DOCKETED

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Description:	July 7, 2017 by Howard Chung, PhD, PE
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Real-Time Active Pipeline Integrity Detection Plus System for Natural Gas Pipeline Safety Management

Agreement No. PIR-14-015

PI: Howard Chung, PhD, PE

Acellent Technologies, Inc.

Natural Gas Infrastructure Safety and Integrity Research Program Workshop

California Energy Commission

1516 9th St., Sacramento, CA

July 7, 2017

RAPID+

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Outline

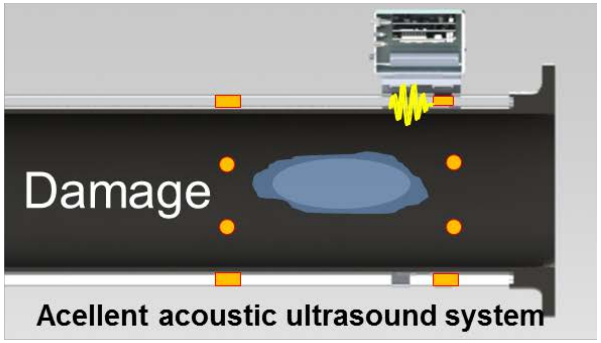
- Background and Motivation for PIR-14-015 Program
- Project Scope
- Technology Development Progress and Readiness
- Field Test Plan with Utlities, Installation Procedures
- Timelines

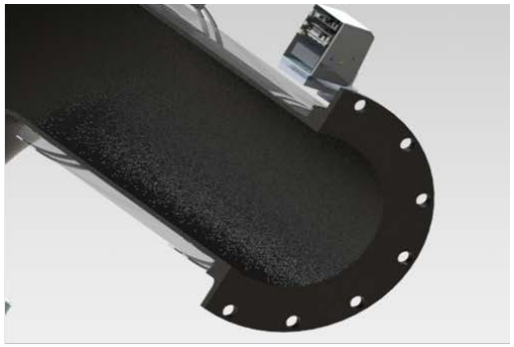
Background

- There are multiple threats on the pipeline right of way (ROW). Third party excavator damage is the primary threat
- In this program, Acellent enhances its real-time active pipeline integrity detection(RAPID) system into the RAPID+ system to provide early detection of incidental or intentional encroachment events that threaten the gas pipeline network in the ground and support the near field measurement of the severity of damage caused by the encroachment events.

RAPID+

RAPID for Corrosion Damage Detection



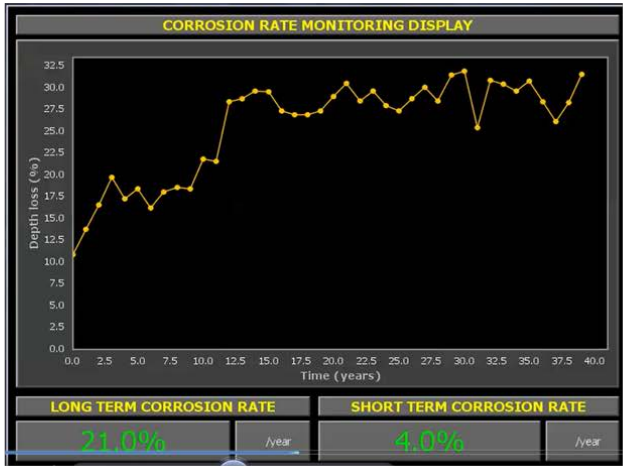


Lamb wave-based acoustic sensor network

Historical Data

Continuous Scanning

Monitor Damage Growth Rate



Pacific Gas and Electric Company

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Real-time Active Pipeline Integrity Detection System (RAPID)

RAPID for Corrosion Damage Monitoring

Straight pipe installation

Posted on July 14, 2014

PG&E Testing New Monitoring Technology for Gas Pipelines

By Debbie Felix

SAN RAMON – At its Applied Technology Services facilities, PG&E recently coordinated a demonstration of new technology the company has been testing for its natural gas pipeline system. Developed by Silicon Valley-based Acellent Technologies Inc., the Real-time Active Pipeline Integrity Detection (RAPID) sensor system was designed to remotely monitor the structural health of pipelines by identifying potential concerns such as corrosion, cracks or other damage.

Tiny sensors embedded between strips of flexible film, which are wrapped around the outside of steel pipes, could one day provide PG&E with real-time, detailed information about the condition of its pipelines, especially in locations that are particularly susceptible to damage. By sending and receiving ultrasonic waves through the thickness of the pipeline steel to a data acquisition box installed on the pipe, PG&E's gas operations' engineers will get an advance warning when the condition of a pipe changes.

"The RAPID technology could one day transmit an alert in real-time to our engineers when it detects damage to a pipeline", said François Rongere, PG&E's research & development and innovation manager in gas operations. "This assures a faster response and repair time."

At the demonstration in San Ramon, two simulated corrosion cells of varying sizes and depths were installed on a test pipe using a plasma cutter. During the demonstration, Acellent's RAPID system located, measured and identified the depth of the corrosion cells. As a next step, PG&E will verify the accuracy of RAPID's findings using a laser scanner.

A data acquisition box sits atop a test pipe wrapped with sensors and covered with protective fiberglass (yellow bands) as part of new technology to remotely monitor pipeline health.

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Project Goals of PIR-14-015

- Finish the engineering work for the integration of event detection sensing mechanisms to the real-time active pipeline integrity detection system framework
- Deploy and Demonstrate the system that can detect ROW encroachments and alert operators in real time
- Three technology areas will be applied during this project:
  - Stationary sensors mounted on the pipe surface to provide continuous monitoring of any intrusive event
  - Proactive acoustic and vibration sensors near the pipeline field to discriminate the potential threat of excavation event before getting to touch the pipe
  - Active corrosion monitoring SHM system
- This project aims to work with utility companies for field tests and validation
- Evaluation of project benefits

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Project Collaborators of PIR-14-015

- Sponsorship and Oversight
  - California Energy Commission
- Technical Direction and Oversight
  - Acellent Technologies, Inc.
- Utility Test sites
  - Pacific Gas and Electric
  - Southern California Gas

RAPID+

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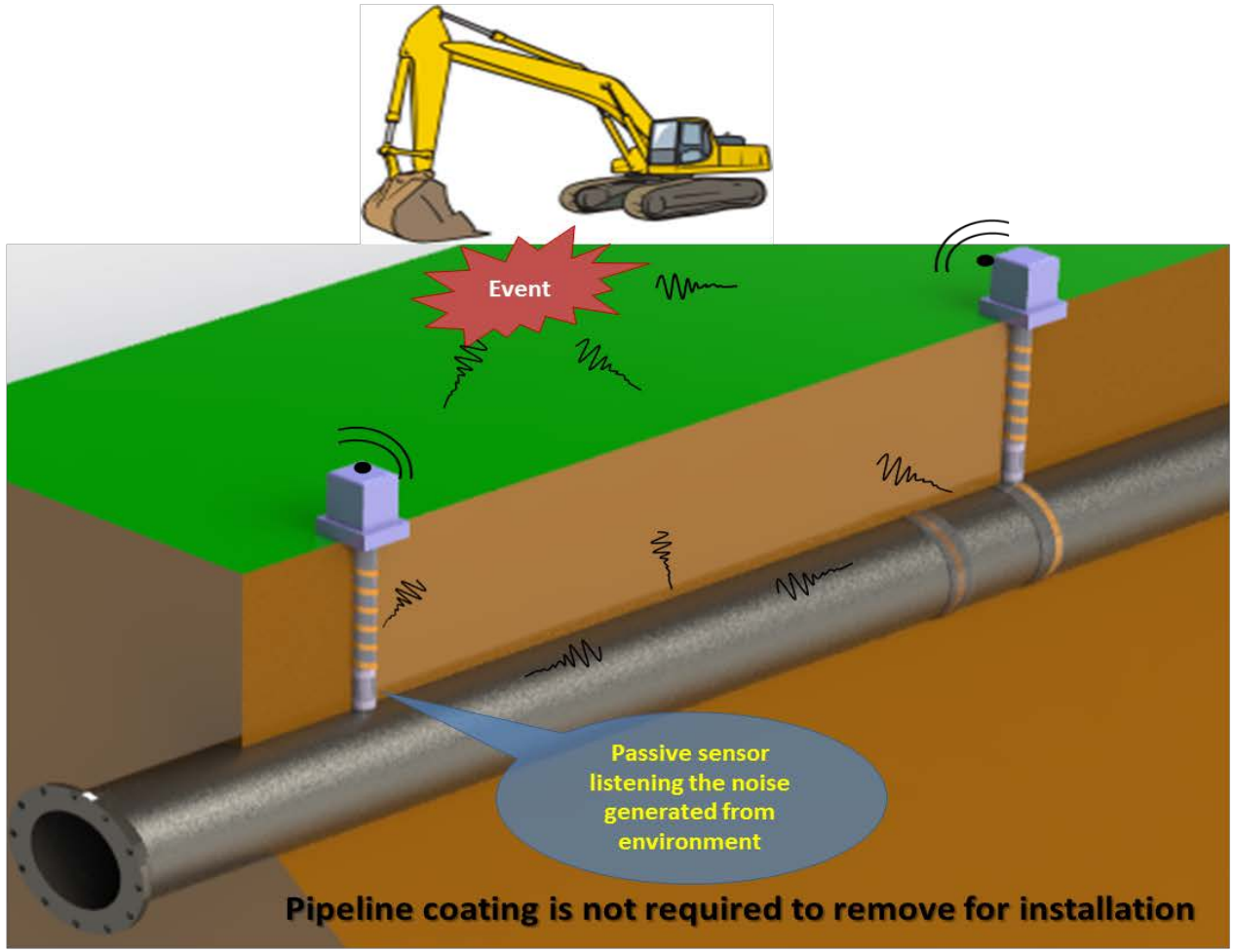
Acellent Encroachment Detection System

