Next-generation Sensor system for ultrasonic wall thickness monitoring

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SENSOR™ NETWORKS, INC

EPRI Buried Pipeline Integrity Group (BPIG)
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Outline

- Motivation
- Inspection vs. monitoring/trending
- The power of data through continuous monitoring/trending
- Applications
- System requirements and concept

Total Annual US Cost of Corrosion: $>1T[1]

Utilities: $47.9B[2]

Electric Utilities: $6.9B[2]

(Nuclear Power: $4.2B)

1. 2013 Estimate - http://www.g2mtlabs.com/2011/06/nace-cost-of-corrosion-study-update/
2. 2003 Estimates - NACE US Corrosion Case Study 2003

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Data Monitoring Evolution

1920s - Manual monitoring

1960s - Analog 4-20mA loop

1980s - Digital Conversion

1990s - Wireless

2010s - Age of Internet of Things (IoT)

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Why installed sensors today?

Costs ($) associated with manual inspections

- Pre-inspection activities:
  - Excavation
  - Insulation preparation
  - Scaffolding
- Access, permitting, approvals
- Personnel cost increasing– technicians, equipment, training, etc.
- Monitoring costs decreasing – wireless, battery technology, IOT, power harvesting, etc.

Costs (intangibles)

- Safety – ropes, ladders, radiation, non-invasive, etc.
- More informed decision making – dig holes one time and benefit for potentially years of data, better planning for asset replacement, outage planning, etc.
- Time/productivity – short & long term decision making/planning

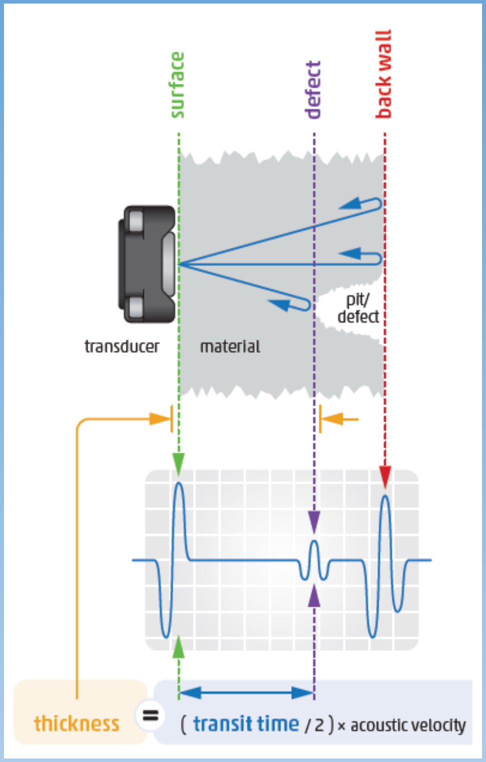
Installed vs Manual UT Systems

Corrosion/Erosion management

- Trending (wall loss per day/week/month, etc.)
- Inspection (is the pipe going to leak or fail)
- Verification of RBI, inhibitor, or other corrosion mitigation techniques

Complementary UT technologies

- Single point manual thickness readings
- Large area manual phased array scanning
- Long range guided wave UT collars



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Technology Comparisons

VS manual UT

- Accuracy and precision is improved due to permanent installation and removal of operator factors resulting in better data quality and trending.
- Installed UT sensors can replace manual UT points, particularly for high cost or critical locations.
- Can augment manual UT locations with a semi-continuous data stream.

VS LRUT

- Point, precise measurement vs. area coverage and screening.
- Use permanently installed sensors to complement LRUT, placing sensors at identified areas of interest.

