PHMSA Internal Quarterly Report

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Project Title: *Dual Purpose PIG for Cleaning and Internal Integrity Assessment for Hazardous Liquid Pipelines*

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1.1. Team Project Activity 1: Task 2: Development of the Attachment Set for Transferring the Cleaning Pigs into Dual-purpose Pigs

Since the last report, the design of Version 3 introduces two major upgrades to enhance the performance and durability of the pipeline inspection system. First, a dual-camera configuration angled at certain degrees to improve visualization of pipeline walls. This setup demonstrated superior image quality and anomaly detection during lab testing compared to previous single-camera versions. Second, the system transitions from threaded to bolted joints to resolve issues with cable twisting and mechanical wear. Bolted connections improve cable management and provide greater structural durability, making the system more robust for repeated field use.

Experiment Setup for Pressurized Water Condition

The pressurized test setup, similar to the configuration described in Report Q5, has been assembled to evaluate the Version 3 (V3) housing. Modifications were made to improve the system for this testing phase, including the addition of a 1-foot pipe section containing a known defect. This addition aims to assess the effectiveness of the V3 dual-camera system in capturing pipeline anomalies under pressurized conditions. The setup provides a more realistic environment to evaluate image quality and the anomaly detection capabilities of the updated configuration. The test assembly are presented in Figure 1.

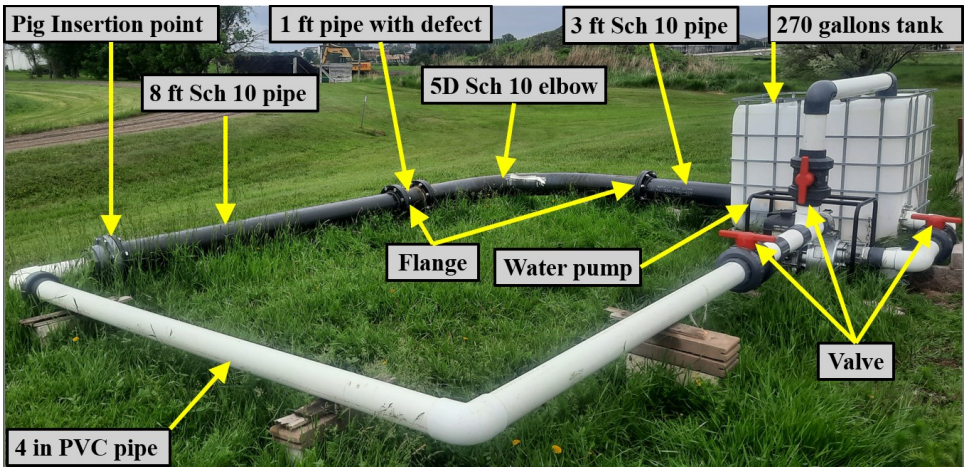

Figure 1. Complete laboratory set up of the pressurized water test.

1.2. Team Project Activity 2: Task 3: Machine Learning based Computer Vision Analysis for Pipeline Integrity Assessment of Hazardous Liquid Pipelines

This quarter, targeted efforts were made to improve the generalizability and accuracy of the crack detection module within the ensemble model. These efforts were aimed at addressing a key limitation of the previous version: reduced detection performance under complex pipeline conditions, particularly in wet environments.

Quantitative Performance of Key Modules and Analysis Workflow Optimization

In the previous reporting period, a preliminary workflow for the digital twin analysis framework was successfully established and validated. During the current quarter, efforts were directed toward refining this framework to enhance its precision and reliability. Quantitative assessment was conducted using standard evaluation metrics. The results demonstrate that the framework delivers high precision and

consistency, providing objective and accurate input data suitable for advanced digital twin analysis and subsequent integrity assessments. Furthermore, the algorithm supports various interactive prompts to guide the segmentation process.

In the geometric restoration stage, the objective is to reconstruct key geometric parameters of corrosion defects with high fidelity, focusing primarily on their planar shape and vertical depth. To correct distortion introduced by the curved pipeline surface during image capture, a perspective transformation algorithm is applied. This algorithm effectively eliminates warping and restores the true contour of the corrosion area. The pipeline inspection data was integrated with service life information to support predictive modeling of future pipeline conditions. The resulting data-driven digital model offers a robust foundation for conducting detailed pipeline integrity assessments and guiding maintenance strategies. By enhancing the objectivity and accuracy of corrosion risk evaluations, this approach contributes significantly to informed decision-making and long-term pipeline reliability.

1.3. Team Project Activity 3: Task 4: User-friendly Software Development for the Dual-purpose Pig and Economic Analysis

Function for Report Generation

A report generation feature has been implemented within the user interface, allowing users to automatically generate summary reports. This functionality serves as an alternative for users who prefer not to engage with interactive maps or video content.

Mobile App Development Progress

With the desktop version of the software largely complete, development efforts have shifted toward creating a mobile application to expand accessibility and usability. The initial phase of this transition focused on selecting appropriate technologies and frameworks, followed by the successful migration of three key user interfaces from the desktop environment.

1.4. Team Project Activity 4: Task 5 Validating Feasibility through Field Testing and Final Report

Field Testing of the Developed Dual-purpose Pig

According to recent communications, several testing proposals are currently under review but have not yet been scheduled. PRCI has committed to notifying the research team as soon as the testing timeline is finalized.

2. Project Schedule –

After thorough evaluation of the project progress and careful review of the items listed in section 2 of this report, Task 5.2 is delayed to due to the testing scheduling with the PRCI Technology Development Center for the field test. A no-cost extension request of 9 months has been submitted in middle May 2025 to ensure that we can include the field testing at PRCI Technology Development Center to validate the developed technologies in this project.