- Acoustic sensors receive the noise created by environment abnormal activity
- Underground sensors near the pipeline can map out the location and distance from the pipeline
- Installation is easy and not required to remove existing pipeline protection/coating materials
- Passive sensing and wireless communication enable mass- distribution to a large service area

RAPID+



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Overall Project Timeline

- Project Initiation: June, 2015
- Scoping Requirements and Planning: Q2 2015 to Q4 2015
- Development of Engineering Work: Q4 2015 to Q3 2016
- Laboratory and Pre-field Tests: Q3 2016 to Q4 2016
- Engineering Work for System Integration: Q4 2016 to Q2 2017
- Deploy Event Detection (RAPID+) sensors starting Q3, 2017
  - Each utility has up to 10 end points and 2 access points available
  - Piggy back on current or near future construction projects
- Begin data collection and visualization Q3-Q4, 2017
  - The data will be flowed to a central server
  - The dashboard view will be available to utilities for testing
- Final report to CEC in Q1-Q2, 2018
  - Provide assessment of technology and recommendations

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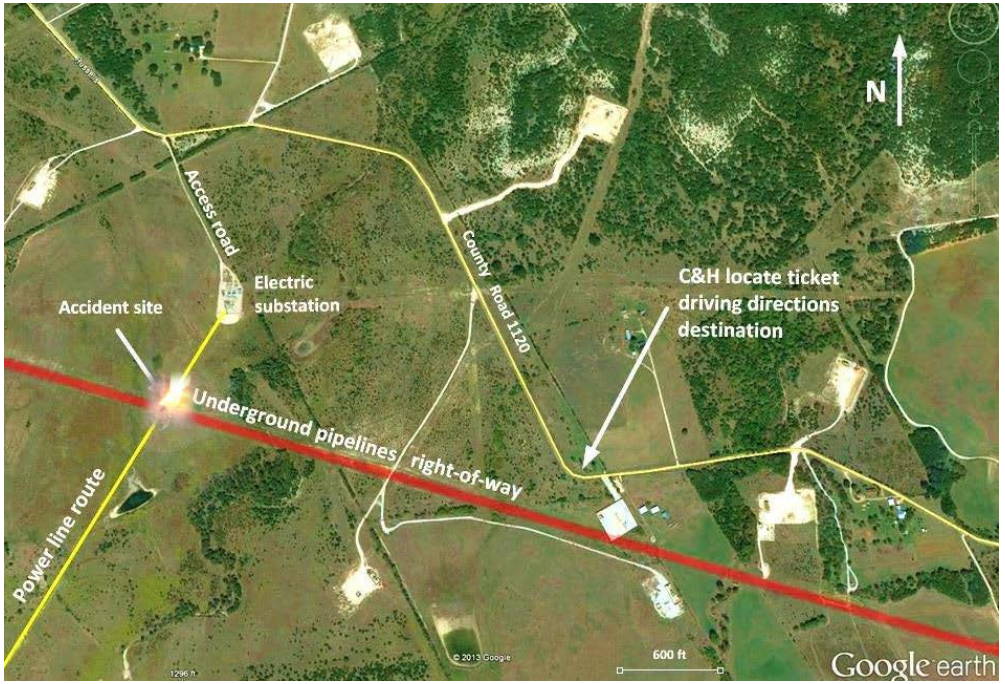
Case Studies

- Non-attended encroachment to right-of-way on natural gas pipeline field cause catastrophic event
- Proactive and early warning to detect encroachment event system is in demand

Case Study: Cleburne Texas on 6/7/2010



RAPID+

Source: National Transportation Safety Board

Encroachment Detection Priorities

Priorities	Description	Requirement Sensitivity
Priority 1 Most Severe & High Risk to cause failure	**The event has uncovered the pipeline to air and impact from excavation tool to the surface of the pipe is made. High risk to cause pipeline failure and catastrophic event**	**Detection of impact from the minor impact can prevent the catastrophic event from severe structural failure. The system must detect completely.**
Priority 2 Moderate Risk Event	The event shows the encroachment is in progress, such as machine or manual digging nearby the field. Moderate risk to cause any serious result without attention.	Detection of activities nearby the pipeline field is required to discriminate what kind of activity, and provide immediate alert to the responder against the violation event.
Priority 3 Low Risk Event RAPID+	Unidentified object may approach the right of way in distance. Potential to become an encroachment event. Low risk to cause problem.	Detection of such activity is not required. The distance in Priority 3 event will be defined as the outer bound of detection sensitivity.

RAPID+ System for Encroachment Detection

- Acoustic sensors receive the noise created by environment abnormal activity
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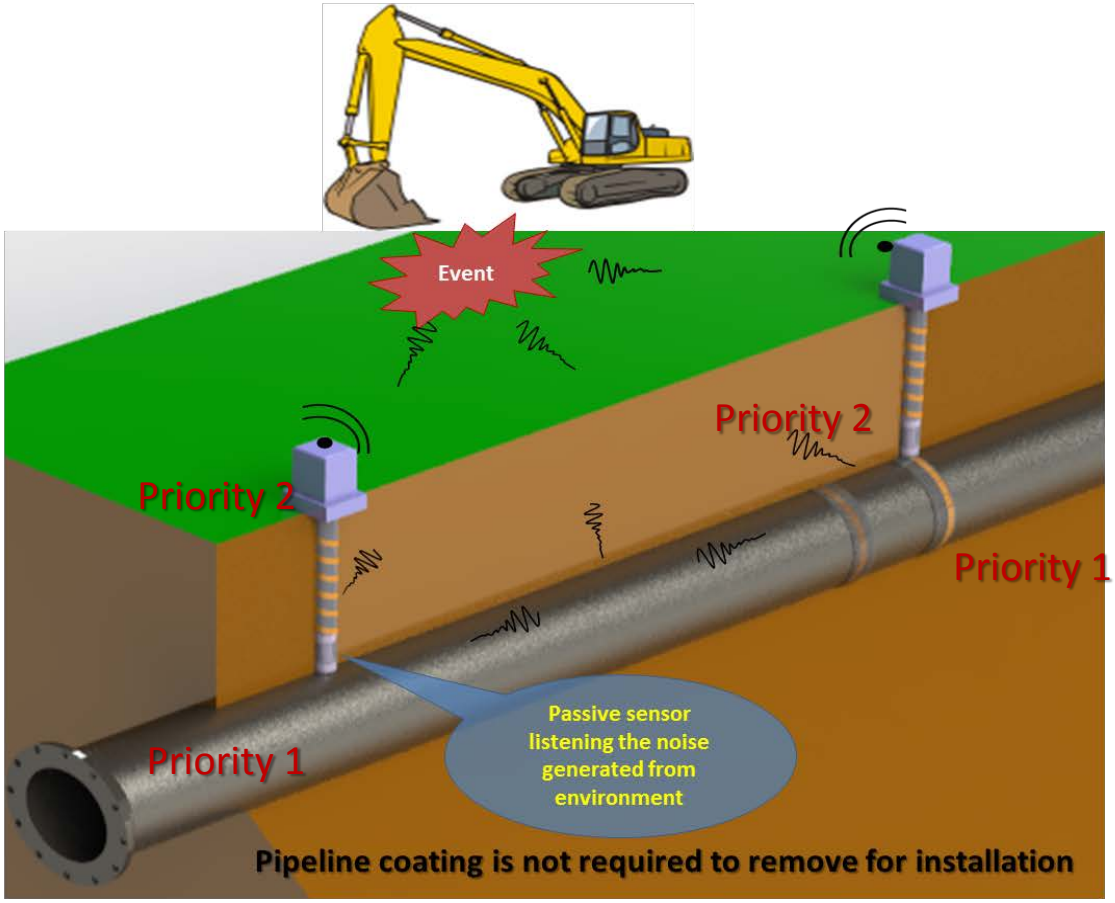

