Monitoring Asset Integrity Using Installed Ultrasonic Sensors

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SENSOR™ NETWORKS, INC

Sensor Networks, Inc.
Steve Strachan
V.P. – Sales North America

Outline

- Motivation
- Inspection vs. monitoring/trending
- Power of Data through Continuous Monitoring & Trending
- Applications
- Case Studies

Corrosion Damage Accounts for the Cost of one Major Facility Annually

- Pipeline , Oil/Gas Production $8 B

- Refining & Petrochemical $1.7 B

* NACE Cost of Corrosion Study

Data Monitoring Evolution

1920s - Manual monitoring

1960s - Analog 4-20mA loop

1980s - Digital Conversion

1990s - Wireless

2010s - Age of Internet of Things (IoT)

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

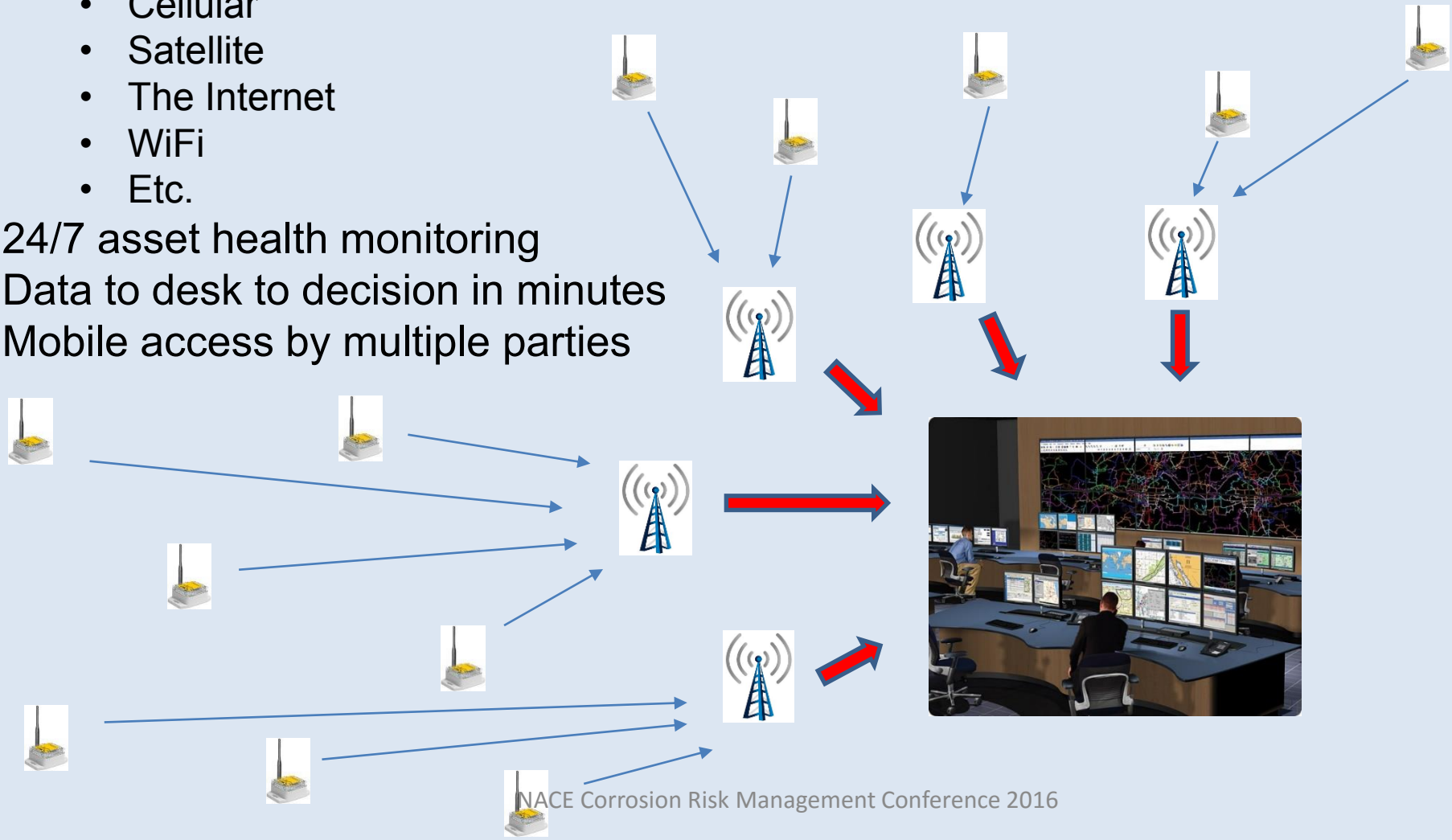
Remote sensors leverage low-cost ubiquitous communication infrastructure

