Permanently Installed Monitoring System for Accurate Wall-Thickness and Corrosion-Rate Measurement

March 9, 2016

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

Outline

- Motivation
- Permanently Installed Sensor System
- Power of Data through Continuous Monitoring & Trending
- Typical 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

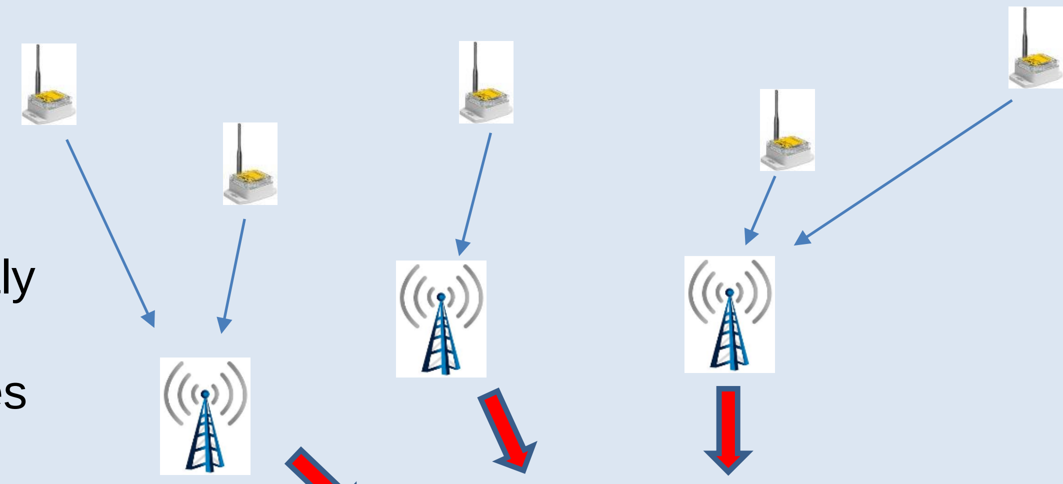
1980s - Digital Conversion

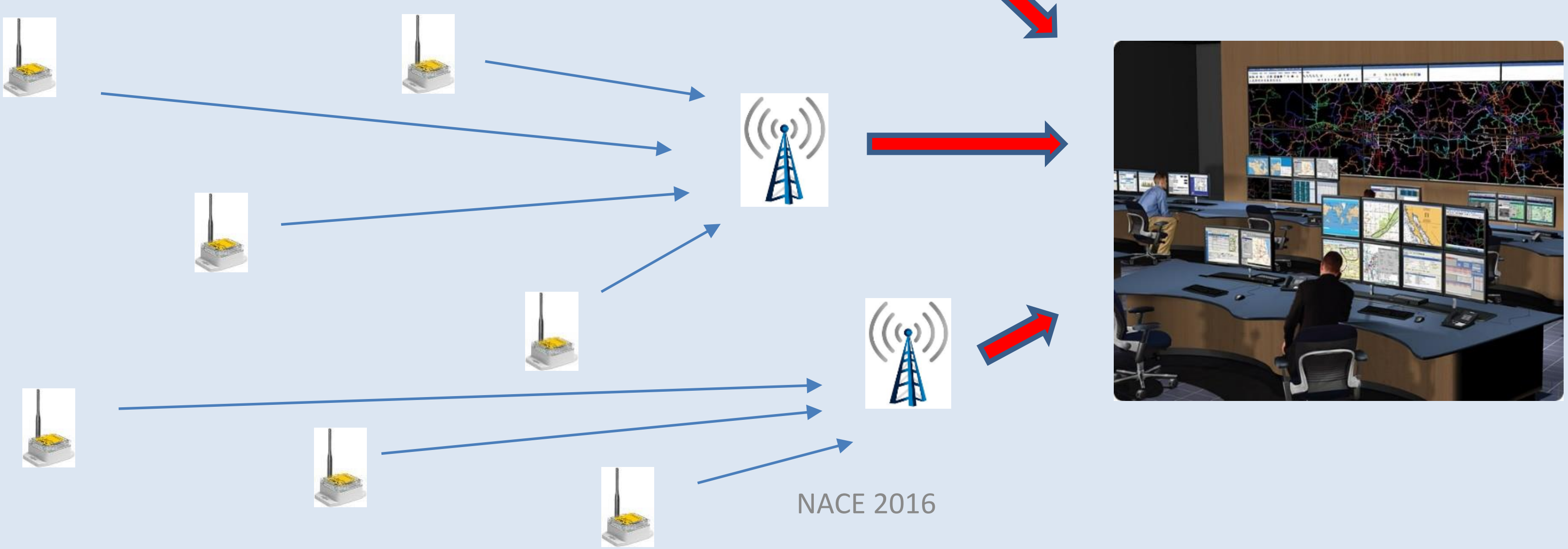
1990s - Wireless

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
  - WiFi
  - Etc.
- 24 x 7 asset-health monitoring
- Data-to-desk-to-decision instantly or in minutes
- Mobile access by multiple parties





