NGA Operations Conference
New Pipeline Integrity Tools & Technologies

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Agenda

- Range of Commercial Unpiggable Inspection Platforms
- New Supporting Technologies for EXP Range of Inspection Platforms
  - Bend Sensor – Complete; technology transfer stage
  - Crack Sensors – nearing project completion
  - Automation – ongoing project
  - Energy Harvesting – Devt phase of project cofunded by PHMSA starting in 8/18
- Software Tool
  - Incident Database – Complete and available for funders
- Analatom Corrosion Sensor – complete; technology transfer tasks underway
- New Project(s) on Plastic Pipe Inspection - underway
- Questions & Answers
LDC Pipeline Integrity Challenges

- Unpiggable Pipes
- Third Party Damage; practical methods for damage prevention
- Continuity in Data Collection; best use of data and data analytics
- Reactive vs. proactive decision-making
- Direct Measurements of Corrosion
Commercial Inspection Tools
EXP Inspection Platforms for Unpiggable Pipes

- Launched and retrieved under live conditions via off-the-shelf fitting
- Bi-directional

- Able to negotiate most pipeline features; short-radius bends, mitered bends, vertical segments, back-to-back bends, plug valves (>20” pipelines)
- Battery-powered
- Tether less (wireless communication)
- Range limited by batteries and wireless
Since 12/11, NYSEARCH¹/Invodane and Pipetel have commercialized
- Six Inspection platforms (X8, X10/14, X6/8, X16/18, X20/26, X30/36)
- Seven MFL sensors (X8, X10/14, X16/18, X20/26, X30/36, X20/22-plug-valve, X24/26-plug-valve)
- 5 LDS mechanical damage/ovality sensors (X8, X10/14, X16/18, X20/26, X30/36)
- In-line recharge system

¹ NGA/NYSEARCH licensed Intellectual Property to Invodane for exclusive commercial sale of Inspection Services. Pipetel is a spin-off service company of Invodane.
New Supporting Techs (for EXP robot)
EXP Supporting Technologies – Ongoing Commercialization Efforts

- Products in Commercialization phase with Invodane/Pipetel
  - Bend sensor (X20/26), (X30/36) – in commercialization phase with Invodane
    - Invodane to build additional bend sensors for other sizes
    - Technology being incorporated into X8 MFL sensor
  - Hardness tester (X20/26)
    - Field testing completed; being optimized for commercialization
  - Seam Weld (Alternate) crack sensor (X20/26)
Supporting Technologies - Pending Commercialization Efforts

- We have developed but not commercialized yet
  - RMD EC Crack sensor (X20/26)
    - Recent successful field test; additional laboratory testing and benchmarking ongoing
  - Cleaning tool with flow (X20/22)
    - Some additional upgrades/changes could successfully address operational and planning issues
    - Little demand to date for commercial tool
Supporting Technologies – Ongoing Developments

- NYSEARCH Ongoing Development Projects
  - Explorer Automation technologies
  - Explorer on-board Energy Harvesting (X20/22)

- Will be initiating in 2019
  - Cleaning Tool for Pipes with No-Flow
  - Expanding Range of wireless communication
Supporting Techs Under Devt - MFL Sensor for Bends

Objective: Design, build and test an enhanced MFL sensor for the EXP platforms that can also inspect bends

- Fully functional in all traditional situations & replace existing MFL sensor

Project for EXP 20/26 completed
MFL Sensor for Bends

Design Features

- Redesign allows the sensor to retract fully on inner surface and extend more on outside surface of bend
- Magnetic bar and wheel system enables robot to remain centered along bend axis
- Sensor module center body has increased strength, flexibility and simplicity
- Strengthened sensor shoe due to increased wear forces
MFL Sensor for Bends
Sample Data from Test Bed
RMD ED Crack Sensor
Program Overview

Objective: Develop and test an Anisotropic Magneto Resistive (AMR) based Eddy Current (EC) crack sensor for integration with Explorer 8.

