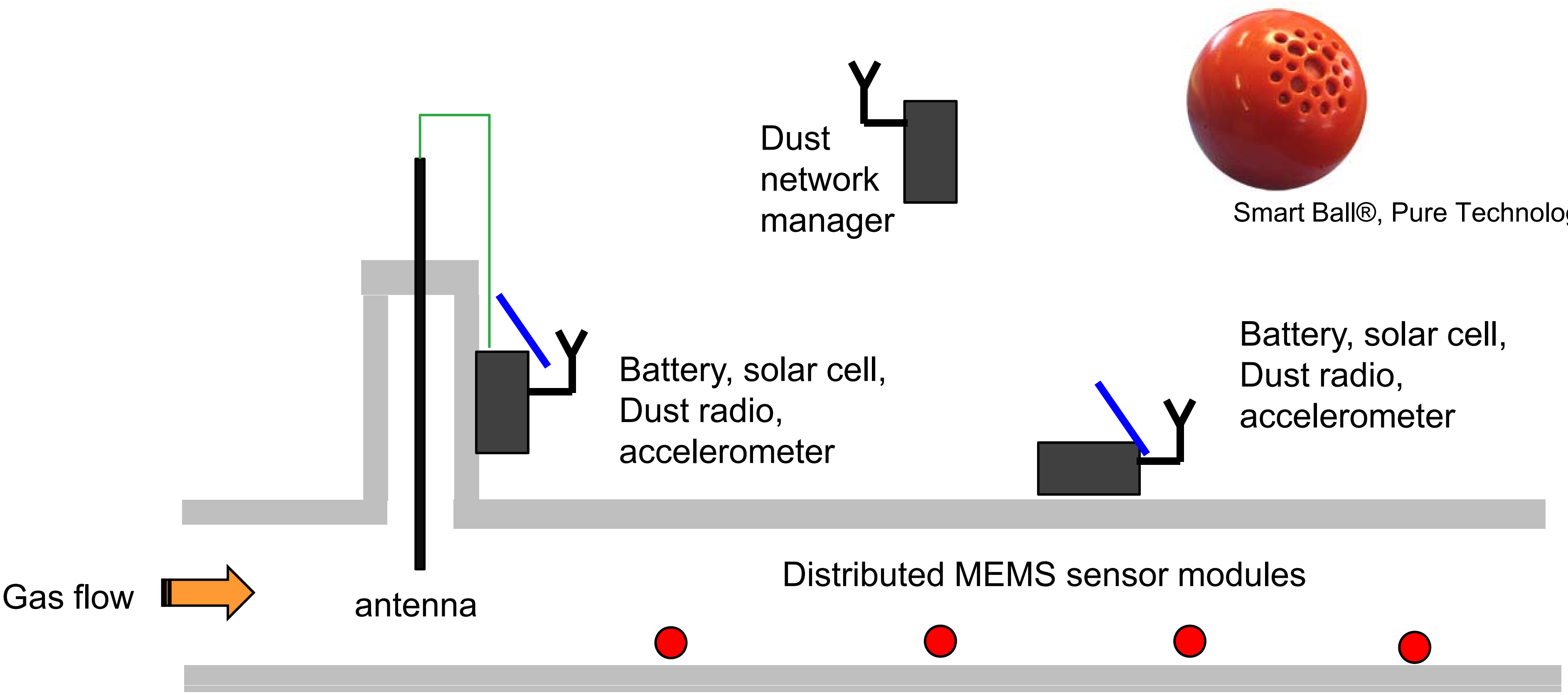
Sensing System Design

- Baseline design
  - Sensors deployed as retractable probes into the gas flow via the ¾ inch access port.
- Sensor suite
  - Pressure
  - Flow
  - Accelerometer (external)
- Wireless infrastructure
  - Dust Networks (~70 μW standby)
- Power
  - Battery/Solar (>10 year lifetime)



Advanced Sensing Concept

- Advanced design concept
  - Self-powered sensor modules, powered by the gas flow, that autonomously instrument section of the pipeline.



Smart Ball®, Pure Technologies

Sensing System Design

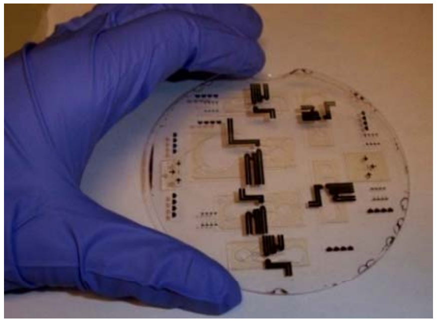
- Online sensors that would be useful

Pressure sensors (MEMS/low cost)	Design 2nd
Flow sensors (MEMS/low cost)	Design
Vibrations sensors (distributed/low cost)	Off the shelf
Moisture sensors (MEMS/low cost)	Pr. Designs
Odorant level sensors (low cost)	Pr. Designs
Methane detector (low cost)	Pr. Designs
Laser Ultrasonic's (Weld/Corrosion detection)	Designs / Collaboration
Ultrasonic flow sensors	Designs / Collaboration

Low-cost MEMS Sensors

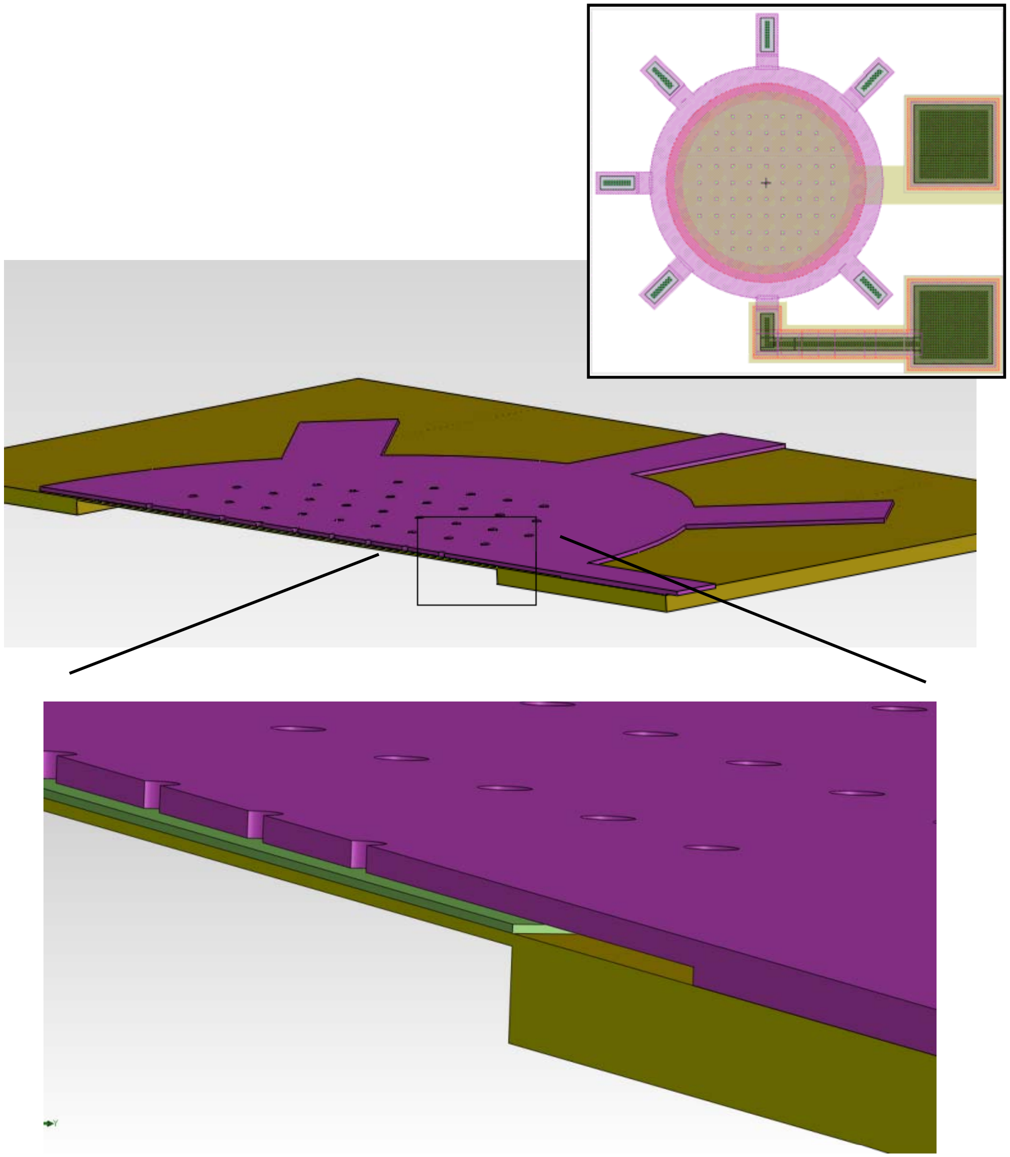
Low-cost MEMS Sensors

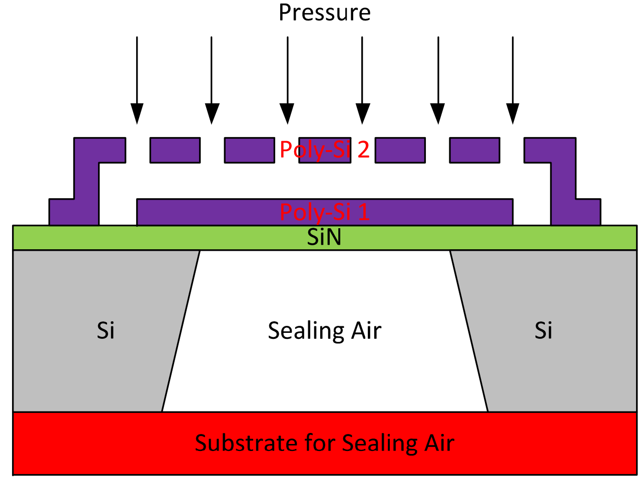
Goal: To use MicroElectroMechanical Systems (MEMS) techniques to develop low-cost sensors for Natural Gas pipelines.

