Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)

University Transportation Center (UTC)

Condition Assessment of Transportation Infrastructure using Space-Borne Sensors and AI
Project No.: UI-25-RP-02

Quarterly Progress Report
For the performance period ending [March 31st, 2026]

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Collaborators / Partners:
- None

Submitted to:
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TRANS-IPIC Quarterly Progress Report:

Project Description:

1. Research Plan - Statement of Problem

This project addresses the need for more effective and continuous bridge condition assessment as transportation infrastructure continues to age under traffic loading, environmental exposure, and material deterioration. It proposes using space-borne sensing data to monitor bridge movements over large geographic regions in a scalable and cost-effective manner. The framework integrates Multi-Temporal Interferometric Synthetic Aperture Radar (MT-InSAR), environmental data, and structural interpretation to extract millimeter-scale displacement behavior from freely available satellite observations. The overall goal is to support bridge condition assessment at both the individual bridge and network levels.

2. Research Plan - Summary of Project Activities

The research plan for this project includes three primary tasks:

Task 1: Satellite Data Collection and Analysis:
Task 1 is devoted to acquiring and analyzing multitemporal InSAR data to evaluate the feasibility of satellite-based bridge monitoring across different geographic and climatic regions of the United States. The study considers medium- to long-span steel and precast concrete bridges and combines meteorological information with long-term satellite observations of surface displacement.

Task 2: Bridge Structural Assessment using MT-InSAR and Climate Data:
Task 2 seeks to interpret the MT-InSAR displacement time histories in terms of bridge behavior and structural condition. The observed movements will be related to thermal effects, traffic loads, and possible deterioration. Representative three-dimensional finite element models will be developed and compared with the satellite-based displacement results to identify abnormal response patterns and potential structural weaknesses.

Task 3: Automation of Bridge Analysis using Machine Learning:
Task 3 extends the framework by automating the interpretation of bridge displacement behavior using machine learning. The MT-InSAR time-series data will be organized into a structured dataset for unsupervised machine learning analysis.

Project Progress:

3. Progress for each research task

Task 1: Satellite Data Collection and Analysis [80 % completed to date]
During this quarter, the main effort focused on demonstrating the applicability of Multi-Temporal Interferometric Synthetic Aperture Radar (MT-InSAR) for bridge deformation monitoring using spaceborne data. Persistent Scatterer Interferometry was implemented in SARPROZ to identify stable scatterer points and extract reliable displacement time histories from satellite observations. Two representative bridge case studies were completed to evaluate the capability of MT-InSAR in capturing both damage-related deformation and thermal bridge response.

The first case study focused on the Memphis Hernando De Soto Bridge, where a fracture had been identified in a critical bottom steel tie girder (**Figure 1**). The MT-InSAR results showed that the largest displacement occurred in the region containing the fracture, and the movement in that region was at least 63% greater than the maximum deformation of any other bridge region (**Figure 2**). The results also showed greater movement on the south side of the bridge than on the north side, indicating a deformation pattern consistent with the known damage location.

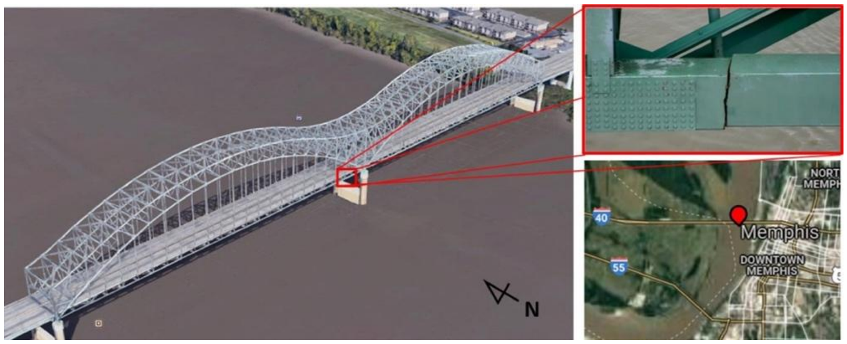
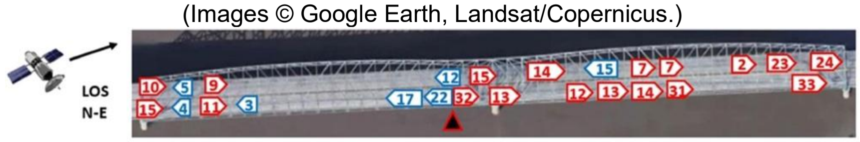


Figure 1. Image of Hernando De Soto Bridge in Memphis, TN, showing fracture of the bottom steel tie girder. (Images © Google Earth, Landsat/Copernicus.)