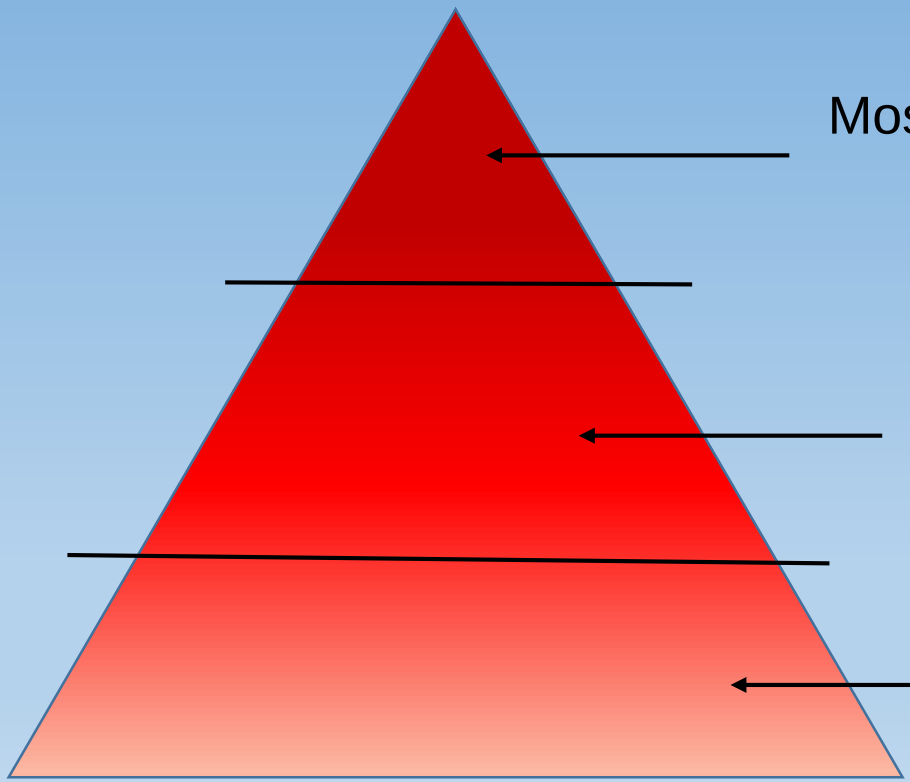
VS PAUT

- Complement PAUT flaw detection with permanently installed monitoring using shear wave transducers.

The Inspection/Monitoring Pyramid

Cost vs. Necessity

- WHERE would I want to put an installed sensor and WHY?



Most expensive/critical areas to inspect (circa 2005)

Moderately expensive/critical areas to inspect (circa 2015)

Least expensive/critical areas to inspect (circa 2020 and beyond)

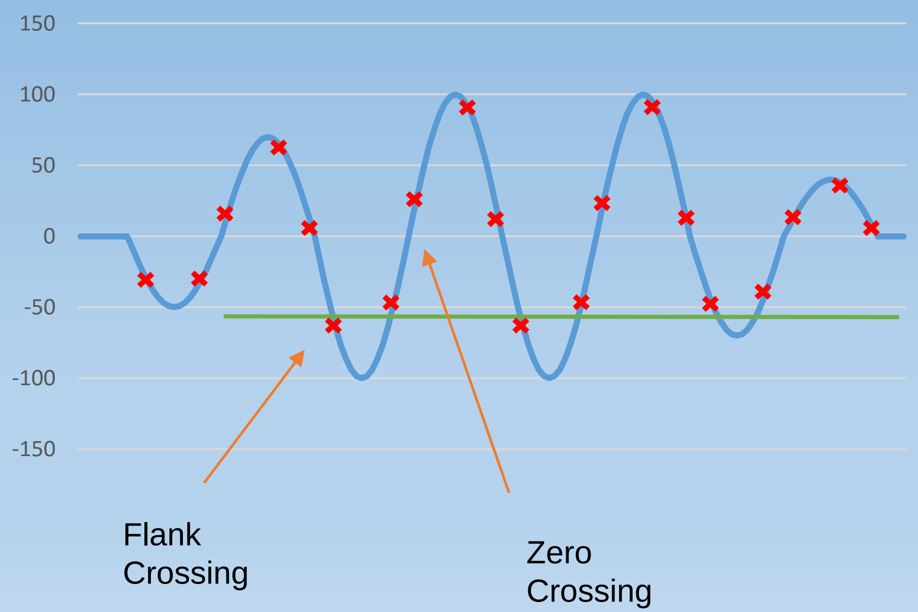
Factors Eliminated From Using Installed Monitoring Systems

Precision   Accuracy   Resolution

Operator variability
Transducer placement variability
Transducer coupling variability
Sound velocity uniformity
Measurement repeatability
Re-measurements

- Instantaneous
- More frequent (trending)