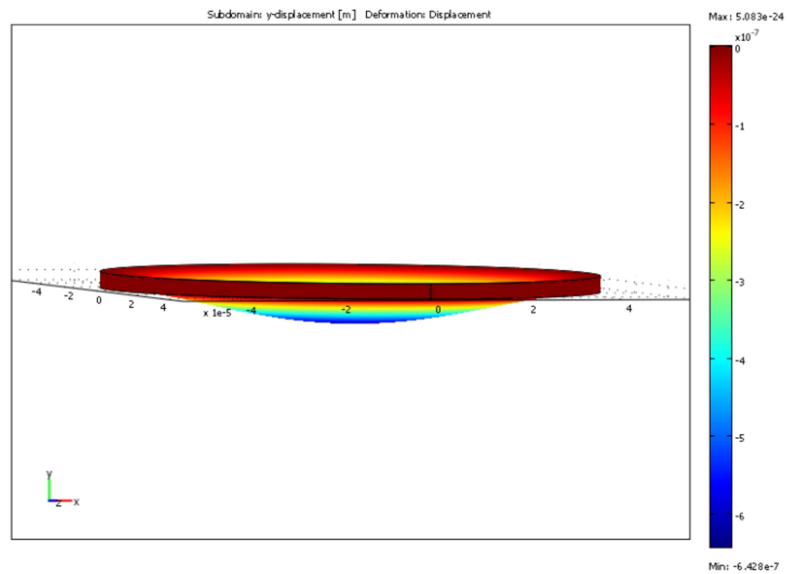


- Primary area of emphasis:
  - Pressure
  - Flow
  - Vibration (acceleration)
- Secondary area of emphasis:
  - Moisture
  - Odorant
  - Methane