Why Installed Sensors Today?

Costs ($) associated with manual inspections

- Pre-inspection activities:
  - T & L – windshield time
  - 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

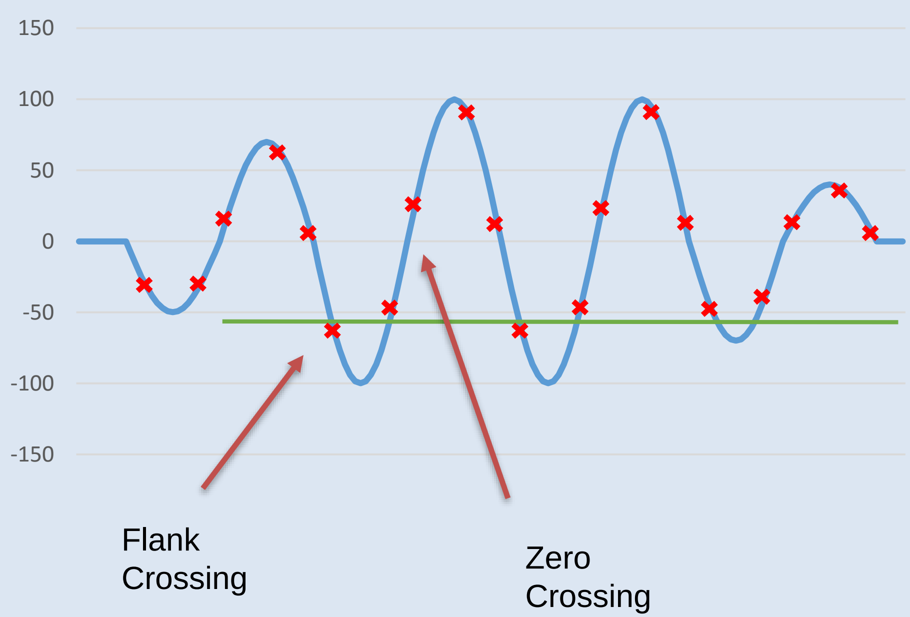
Costs (intangibles)

