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Human Centric Design
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Human Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability

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Project Background

The government and Industry Pipeline Research and Development forum was held in Chicago, Illinois in August 2014. The workshop resulted in a common understanding of current research efforts, a listing of key challenges facing government and industry, and a compilation of potential research areas whose exploration will assist with meeting these challenges and should therefore be considered in the development of new research and development applications.

PHMSA pipeline safety representatives determined that the following major research areas need to be addressed:

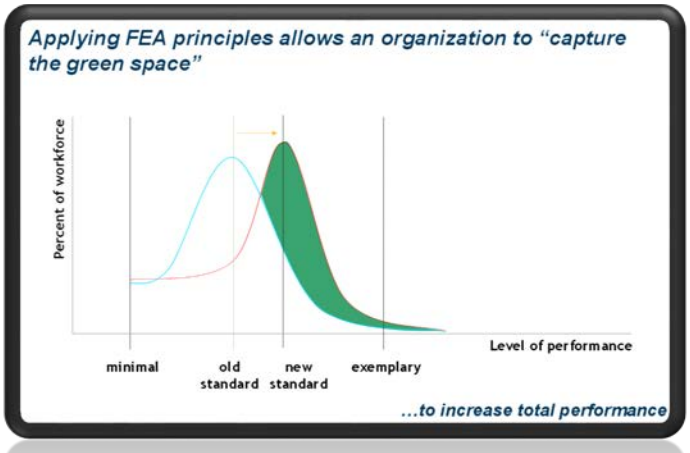
(a) Damage Prevention
(b) Leak Detection/Fugitive Methane
(c) Anomaly Detection & Characterization
(d) Materials
(e) Risk Models

On November 5, 2014, PHMSA issued Research Announcement, # DTPH5615RA00001, addressing each of these major areas. This Agreement addresses Anomaly Detection & Characterization.

Project Background

While human factors typically are not attributed as the sole source of pipeline incidents, they contribute substantially to incident prevalence and severity.

The Battelle Team proposed a phased approach to first conduct a Front-end Analysis (FEA) to identify major human factors influences on NDE inspector performance and then address those high-impact positive and negative influences in subsequent phases with human and technology interventions designed to improve inspection performance across the work population.



Three objectives correspond to three program phases:

- **Phase 1**→ Identify *human factors' influence* on in-the-ditch NDE inspector performance
- **Phase 2**→ Identify and validate high-impact *human interventions* to improve NDE inspector performance
- **Phase 3**→ Identify and validate high-impact *technology interventions* to improve NDE inspector performance

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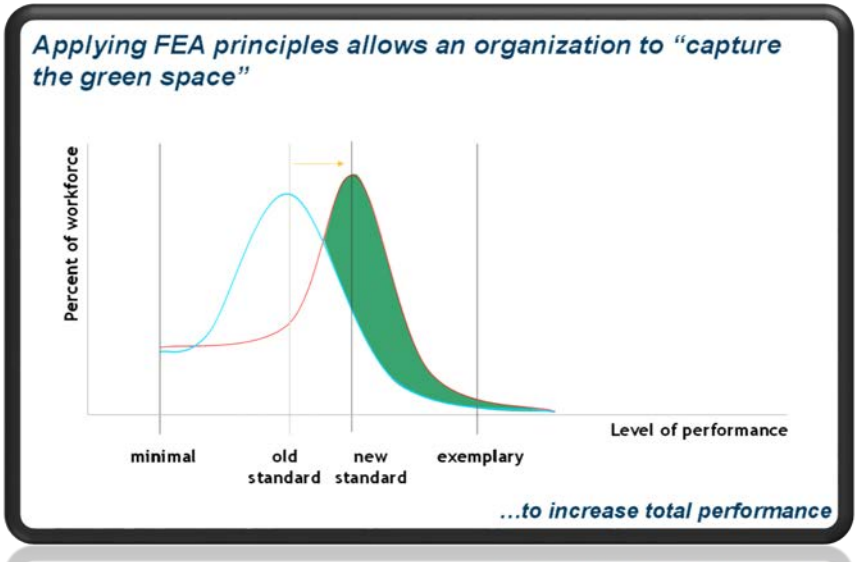
Overall Technical Approach