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

24/7 asset health monitoring

Data to desk to decision in minutes

Mobile access by multiple parties



Structural Health Monitoring Meets NDT

Metrology

Condition Monitoring

Quality Control

Process Control

Asset Integrity

Materials Analysis

Time-Based Maintenance vs. Predictive Maintenance

Why Installed Sensors for ID Corrosion Monitoring?

Costs ($) associated with manual inspections

- Pre-inspection activities:
  - Excavation
  - Insulation preparation
  - Surface Preparation
  - Scaffolding
  - Rope access
- Access, permitting, approvals
- Personnel cost – technicians, equipment, training, etc.
- Cost per point is less for applications than manual data collection

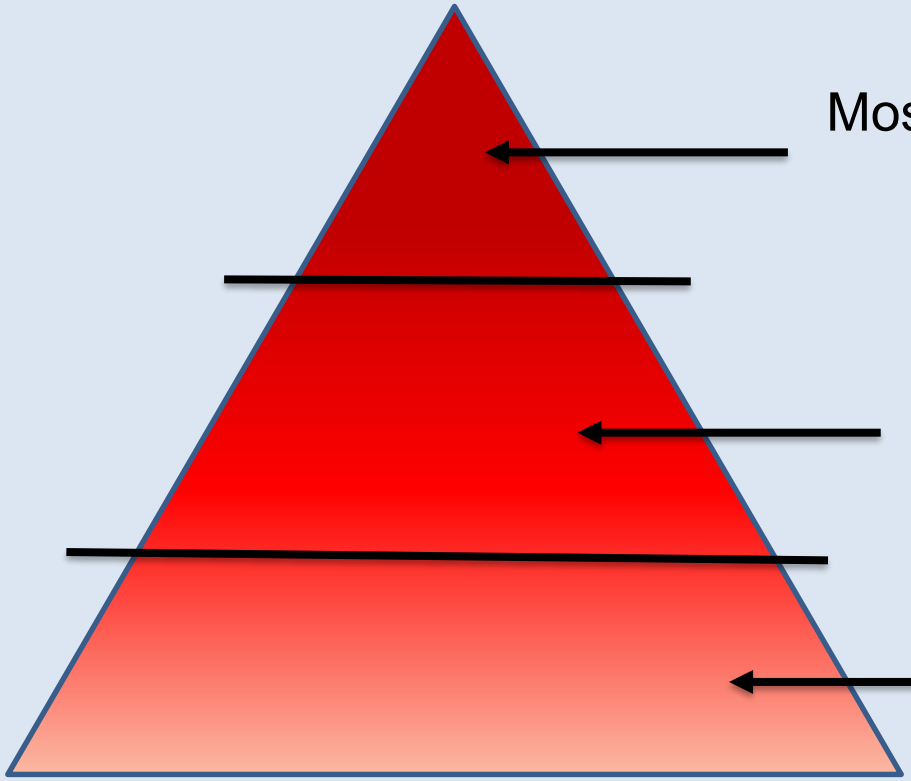
Costs (other)

- Safety – ropes, ladders, radiation, non-invasive, etc.
- Damages – environmental, reputation,
- Time/productivity – short & long term decision making/planning
- Data quality – transcription errors, precision & repeatability

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 2010)

Least expensive/critical areas to inspect (circa 2017 and beyond)

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Installed ultrasonic sensors for asset-integrity monitoring

