PHMSA Internal Quarterly Report

Date of Report: *8th Quarterly Report- September 18th, 2025*

Contract Number: *693JK323RA0001*

Prepared for: *PHMSA, Government Agency: DOT*

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

In the previous report, Version 3 was redesigned to incorporate a dual-camera configuration, with the goal of enhancing inspection performance by enabling the capture of more comprehensive and detailed video footage. In this reporting period, Version 3 was fabricated and successfully tested under pressurized water conditions. The test results demonstrate a significant enhancement in video capture quality, offering more comprehensive and detailed imagery of the pipeline interior compared to earlier versions. These improvements support the effectiveness of the upgraded design for in-line inspection applications.

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

1.2.1. Digital Twin-Based Evaluation of Pipeline Failure and Mechanical Performance (Task 3.3)

In the previous stage, a preliminary framework was established and validated based on segmentation accuracy and corrosion rate prediction. In this quarter, the focus shifted toward defining failure criteria, conducting mechanical analysis, and developing a graphical user interface (GUI) to support user interaction with the digital twin system. Therefore, this quarter delivered a complete B31G-based route from assumed corrosion growth to remaining-life prediction. The workflow links inspection inputs to finite-element stress results and converts them into two decision metrics: the time to failure and the safe-pressure boundary. The approach follows an established code, makes assumptions explicit, and returns reproducible outputs. For operators, this means clearer planning of inspection intervals, pressure de-rating, and repair windows, with evidence that can be traced from inputs to conclusions. The GUI packages the methodology in a user-friendly format, allowing results to be generated, reviewed quickly, and stored for future auditing purposes. It is also designed to interface seamlessly with the software developed in Task 4, enabling integrated analysis and visualization.

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

1.3.1. Data Flow Integration from ML and Digital Twin Groups to Web Deployment (Task 4.1 and 4.2)

During this quarter, several new features and enhancements were introduced to the existing web-based application. In parallel, the development of a mobile version of the platform is also underway, incorporating these improvements to enhance accessibility and usability on mobile devices. The following discussion presents detailed progress made, which applies to both the web and mobile interfaces.

Integration of Machine Learning and Digital Twin Data: Significant progress was made in integrating the data flow from the machine learning (ML) and digital twin models directly into the web deployment pipeline. This process begins with the data processing team analyzing pipeline inspection videos using ML models, which generate both 3D digital twin models and HTML files for corrosion size prediction.

Video Optimization for Web Streaming: To optimize videos for web playback, the original and ML-processed videos are subjected to web optimization using HandBrake, an open-source video transcoding

software that can transcode video files into a format optimized for web streaming playback. This step reduces video size dramatically while preserving quality, supporting progressive download capabilities, which facilitate smoother streaming and quicker load times. For instance, an original video of 2.7 GB (5 minutes in duration) can be compressed down to approximately 100 MB, significantly enhancing streaming performance.

Enhanced Visualization and Metadata Integration: Additionally, scripts leveraging the Google Maps API are employed to generate geographic thumbnails for the videos and extract screenshots of anomalies based on the provided Excel data. These images enrich the user interface, making anomaly identification and ready for report generation. Upon completion of this process, the web platform seamlessly incorporates the newly processed videos and corresponding analysis results, providing comprehensive, easy-to-navigate visualizations of pipeline conditions and anomalies.

User Interface Improvements for Digital-twin Models: The user interface was expanded this quarter to handle new data outputs from machine learning processes. The following components, which includes the video page and digital twin page, highlight the key additions and improvements made across the web application.

Video Page: A new feature has been added to the Video Details Page during the development process in this quarter to provide users with deeper insight into individual pipeline inspection videos and associated anomalies.

Digital Twin Page: A new Digital Twin Page was developed to allow users to view and interact with AI-generated representations of pipeline anomalies. Similar to the Video Details Page, users begin by selecting markers displayed on an interactive pipeline map, where each marker corresponds to a detected anomaly.

1.3.2. Technology Transfer (Task 4.3)

In the last report, a disclosure application was submitted to the NDSU Research Foundation. In this quarter, following the disclosure, a provisional patent application was filed (U.S. Patent Application No. 63/862,097). The additional time provided by the no-cost extension allows the team to complete the remaining technical work and compile supporting data and a comprehensive summary to strengthen the upcoming non-provisional patent filing.

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

1.4.1. Field Testing of the Developed Dual-purpose Pig (Task 5.1)

The research team has been actively coordinating with the PRCI Technology Development Center to arrange access to their Liquid Test Loop facility for field testing.

2. Project Schedule –

After thorough evaluation of the project progress and careful review of the items listed in section 2 of this report, we confirm that the project is currently on time, aligning with our projected timeline and milestones.