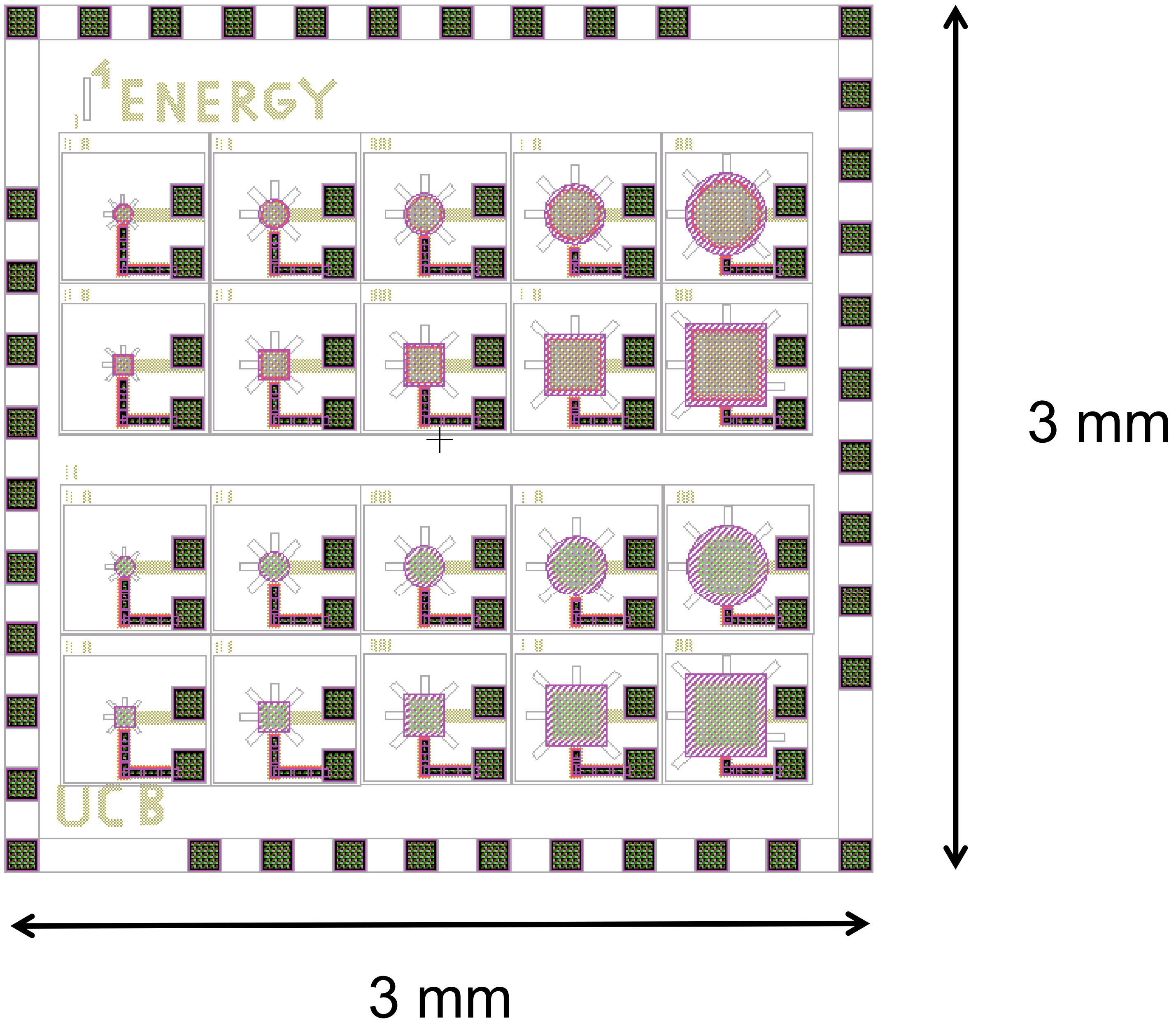
Capacitive MEMS Pressure Sensors



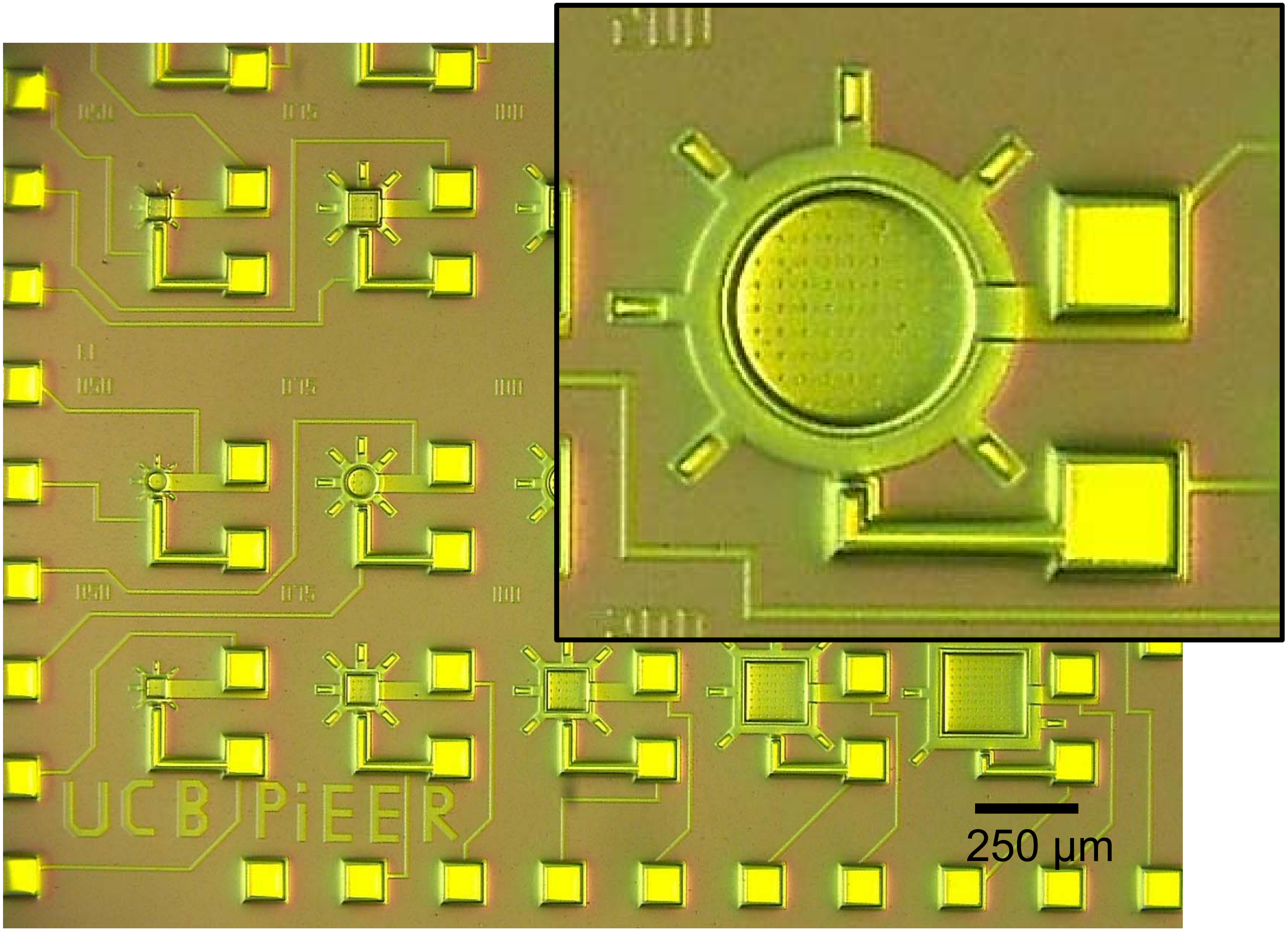




Capacitive MEMS Pressure Sensors

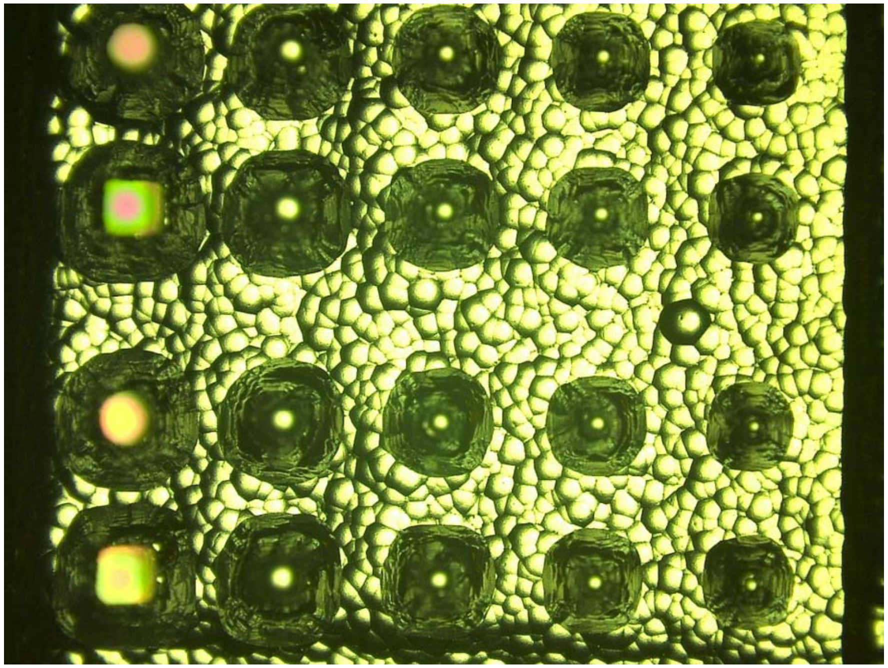


Capacitive MEMS Pressure Sensors

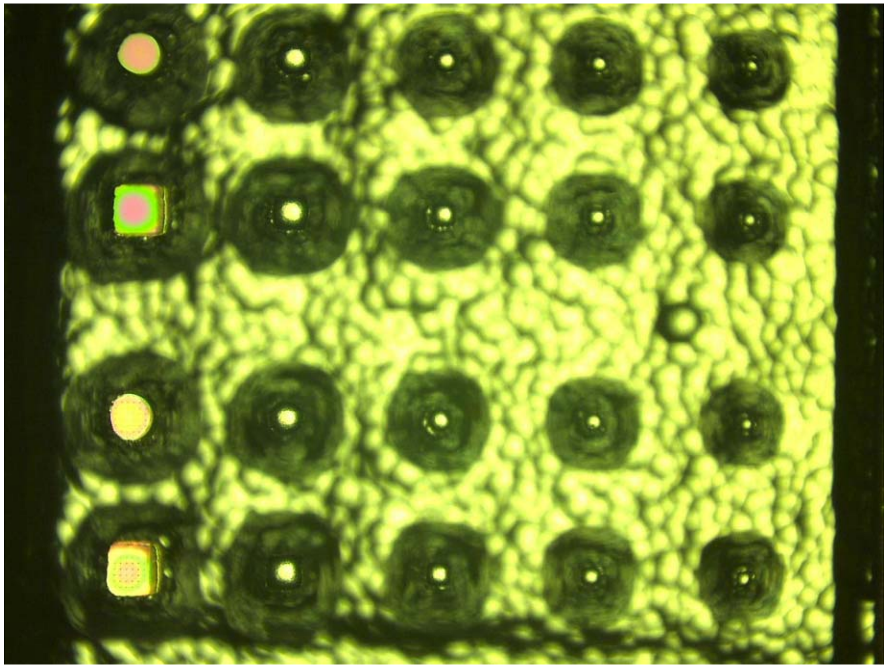


Capacitive MEMS Pressure Sensors

Backside 1

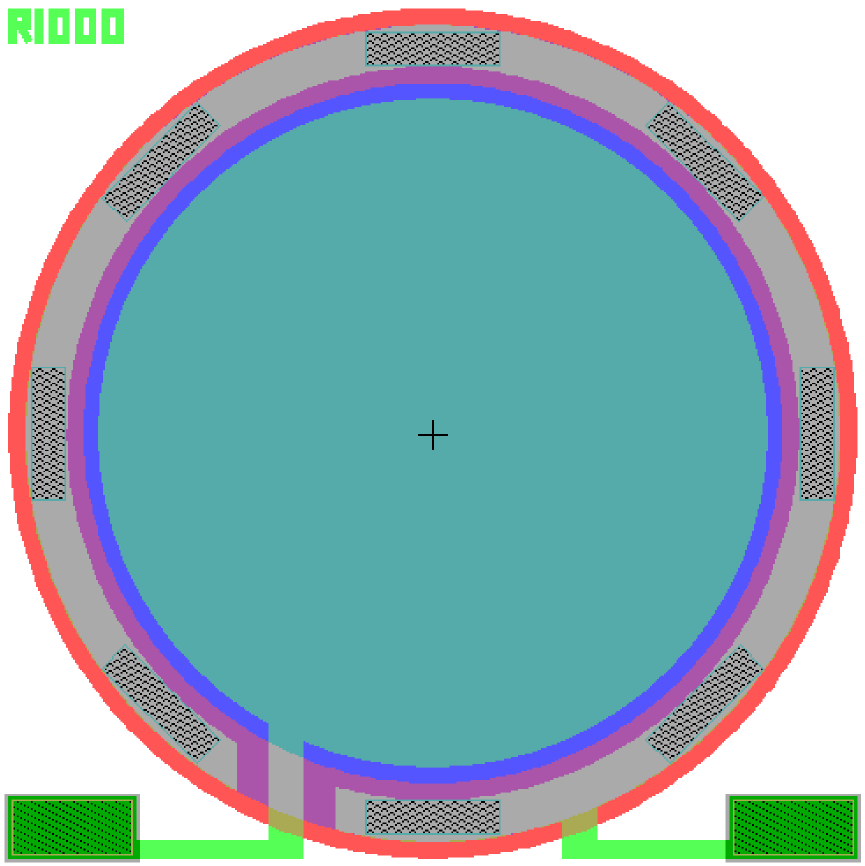


Backside 2

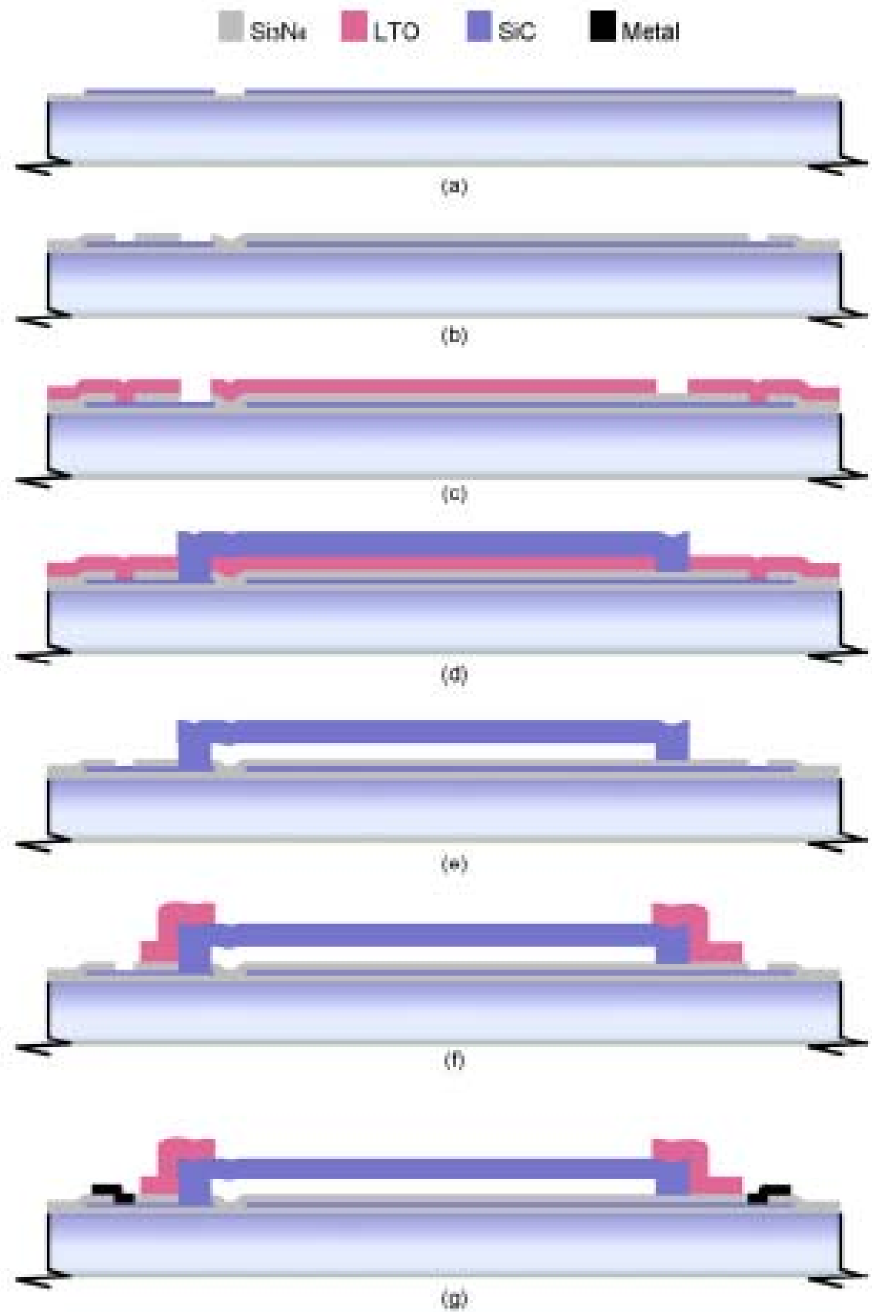


Etching problems - modified fabrication process