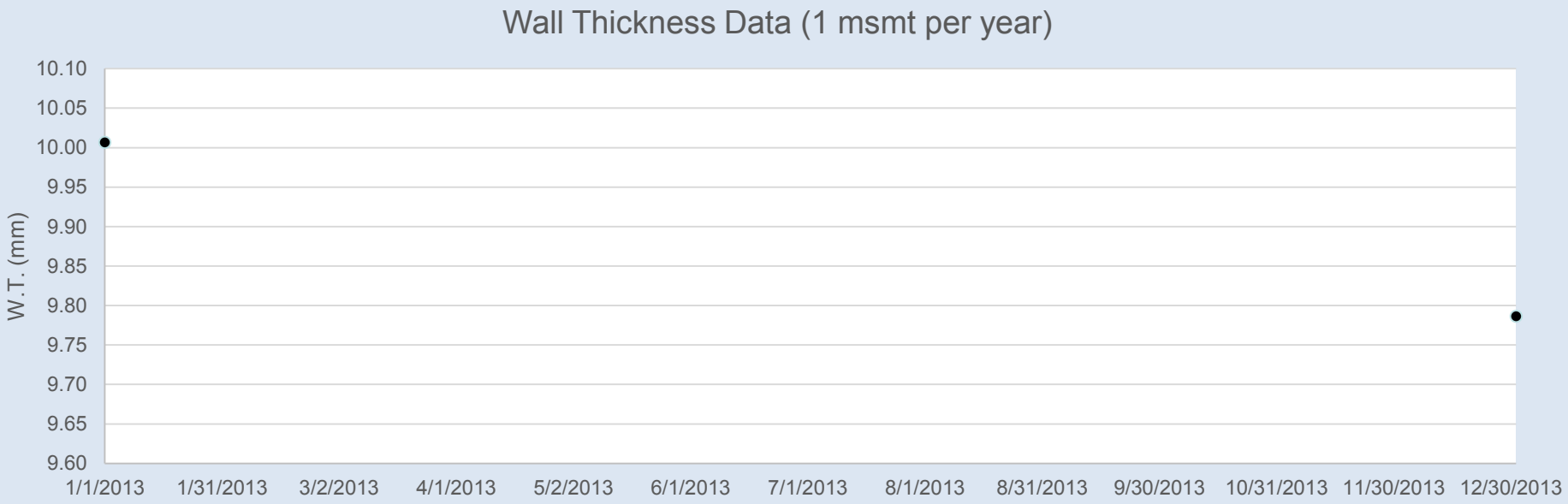
Data Quality Enhanced Using Installed Sensor Systems

Precision Accuracy Resolution

Operator variability
Transducer placement variability
Transducer coupling variability
Sound velocity uniformity
Measurement Precision
- 6 picosecond resolution

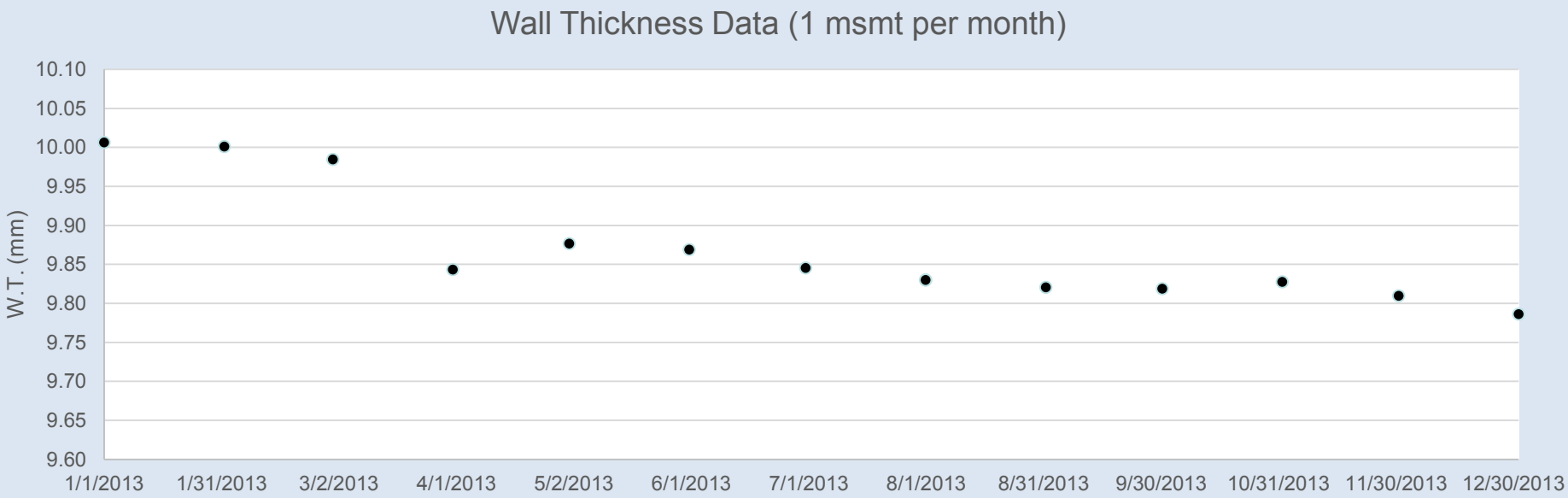
Temperature Compensation
Accurate Corrosion Rates
Data Accessibility