Bridge Region	West Span		East Span	
North	15	27	29	24
South	19	54	31	33

▲ Fracture Location   # Away from Satellite   # Towards Satellite

Figure 2. Final averaged cumulative bridge displacement values throughout the entire monitoring period (in millimeters). (Base image © Google Earth, Landsat/Copernicus.)

The second case study focused on the IL-251 Bridge to examine seasonal thermal deformation behavior (**Figure 3**). The displacement histories showed a clear and repeatable thermal trend, with displacement shifting in the negative direction during warmer months and in the positive direction during colder months (**Figure 4**). These trends were consistent across both monitoring periods and showed no significant abnormalities, indicating stable bridge behavior and demonstrating the reliability of MT-InSAR for tracking long-term environmental response.

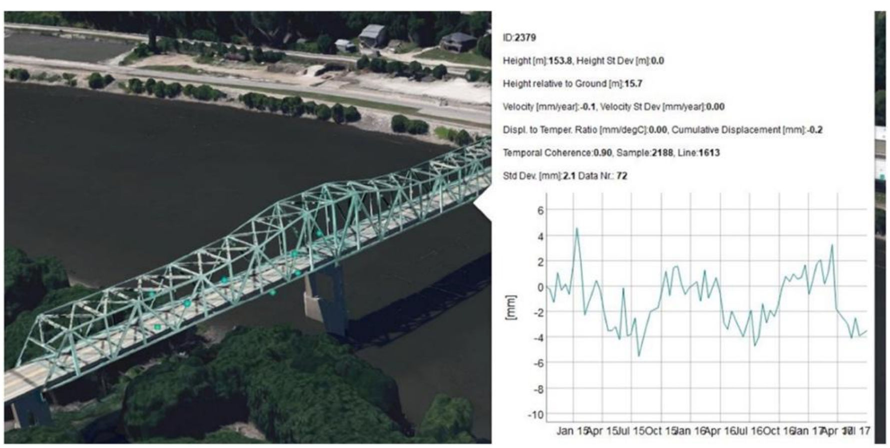


Figure 3. Thermal deformation trend of the scatterer at midspan of IL-251 Bridge. (Base image © Google Earth, Image © 2025 Airbus, Image © 2025 CNES/Airbus.)

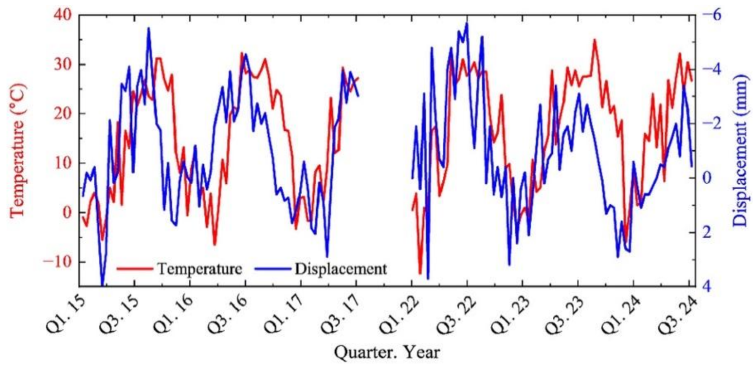


Figure 4. Plot shows the correlation of displacement with the temperature of the scatterer on the bridge during both acquisition periods.

Overall, the work completed under Task 1 demonstrated that MT-InSAR can effectively capture both localized damage-related deformation and routine thermal deformation in bridge structures. These results established the technical foundation for the project and confirmed the feasibility of using satellite-based monitoring for bridge health assessment.