Data Accessibility



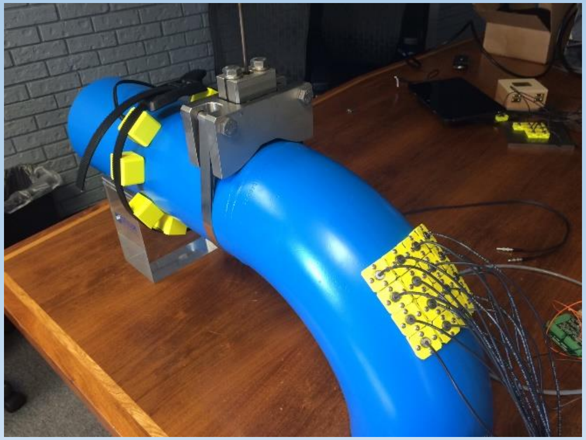
Installed Sensor Corrosion Monitoring

Internal Diameter (ID) vs. Outside Diameter (OD)

- ID measurements: Sensor placed on OD, measure ID (piping)
  - Coatings … recommended removal, however, if thin enough, can be calibrated out using dual sensor technology
  - Insulation … can insulate over top of some sensors, not useful for CUI applications
- OD measurements: Sensor placed on ID, measure OD (tanks/containers)
  - Requires environmentally protected/housed, etc.
  - Data communications can be limited – often hard wired

Permanent (PMOD) vs. Temporary (TMOD) Solutions

- Magnetic
- Banded
- Adhere
- Clamped
- Weld direct or via bracket



Installed Sensor Corrosion Monitoring (ctd.)

Coverage

- Single point or multi-point/channel instruments
  - Grid, matrix, array, indiscriminate points (1"x1" housing w/ .250" contact face)
- High temperature & low temperature
  - Low: -30F – 300F
  - High: -90F – 900F

Communication

- Tethered (Modbus / RS-485) … manual data collection
- Cellular
- Wireless

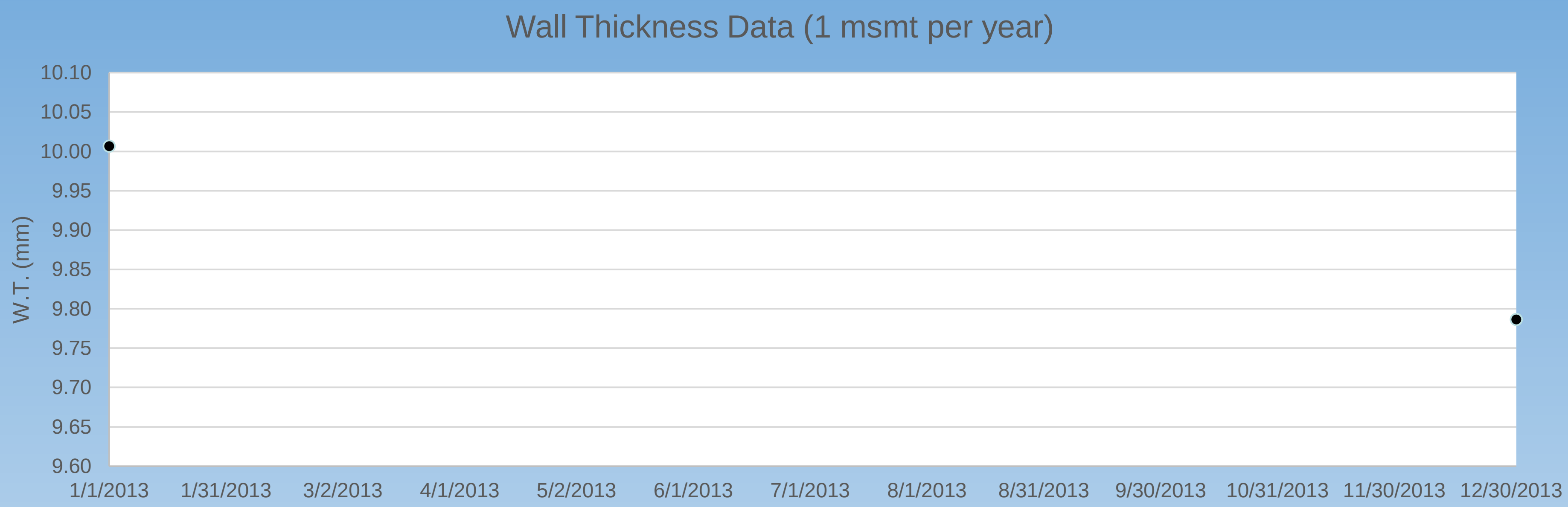
automated to log readings in defined intervals

- Other (RPMA, Lora, etc.)

