



Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)

University Transportation Center (UTC)

Condition Assessment of Transportation Infrastructure
using Space-Borne Sensors and AI
Project Number UI-25-RP-02

Quarterly Progress Report
For the performance period ending [June 30th, 2026]

Submitted by:

PI: Bassem Andrawes, andrawes@illinois.edu
Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign

Collaborators / Partners:

- None

Submitted to:

TRANS-IPIC UTC
University of Illinois Urbana-Champaign
Urbana, IL

TRANS-IPIC Quarterly Progress Report:

Project Description:

1. Research Plan - Statement of Problem

The 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 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 (Tasks)

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. MT-InSAR analysis is performed using C-band satellite data, while persistent scatterer points are identified and filtered in SARPROZ to ensure reliable deformation measurements. This task establishes the satellite-data and deformation-analysis foundation for detecting both damage-related deformation and routine thermal bridge response.

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 analysis, and methods such as K-means clustering and Isolation Forest will be used to group similar bridge responses and detect anomalous displacement patterns.

Project Progress:

3. Progress for each research task

Task 1: Satellite Data Collection and Analysis [100 % completed to date]

Task 1 was completed during this quarter. The satellite-data workflow established in the previous quarter was finalized and converted into analysis-ready outputs for structural interpretation. The completed products include screened persistent scatterer (PS) locations, line-of-sight (LOS) displacement histories, bridge metadata, and acquisition-date temperature and traffic information needed for Task 2.

The final Task 1 quality-control effort focused on retaining PS points with stable amplitude, coherence, and temporal behavior, while excluding points that did not reliably represent bridge response. These outputs provide the completed foundation for finite-element comparison, thermal-response interpretation, and future network-level anomaly detection. No additional case-study repetition is included here; the Q2 work focused on closing Task 1 and transferring its results into the structural assessment workflow.

Task 2: Bridge Structural Assessment using MT-InSAR and Climate Data [75% completed to date]

The primary effort in this quarter was the structural interpretation of MT-InSAR displacements through finite-element analysis (FEA). The IL-251 Bridge was used as the representative bridge because it provides stable PS coverage, available structural information, and a clear seasonal thermal response. A three-dimensional SAP2000 model was developed using bridge geometry and support conditions obtained from structural records; the completed model is shown in **Figure 1**. Steel truss members, stringers, floor beams, and bracing were modeled as frame elements, while the concrete deck was modeled using shell elements. The end pot bearings were represented by translational springs based on auxiliary ABAQUS bearing simulations. The analysis was based on 223 Sentinel-1A acquisitions covering three monitoring intervals from 2015 to 2024.

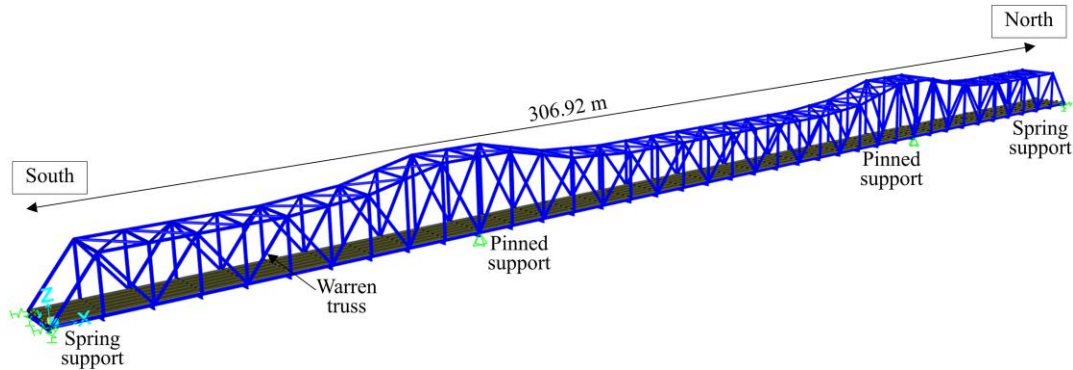


Figure 1. Three-dimensional finite-element model of the IL-251 Bridge used for thermal-response simulation.

The finite-element model was validated using bridge deflection information from inspection and structural records. The model predicted a midspan dead-load deflection of approximately 147 mm, which closely matched the reported value of approximately 149 mm. This agreement increased confidence in the model stiffness, boundary conditions, and suitability for thermal-response analysis.