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

Data Quality Enhanced Using Installed Sensor Systems

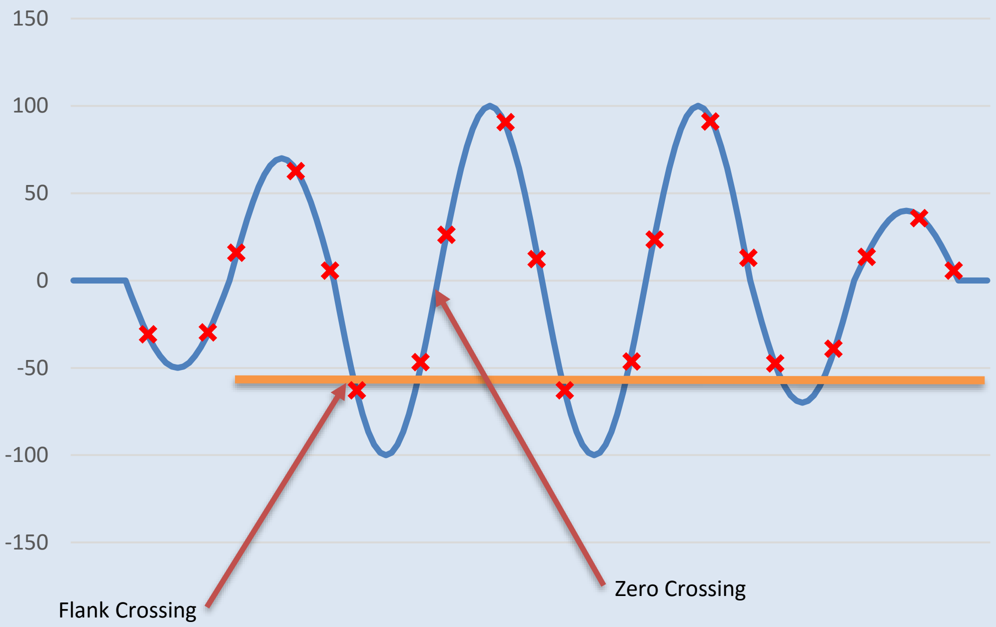
Precision   Accuracy   Resolution

- ❑ Operator variability
- ❑ Transducer placement variability
- ❑ Transducer coupling variability
- ❑ Acoustic velocity uniformity
- ❑ Measurement Precision
- ❑ Temperature Compensation
- ❑ Accurate Corrosion Rates
- ❑ Data Accessibility



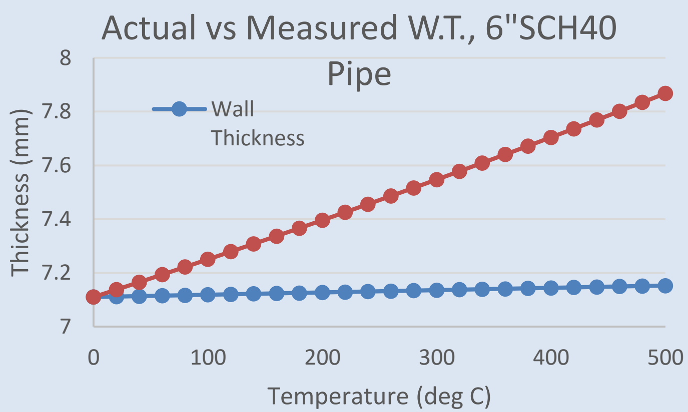
Measurement Precision

- Accurate and Precise UT thickness gauging requires a high precision measurement of the arrival time of the ultrasonic pulse
- Measurement principles:
  - Depends on the precision of the TOF measurement, not the carrier frequency of the UT signal.
  - Choose high slope portion of the waveform (zero crossing) rather than a peak.
  - Waveform needs to be sampled at a sufficient speed (Nyquist +)
  - Digitizer precision needs to be enhanced: 40MSPS -> 25nS steps -> 0.003” (0.07mm)
  - Solution: 8X Upsample using low pass filter. 320MSPS -> 3nS steps -> 0.0004” (0.009mm)
  - Interpolate between points yields even greater resolution ~6.1 picosecond resolution.



Compensation for Temperature Change

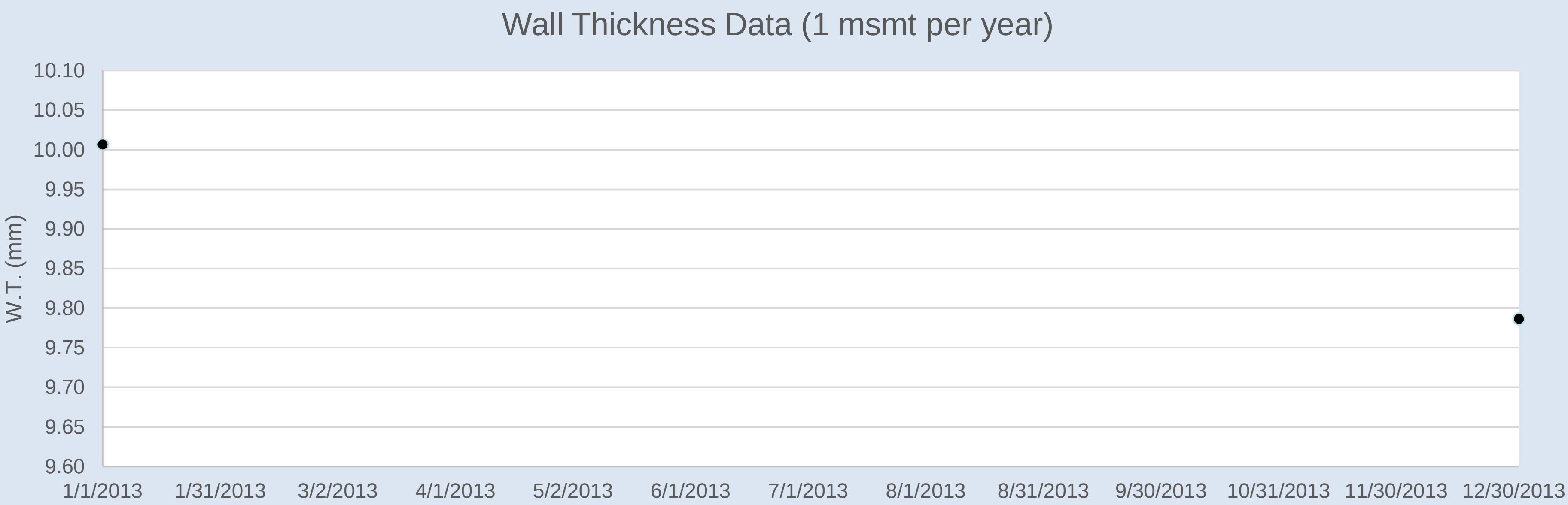
- Temperature change can be a significant factor in performing accurate thickness measurement.
- Material velocity AND wall thickness changes, but material velocity effect >10X linear expansion effect.
- Velocity in steel changes by approximately -1% per 100°F (55°F)
- ASTM E790 and API 570 make recommendations for when corrections should be made and how they should be applied.
- Permanently installed monitoring system requires a temperature measurement device such as a RTD or thermocouple to implement the correction