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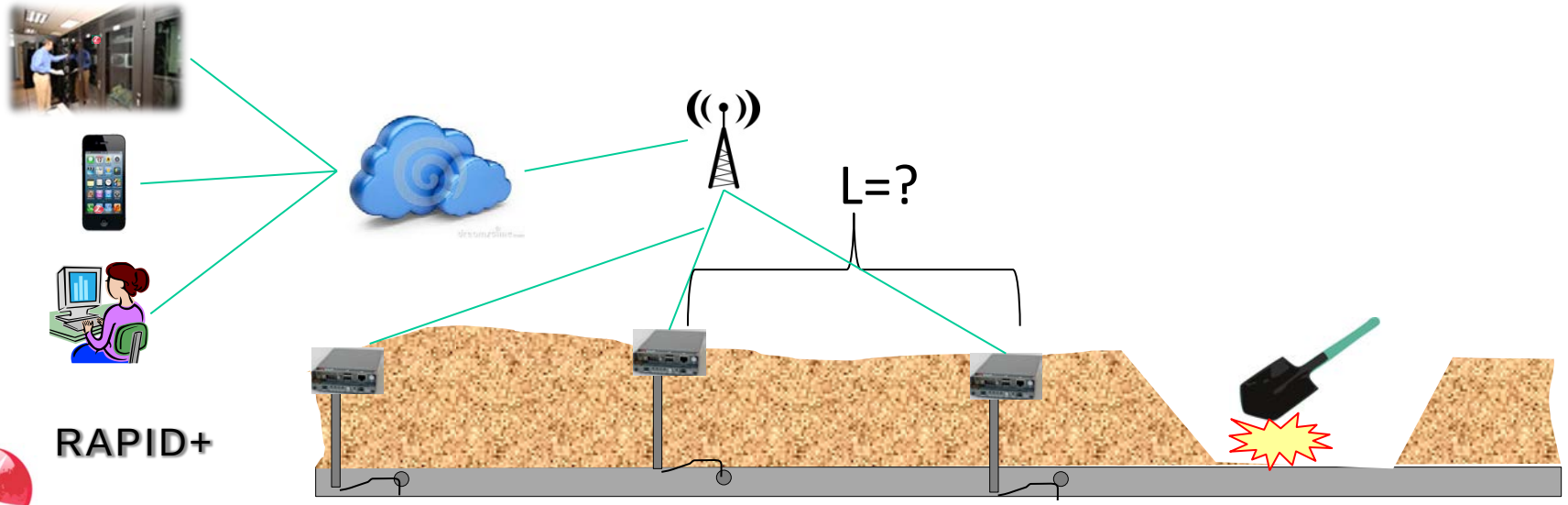
Method of Priority 1 Detection

- Passive system to listen to the impact event
  - Sensor: 0.25” diameter round PZT sensors
  - Hardware: IMGenie™ System
  - Event Detection Technique:
    - Show wave propagation distance v.s. impact energy



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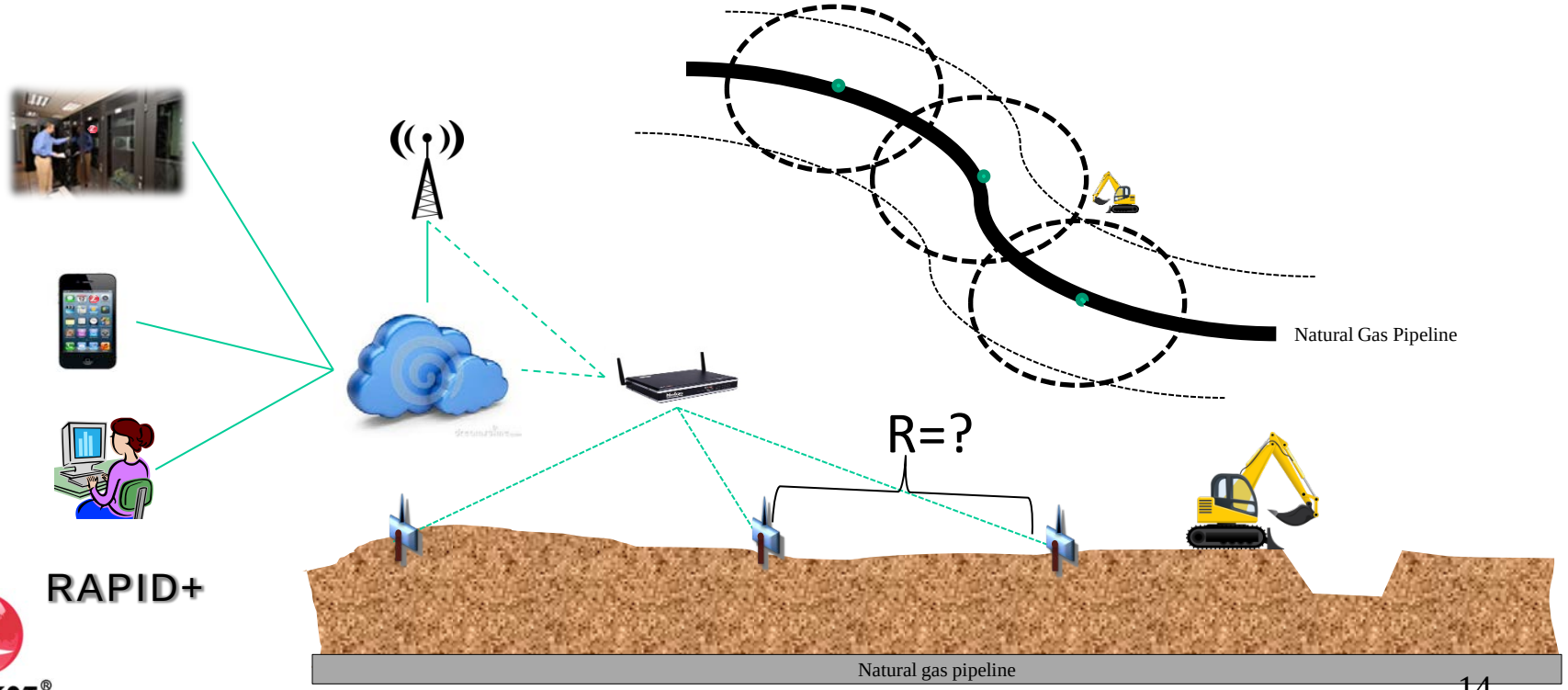
Priority 2 Event Detection Sensors

- Active system to listen to the monitoring pipeline fields
  - Microphone Sensors
  - Low Power Embedded MCU with wireless comm. stations
  - Event Detection Technique:
    - Frequency discrimination method to detect encroachment event in progress



System Setup for Impact Energy and Wave Propagation Distance Tests

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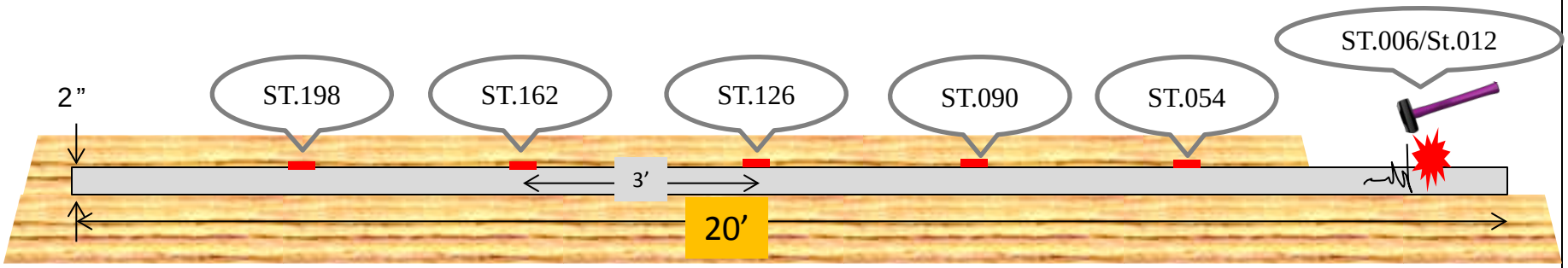
Test Procedures

Case 1.

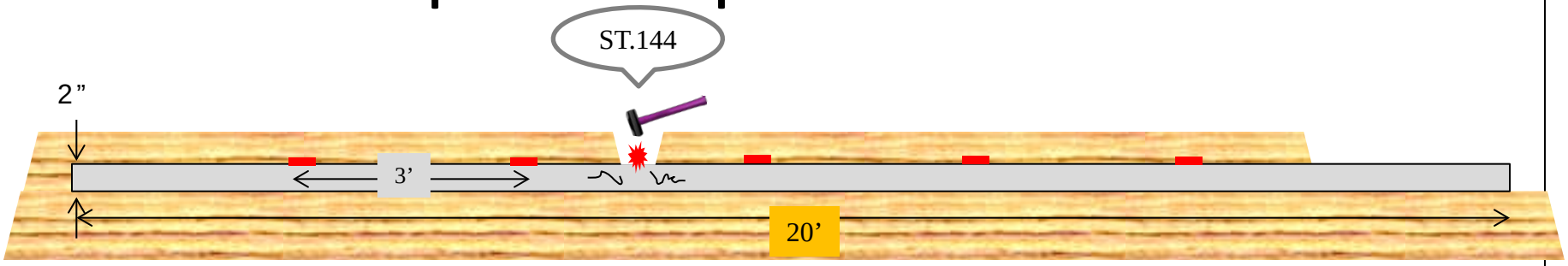
Impact at the open surface St.006 and St.012

"Stack ID: Inches"



Case 2.

