10th Program Progress Performance Report
for
National University Rail (NURail) Center:
Tier 1 University Transportation Center

National University Rail Center - NURail
US DOT OST-R Tier 1 University Transportation Center

Submitted to
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

Grant Period:
30 September 2013 through 30 September 2020

Reporting Period:
1 April 2018 through 30 September 2018

Submitted:
09 November 2018

Submitted to:

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Grant: DTRT13-G-UTC52
Duns: 04-154-4081
EIN: 37-6000511

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1. Accomplishments

The NURail Center is a rail-focused seven-university consortium led by the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign (UIUC). NURail's principal goals are to achieve a set of Research, Education, Technology Transfer Collaboration and Leadership objectives that not only fulfill center objectives, but support and assist achievement of goals beyond the consortium members. These include the rail industry, AAR and FRA research and workforce development goals. They also include working with other colleges and universities, both domestically and internationally, to advance academic rail education and research quality and quantity.

a. What was accomplished under these goals? (major activities; specific objectives; significant results (positive and negative); key outcomes)

NURail Consortium

- The NURail Center Annual Meeting was held in Chattanooga, TN on August 1-3, 2018 in conjunction with SummeRail 2018, which is sponsored by the Freight Rail Transportation Committee (AR040) of TRB.
- Consortium partners wrote four final reports in the past six months and three project proposals.
- Over 25 students from NURail partner schools attended the AREMA Conference on September 16 – 19, 2018 in Chicago, IL. In addition to competing in the student quiz bowl and attending the poster competition, students also had the opportunity to network with people and companies involved in the rail industry.
- NURail partner universities had a strong showing at the Joint Rail Conference (JRC) held on April 18 - 21, 2018 in Pittsburgh, PA. NURail universities were responsible for 38 technical papers.

University of Illinois Urbana-Champaign (UIUC)

- Two Hay Seminars were held in the past six months. They reached over 100 people on campus and over 65 people online.

Date	Name	Company	Presentation Title
April 27, 2018	Mike Franke	Amtrak (retired)	Career Experiences of a U of I Railroad Engineering Graduate (On campus participation only)
September 28, 2018	Tila-Riikka Loponen and Riku Varis	Tampere University of Technology, Finland	Railway Track Superstructure Research at Tampere University of Technology, Finland

- For the fifth straight year, the UIUC AREMA Student Chapter won first place in the AREMA conference quiz bowl.
- NURail Center Director, Chris Barkan, attended the Council of University Transportation Centers meeting in Minneapolis, MN from June 4-6, 2018.

- *Optimal Planning of Rail Grinding Activities in Large-scale Networks* project was completed.
- *Schedule Flexibility and Railway Line Capacity (Line Capacity)* - Simulations and analysis are complete. Two journal papers have been accepted for publication and are currently in press.
- *Capacity of Hump Classification Yards (Yard Capacity)* - Simulations with the Belt Railway of Chicago hump yard model have been completed and analysis of the results has started. A preliminary dissertation document was completed and approved by the doctoral committee advising the student conducting this research.
- *Intermodal Terminal Capacity Factor Interactions (Terminal Capacity)* - AnyLogic sub-models of various intermodal terminal operating components (including a transloading model, switching logic and roadway/parking network) have been integrated into a single terminal model to support ongoing capacity experiments.
- *Shared Rail Corridor Adjacent Track Accident Risk Analysis – Phase 2 (Shared Corridor)* - Refined train presence model developed to provide a more accurate estimation of train collision probability on adjacent tracks. Model incorporates train and track characteristics and provides a collision probability distribution instead of a single-value probability estimate for more practical use.
- *Railroad Grade Crossing Micro-Level Safety and Risk Analysis – Phase 2 (Grade Crossing)* - Further analysis using the most recent 5 years (2011-2016) data from FRA was conducted to make sure the analyses that were based on 2011-2015 were still valid. Draft final report going thru internal review. Report describes how to do risk analysis using the FRA accident prediction formula and additional adjustments to the formula.
- *Track Substructure Designs and Settlement due to Complex Dynamic Loads (Track Substructure)* Simulations and analysis of linear train-track model complete.
- *Numerical Investigation of Impact Load Effects on Railroad Track Systems (Load Effects)* Additional field data analyzed for light rail transit, heavy rail transit, and heavy haul freight railroad systems for the flexural performance of crossties, to further the initial investigation into the wheel-rail interface loads. These data were compared to existing data from heavy haul freight systems and passenger data analyzed in previously.
- *Improved Concrete Crossties Design: Quantifying Cyclic Loading Failure Criteria (Concrete Crossties)* - Cyclic load test setup was established and test with intermittent water addition was started. Plan for casting of additional prisms was developed and provided to the UIUC Machine Shop for manufacture.
- *Advanced Study of Resilient Materials: Effects on Track Stability, Crosstie Bending Moments, and Impact Attenuation (Resilient Materials)* - Set up testing fixture. Constructed first support conditions (center bound and uniform support). Ran shake-down test. Developed presentation on relevant research to be presented at AREMA Committee 30 (TIES) in October.

