MarTREC Tier 1 UTC Project Request Form
MarTREC Project 7032
Completed form cannot exceed 2 pages

Submission Date *(select from calendar)*: 5/1/2026

Lead Recipient/Grant Number: University of Arkansas / 69A3552348331

Principal Investigator Institution *(select drop down)*: Jackson State University

Center Name: Maritime Transportation Research and Education Center

Research Priority: Preserving the Existing Transportation System

Principal Investigator(s) with ORCID(s) and Contact Information: *Sadik Khan, Ph.D., P.E., Professor, https://orcid.org/0000-0002-0150-6105; Department of Civil & Environmental Engineering, Jackson State University, 1400 J. R. Lynch St., Jackson, MS, 39217, sadik.khan@jsums.edu, 601-979-6373*

Project Partners: *Mississippi Department of Transportation*

Project Type (*select drop down*): Technology Transfer

Project Research Topic Type (*select drop down*): Resilient Maritime Infrastructure

Transportation Modes Involved (*check all that apply*): ☒Waterway ☒Road ☐Rail ☐Pipeline ☐Other

Total Funding Requested ($): *$82,500* | **Federal Funding Requested ($):** *$55,000*

% of Total for Tech Transfer (%): *% for TT here* | **Non-Federal Match Requested ($):** *$27,500*

Project Start and End Dates (*month/day/year to month/day/year*): 07/01/2026-06/30/2027

Project Title: Physics Informed Neural Network (PINN) enabled Predictive Resilience Framework for Maritime and Multimodal Levee Infrastructure.

Project Abstract (Brief Description): The performance and resilience of levee systems are governed by complex hydro-mechanical interactions influenced by transient seepage, soil stratification, and environmental loading. Conventional monitoring approaches, while effective in capturing field conditions, lack predictive capability and often fail to integrate subsurface characterization with real-time system response. This study proposes a Physics-Informed Neural Network (PINN) enabled predictive resilience framework for maritime and multimodal levee infrastructure, integrating multi-source sensing, geophysical imaging, and physics-based modeling. The framework leverages IoT based sensor networks, including IMU derived tilt and displacement measurements, and environmental variables such as rainfall, temperature, and soil moisture. To enhance subsurface characterization, Electrical Resistivity Imaging (ERI) and Multichannel Analysis of Surface Waves (MASW) are incorporated to capture spatial variability in moisture distribution, stiffness profiles, and potential seepage zones. These datasets are fused with UAV based LiDAR point cloud models to develop high-resolution, temporal geospatial conditional representations of levee geometry and deformation. The integrated dataset is utilized to calibrate finite element method (FEM) based seepage and stability models, enabling accurate representation of coupled hydro-mechanical behavior. The PINN architecture embeds governing equations of transient flow and unsaturated soil mechanics into the learning process, allowing physically consistent prediction of pore pressure, volumetric moisture content, and deformation fields. A hybrid physics-guided, data-driven digital twin will be developed to continuously assimilate field and geophysical data, providing real-time predictions and identifying anomaly thresholds indicative of instability. The proposed framework advances geotechnical asset management by enabling predictive failure assessment, risk-informed decision-making, and proactive maintenance strategies, thereby enhancing the resilience of critical maritime and multimodal infrastructure systems under extreme environmental conditions.

USDOT Priorities: Section left blank until USDOT’s new priorities and RD&T strategic goals are available in Spring 2026

Outputs (results of the work performed): *The proposed project will develop a comprehensive Physics-Informed Neural Network (PINN)-based predictive framework for levee systems by sequentially integrating multi-source data, physics-based modeling, and digital twin technologies. Initially, a multi-sensor data acquisition and fusion pipeline will be established, incorporating IoT-based IMU measurements (tilt, acceleration, and displacement), along with geophysical datasets from ERI and MASW, and high-resolution UAV-based LiDAR data. These datasets will be used to characterize both surface and subsurface conditions of levee systems. Subsequently, the integrated data will be utilized to calibrate finite element method (FEM)-based seepage and stability models, enabling accurate representation of coupled hydro-mechanical behavior under varying environmental conditions. Building upon this, a PINN architecture embedding governing equations of transient seepage and unsaturated soil mechanics will be developed to predict key response variables such as pore pressure, volumetric moisture content, and deformation. The trained model will then be incorporated into a digital twin framework, allowing continuous data assimilation, real-time state updating, anomaly detection, and predictive simulation. Finally, the project will generate high-resolution, multi-modal datasets and predictive analytics tools, which will be documented through technical reports, peer-reviewed journal publications, and conference presentations.*

Outcomes/Impacts: *The proposed research will advance geotechnical asset management by transitioning from traditional reactive monitoring to a* ***proactive****, risk-informed decision-making framework for levee systems. By integrating physics-informed AI with multi-source sensing and geophysical characterization, the project will enable early detection of instability, seepage anomalies, and deformation, significantly reducing the likelihood of catastrophic failures. The development of a digital twin system will enhance the resilience and reliability of maritime and multimodal infrastructure under variable and extreme* ***climatic*** *loading conditions. Additionally, the use of scalable, low-cost IoT-based sensing combined with advanced analytics will improve cost-efficiency and accessibility of monitoring systems. The project will also contribute to a deeper understanding of coupled hydro-mechanical behavior in levee systems, supporting more accurate performance assessment and maintenance planning. These advancements will strengthen infrastructure safety, minimize service disruptions, and support national economic stability and supply chain continuity. Furthermore, the research will foster workforce development and knowledge transfer by training students and professionals in emerging technologies such as physics-informed machine learning, digital twins, and integrated geotechnical monitoring systems.*

Technology Transfer Activities: *The outcomes of this research will be disseminated through a comprehensive technology transfer strategy aimed at both professional and educational audiences. Findings will be published in peer-reviewed journals (e.g., Transportation Research Record, Transportation Geotechnics, ASCE journals) and presented at national conferences. A dedicated Geo-Lesson webinar series will be utilized to translate research findings into accessible knowledge for students, practitioners, and industry professionals. These monthly sessions will feature topics such as geophysical monitoring (ERI, MASW), LiDAR-based mapping, and physics-informed AI modeling, promoting practical understanding and adoption of advanced technologies. Additionally, research outputs will be shared through digital platforms and social media channels to broaden outreach and engagement. A K–12 educational module will be developed to introduce fundamental concepts of infrastructure monitoring, sensor technologies, and AI-based prediction through interactive demonstrations and simplified case studies, supporting early STEM exposure and workforce development. Workshops, short training sessions, and collaborative engagements with agencies (e.g., MDOT, USACE) will further facilitate the translation of research into practice, ensuring adoption of predictive monitoring frameworks for resilient infrastructure management.*

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

Project Deliverables: ☒ PI agrees to submit all deliverables within 4 weeks of the project end date.

Data Management Plan (DMP): ☒ PI has reviewed and agrees to adhere to MarTREC DMP. Proposed project DMP must be submitted with this form.

USDOT Approval Date: 7.20.26