The Power of Data …



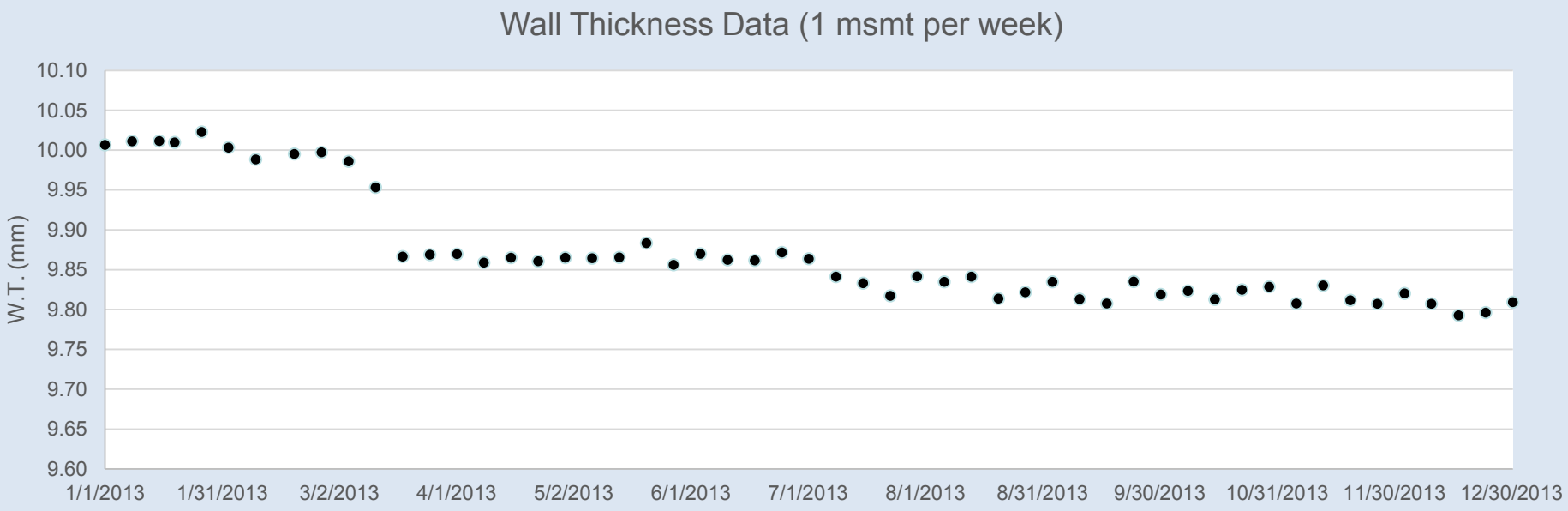
- Sufficient for **<u>inspection</u>** probably NOT for **<u>monitoring</u>**
  - 1/1/2013 inspection = 10.00mm
  - 12/30/2013 inspection = 9.79mm
- Gross corrosion rate – cannot calculate, not enough information