Components

- Tablet (commissioning/data collection)
- Instrument (single/multi-channel)
- Sensors

The power of data…



- Sufficient for **<u>inspection</u>** probably NOT for **<u>monitoring</u>**
  - 1/1/2013 inspection = 10.00mm
  - 12/30/2013 inspection = 9.77mm
- Gross corrosion rate – cannot calculate, not enough information

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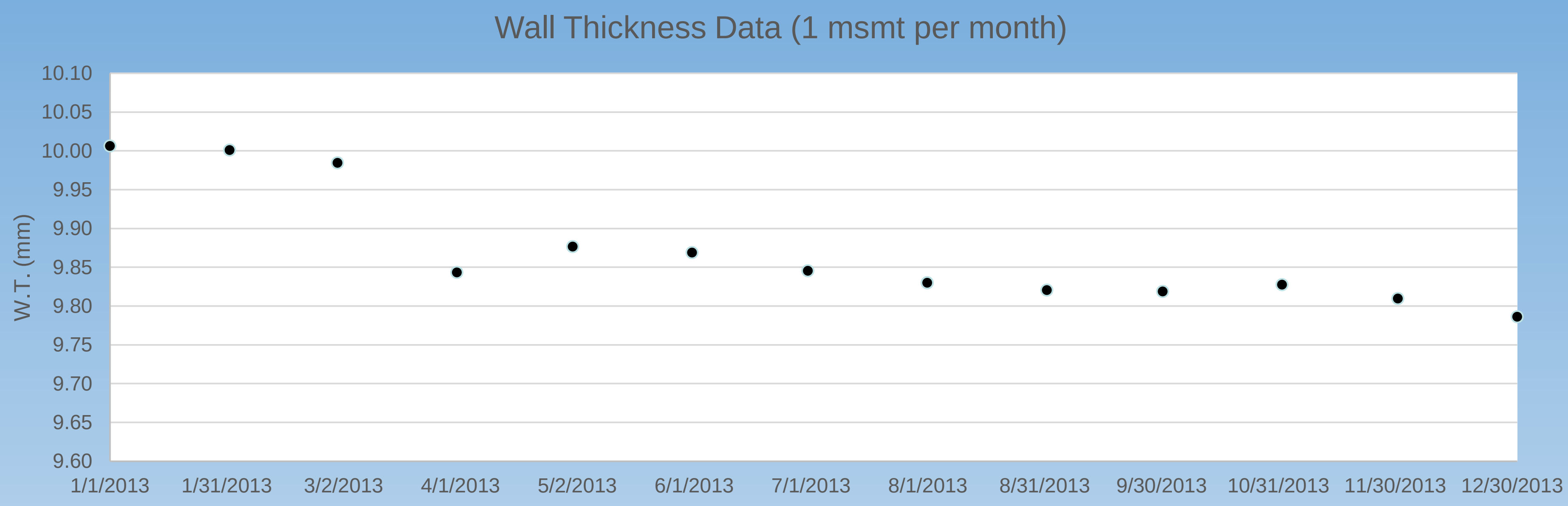
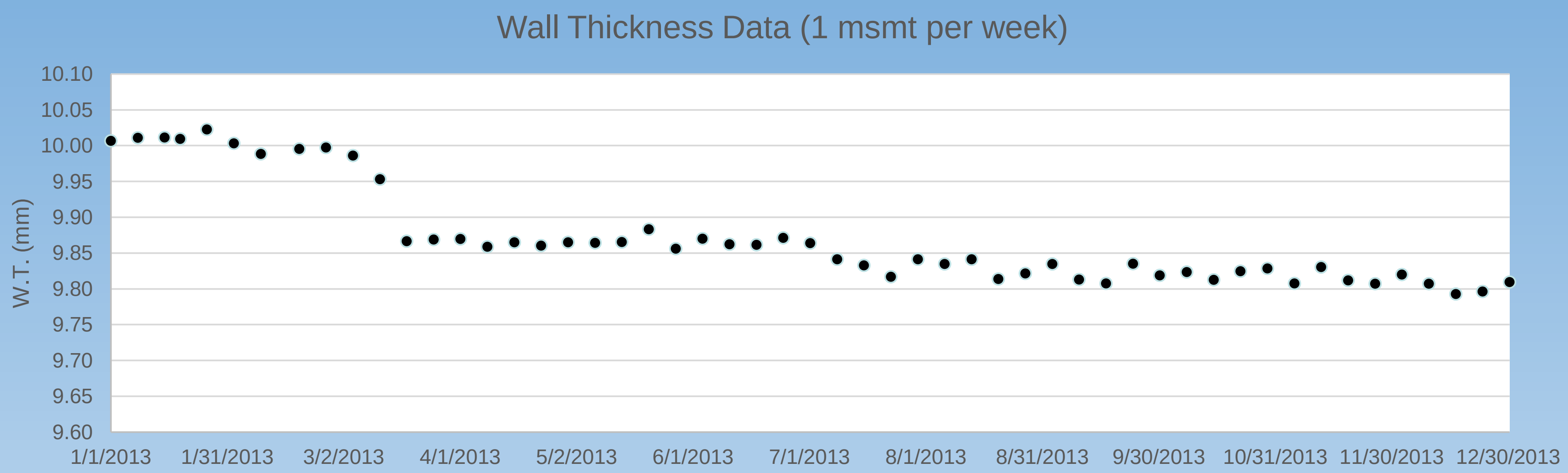
The power of data…