- Three objectives correspond to three program phases. Each objective had a dedicated task for clear go/no-go funding decisions.
- Phase 1 → Identify human factors' influence on in-the-ditch NDE inspector performance through intensive front-end analysis interview activity. Inspection techniques under investigation include:
  - Traditional → Magnetic Particle
  - Advanced → Ultrasonic (emphasis on Phased Array)
  - Upcoming → Acoustic Imaging; Eddy Current
- Phase 2 → Identify and validate high-impact human interventions to improve NDE inspector performance. Human interventions such as improved/modified training, personnel selection aids, etc. are to be identified within first quarter of Ph2, with implementation and validation to occur 12 – 24 months afterwards.
- Phase 3 → Identify and validate high-impact technology interventions to improve NDE inspector performance. To be run in parallel with the human interventions in Phase 2. Will examine how improved equipment could aid the reliability of existing techniques or how novel inspection technologies can make inspection inherently more reliable.

Phase I Summary

Human Performance Technology Front End Analysis

- Implement Human Performance Technology (HPT) Front-end Analysis (FEA) process of analyzing, designing, developing, implementing, and evaluating task activities to influence human behavior
  - HPT FEA methodology comprises observational and in-depth interview techniques to extract key task- and skill-related information from “accomplished performers”
  - Focuses on the outputs produced by top performers and builds upon these outputs to create strategies for disseminating expertise across the work population



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Phase I Summary

Study Population

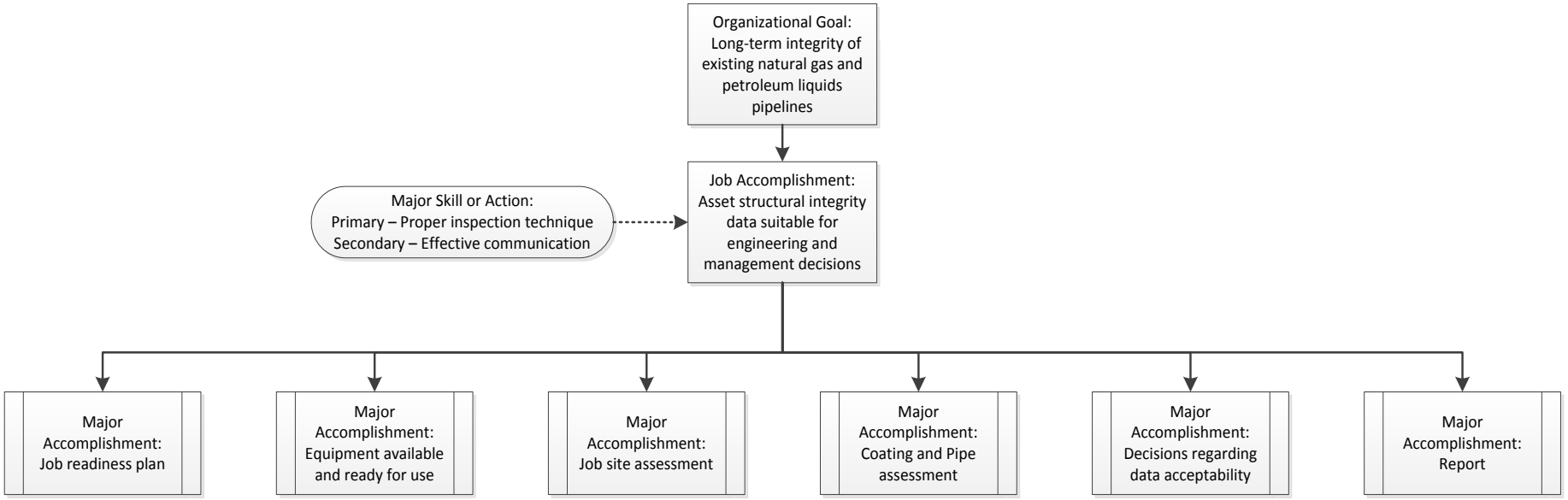
- 24 APs participated in interviews and task observations.
- APs were NDT Level II & III inspectors or technical specialists experienced with:
  - Techniques of interest (e.g., visual, liquid penetrant, magnetic particle, phased array, ultrasonic)
  - In-the-ditch and/or in-the-shop pipeline inspection
  - Refinery/above ground storage environments.