The validated model was then used to conduct thermal analyses corresponding to the Sentinel-1A acquisition dates. **Figure 2** summarizes the simulated bridge response under representative warm and cold temperature cases. The finite-element displacement components were converted into satellite line-of-sight (LOS) displacement so that the numerical results could be compared directly with the MT-InSAR measurements. The comparison in **Figure 3** shows that both methods captured the same seasonal response, with negative LOS displacement during warm periods and positive LOS displacement during colder periods. The response remained within a consistent range of approximately -6 mm in summer and +4 mm in winter, with no evident long-term drift. This supports the interpretation that the IL-251 Bridge exhibited stable thermal behavior during the monitoring period.

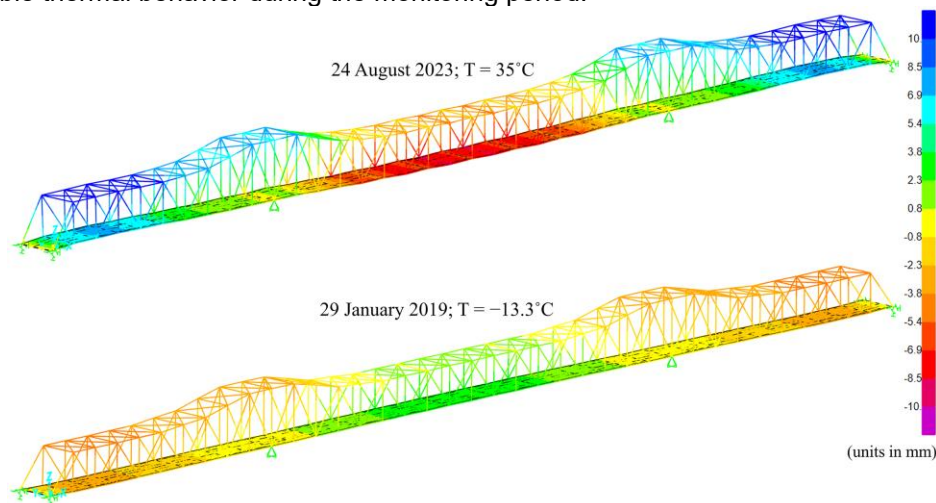


Figure 2. FEA-predicted vertical displacement patterns for representative summer and winter temperature cases.

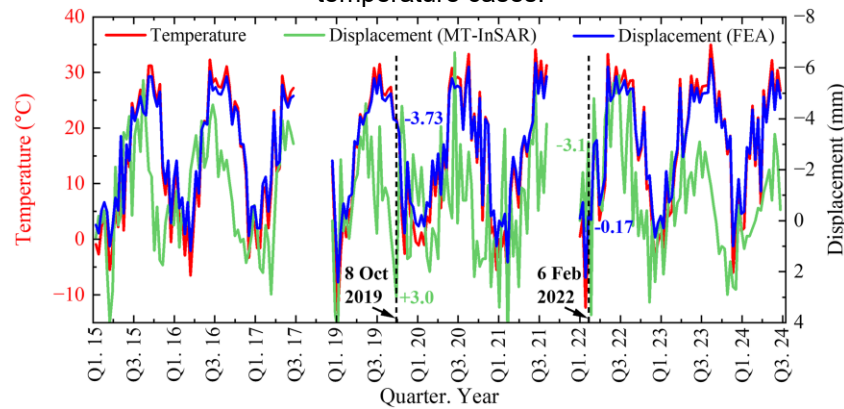


Figure 3. Comparison between MT-InSAR-derived LOS displacements and FEA-predicted LOS displacements at the IL-251 Bridge midspan.

Because MT-InSAR records the total field response of the bridge, thermal-only FEA did not explain all measurement differences. Therefore, traffic loading was introduced as an operational variable. Estimated live-load cases were added to the thermal model, and the combined thermal and live-load simulations reduced representative discrepancies between MT-InSAR and FEA, as shown in **Figure 4**. MT-InSAR observations were classified into normal and peak traffic conditions, and this classification improved the displacement-temperature correlation, with R values reaching up to 0.89 in the best subset. Additional FEA cases combining thermal loading with estimated live loads also explained selected residual differences between FEA and MT-InSAR results. For example, combined-load FEA produced LOS displacements that closely matched satellite measurements for cases with large thermal-only discrepancies. These findings confirm that thermal effects are the dominant driver of long-term seasonal movement, while estimated traffic effects can partly explain individual deviations from the thermal trend.