Impact at the open surface St. 144



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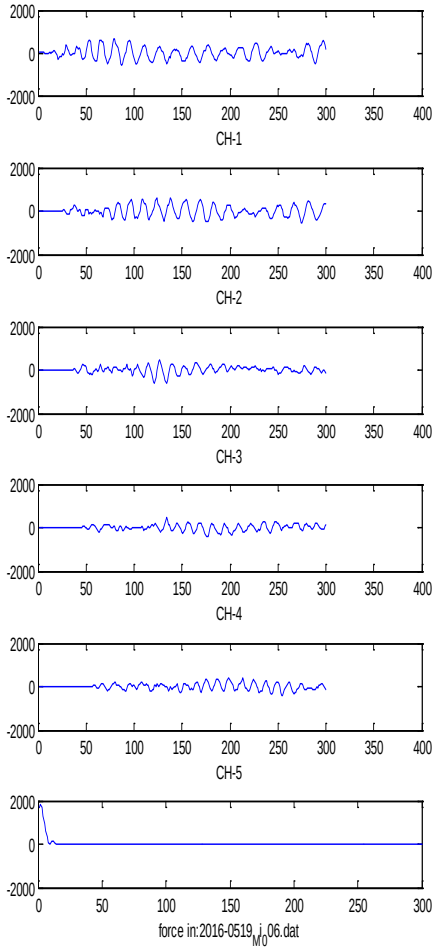
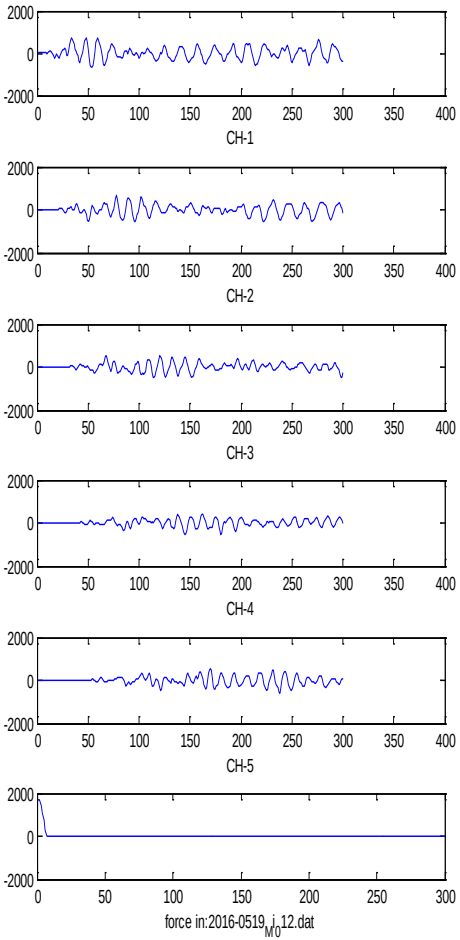
Test Data Overview

In warehouse

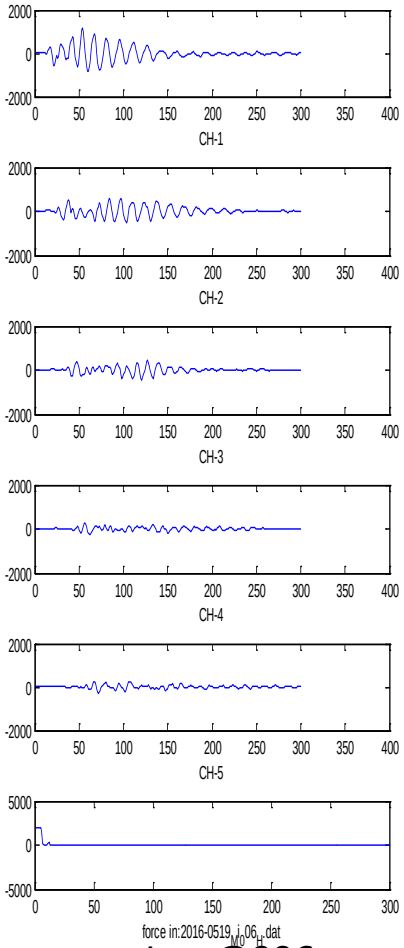


Imp@006

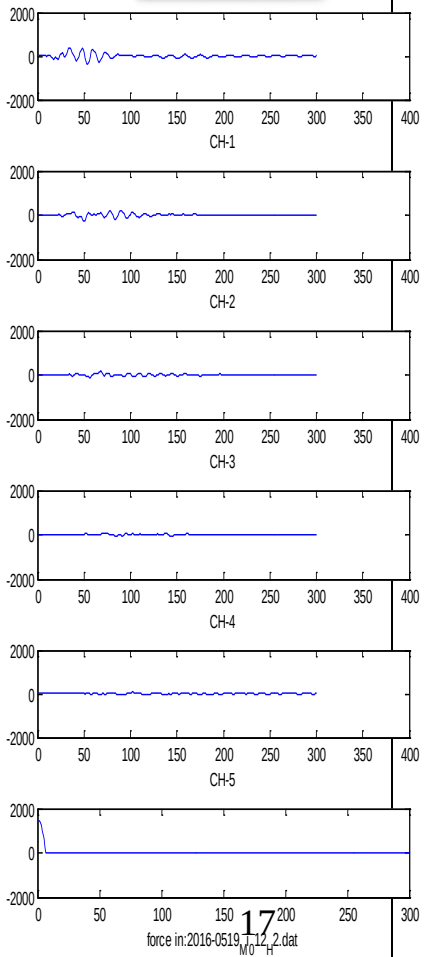


Imp@012

Underground

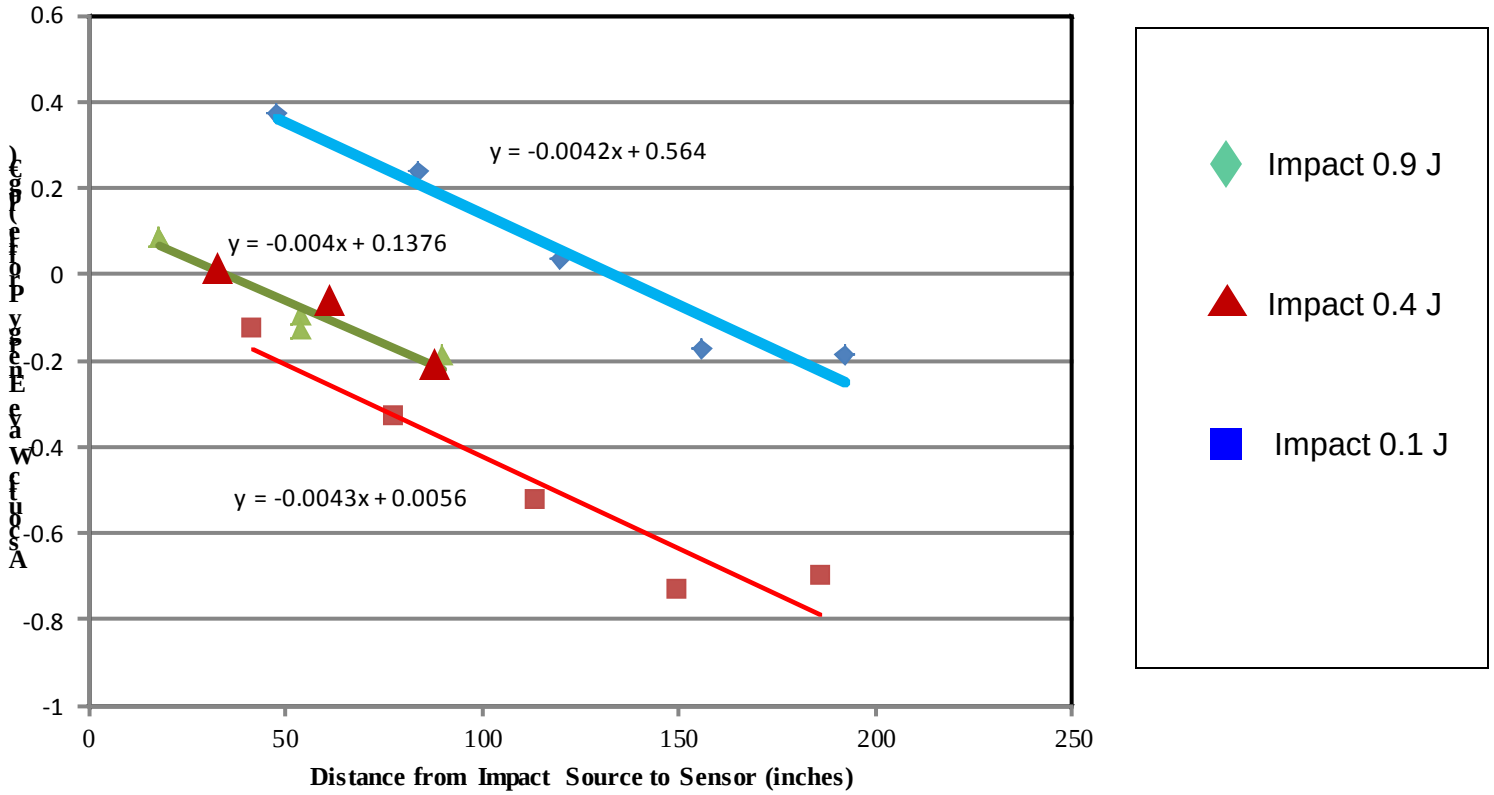


Imp@006



Imp@012

Acoustic Energy Profile in Log Scale v.s. Distance at Different Impact Energies



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a b

$$Log(E) = -0.0042\,L + 5.8\,\{\Sigma f \Delta t\}^2 / 2\rho A_c$$

Summary of Priority 1 Sensor

$$Log(E) = -0.0042\,L + 5.8\,\{\Sigma f \Delta t\}^2 / 2\rho A_c$$

Propagation Range:

$$L = 5.8\,\{\Sigma f \Delta t\}^2 / 0.0084\rho A_c - Log(E)$$

Therefore,

$$L = 1381\,E_i - Log(E_o)$$

Usually,

$E_o = \phi E_i$ *where* ϕ *is a reduction factor <<1*

For any 1-joule impact energy, a sensor in 1.3km away can sense this event

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Priority 2 Event Detection Sensors