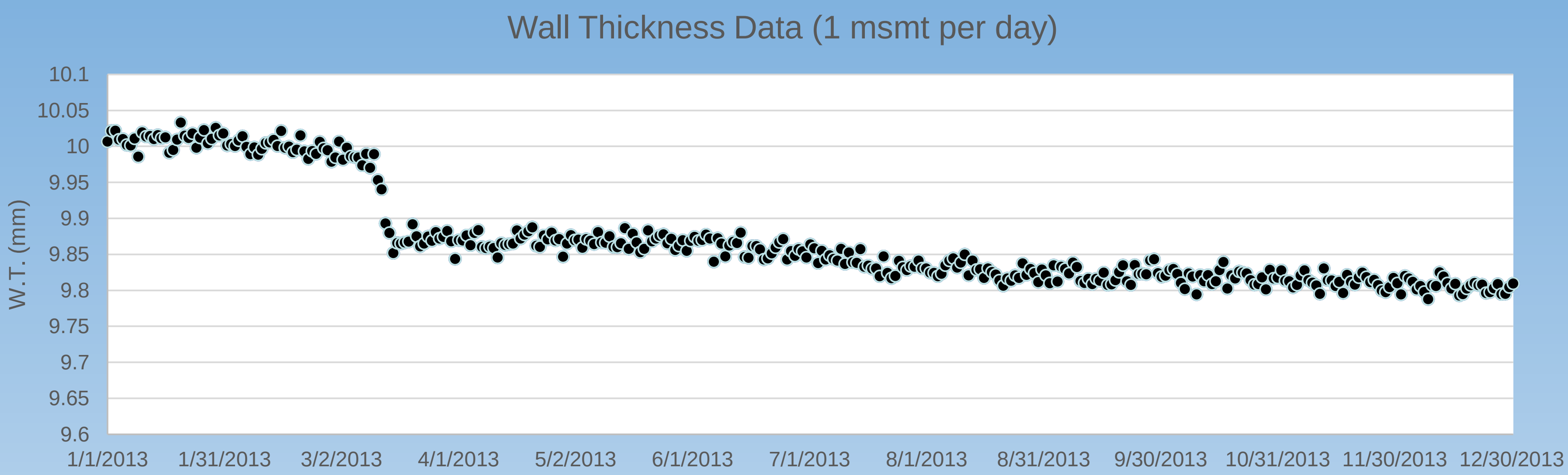
- Various corrosion rates evident
- Trends evident but still large uncertainty due to measurement precision
- Summary – better!

The power of data…



- Various corrosion rates evident
- Regression can be used to obtain accurate corrosion rates over medium time scales.

The power of data…



- Various corrosion rates evident
- Regression can be used to remove measurement noise and produce very accurate corrosion rate data
- GREAT!