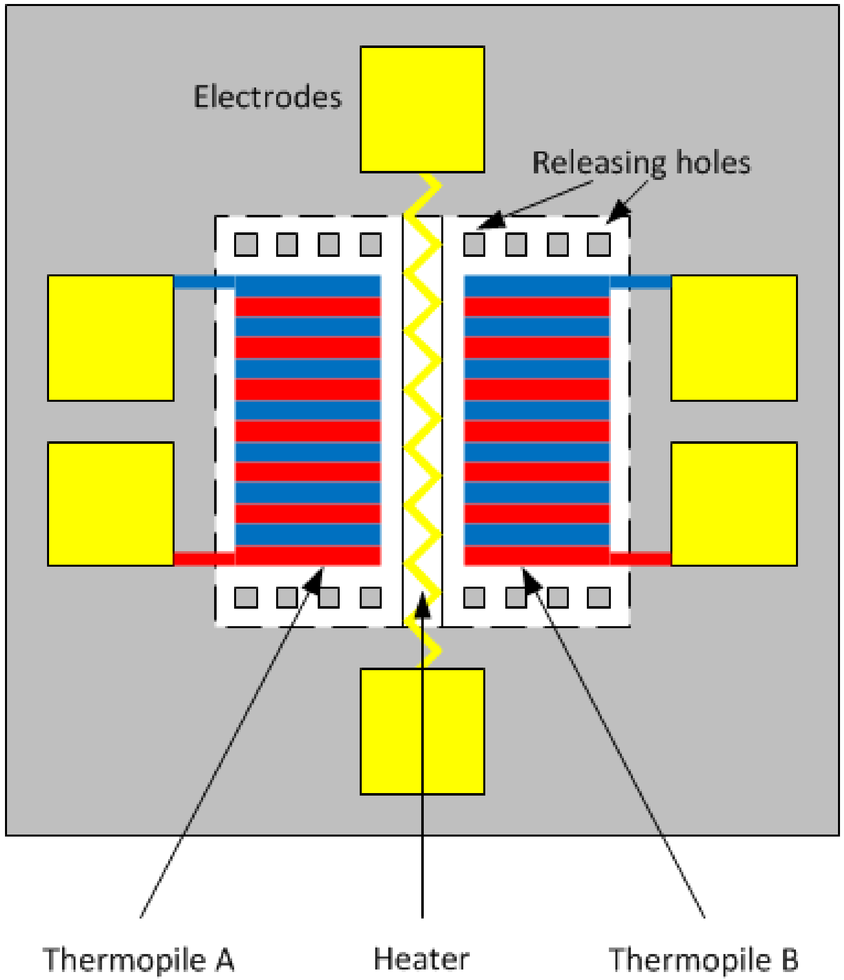
Capacitive MEMS Pressure Sensors

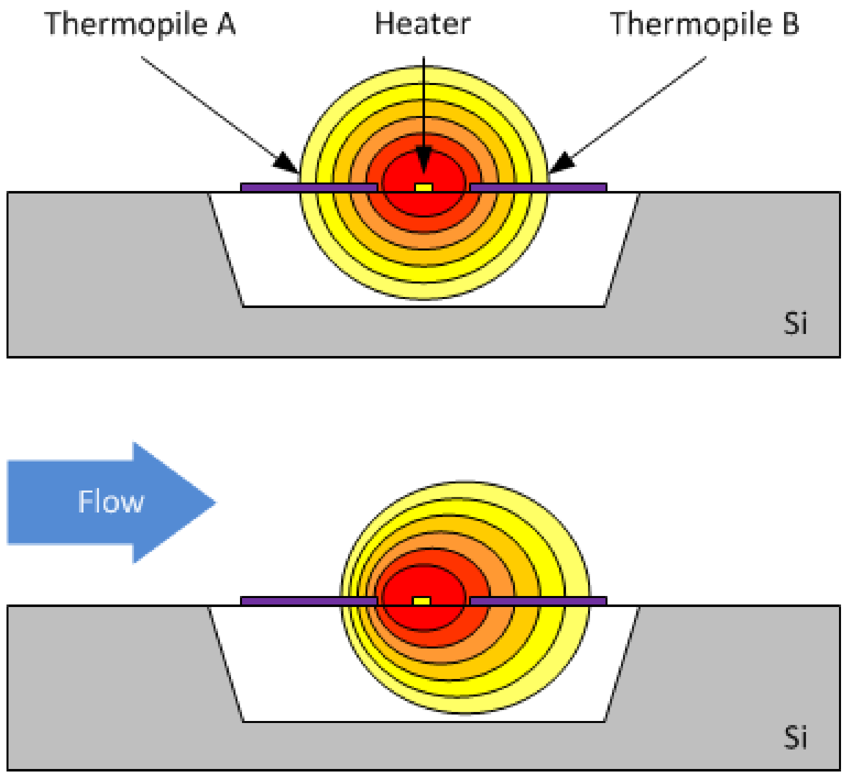


New pressure sensor design



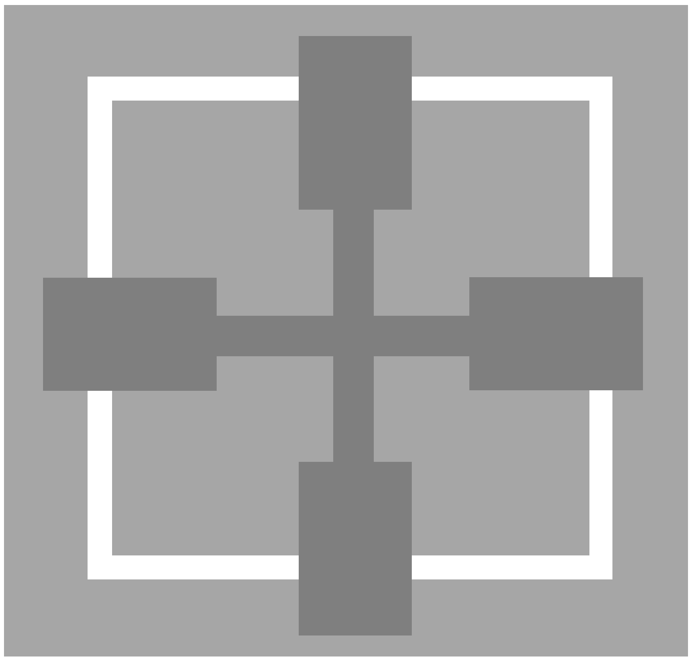
MEMS Flow Sensors

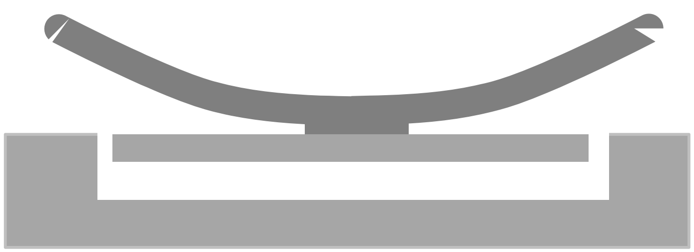


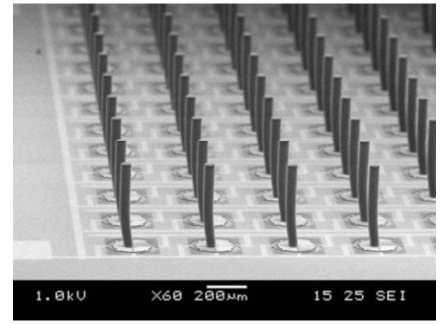


Non-thermopile MEMS design

- Dynamic pressure sensing:
  - Paddle or whiskers







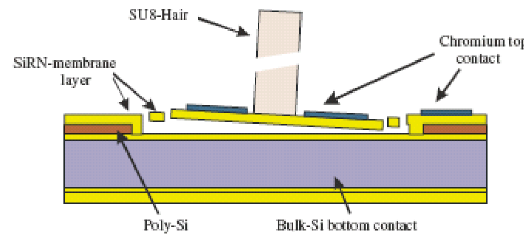
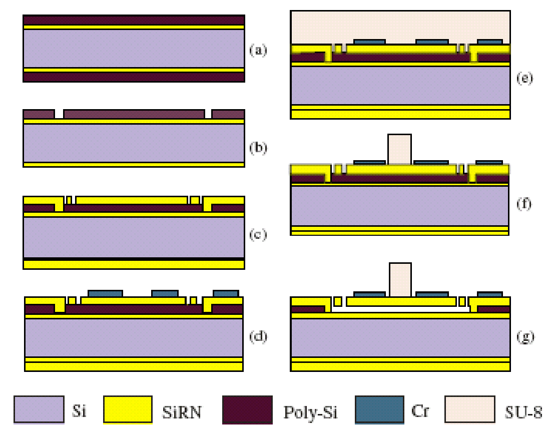