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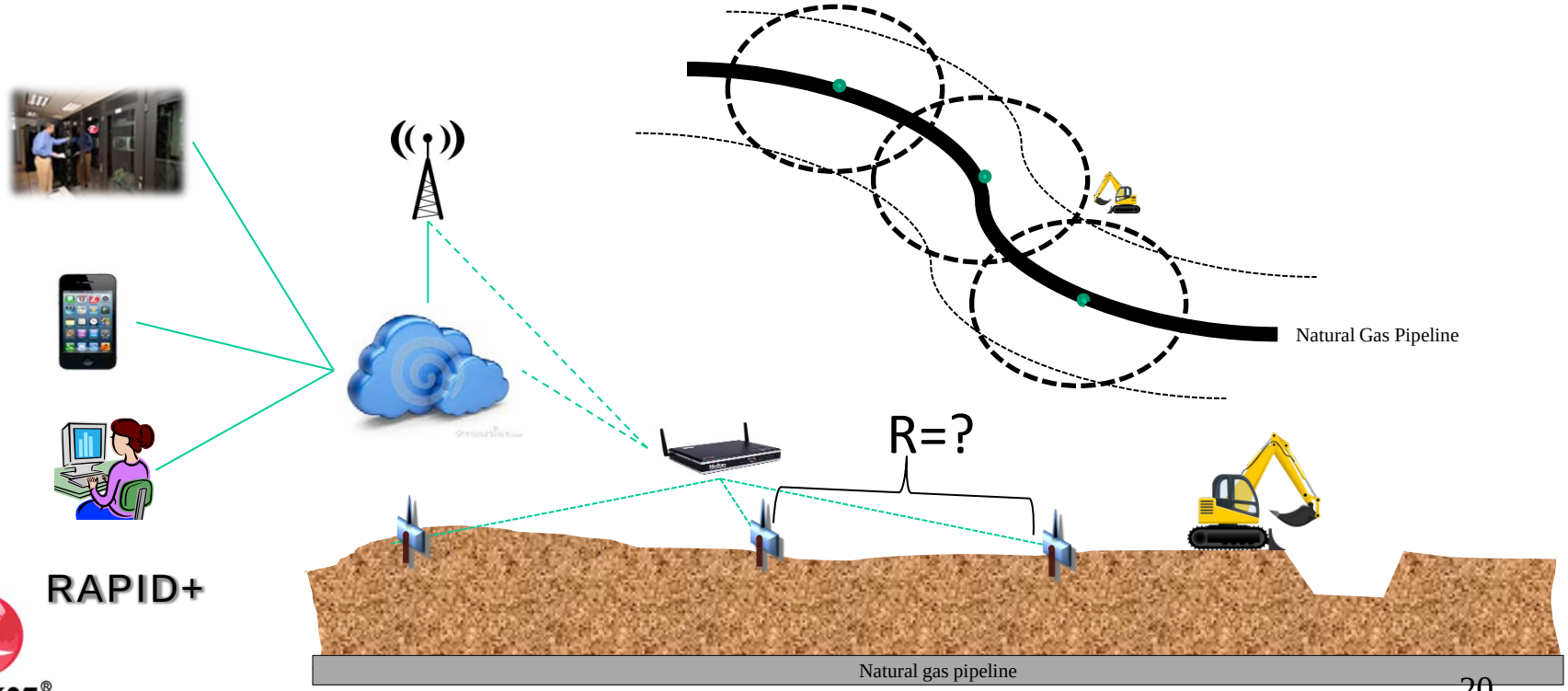
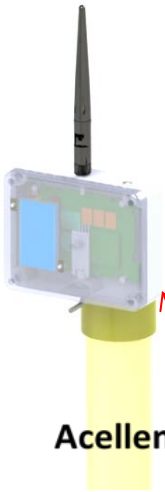
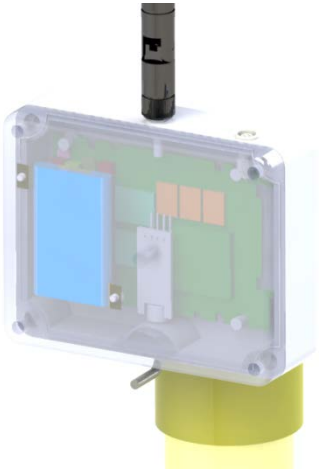
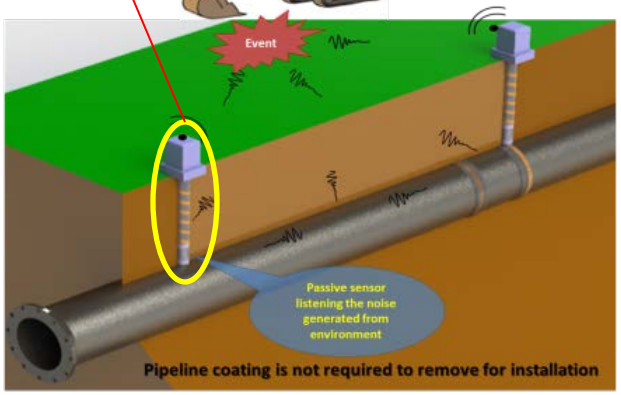


Task 4. Engineering Work to Finish the Encroachment Detection System



Acellent Encroachment Detection System





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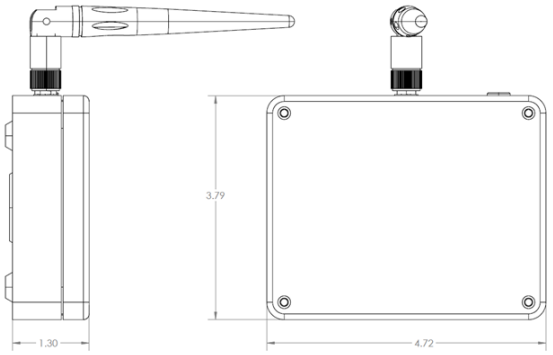
RAPID+