The Power of Data (ctd) …



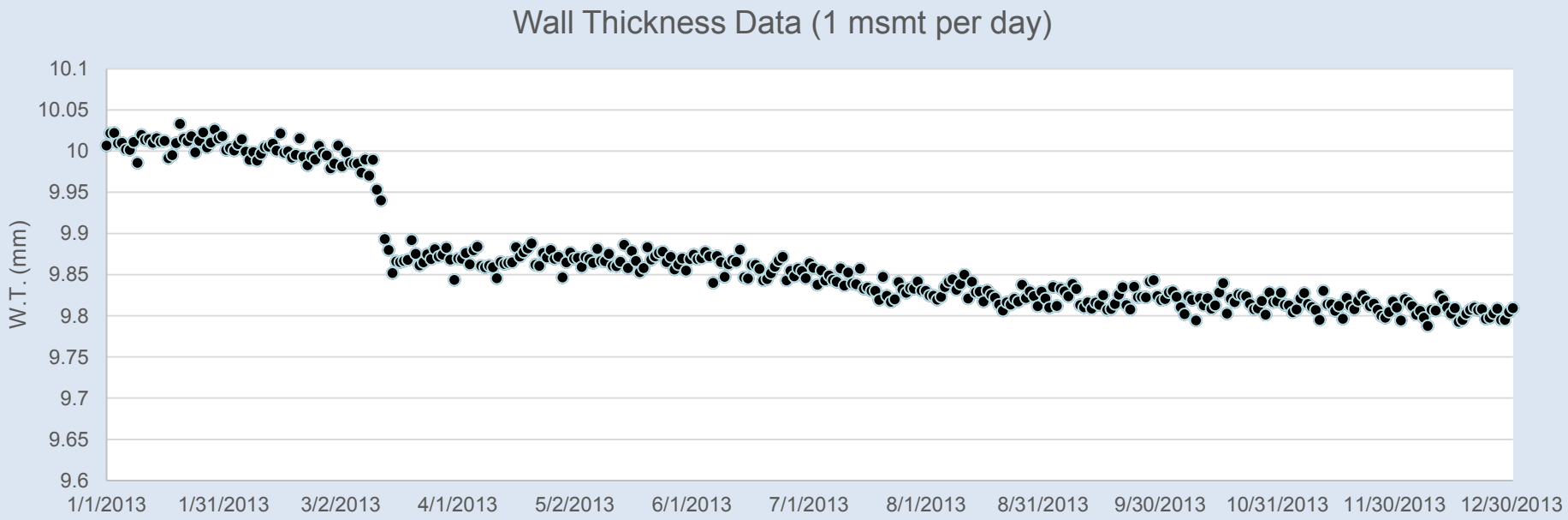
- Various corrosion rates evident
- Trends evident but still large uncertainty due to measurement precision
- Summary – better!

The Power of Data (ctd) …



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

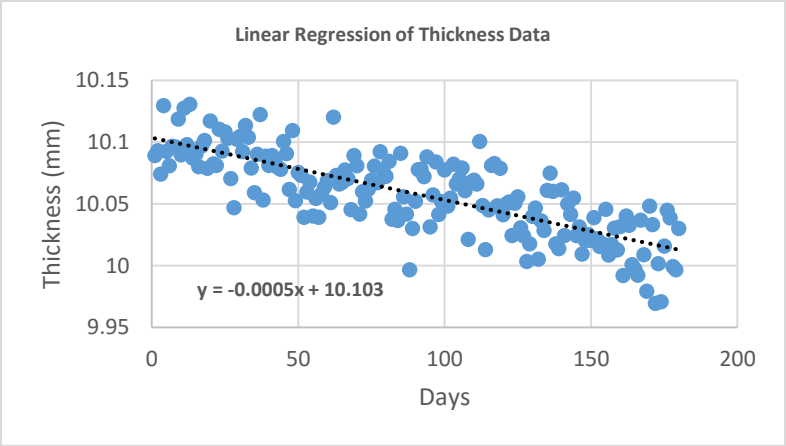
The Power of Data (ctd) …

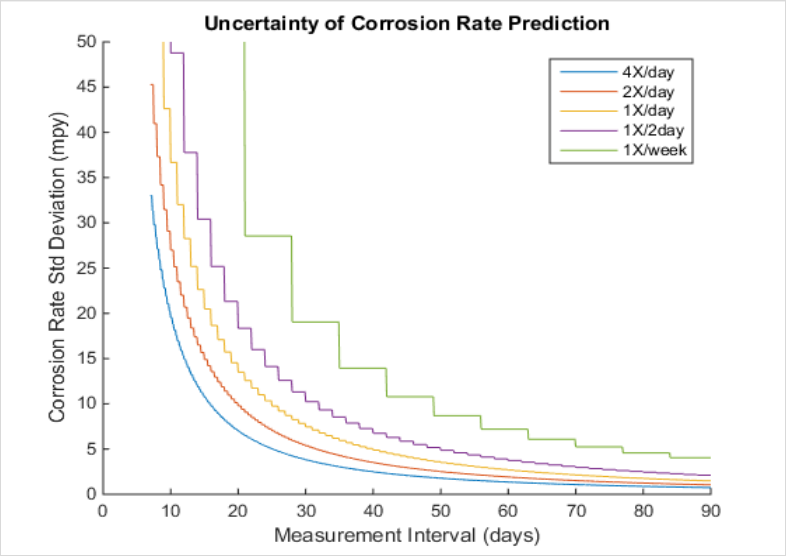


- Various corrosion rates evident
- Regression can be used to remove measurement noise and produce very accurate corrosion rate data
- GREAT!