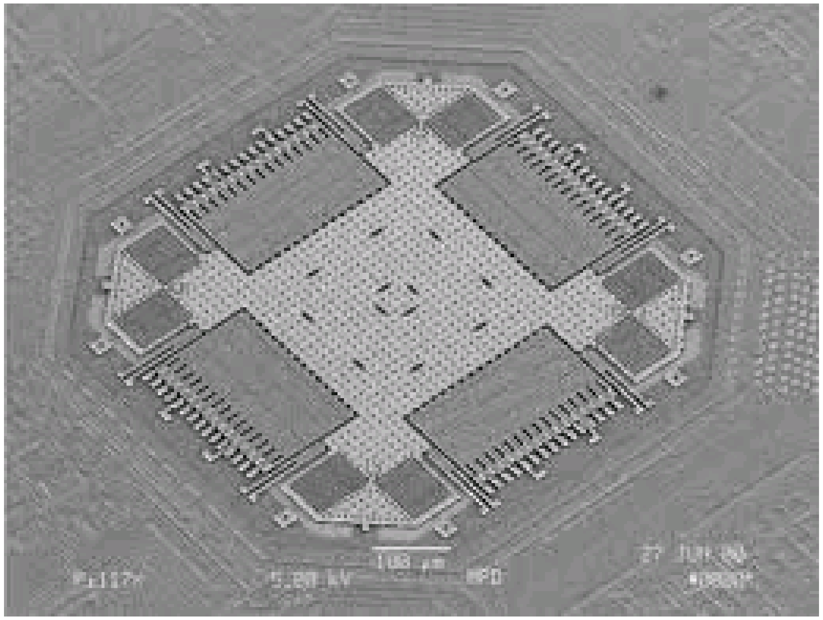
Figure 2. Sensor structure with SU-8 hair.

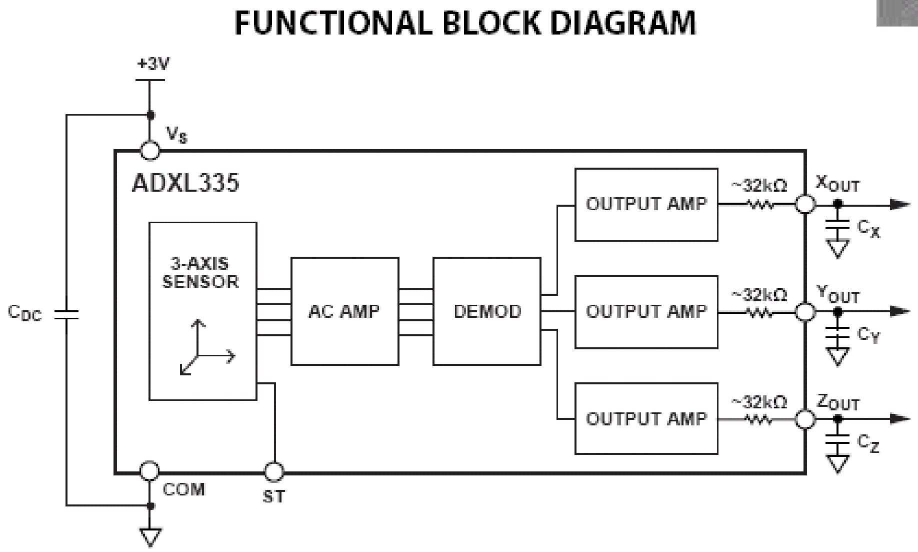


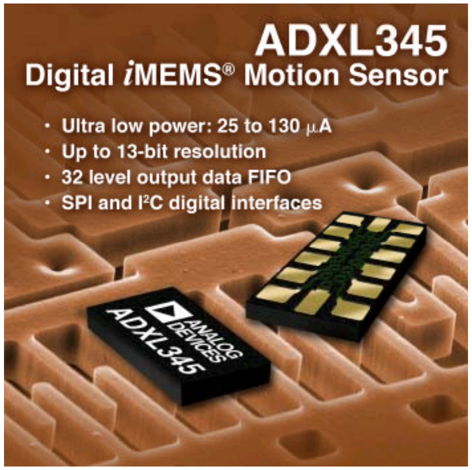
Krijnen et al, 2006

MEMS Accelerometers

- Excellent off-the-shelf accelerometers w. post-processing circuitry available from several vendors.
- Price: $3.70.







Images from Analog Devices

MEMS Sensors - Next Steps

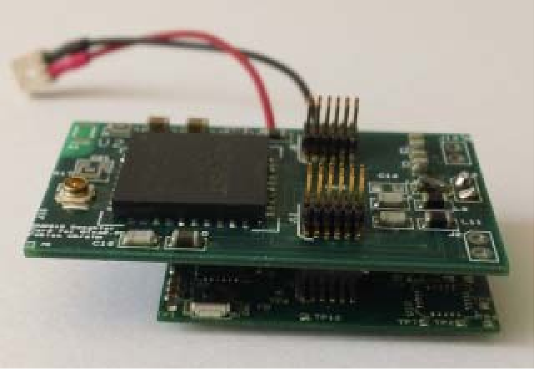
- Fabricate 2nd generation MEMS pressure sensors
  - Mount and test in laboratory setting
  - Integrate with the wireless mesh network
- Fabricate flow sensors
  - Mount and test in laboratory setting
  - Integrate with the wireless mesh network
- Perform a limited pilot deployment and testing of the sensor packages in collaboration with the utilities.
  - Limited accelerated life-time testing
  - System integration analysis

Low-power Wireless Mesh Network (System Integration)

WirelessHART Interface Module (WHIM)

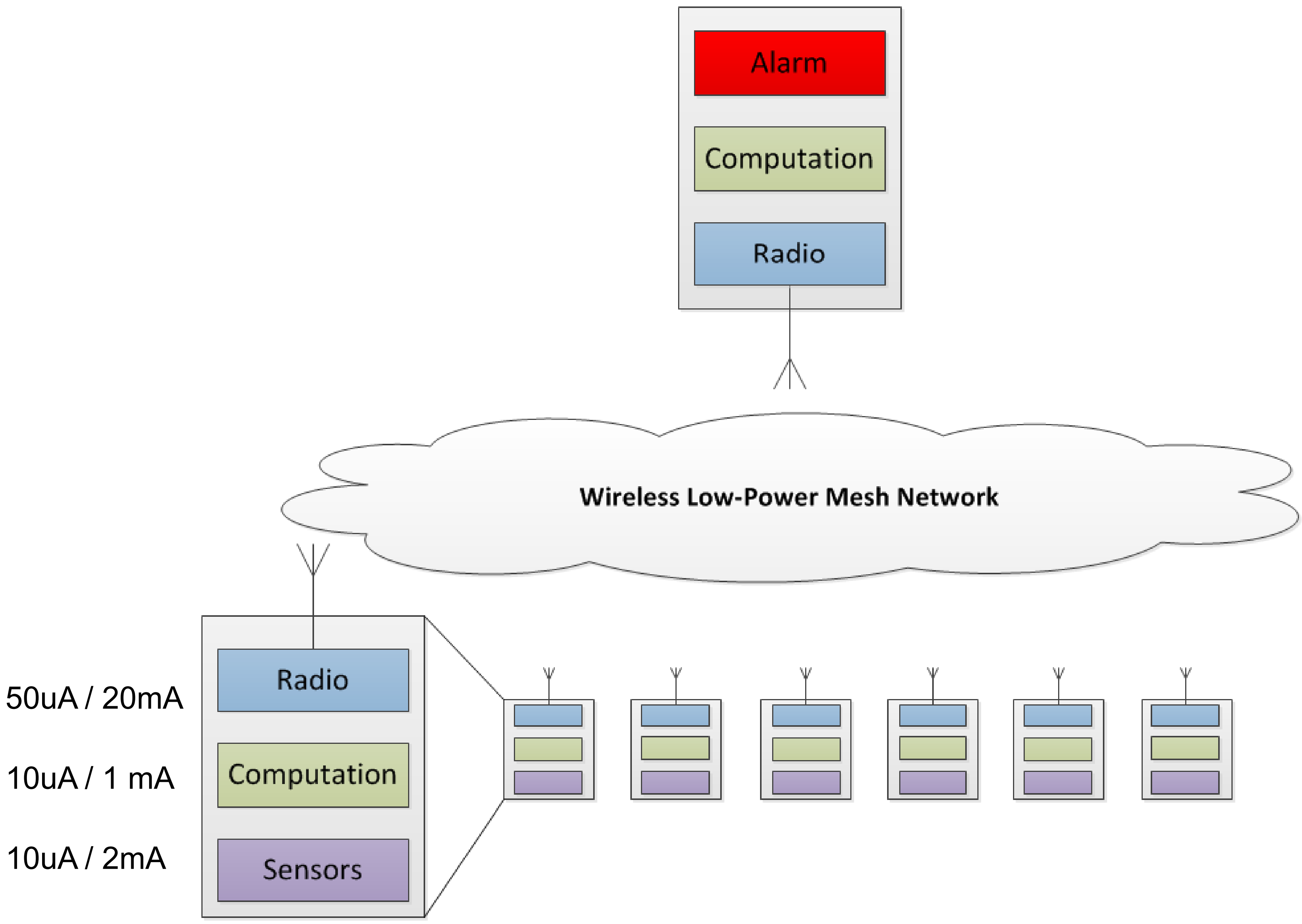
- Chevron-Richmond: 80% WirelessHART coverage on the refinery grounds => virtually any sensor can join and start reporting