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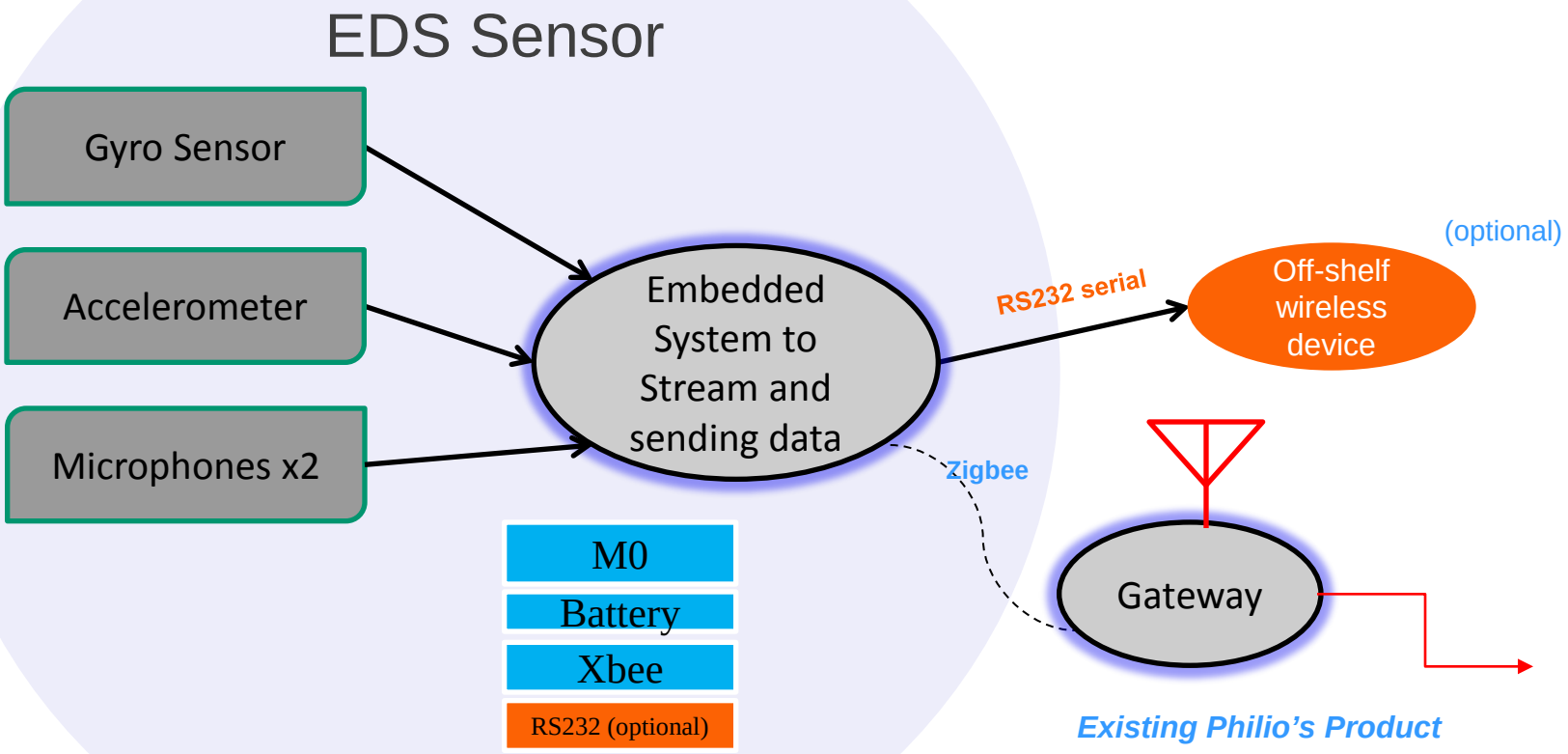
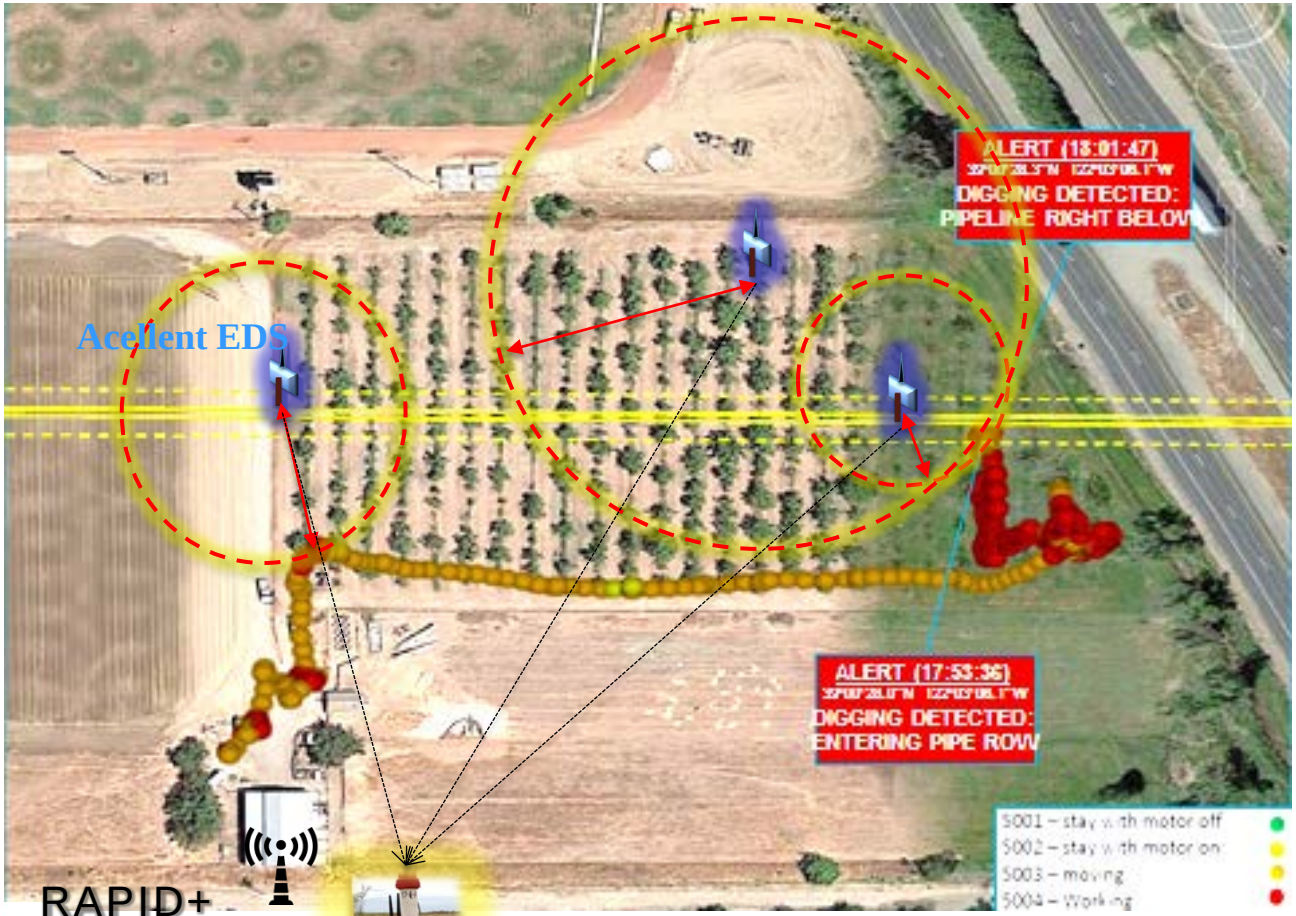
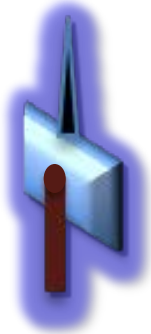
Acoustic Infrasonic Sensor High Level Architecture