$$C_1 = C_0(1 + k(T_1 - T_0)/100)$$

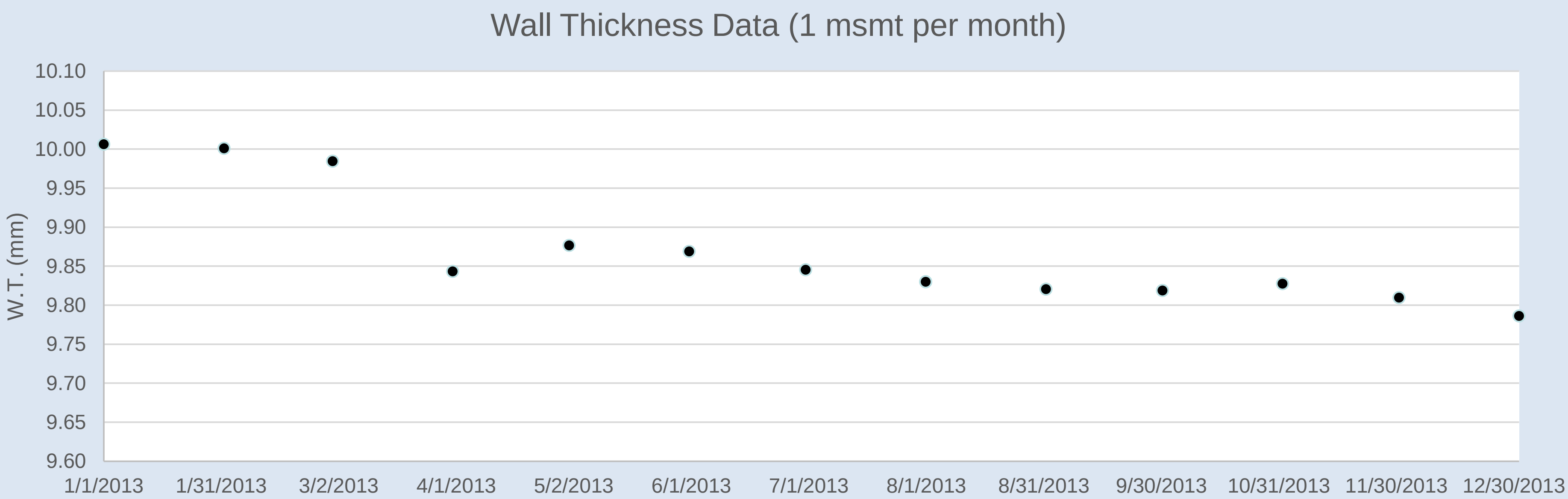
d_1	Temperature corrected thickness
C_1	Temperature corrected velocity
C_0	Reference or calibration velocity
Δt	Measured, round-trip time of flight
T_1	Measurement temperature
T_0	Reference or calibration temperature
k	Correction factor in % per °F or °C