Partner Organization	No. of APs Interviewed
Mistras Group	20
Applus RTD	2
JENTEK	2

Demographic	Results (N=24)
Age	Average = 34 years old (range 20 – 49 years)
Years of Experience	Average = 7.5 years (range 1 – 16 years)
Education Level	
High School	10
Some College	3
College Degree	11*

Phase I Summary

Job and Major Accomplishment Hierarchy



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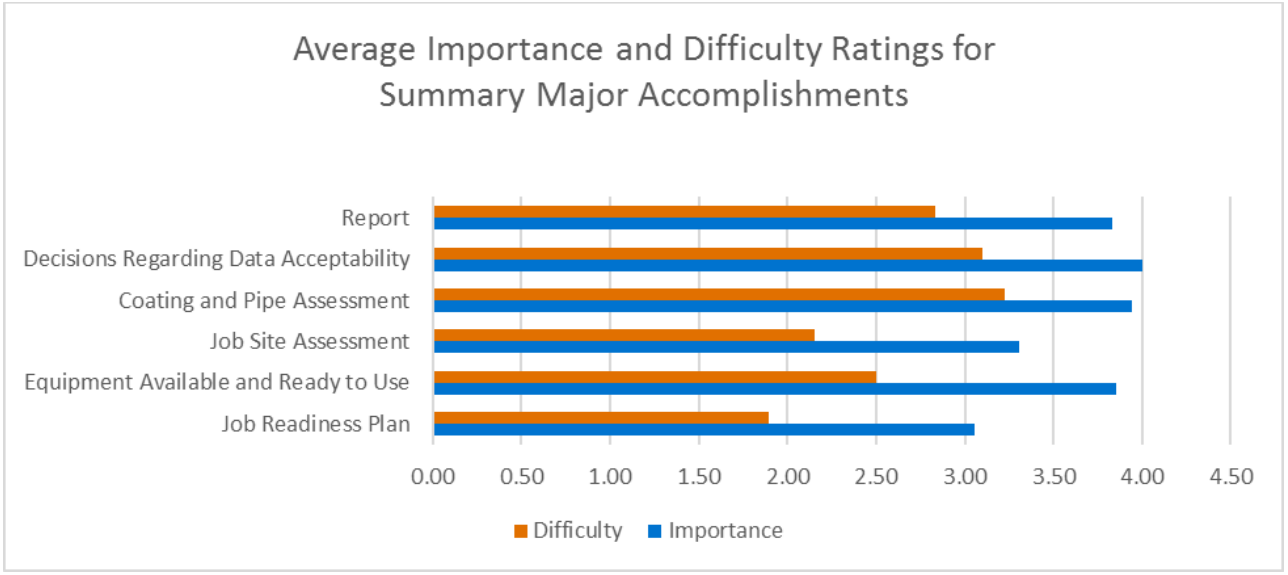
Phase I Summary

Importance and Difficulty Ratings for Major Accomplishments



- **Coating and Pipe Assessment:** Requires skill, experience, & patience to collect quality data. Extreme environments also impact inspection process
- **Decisions Regarding Data Acceptability:** Unrealistic to cover all scenarios in training. Requires contact with experienced inspectors and conversations with client representative

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Phase I Summary

Performance Shaping Factors

1. **Organizational**
   a) Organizational structure
   b) Actions by supervisors, coworkers
   c) Rewards, recognitions, benefits
   d) Team structure and communication
   e) Plant policies
   f) Feedback of results
   g) Threats (of failure, job loss)
2. **Operational**
   a) Procedures required
   b) Work methods
   c) Plant policies
   d) Training provided
3. **Work Task**
   a) Work hours/breaks
   b) Work methods
   c) Task speed
   d) Task load
   e) Task frequency & repetitiveness
4. **Technology**
   a) Availability & adequacy of equipment/tools
   b) Man-machine interface factors
5. **Physiological/Cognitive**
   a) Long- and short-term memory
   b) Calculating requirements
   c) Interpretation requirements
   d) Stress (onset and duration)
   e) Fatigue
   f) Pain or discomfort
6. **Personality**
   a) Intelligence
   b) Motivation and attitude
   c) Emotional state
   d) Group identification
7. **Environmental**
   a) Temperature
   b) Humidity
   c) Air quality
   d) Lighting
   e) Noise
   f) Vibration
   g) Degree of general cleanliness
   h) Movement constriction