Corrosion Rate Measurement

- Corrosion Rates(CR) used for maintenance & process.
- Monitoring enables accurate(CR).
- CR Precision enhanced by linear regression.
- Factors:
  - Standard deviation of the measurement system
  - Measurement frequency
  - Measurement interval



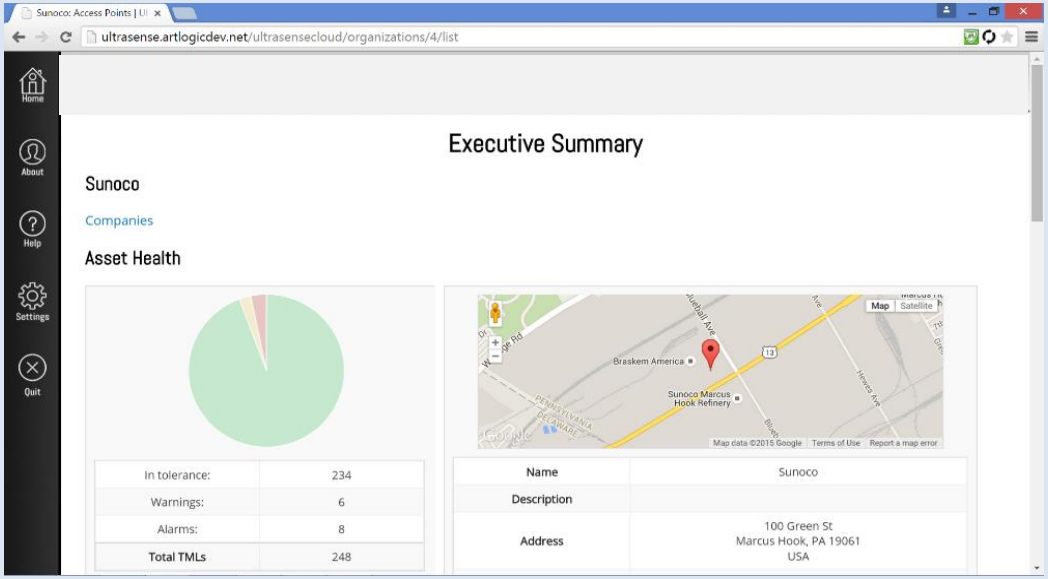


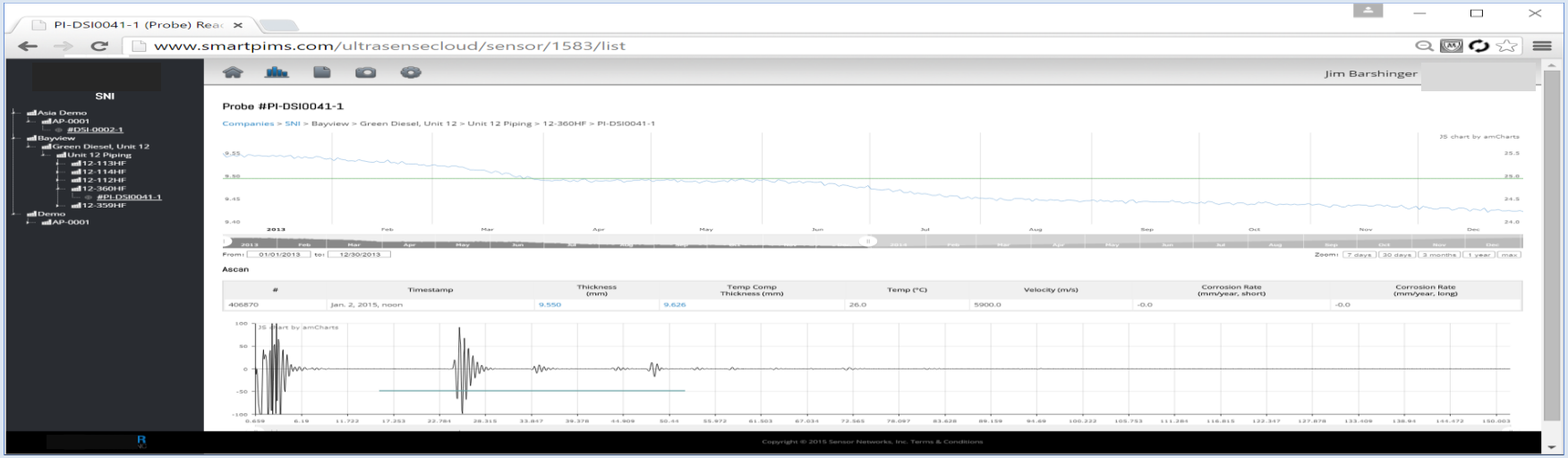
$$s_m^2 = \frac{\frac{1}{n-2}\sum_{i=1}^{n}(y_i - Y(x_i))^2}{\sum_{i=1}^{n} x_i{}^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2}$$