The Power of Data …



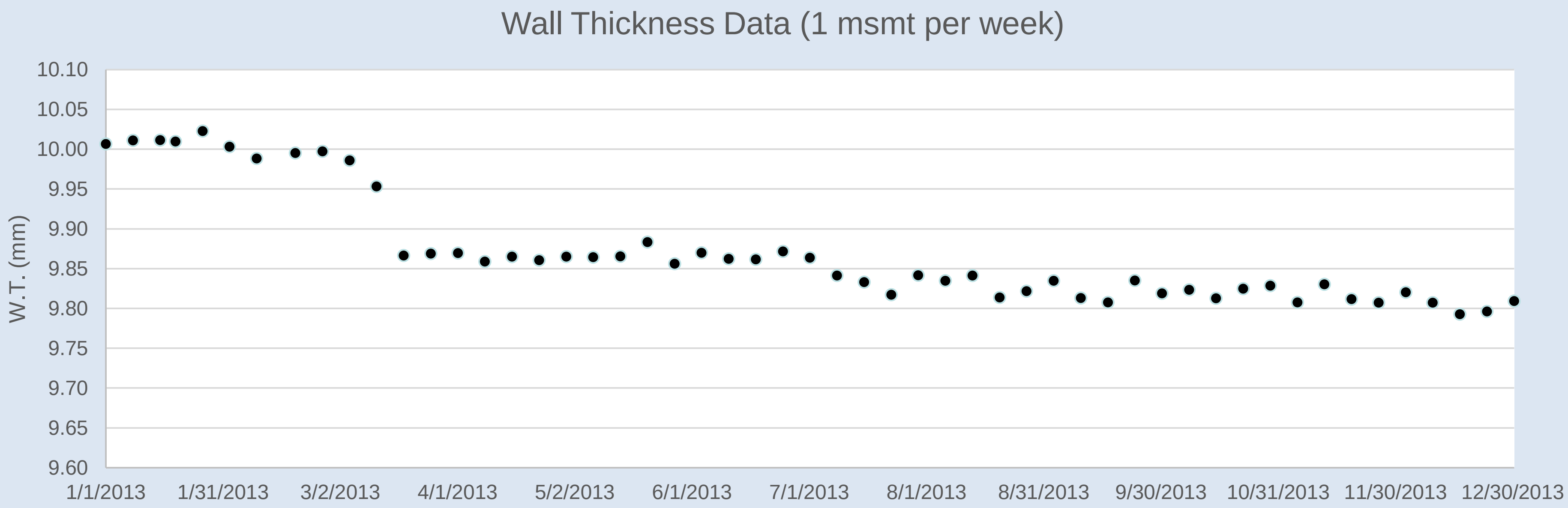
- Sufficient for **inspection** probably NOT for **monitoring**
  - 1/1/2013 inspection = 10.00mm
  - 12/30/2013 inspection = 9.79mm
- Gross corrosion rate – cannot calculate, not enough information

The Power of Data (ctd) …



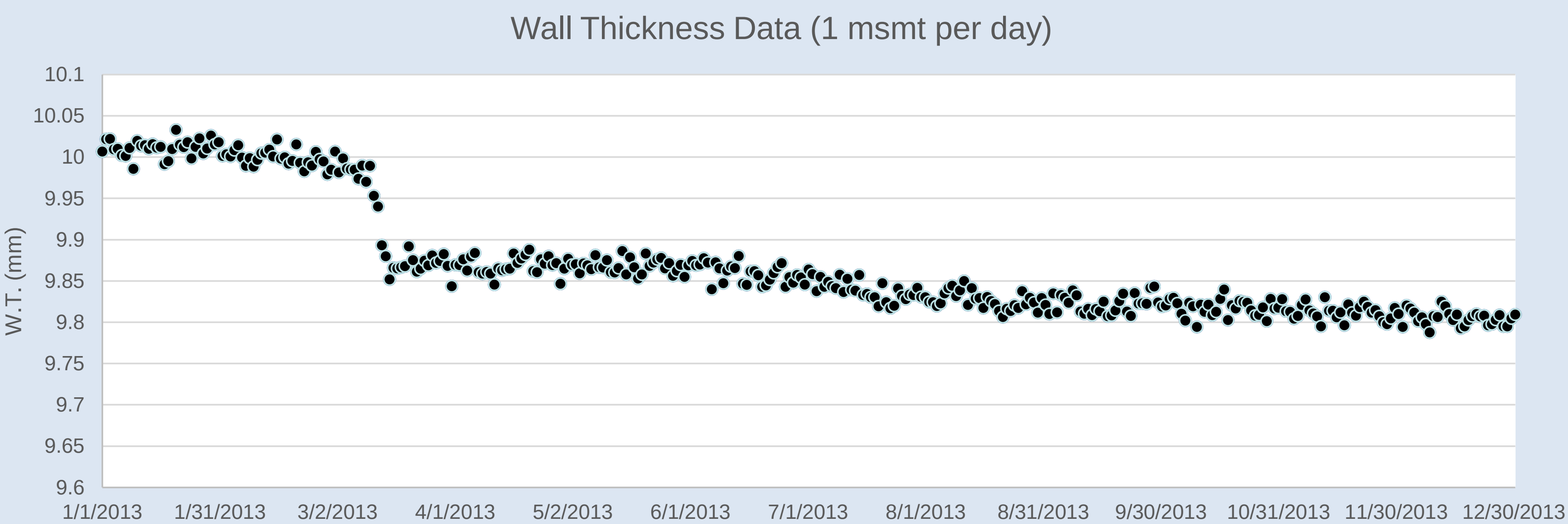
- Various corrosion rates evident
- Trends evident but still large uncertainty due to measurement precision
- Summary – better!