Phase II and III Approach

Proposal Process

- Upon PHMSA approval to proceed into the next phases of the project in October 2016, Battelle issued a request for proposal (RFP) to each partnering organization (Mistras, Applus, and JENTEK)
  - The RFP sought proposals to implement and evaluate human or technology interventions that had the potential to improve inspection/inspector performance
- Each RFP outlined broad areas for potential interventions related to

  (1) improved client service provider communication

  (2) improved or new training resources

  (3) improved or new inspector work engagement resources

  (4) inspection technology improvements
- Bidders were invited to respond with interventions having the potential to improve inspection performance in any category of PSFs

Phase II and III Approach

Proposed interventions by partner, phase, and PSF addressed

Partner	Phase	Planned Intervention(s)	PSF Addressed
Mistras Group	2	• Additional employee training/Mentoring program • Improved Traveler Form • Wellness program/Online training webinars • Lessons learned webinars • Improved employee recognition program	PSF1c, d, f PSF2a, d PSF5d PSF6c
ApplusRDT	3	• Improvements to Applus Inverse Wave Field Extrapolation (IWEX) technology to improve identification and interpretation of inspection images	PSF2a PSF3d, f, i PSF4b PSF5b, c
JENTEK Sensors	3	• Improvements to JENTEK Stress Corrosion Cracking (SCC) mapping and crack depth analysis tool to improve speed and accuracy of inspection	PSF2a PSF3b, c, d, e, f, h, i PSF4b PSF5a, b, c, e, f PSF7h

Phase II Results (Mistras)

Phase II Results (Human Interventions)

Intervention Metrics

Quality	Quantity	Efficiency	Organization
Number of reports needing revision	Number of points inspected	Preparation time for an inspection	Time management onsite
Number or reworked points	Number of reports produced	Time to produce report	Ability to complete pre-inspection and post inspection tasks
Completeness of documentation (traveler, timesheet, permits, other)	Inspections performed per period	Time to complete inspection documentation	Ability to document activities
Calibration/Verification of system and materials for inspection			Ability to communicate status to the team or manager
Technical ability of method being performed			Ensure all proper equipment to perform job correctly/efficiently and is in good working order
Understanding of procedure and acceptance criteria			

Phase II Results (Human Interventions)

Additional Employee Training/Mentorship Program

- A 1-day “Pipeline 101” seminar presenting industry procedures and requirements for performing testing inspections was provided to participating inspectors

- Each inspector who completed the Pipeline 101 seminar was paired with a mentor and participated in an additional “Introduction to Pipeline Operation and Protocol” seminar

- Technician scorecard data were captured for participants in both the intervention and the control groups for a period of 6 months at one facility (Heath, OH) and 3 months at a second (Long Beach, CA)

Phase II Results (Human Interventions)

Additional Employee Training/Mentorship Program

- Results in the Heath facility (6 months of implementation) suggest an overall improvement in inspector performance
  - Prior to training/mentorship, the only category in which the mentee group was statistically significantly improved from the control group was the “arrived on-site on time and notified contact” evaluation element
  - After the training was delivered, however, the mentee group showed a statistically significant improvement in 11 of the 13 evaluation elements
- Results in the Long Beach Facility (3 months of implementation) showed little change in performance of the participating inspectors as compared to the control group

Phase II Results (Human Interventions)