Component	Part Number	Specs
microcontroller	TI MSP430F2618	16-bit, 16MHz, 116kB flash, 8kB RAM
radio	DUST Networks DN2510	2.4GHz, WHART compliant
3-axis accelerometer (sensitive)	STMicroelectronics LIS344ALHTR	+/-2 Gs or +/-6 Gs, 1.8 kHz, 660 mV/G, 50 uG/rtHz
3-axis accelerometer (large range)	Kionix KXSD9-1026	+/-8 Gs, 2 kHz
3-axis gyroscope	Invensense ITG3200	2000 degs/s
3-axis magnetometer	Honeywell HMC5843	compass
temperature sensor	TI TMP20AIDRLT	+/-2.5 C, -55 C to 130 C



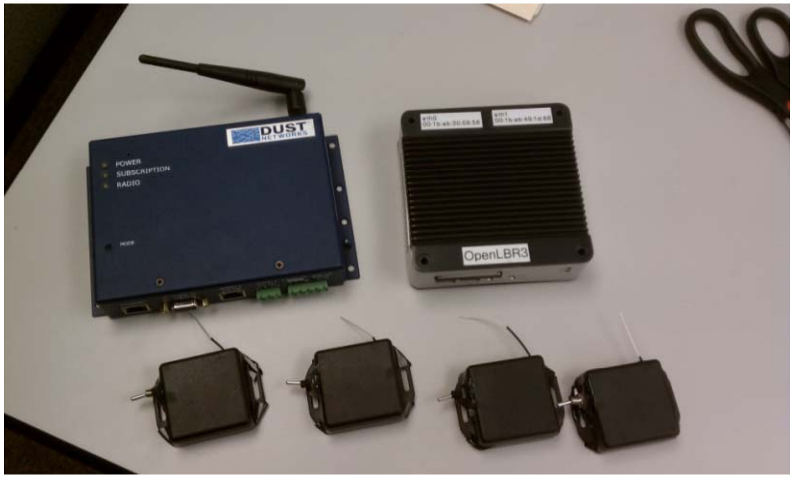
- Expandable
- In sleep mode ~70uA => extended battery life (years)
- Time Synchronized Channel Hopping network => efficient end-to-end communication with few retransmissions

Proposed System Architecture

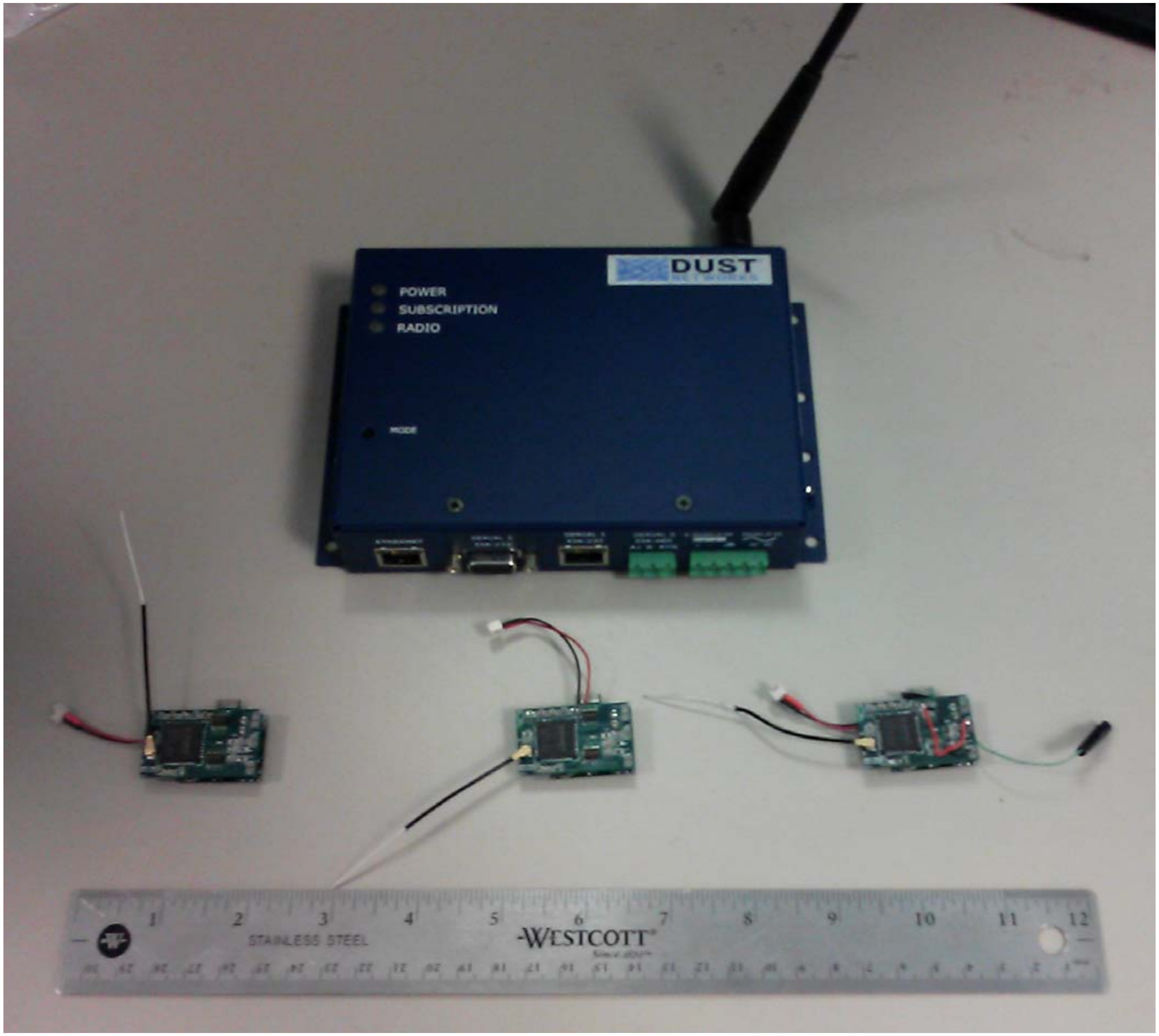


Legacy Pilot Deployment - Chevron

- 6 weeks long (November/December)
- No false positives
- 100% detection
- Box withstood rain, strong winds and sunlight exposure (IP65)



The Dust Network Devices



Ultrasonic Diagnostic and Test Devices for Natural Gas Pipelines

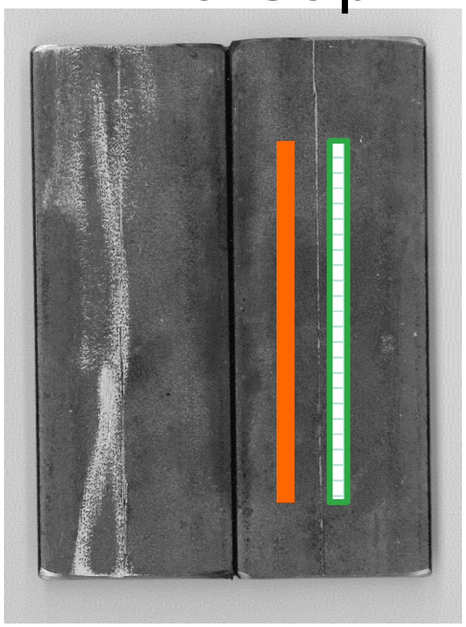
Outline

- Laser Ultrasonic Inspection Tools (welds, pipe offsets)
- Microfabricated Ultrasonic Flow Sensor
- Lab Sensor Test Set-Up
- Looking Forward – Next Steps

Laser Ultrasonic Inspection Tool

Testing Welds

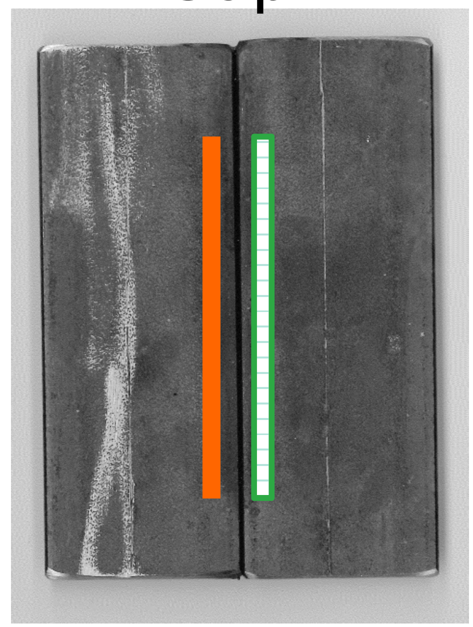
No Gap



Generation laser

Detection laser

Gap



Gap is not between generation laser and detection laser, so is not surveyed.