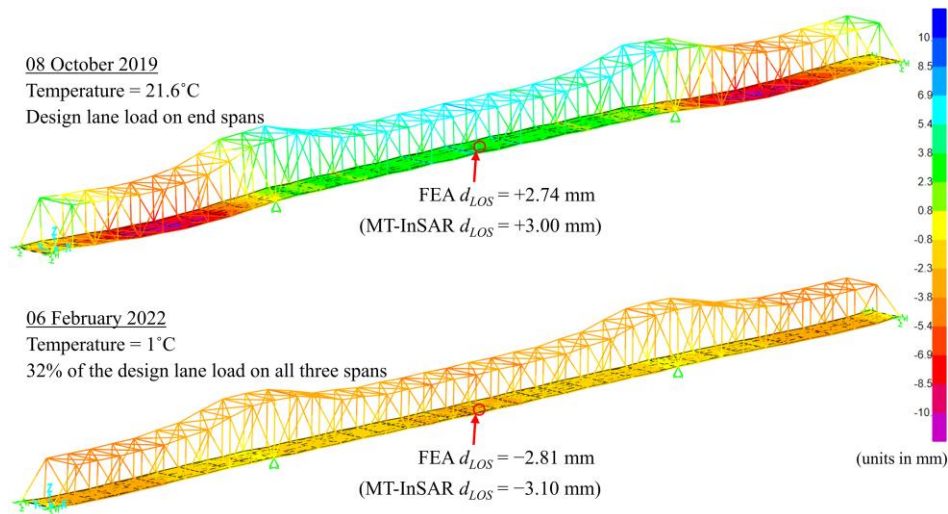


Figure 4. FEA-predicted LOS displacements at midspan under combined thermal and estimated live-load conditions.

Overall, Task 2 has advanced substantially from qualitative interpretation to physically based structural assessment. The remaining work will focus on extending this interpretation to additional bridge types, formalizing criteria for expected versus abnormal response, and preparing the Task 2 results for integration with the automated screening framework in Task 3.

Task 3: Automation of Bridge Analysis using Machine Learning [0% completed to date]

Nothing to report yet.

4. Percent of research project completed

Total project completed through the end of this quarter = [60% completed to date]

5. Expected progress for next quarter

The remaining Task 2 work will be completed by extending the finite-element interpretation from the representative bridge to additional bridge cases and by defining practical indicators for distinguishing expected thermal and traffic-related responses from potentially abnormal structural behavior.

Task 3 will begin in the next quarter. The structured MT-InSAR displacement dataset will be used to apply unsupervised machine learning methods, including K-means clustering and Isolation Forest anomaly detection. The analysis will focus on grouping bridges with similar displacement behavior, identifying outlier bridges, and validating flagged cases using bridge inspection information and structural context.

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>.

A.Q. Khan, B. Andrawes, MT-InSAR Assessment of Bridge Monitoring Using Finite-Element Analysis under Thermal and Traffic Loads, Journal of Bridge Engineering 31 (2026) 04026031. <https://doi.org/10.1061/JBENF2.BEENG-7850>.

A.Q. Khan, B. Andrawes, Multi-bridge deformation monitoring and abnormal behaviour detection using MT-InSAR and machine learning, Structure and Infrastructure Engineering (2025) 1–16. <https://doi.org/10.1080/15732479.2025.2601114>.

Bassem Andrawes “Regional-scale monitoring of bridge performance using MT-InSAR and ML” 13th International Conference on Bridge Maintenance, Safety, and Management. IABMAS 2026, Orlando, FL, July 7-10, 2026.

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

Bassem Andrawes “Multi-Bridge Deformation Monitoring and Abnormal Behavior Detection using MT-InSAR and Machine Learning” 2026 Transportation Research Board Annual Meeting, Washington DC, January 11-15, 2026.

Bassem Andrawes “Regional-scale monitoring of bridge performance using MT-InSAR and ML” 13th International Conference on Bridge Maintenance, Safety, and Management. IABMAS 2026, Orlando, FL, July 7-10, 2026.

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) =
 - Research Tool #2 (Name, description, and link to tool) =
 - Research Tool #3 (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 = 2
 - 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>.

A.Q. Khan, B. Andrawes, *MT-InSAR Assessment of Bridge Monitoring Using Finite-Element Analysis under Thermal and Traffic Loads*, *Journal of Bridge Engineering* 31 (2026) 04026031. <https://doi.org/10.1061/JBENF2.BEENG-7850>.

A.Q. Khan, B. Andrawes, *Multi-bridge deformation monitoring and abnormal behaviour detection using MT-InSAR and machine learning*, *Structure and Infrastructure Engineering* (2025) 1–16. <https://doi.org/10.1080/15732479.2025.2601114>.