Source to Site (sensor) Relationships

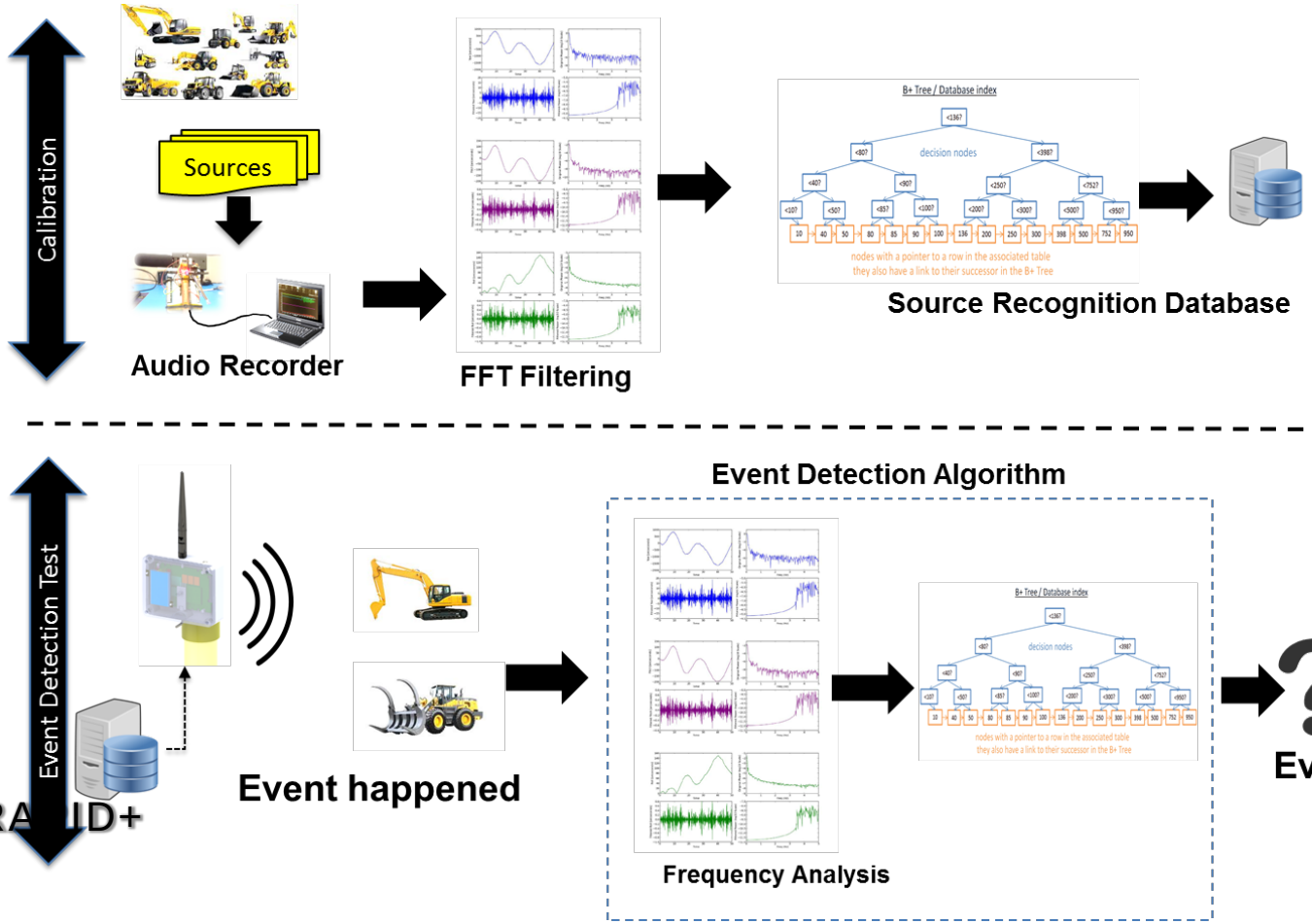




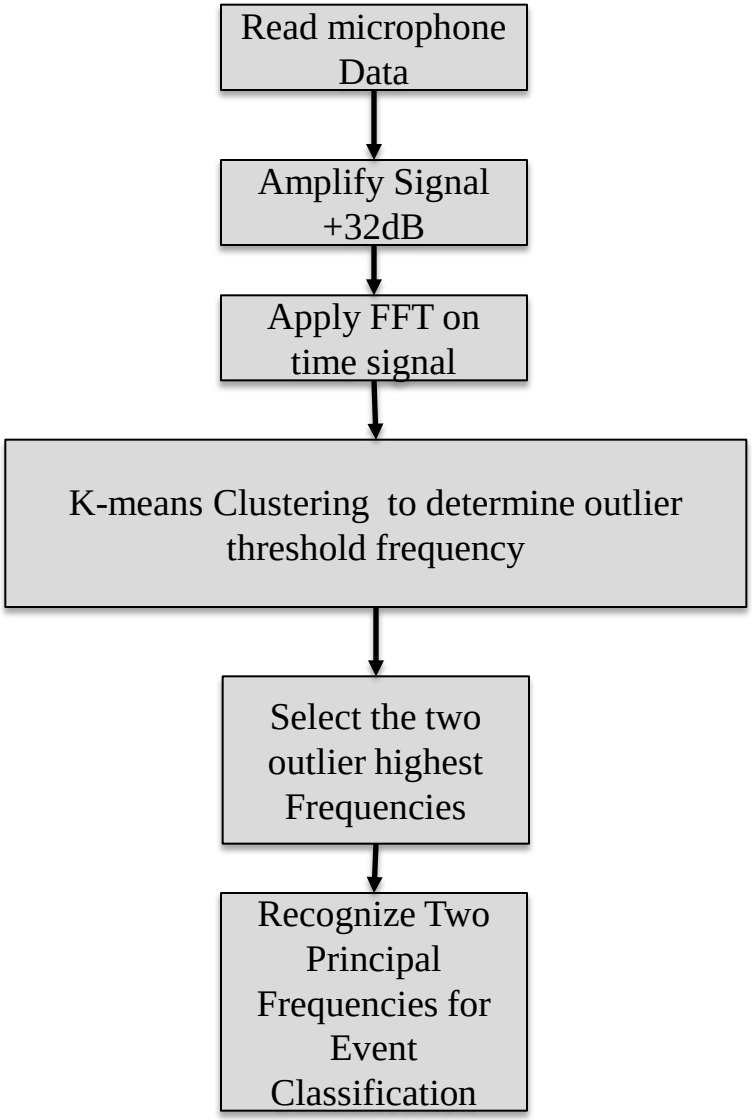
Acellent EDS

Gateway for Long Range Low Power Radio

Event Detection Algorithm Development



Frequency Analysis and Event Classification



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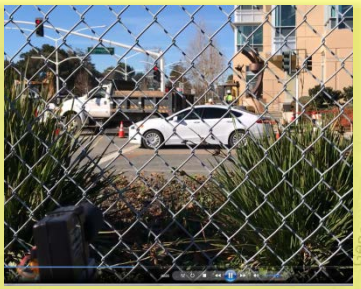
67yd



33yd

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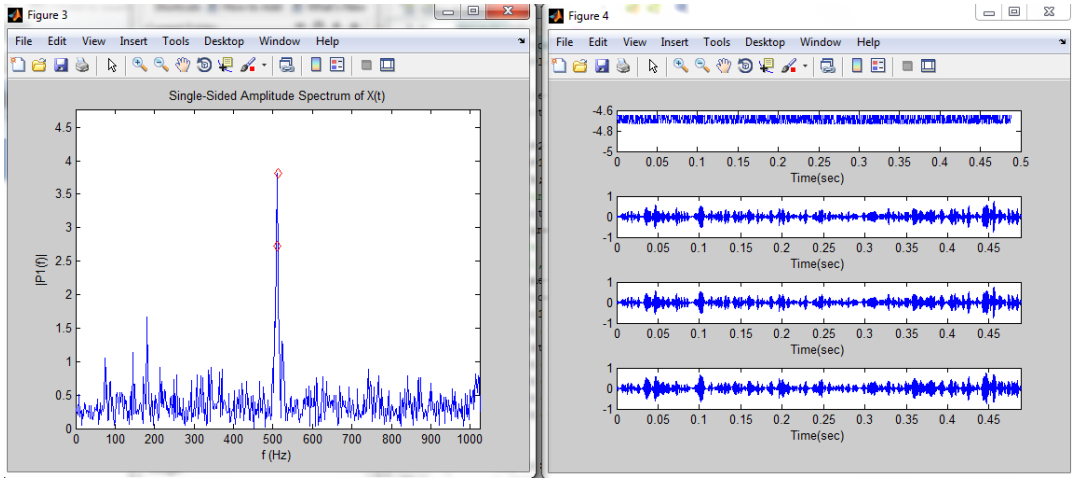
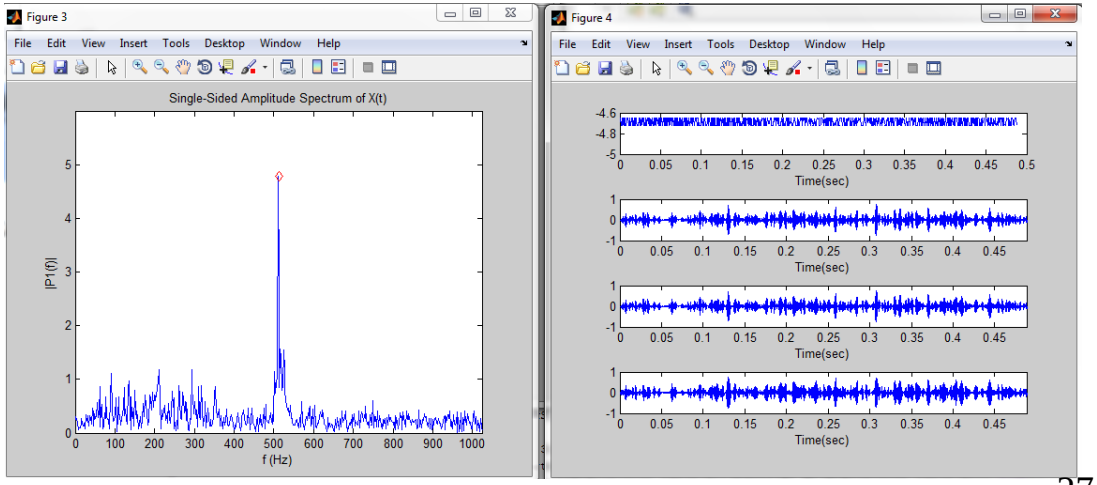
Road Tests on Source Recognition Algorithm

Event Detection System Frequency Analysis

Construction @33yd



Construction @67yd



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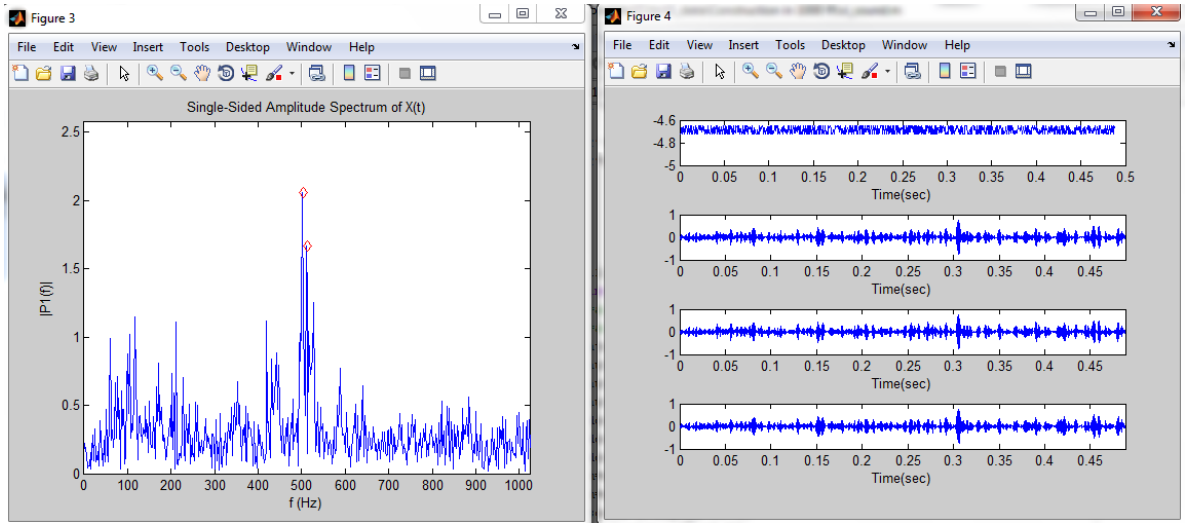
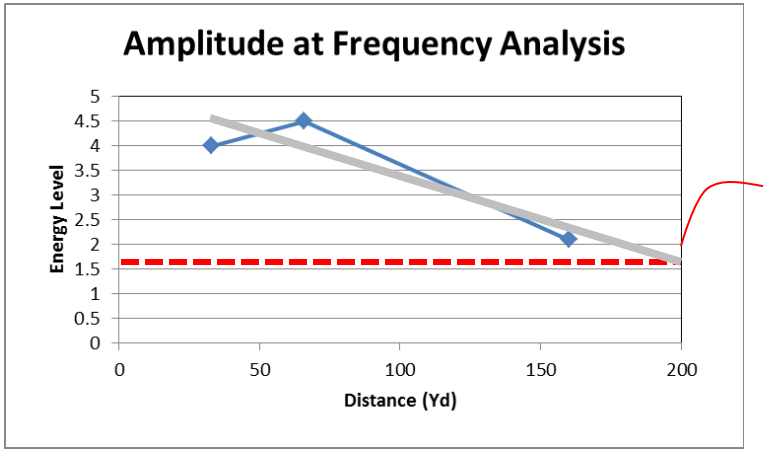
Event Detection in Energy Profile

Construction @160yd



Summary



The event alerting distance threshold can be set b/o calibration result from the acoustic frequency profiles v.s. distances

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Test Plan with Utility Partners

- Verify the sensor installation procedures
  - Maintain the sensitivity performance
  - Durability of spot welded sensor shims on the pipe and test with corrosion resisting coating materials
- Verify the source-to-sensor site event detection systems
  - Test the impact energy and distance of vibration sensor sensitivity verification
  - Test the discrimination algorithms from infrasonic event detection system

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Work Meeting with Utilities

- Vibration sensor technologies deployment and installation procedures review
- Wireless technologies for the collection of the sensor data
- Requirements for utility test sites to host these sensor packages
- Cross check the proposed schedule for deploying this demonstration