Gap is between generation laser and detection laser, so is surveyed.

Laser Ultrasonic Inspection Tool

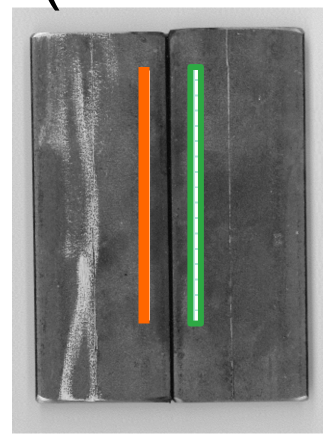
Weld Test Results

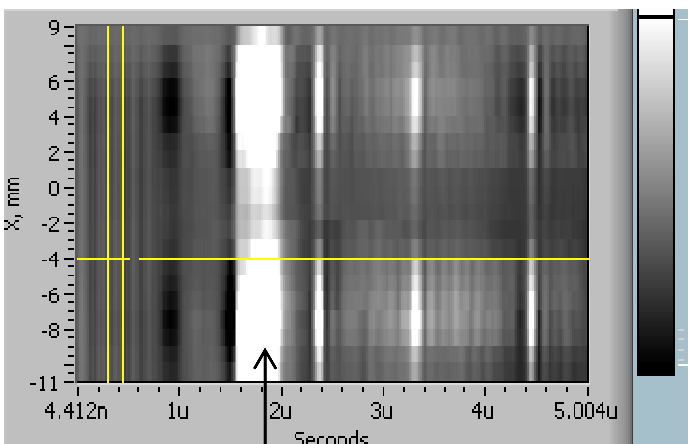
Not over gap
(good weld)

Generation laser

Detection laser

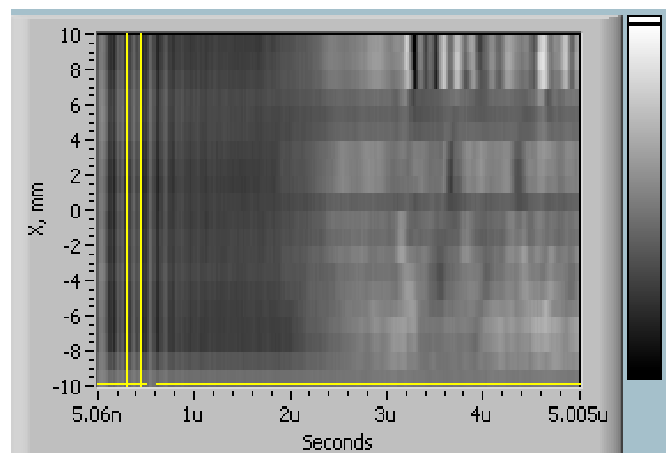
Over gap
(bad weld)





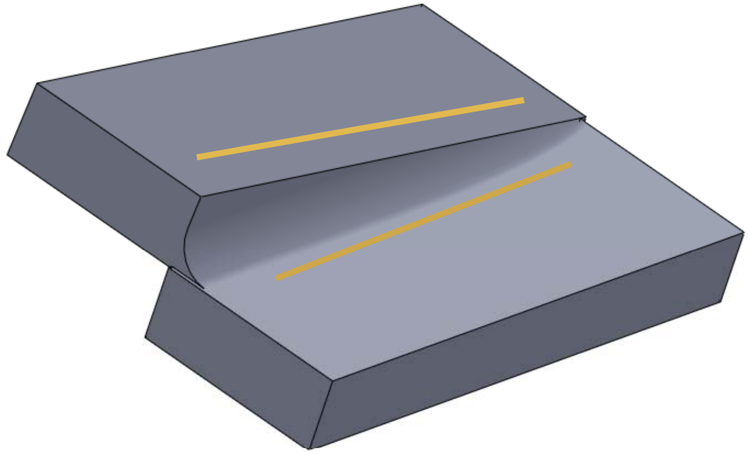
Location

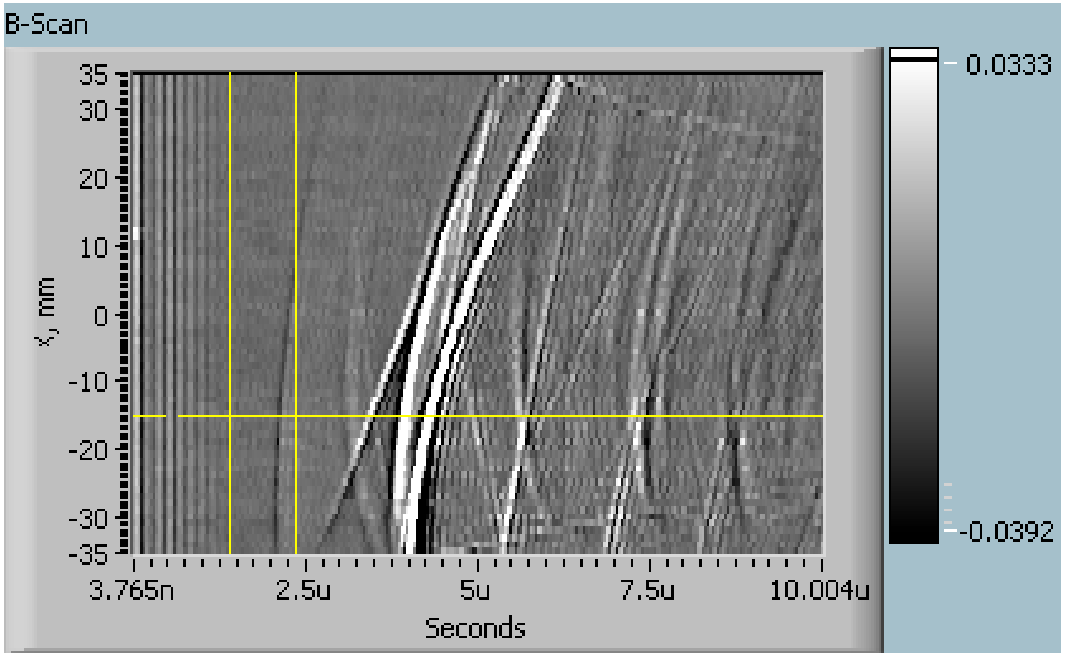
Time



Detected Signal

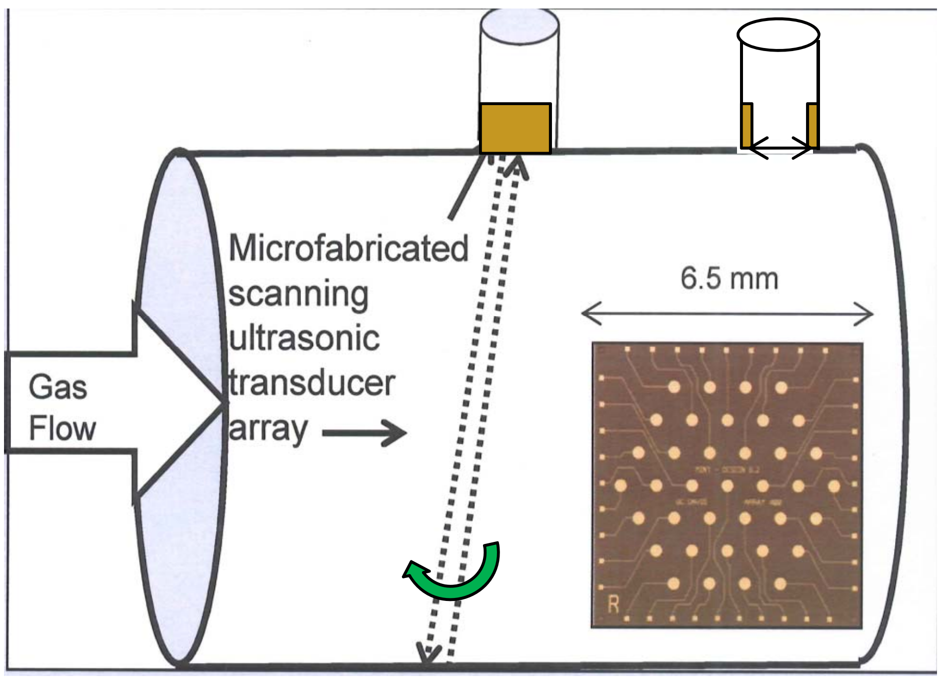
Laser Ultrasonic Inspection Tool
Pipe Offset Test