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) …



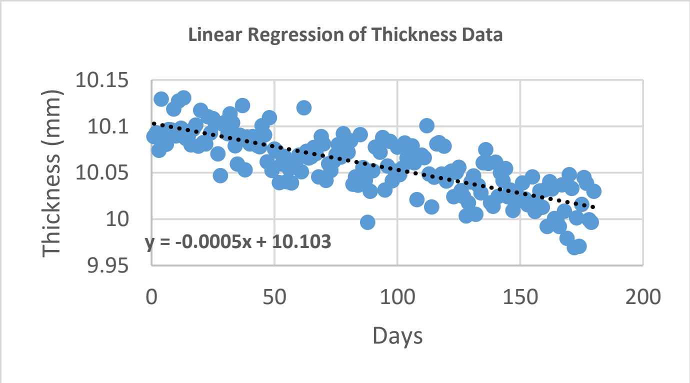
- Various corrosion rates evident
- Regression can be used to remove measurement noise and produce very accurate corrosion rate data
- GREAT!

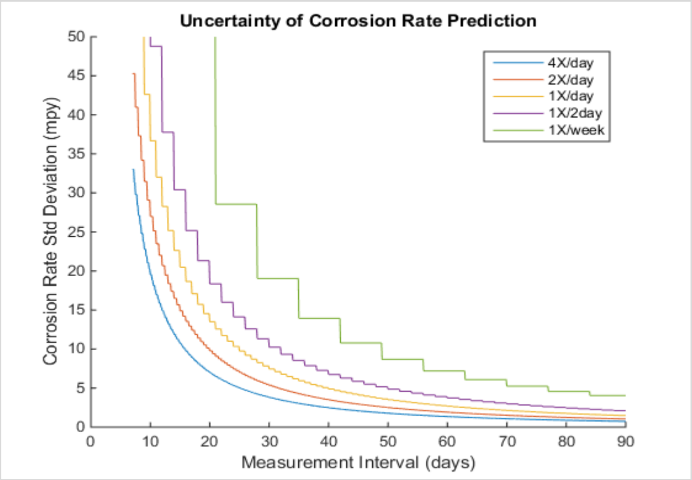
Corrosion Rate Measurement

- An important by-product of wall thickness measurement and monitoring is the ability to measure corrosion rates.
- Corrosion rate measurements can be used for predictive maintenance as well as for process feedback.
- CR achieved through linear regression.
- Precision is achieved that exceeds the precision of the base measurement.
- Factors:
  - Standard deviation of the measurement system
  - Measurement frequency
  - Measurement interval