Data-to-Desk & The Internet of Things (IoT)

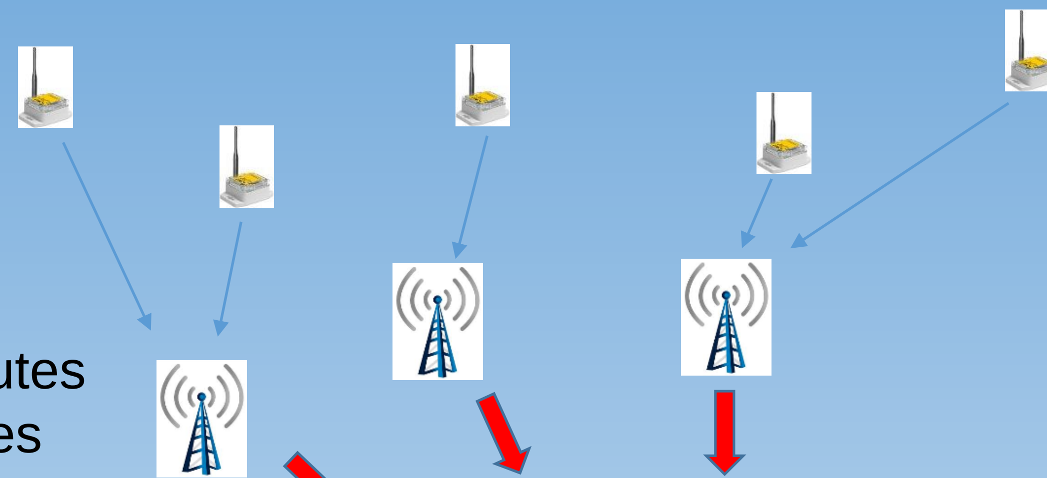
Remote sensors leverage low-cost ubiquitous communication infrastructure

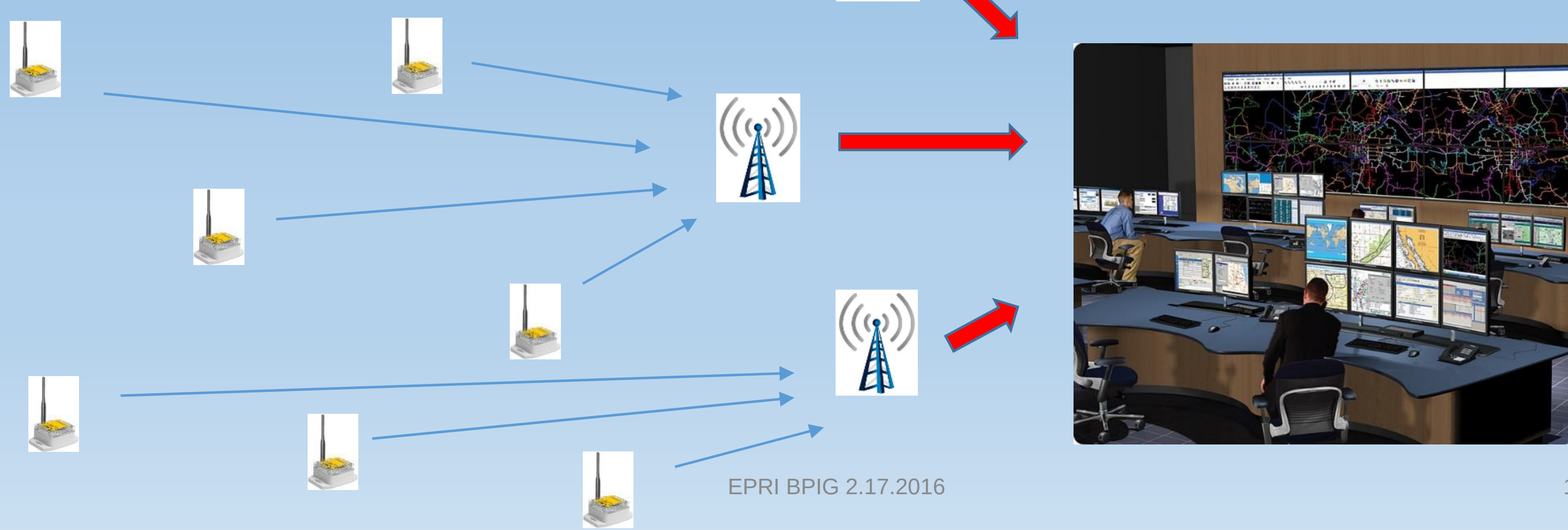
- Modbus / RS-485
- Cellular
- Satellite
- WiFi
- Etc.