Contractors
- InvoDane Engineering
- RMD, Inc.
RMD ED Crack Sensor
Field Testing

- System development completed in spring ‘18
- Sensor performance replicates previous results from Phase II
- Agreed to test mechanical/electrical/firmware systems in a realistic environment
  - Launch and receive
  - Collect data on a live, pressurized pipeline
  - Assess impact of liftoff due to debris/welds on signal
  - Evaluate sensor repeatability (scan in both directions)
  - Characterize performance
Carried out field testing on August 2, 2018, in a pipeline operated by San Diego Gas & Electric

Location: Escondido, CA

8” pipe, 0.322” wt

Scan length: 369 ft

MAOP: 640 psi
RMD ED Crack Sensor
Field Testing (cont’d)
RMD ED Crack Sensor Field Testing (cont’d)

8 in Explorer with AMR EC Sensor installed

8 in Launcher
Two sensor configuration at two locations on the robot was selected to provide 100% coverage and bi-directionality.
Seam Weld Crack Sensor Lab In-Pipe Scanning

- Initial lab results from seam weld scanning
Carried out field testing at the NYSEARCH Test Bed in Johnson City, NY, with the sensor integrated on Explorer 20/26 in 20” loop

Components tested

- sensor mechanical and electronic systems
- sensor control software
- sensor-robot integration software
- manual and automated weld tracking routines (ERW welds)
- defect detection routines
Scenes from Field Testing of Seam Weld Crack Sensor

NGA Weld Sensor Field Trial 7/24/18 - Manual Sweep

NGA Weld Sensor Field Trial 7/24/18 - Following Sensor
Automation of EXP
Program Objectives

- Reduce the level of operational complexity associated with deployment of Explorer, while increasing its overall capability, by automating its operation/control.
- Aim is to lower deployment costs, improve pipeline data quality, and add robot robustness.
Automation Example
Feature Recognition

- Currently operator uses drawings (if they exist) and visual feedback to determine features
- Use visual data to identify features

Feature Detection – Line recognition through a bend; Circle video

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The range of the robots is limited by:

- Battery capacity
- Wireless com range

In mid-2000s, range of battery was about half a mile, while wireless was about one mile.

With adoption of newer battery technologies, both wireless and battery ranges stand at about one mile.
Energy Harvesting for Range of EXP Platforms

- **EXP PLATFORM – SYSTEM CONCEPT – BASE DESIGN 20” PLATFORM**
  - Harvest energy available in gas flow
  - Partially convert into tow force
  - Partially convert into electrical power

- **Turbine with Generator operating at 6500 RPM**
Overall Program for EXP Energy Harvesting

- Develop, build, and test an onboard, power generating module for Explorer 20/26
- Based on Phase I concept development experience
  - Address electronics efficiency issue
  - Address turbine by-pass ratio issue
  - Explore providing additional towing force through a “sail” concept
- Phase I: Concept development - $500K – initiated 1/17, completed 9/17
- Phase II: Design, build and test - $1.5 MM; request for PHMSA cofunding of $741K; contract start 8/1/18 – 27 mon program
Software Tool
Objective: Create a searchable database from detailed NTSB Incident Reports

Technical Approach
- Download and review of reports from NTSB and NTIS
- Analyze data to determine links between causes of accidents and pipeline properties
Incident Database
Types of Information

- NTSB Report Information
  - Report date, number, title, etc.
- Pipeline Incident Data
  - Type of system, accident type, owner, injuries/fatalities, etc.
- Pipeline Properties and Related Integrity Information
  - Diameter, wall thickness, MAOP, etc.
- Flaw-Related Details
  - Defect type, length, orientation, etc.
- External Conditions
  - Ground conditions and soil type
- Interaction with Subsurface Utilities
  - Water, sewer, and electric
Incidents Database

Results

- 120 NTSB Reports were reviewed and categorized
- Assessments were made on statistics of threats and interacting threats
- Supplemental information received from PHMSA reports
- Spreadsheet distributed; database contains (60) fields
Real-time Corrosion Sensing
Analatoom Corrosion Sensor Array

- **Linear Polarization Methodology**
  - Electrochemical technique
  - Detects the corrosion during earliest stages

- **How it works**
  - Apply +/-10mV signal about the open-circuit potential
  - Measure corresponding current
  - Compute polarization resistance
  - Apply material properties/Tafel constants to infer corrosion current
  - Convert corrosion current to mass loss using Faraday's Law
Analatomo Corrosion Sensor Array 35
Installation Requirements

- Install Sensor Flex Tape (10 – 15 mils with protective coating) on 8’ x 2’ strip of brushed bare pipe (following coating removal). Use temperature resistant epoxy; recoat.

