Autonomous Rail Surface Defect Detection

Exhibit D

Research Project Requirement Template

Recipient/Grant (Contract) Number: University of Texas Rio Grande Valley (UTRGV), University of South Carolina (UofSC)/Grant No. 69A3552348340

Center Name: University Transportation Center for Railway Safety (UTCRS)

Research Priority: Promoting Safety

Principal Investigator(s): Dr. Yu Qian (PI, UofSC), Dr. Nikolaos Vitzilaios (Co-PI, UofSC)

Project Partners: N/A

Research Project Funding: $51,810 (Federal), $26,741 (Non-Federal Cost Share)

Project Start and End Date: 06/01/2023 to 08/31/2024

Project Description: Rail surface defects are a major type of rail defect which progressively propagate with the accumulation of tonnage. It is reported that around 90% of railway accidents have rail surface defects, as either a direct or indirect factor. Historically, railway tracks are inspected by trained personnel. However, manual inspection has low efficiency and low accuracy because it is heavily dependent on the experience of the inspectors. Many automatic track inspection systems have been developed over time, usually mounted on an inspection car or a hi-rail vehicle with various types of sensors. Those systems are mainly based on laser, acoustic emission, LiDAR, ultrasonic wave, and ground penetration radar (GPR) technologies, which are effective in identifying rail internal defects, hollow timber ties, fouled ballast, and drainage problems. However, those systems have limited effectiveness in detecting and quantifying the rail surface defects. Visual inspection systems using the image processing algorithms and deep learning-based object detection methods have been introduced for the rail surface inspection over the past decade, which typically use images taken by cameras mounted on rail inspection vehicles. The models are usually developed based on images taken with a consistent angle and good contrast between the rail surface and the track. However, these approaches cannot handle arbitrary-oriented rail surface in images.

Recently, using UAV-based cameras has drawn great attention due to its convenience. More importantly, using UAVs to acquire rail surface images does not require track time and does not disturb normal train operations. The hardware cost is also much lower compared to the previous vehicle mounted systems. However, issues associated with consistency of image quality of track due to environmental and drone operations are the current barriers to taking full advantage of the UAV benefits. The objective of the proposed research is to develop an automatic rail surface defect detection system based on machine learning and convolution networks that is suitable for UAV implementation. This research addresses questions pertaining to the consistency and quality of images acquired by UAV-based cameras during flight and will focus on mitigating effects of: (i) vibrations and other operating/environmental conditions, (ii) variations of track width, location, and orientation, and (iii) shadows, rail reflectivity, and sunlight intensity. Furthermore, the proposed system will be integrated to the proposed Intelligent Aerial Drones for Traversability Assessment of Railroad Tracks project.

US DOT Priorities: This project aligns with the following USDOT strategic goals, as established in the USDOT Strategic Plan for FY2022-FY2026: **(a) Safety:** Enhanced rail inspection practices can improve rail operation safety and potentially reduce the incidence of train derailments and related accidents, ensuring safer travel for

both passengers and freight, which in turn boosts public confidence in rail transportation. **(b) Economic Strength:** Efficient track inspections can help detect maintenance needs earlier, thereby reducing costly repairs and minimizing service disruptions, leading to more reliable freight supply chains and passenger services.

Outputs: The expected products include:

a. A tailored image training library for future track inspection model development.
b. An Artificial Intelligence (AI) model that is customized to detect and quantify rail head surface defects from images taken by drones.
c. A prototype integrated edge computing system.
d. A report including performance validation results compared with other state-of-the-art models on rail head surface defect detection and quantification.
e. One or more conference or journal publications

Outcomes/Impacts: The broader impact of this project addressing the rail surface defect inspection challenge is multifaceted, significantly influencing public safety and economic efficiency. Enhanced rail inspection practices can improve rail operation safety and potentially reduce the incidence of train derailments and related accidents, ensuring safer travel for both passengers and freight, which in turn boosts public confidence in rail transportation. Economically, efficient track inspections can help detect maintenance needs earlier, thereby reducing costly repairs and minimizing service disruptions, leading to more reliable freight supply chains and passenger services.

Final Research Report: Upon completion of the project, a URL link to the final report will be provided.