Task 2: Bridge Structural Assessment using MT-InSAR and Climate Data [5%completed to date]
The bridge-response patterns identified in Task 1 provide the initial basis for the structural assessment work in Task 2. In particular, the Memphis Hernando De Soto Bridge case showed localized deformation consistent with a known damage location, while the IL-251 Bridge case showed stable thermal deformation behavior over two monitoring periods. These results support the next phase of the project, in which MT-InSAR displacement histories will be interpreted further in relation to bridge behavior and condition.

Task 3: Automation of Bridge Analysis using Machine Learning [0%completed to date]
Nothing to report.

4. Percent of research project completed
Total project completed through the end of this quarter = [25 % completed to the date]

5. Expected progress for next quarter
The MT-InSAR analysis in Task 1 will continue and will be expanded to a broader set of bridges using Sentinel-1A data, temperature records, and estimated traffic information. This work will provide more complete displacement time histories for interpreting bridge deformation behavior.

For Task 2, the next step will be to interpret the MT-InSAR displacement histories in relation to bridge behavior and condition. The observed deformation patterns will be examined together with bridge characteristics and inspection-based condition information to identify whether they reflect expected behavior or possible abnormal response.

6. Educational outreach and workforce development
Nothing to report yet.

7. Technology Transfer
Nothing to report yet.

Research Contribution:
8. Papers that include TRANS-IPIC UTC in the acknowledgments section:
B. Andrawes, I.A. Colombani, A.Q. Khan, Using Spaceborne Sensors to Evaluate the Performance of Civil Infrastructure Systems, Journal of Performance of Constructed Facilities 39 (2025) 06025004. https://doi.org/10.1061/JPCFEV.CFENG-5114.

9. Presentations and Posters of TRANS-IPIC funded research:

Nothing to report yet.

10. Please list any other events or activities that highlights the work of TRANS-IPIC occurring at your university (please include any pictures or figures you may have). Similarly, please list any references to TRANS-IPIC in the news or interviews from your research.

Nothing to report yet.

Appendix 1: Research Activities, leadership, and awards (cumulative, since the start of the project)

A. Number of presentations at academic and industry conferences and workshops of UTC findings
   - No. = 1

B. Number of peer-reviewed publications submitted based on outcomes of UTC funded projects
   - No. =

C. Number of peer-reviewed journal articles published by faculty.
   - No. = 1

D. Number of peer-reviewed conference papers published by faculty.
   - No. =

E. Number of TRANS-IPIC sponsored thesis or dissertations at the MS and PhD levels.
   - No. MS thesis =
   - No. PhD dissertations =
   - No. citations of each of the above =

F. Number of research tools (lab equipment, models, software, test processes, etc.) developed as part of TRANS-IPIC sponsored research
   - Research Tool #1 (Name, description, and link to tool) =

G. Number of transportation-related professional and service organization committees that TRANS-IPIC faculty researchers participate in or lead.
   - Professional societies
     - No. participated in = 7
     - No. lead =
   - Advisory committees (No. participated in & No. led)
     - No. participated in =
     - No. lead =
   - Conference Organizing Committees (No. participated in & No. led)
     - No. participated in = 1
     - No. lead =
   - Editorial board of journals (No. participated in & No. led)
     - No. participated in = 1
     - No. lead =
   - TRB committees (No. participated in & No. led)
     - No. participated in = 1
     - No. lead =

H. Number of relevant awards received during the grant year
   - No. awards received =

I. Number of transportation related classes developed or modified as a result of TRANS-IPIC funding.
   - No. Undergraduate =
   - No. Graduate = 2

J. Number of internships and full-time positions secured in the industry and government during the grant year.
   - No. of internships =
   - No. of full-time positions = 1

References:

B. Andrawes, I.A. Colombani, A.Q. Khan, Using Spaceborne Sensors to Evaluate the Performance of Civil Infrastructure Systems, Journal of Performance of Constructed Facilities 39 (2025) 06025004. https://doi.org/10.1061/JPCFEV.CFENG-5114.