$$95\%\ C.I. \cong m \pm 2s_m \quad (n-2 \geq 6)$$

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

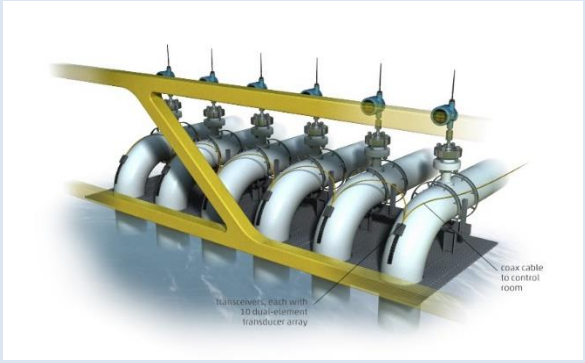
- Data available across the organization – remote viewing for critical decision making
- Archiving & record retention simplicity
- Alarms & Warnings
- Saving raw data: RF Signal
- Google Maps & GPS





Typical Applications

Downstream	Midstream	Upstream
Replacement of invasive technologies – ER probes/coupons	Post repair or replacement baseline of new infrastructure	Wellhead monitoring for initial start-up & injection/storage
Process control for chemical inhibitor optimization	Monitoring of known/existing localized corrosion events	High pressure pumping instrumentation health monitoring
High Temp Naphthenic acid monitoring	Used in lieu of pigging/ILI for river/road crossings or 49 CRF 192 & 195	Sand erosion/wash-out for offshore platforms & FPSOs



UT Sensor Case Studies – Oil & Gas

Process Control

- Corrosion RATE monitoring
- Chemical inhibitor injection mgmt.
- Different crude TAN rates require more/less chemical to reduce exposure to wall loss
- **Temporary UT wireless sensors** placed in misc. areas **(1 reading per hour for 3 months)**
- Reduction in chemical inhibitor spend varying based on crude slate (in this instance is estimated to be **~$20K/wk.**)

Inspection

- Localized corrosion monitoring
- Gas spheres
- "underbelly" pitting/corrosion
- Inspection crews sent bi-weekly to inspect known areas on 4 spheres
- **Cost $25K** each time
- Manual UT gauges marked "low" spots, **tethered UT sensors** placed (**3 readings per wk. using tablet**)
- Saved **>$150K in first 3 months** of program

Re-Engineering

- TML reduction programs
- **Cellular UT sensors** in lieu of manual inspection (**2 readings per month**)
- <1 mil/yr. for +5 yrs.
- 27,000+ TML locations, **cost >$3M to inspect** 1/3 per year
- Were able to reduce from 27,000 TML points to 13,000 TMLs
- **Saving ~$1.7M/yr** in manual inspection cost

UT Sensor Case Studies – Power Gen.

Transmission

- Regulation driven
- Buried river & road crossings
- UT sensors placed on defined areas - **tethered/manual collection**
- Junction boxes placed 100’ from road tethered UT sensors installed (**1 reading per qtr.**)
- Savings in **government fines**

Storage

- Buried high pressure storage lines
- Installed tethered/manual UT sensors on **new (replaced) segments of pipe** where corrosion had previously been found (**2-3 readings per yr.** or as necessary via tablet)
- Savings from **avoiding unplanned outages**

Inspection

- Ongoing projects & evaluation …
- **FAC** programs
  - Corrosion rate R&D
- **MIC** programs
  - Installed sensors in lieu of manual inspections for known pitting between outages
- **High-point vent**
  - Installed sensors in lieu of manual inspection to **detect gas voids**
  - **EHS** – avoid radiation areas where possible

Summary & Q/A

The digital world is changing quickly … use it to your advantage

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

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 any project/program

Sensor Networks, Inc.

Steve Strachan

V.P. Sales – North America

Strachan@installedsensors.com

www.installedsensors.com