Improved Traveler Form

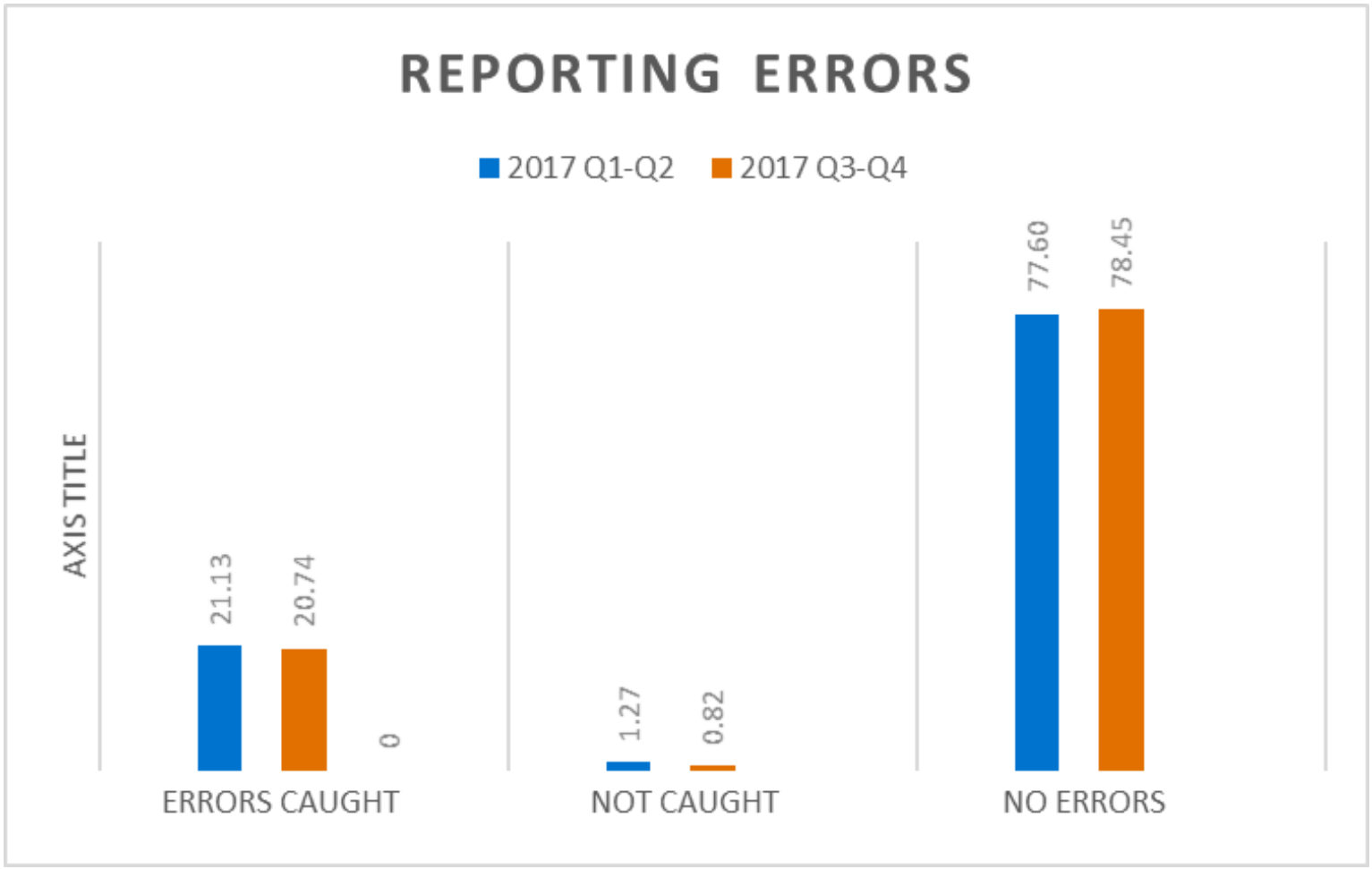
- Focused on simplifying the job traveler form and format to combine several existing fields into one field called “Project Description.”