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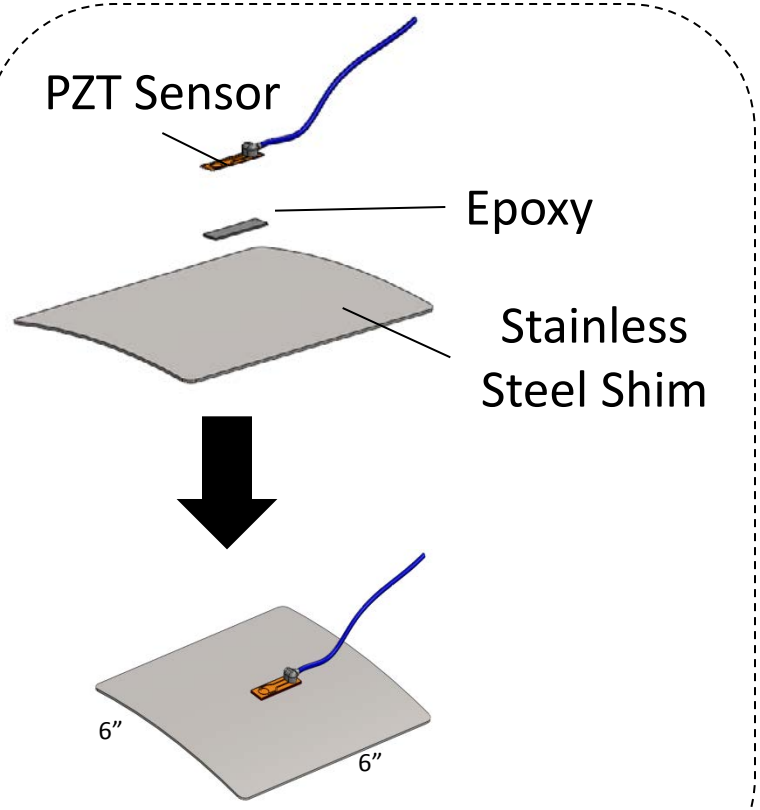
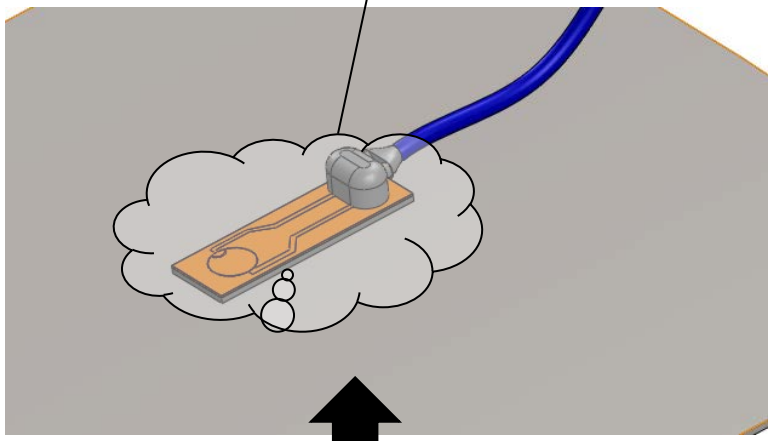
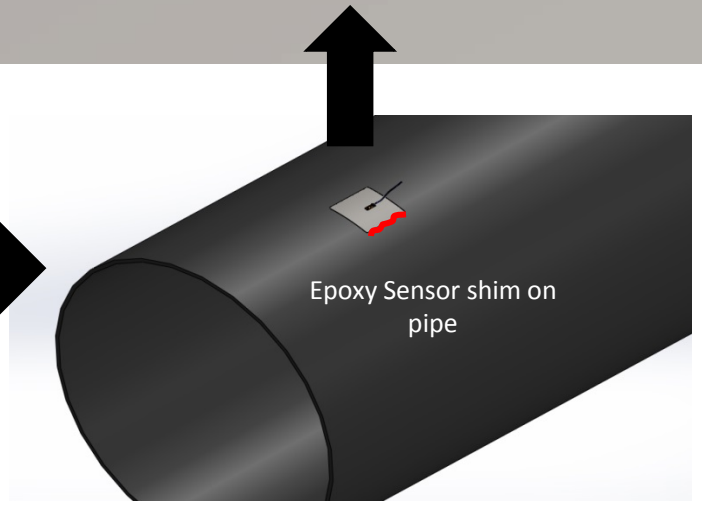
Pipe Sensor Installation Process



Pre-assembly Process of PZT Sensor on metal shim

Epoxy to seal the conductor and cable interface for water proof





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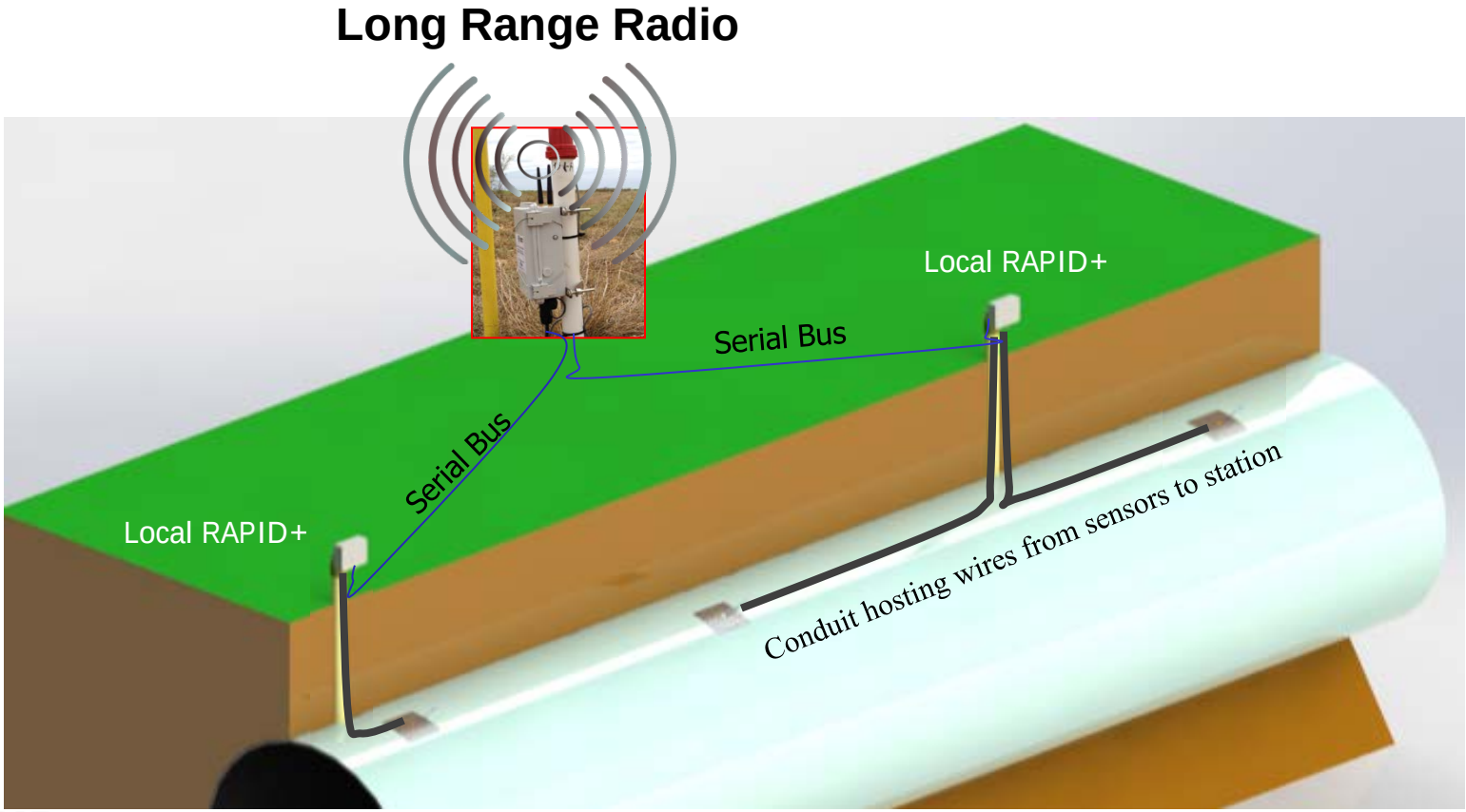
Pipe Sensors Installation



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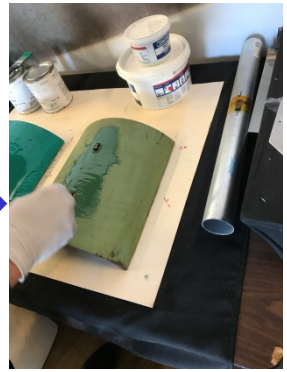
Test on Corrosion-resisting Adhesives Coating for Vibration Sensors

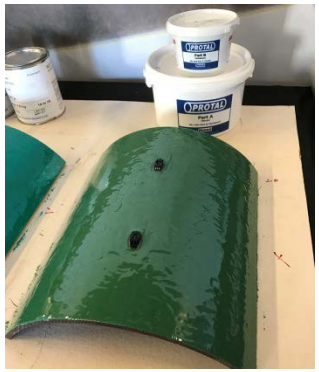
3M Liquid Epoxy 323

>24 hours

Amplitude is increased by 50%

PROPAL 7200





>24 hours

Amplitude is increased by 200%

RAPID+

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Projected Schedule and Milestones

- Deploy Event Detection (RAPID+) sensors starting Q3, 2017
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- Begin data collection and visualization Q3, 2017 – Q2, 2018
  - The data will be flowed to a central server
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RAPID+

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Questions and Answers

Thank you!