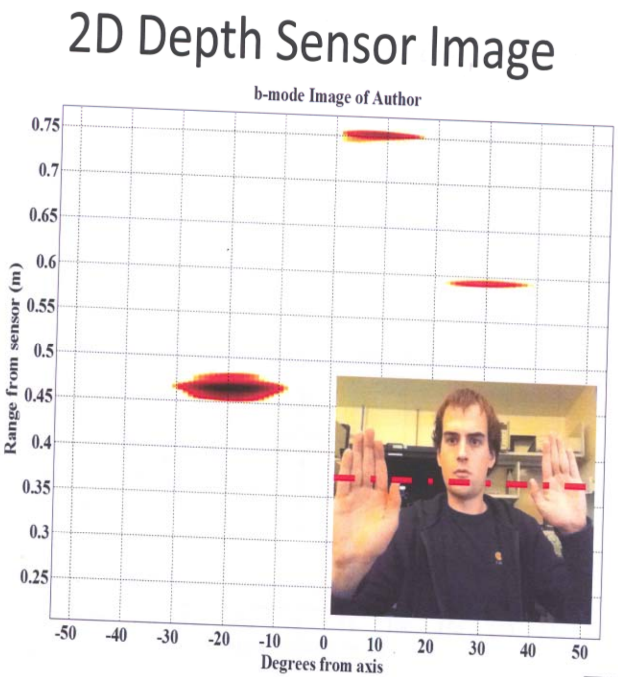




Microfabricated Ultrasonic Gas- Flow Sensor

- Novel microfabricated ultrasonic array transducer recently announced at BSAC could be used to measure natural gas flow rate (Profs. Horsley, Boser, and students R. Przybyla *et al*.)
- By scanning angularly or propagating within side stub as shown at left could measure flow rate (angular scanning capability shown at right)





Microfabricated Ultrasonic Gas Flow Sensor (continued)

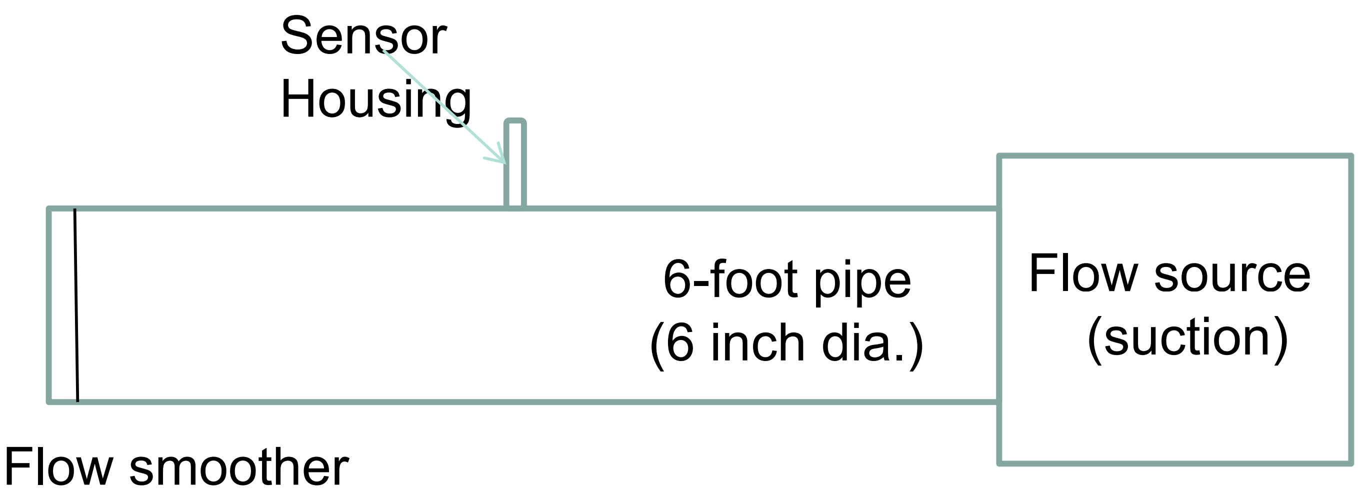
Features:

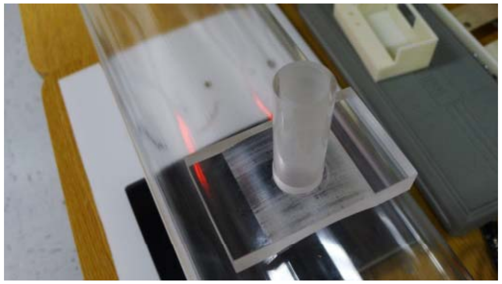
- Single transducers, multi-element transducer arrays
- Sub-milliwatt transmitter drive power
- Transmit range to few meters
- Previous ultrasonic gas flow sensors were successful but large and power hungry (Lynnworth)
- Ultrasonic velocity in gases independent of pressure, virtually independent of humidity; temperature dependence few percent over 20 degree C range (in air)
- Two companies in US provide ultrasonic flowmeter calibration services

Plan:

Test in our lab flow sensor setup

Lab Flow Sensor Test Set-Up





Flow Sources

Fan	240 cfm
Leaf Blower	1200 cfm

Looking Forward – Next Steps

1. Continue interaction with laser ultrasonic manufacturer and utility to evaluate compatibility with existing pipeline crawler
2. Complete analysis of ultrasonic flow sensor based on available prototype microfabricated scanning arrays
3. Test ultrasonic flow sensor in our lab air-flow tube setup
4. Design for incorporating ultrasonic flow sensor in operating gas pipe (test if possible)

Lunch

Workshop will resume at 1:00

Panel Discussions

- There is an upcoming $2M solicitation to demonstrate pipeline inspection and integrity management technologies.
- The following are the technologies that we see as most promising to enhance IMPs.
- Each of them will now be described in detail.
- Your input will aid us in validating the benefits of the technology.
- We would like to prioritize the technologies to narrow the focus of the upcoming solicitation.
- If there are other beneficial technologies we have not presented, please let us know.

Recommended Areas of Emphasis for Solicitation

- Methods to reduce operating costs and optimize field data collection
- Enhanced operational awareness using low cost/low power sensors
- Enhanced IMPs through risk analysis, prediction, and decision based methodology
- Integrating multiple crack inspection devices on a single pipeline crawler
- Input from attendees on areas not presented

Methods to Reduce Operating Costs and Optimize Field Data Collection

- Technologies capable of:
  - Addressing the issue of not knowing what's where
  - Ensuring that when the field portion of the job is completed the paperwork portion is also completed
  - Reducing manual data entry while not transferring the burden to the back office
  - Reducing or eliminating data collection errors and unknowns
  - The capability to integrate with other enterprise systems
- Comments and Questions on this technology area.

Enhanced Operational Awareness using Low Cost, Low Power Sensors

- Methods should result in:
  - Field Verification of the Advanced Metering Infrastructure (AMI) two way communications and sensor capabilities
  - Optimal integration mix of AMI & non-AMI communication technologies
  - Confirmation of full interoperability and security of the AMI communications system
    - Protection from vandalism and/or cyber attack

Enhanced Operational Awareness using Low Cost, Low Power Sensors

- Methods should result in (cont.):
  - Determination of the life cycle analysis of low cost, low power sensors compared to existing technology that requires retrofits to be compatible with the AMI
  - Interoperability of the low cost, low power sensors under development
  - Redundant paths for data flow
  - Improved monitoring of critical parameters
- Comments and Questions on this technology area.

Enhanced IMP's through Risk Analysis, Prediction, and Decision Based Methodology

- The objective is to develop, implement, and deploy tools and methodologies that will provide operators an enhanced working knowledge of their pipeline systems to supplement and complement existing IMPs.
- Tools and methodologies should focus on reducing operator risk.
- Standards should provide guidance on individual threats, and methods threat interactions should be addressed.
- There is limited industry knowledge on the interactions of various threats and how they should influence the overall risk of a pipe segment.

Enhanced IMP's through Risk Analysis, Prediction, and Decision Based Methodology

- **Research in this area should include:**
  - Risk modeling and incident prediction tools
  - Predictive performance based tools that surpass the current prescriptive approach
  - Techniques that incorporate leading rather than lagging indicators
  - Methodologies should include the ability to assess risk using a set of known and unknown threats
  - The end product should provide operators the ability to identify, rank, mitigate, and continually track threat interactions
- **Comments and Questions on this technology area.**

Integrating Multiple Crack Inspection Devices on a Single Pipeline Crawler

- **The focus should be on technologies currently in the development state, with the capability to be deployed within the next 24 months.**
  - Pipeline inspection crawlers with the ability to locate and accurately measure a defect in one inspection run
  - Technologies to accurately measure a crack while in the ditch and transmit data back to the office
  - Automated internal girth and seam weld inspection tools
- **Comments and Questions on this technology area.**

Input from Attendees and Areas not Presented

- Are there any technologies that would provide significant benefits to IMPs and the safety of California's natural gas pipelines that have not been mentioned?
- Of the technologies presented, which have the highest priority?

Conclusion & Next Steps

- We appreciate your participation
- Input will be used to prepare a $2M competitive solicitation to demonstrate the discussed technologies
- The solicitation will be posted by the end of 2012 and awards will be made in early 2013

Questions & Comments

- Written comments and questions can be sent to: Johann.Karkheck@energy.ca.gov
- Presentation and recording will be posted on the CEC website at:

  http://www.energy.ca.gov/research/notices/#08072012