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

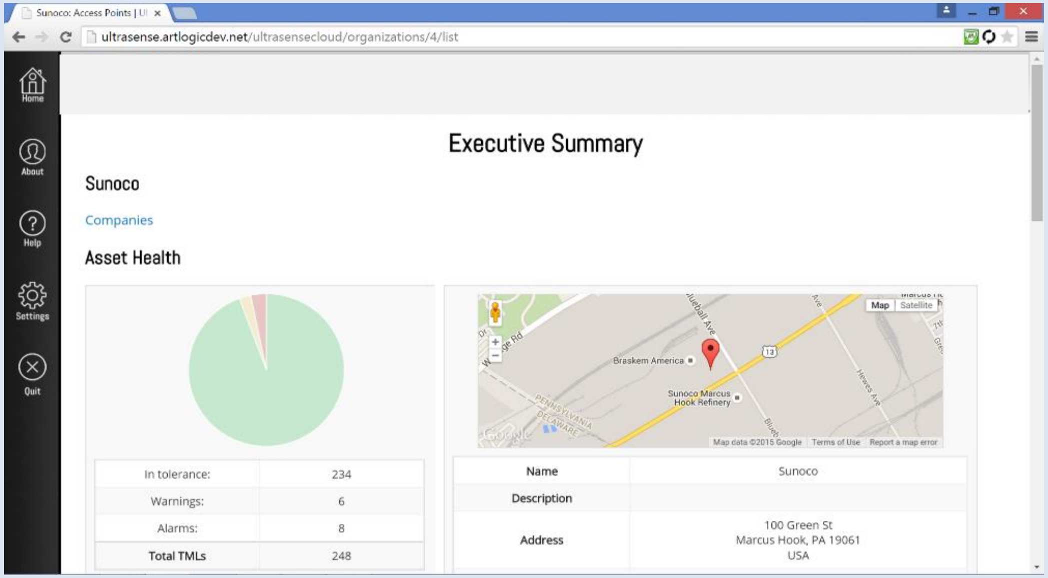
$$95\%\ C.I. \cong m \pm 2s_m \quad (n-2 \geq 6)$$

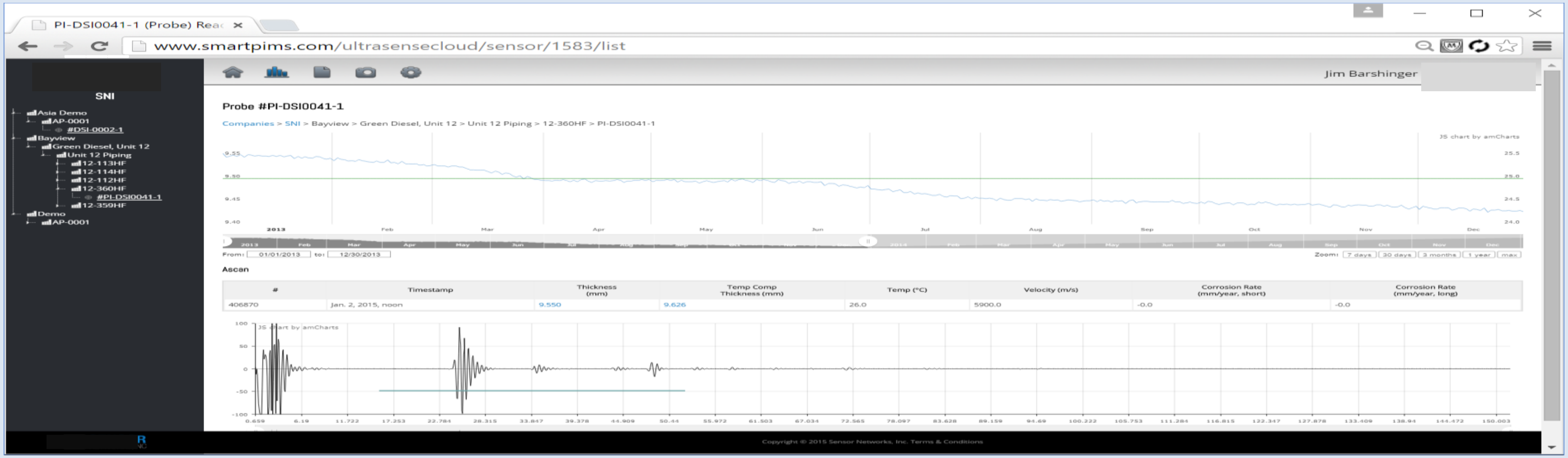




Data-to-Desk & The Internet of Things (IoT)

- 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

- Replacement of ER probes/ Corrosion Coupons
- Baseline of new infrastructure
- Crude Unit Overhead w/ chemical Injection and/or Water Washes
- Injection/Mix-point Corrosion
- High temperature (900F) real-time monitoring
- Gas Spheres / containers
- Sand erosion/corrosion in offshore production
- Buried Pipelines
- General Inspection

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 world is changing … use technology to your advantage

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

The **power of data** … predictive uptime, real-time asset health monitoring, reduce 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