- Install 8’ of hybrid Flexible Printed Circuit Board (FPCB) cable; 30’ of flexible flat cable. (8) MicroLinear Polarization sensors; at 1’ intervals of FPCB; bring cable up to above-ground station through 2” duct/PVC pipe.
Utilize reliable Wireless Communication (Verizon 3G network) and good wireless signal from pipe monitoring points

Data collected down to (15) min intervals; information sent to secure FTP site once daily (current location: Santa Clara Ca)

Wireless communication module in above-ground Analatom control panel enclosure

Non-metallic NEMA outdoor enclosure

4 hours of sunlight per week for tablet-size solar panel to recharge data collection/control panel; life of lithium battery is 5 years
Analatom Corrosion Sensor Array
Field Sites

- National Fuel
  - 20” Main near Buffalo NY
  - CP low spot area
  - Longitudinal sensor installation to monitor general corrosion
  - FBE coating
  - Monitoring corrosion for minimum of (6) months
Con Ed Field Test Site

Sensor connection for monitoring station
Sample corrosion rate results
Analatom Corrosion Sensor Array
Conclusions from overall program

- Proven method for real-time monitoring of hotspots; one system covers 10-15' linear distance
- Impervious to wide swings in temperature and humidity; epoxy/adhesive good to 100°C
- Accuracy of corrosion rate sensors - +/-10%
- Can work in the presence of AC power lines
- Data to show that system works reliably and remote monitoring is meeting performance expectations
- Sensor life equivalent to or better than life of coating
New Program for developing Plastic Pipe Inspection Capability
Terahertz Inspection

- New technique developed in the ‘00s
- Shows early promise for many materials
- Limited testing with PE shows promising results due to higher resolution and greater penetration depths
  - 2007 German study showed promise
  - Able to detect presence of contaminants in butt fusion joint and poorly welded area
- Equipment evolving fast as it shrinks in size
  - German development of terahertz probe that could fit inside a pipe
Regarding inspection of PE pipe

- Offers potential for significant advancements especially in thicker wall/joints applications
- Equipment is shrinking in size; already available in sizes that allows portability and ILI applications
- Various equipment manufacturers
- Limited number of academic research in plastic pipe applications
Establish an R&D effort to determine capabilities for in-situ inspection of pipe and joints via portable equipment.

Multiphase effort to take technology from proof of concept to eventual commercialization.

Figure 1.24 Indications more clearly detected in butt-fused joint of UHMWPE plate at oblique incidence.
Defects to be studied

- Sharp cut on pipe wall
- Blunt gouge on pipe wall (multiple depths?)
- Sand in butt fusion weld
- Grease in butt fusion weld
- Water in butt fusion weld
- Crack on pipe/joint (Slow crack growth defect)
- “Cold” butt fusion
### Initial test matrix

<table>
<thead>
<tr>
<th>PE Pipe</th>
<th>Wall Thk</th>
<th>Material</th>
<th>None Standard</th>
<th>Simulated Defects</th>
<th>Internal to butt fusion</th>
<th>External pipe wall</th>
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<tbody>
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<td></td>
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<td></td>
<td></td>
<td>Sand</td>
<td>Water</td>
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<td>SDR 11 (0.216)</td>
<td>MDPE</td>
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<td>MDPE</td>
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<td>10</td>
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<td>MDPE</td>
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<td>HDPE</td>
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NGA/NYSEARCH has licensed Invodane/Pipetel and has collectively commercialized several robotics platforms from 6” – 36” with a range of capabilities.

NYSEARCH’s Supporting Technologies program has components/enhancements that are developed and being commercialized.

Our program for real-time sensing of corrosion has innovations such as the Analatom Sensor Array where confirmatory laboratory and field test results have been obtained; technology needs little additional work ahead of commercialization.

Through investigation into solutions for other industries, NYSEARCH is now pursuing innovations for inspection of PE Pipe.

Member support for Pipeline Integrity management tools continues to be a key area of RD & D.