24/7 asset health monitoring

Data to desk to decision in minutes

Mobile access by multiple parties



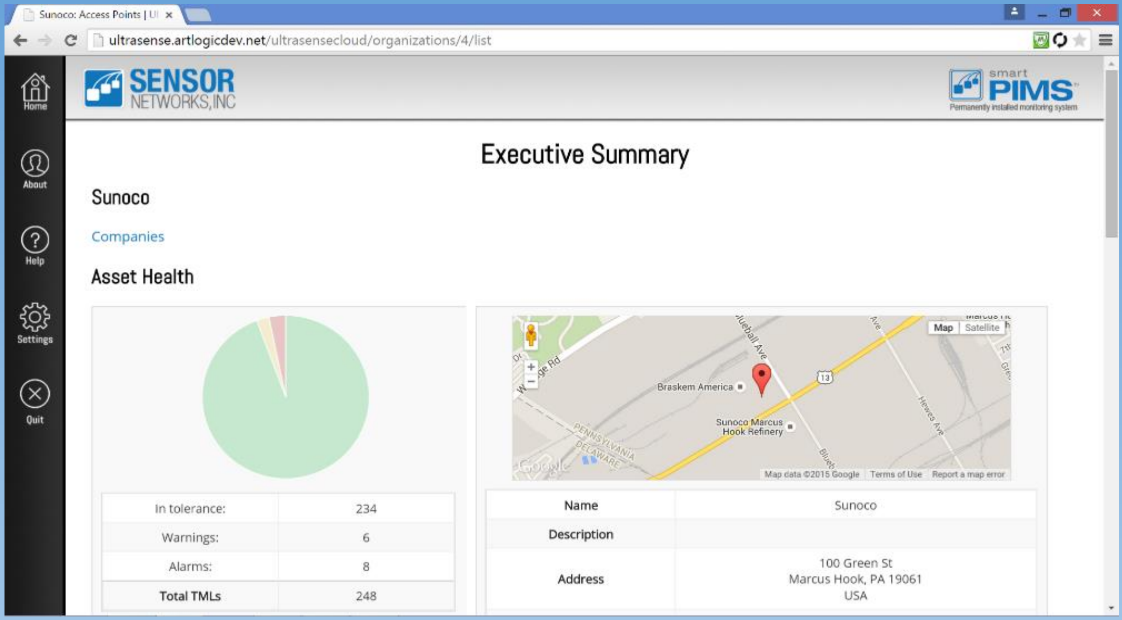


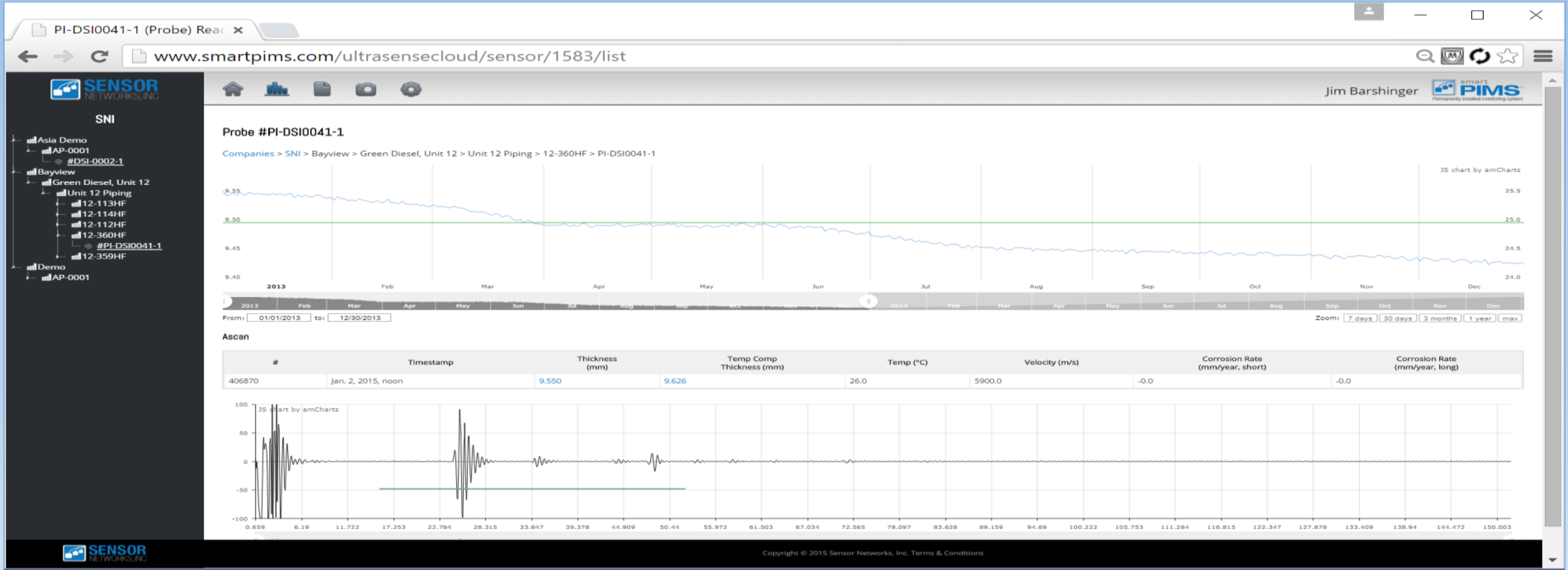
Data/Cyber Security

	Proprietary (In-House) Network	Public Network
Cost	Expensive (To purchase, manage & maintain)	Cheap
Control	Managed internally (good & bad)	Rely on outside data repository (cloud) … Amazon Web Services, Google Cloud, etc., standard encryption schemes: HTTPS
Compromise-ability	Low	Medium
Data Relevancy	Confidential / regulated: Ex. SSNs, medical records, salaries, banking information etc.	Not Relevant: Ex. Thickness data, asset temperatures & pressures
Access	Within Site or through VPN	Global

Web-based Data Management

- Remote collaboration / accessibility
- Archiving & record retention simplicity
- Alarms & Warnings
  - Ex. .500”, .300”, .100”
- Automated reporting
- Google Maps & GPS

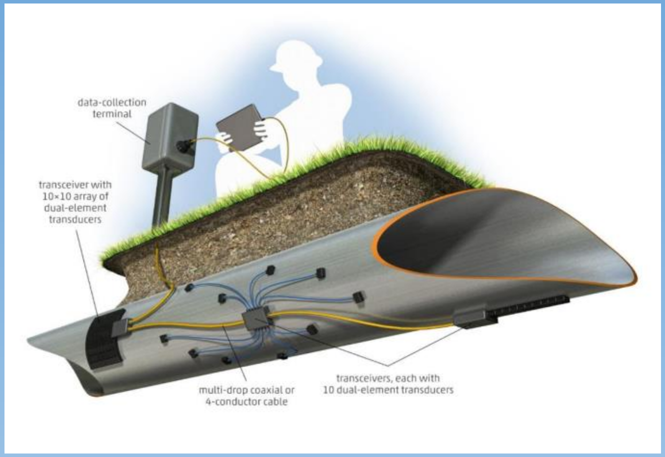




Field Applications

Buried / Underground Assets:

- Pigables – verification of ILI reports
- Unpigables – information & general maintenance
- Known defect monitoring from guided wave/other NDE mass screening techniques
- Single point or mat sensors
  - Low profile / rugged / durable
  - Tethered, no battery (20+ year life)



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Oil and Gas / Petrochemical

Crude Unit Overhead w/ chemical Injection and/or Water Washes

- Utilization of installed UT sensors for corrosion rate calculations of inhibitor optimization

Sand erosion in offshore production

Naphthenic acid detection

- High temperature monitoring

Baseline of new infrastructure