- The format change was intended to direct the technician to verify the work procedure

- Modifications were intended to simplify the effort of filling-out the document by reducing the amount of detail needed

Phase II Results (Human Interventions)

Improved Traveler Form



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Phase II Results (Human Interventions)

Wellness Program/Online Training Seminars

- This intervention was intended to increase employee engagement and employee satisfaction
- The program involved the presentation of handouts, videos, podcasts, and webinars related to various topics (organizational skills, stress management, etc.)
- The effect of the online training webinars and wellness program was not apparent on inspector performance
- Mistras would likely need to invest significant time and resources to see a measurable impact on inspector performance

Phase II Results (Human Interventions)

Lessons Learned Webinar

- Inspectors attended two round table “lessons learned” webinars to share information about successful inspections and problem-solving strategies
  - Inspectors also discussed the decision-making process that helped lead to the overall outcome of the projects
- The webinars provided a forum for technicians to show their work and approach to others
- The effect of the lessons learned intervention was not apparent on inspector performance results

Phase II Results (Human Interventions)

Improved Employee Recognition Program

- Mistras currently utilizes a *Technician Evaluation Form* to gain customer feedback on inspector performance after the completion of a given job
  - Mistras intended to use the information from the *Technician Evaluation Form* to provide personal recognition to inspectors
- Due to lack of customer follow up by Mistras project management, this intervention was proposed but never fully implemented
- These findings indicate that some human-based interventions need to account for corporate bureaucracy and properly identify all stakeholders prior to implementation

Phase III Results (Technology Interventions)

Phase III Results (Applus RTD)

Inverse Wave Extrapolation

Description	Performance Shaping Factor(s) Addressed
Improved Automated Calibration	PSF3f PSF2b
Decision Tree for IWEX Inspection Procedure	PSF2a, b PSF5b, c
Automated Detection, Sizing, and Classification of Field Scan Image data	PSF2a PSF3e, f, i PSF5a, b

Phase III Results (Applus RTD)

Inverse Wave Extrapolation

Operator/Technician	Time to set up		Time to calibrate		Time to collect data/avg per sample		Time to analyze data		Time to report	
	Before	After	Before	After	Before	After	Before	After	Before	After
Technician 1	40min	20min	55min	15min	3min	3min	6hr	45min	1day	2min
Technician 2	1hr	25min	1hr	20min	3min	3min	2hr	30min	1day	2min
Technician 3	2hr	25min	2hr	18min	3min	3min	8hr	45min	1day	2min

Phase III Results (Jentek Sensors)

Modified Scanner and Inspection Procedure Using Eddy Current

Description	Performance Shaping Factor(s) Addressed
• The automated scanner only requires an initial setup (i.e. no additional positioning is required for each scan pass), which eliminates scan-to-scan variation. Whereas the manual scanner must be placed by hand for each scan pass, with the potential for positioning errors the can exceed ±0.1 inches.	PSF2a PSF3b, c, e, h, i
• The inspector does not have to mark the pipe.	PSF3c, d, f PSF5b, e
• Better spatial registration when generating scan images that are constructed from multiple scans. Registration errors with the manual system can cause cracks that span multiple scans to appear as two or more cracks in the scan images.	PSF4b PSF5b, c
• Communication and positioning errors often seen with the manual system (e.g. losing count of which scan is being performed, performing scans out of order by scanning one area more than once or skipping an area) are eliminated.	PSF2a PSF3e, f, i PSF5a
• Automated scanning results are much more reproducible.	PSF3e PSF5b
• It is easier (i.e. less work) to inspect the bottom of a pipe.	PSF5e, f PSF7h
• Appropriate scanning speed can be maintained with operators of any experience level and across all areas of the pipe – including the bottom where operator fatigue often plays a part in inconsistent scan rates.	PSF2a PSF3c, e, f, h, i PSF5e, f PSF7h

Phase III Results (Jentek Sensors)

Modified Scanner and Inspection Procedure Using Eddy Current

	Manual Scanner (minutes:seconds)	Automated Scanner (minutes:seconds)
Calibration Time	3:15	1:25
Cycles on the sensor connection	2 count	0 count
Scanner Setup	5:00	9:00
Pipe setup/marking	30:00	None
Calibration Verification	No	Yes
Scan Time	6:00	5:30
Example Crack Depth Data Processing Time	2:22	0:02
In-process Crack Depth Processing	Not possible due to data processing time	Yes
Reporting	Not automated/not performed	1:30 Automated

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It can be done

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