- Flow, pressure, product evaluation for understanding effects on localized corrosion

Daily monitoring of known defects b/t outages

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Power Generation

- High point vent (gas void detection, measurement & evaluation)
- Microbiological corrosion (MIC) monitoring
- Flow accelerated corrosion (FAC) trending/modeling

The Future for Installed Sensors

- Internet of Things (IoT) is fueling the flame
  - In the next 5 years*:
    - $6 trillion will be spend on equipment and infrastructure
    - IoT will connect over 20 billion assets
    - Projected revenues from IoT are estimated at $14.4 trillion

- Communication / Data Transmission
  - Internal vs. public networks (trending to public)
  - Why public?
    - Cheaper
    - More widespread, data accessibility
    - Google/Amazon/etc. are getting better at security/managing data
    - Faster acquisition, higher bandwidth, longer range
- Lower cost per point sensors
- Longer battery life / further reaching
- Other?

*Source: BusinessInsider 2016

Summary

The world is changing … use it to your advantage!

Installed sensors can be used to optimize **inspection** as well as **monitoring** for corrosion/erosion & cracks

Installed sensors should be evaluated on a "cost per point" basis as it relates to tangible & intangible accumulated costs over an assets' useful life

The power of data … predictive uptime, real-time asset health monitoring, reduced unplanned outages

Applications for installed sensors exist everywhere, know your short and long term goals for the project

Questions

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