University of Illinois Chicago (UIC)

- *Coupled Multibody and Finite Element Analysis of Rail Substructure Behavior (Substructure Behavior)* - Study on vibrations in nearby buildings completed.
- *The History of the City of Chicago Central Area Transit Circulation Efforts (Chicago Transit)* – The Urban Transportation Center (UTC) at UIC completed this project.

Michigan Tech University

- Submitted draft final report on research project "*Evaluation of Driver Behavior at Railroad-Highway Grade Crossings Using Naturalistic Driving Study Data*", co-funded with the Federal Railroad Administration.
- Initiated a new research project "*Log Movement in the Superior Region – Rate and Capacity Based Analysis of Modal Shares",* co-funded collaboratively by the Michigan Economic Development Corporation, Michigan Department of Transportation, Michigan Department of Agriculture, Michigan Tech and NURail.
- Completed student senior design project*; LSRC Gaylord Conceptual and Preliminary Design (Lake State Railway Company).*
- Completed undergraduate fellowship (Aaron Dean, MEEM) for *Using Naturalistic Driving Data and Machine Learning to Predict Accident Risk at Highway-Rail Grade Crossings.*
- Presented papers at Joint Rail Conference (JRC), AREMA 2018 Annual Meeting, and Human Computer Interface (HCI) conferences.
- Conducted 2018 Michigan Rail Conference and 2018 Summer Youth Program in Rail and Intermodal Transportation.
- Supported coordination of the 2018 Railway Engineering Education Symposium.
- Organized Railroad Night XIV and Transportation Day at Michigan Tech.

University of Kentucky

- Completed the Experimental In-Track Tie/Ballast Pressure Tests and Evaluations at the trackbed test site on the NS Railway line at Mascot, TN. Detailed analysis of test results for revenue trains is finished.
- Conducted a series of trackbed pressure tests using the Federal Railroad Administration's DOTX 218/220 Track Quality Test Car on the NS Railway line at Mascot, TN. The pressure test results were compared to the wheel/rail impact loadings obtained from nearby wheel impact load detectors (WILDs). Analysis of the data is finished.
- Finished the development of a proto-type test trackbed for laboratory evaluation of the distribution and magnitudes of pressures at the tie/ballast interface. The testing series and the analysis of the test results are finished. The applied pressures and trackbed deflections utilized in the laboratory were similar to those measured for revenue trains at Mascot.

University of Tennessee, Knoxville

- *Seismic Performance of Stone Masonry and Unreinforced Concrete Railroad Bridge Substructures (Bridge Substructures)* - Dissertation proposal for the bridge pier project was defended in April. Shake table experiments that focus on the dynamic behavior of rigid body pier blocks with rail track restraint at the top and the corresponding FE modelling were carried out.
- Though the tie pressure project phase under NURail funding is technically complete, the UT/UK team is continuing to take measurements and analyze the resulting data. The FRA brought its rail test vehicle to apply measured loads at the Knoxville site during August 2018. The railroad has authorized installation of a second site in Kentucky. Work to adapt the GEOKON pressure cell to the steel crosstie continues.

b. How have the results been disseminated?

NURail Consortium

- Between April 1, 2018 and September 30, 2018, the NURail website had over 1,880 unique visits and 3,275 page loads.

University of Illinois Urbana-Champaign

- *Line Capacity* - Two journal papers have been accepted for publication and are currently in press.
- *Yard Capacity* - A research update was presented at the TRB/NURail SummeRail Meeting in August 2018. The PI participated in a panel discussion on the topic of flat vs. hump yard planning and operations at the 2018 AREMA Annual Meeting in September.
- *Shared Corridor* - A conference paper abstract was submitted to an international railroad conference for presentation.
- *Grade Crossing* - Results have not been disseminated yet. Final report will be published by NURail once it is reviewed and approved. Anticipated to be published in late 2018.
- *Load Effects* - Latest results shared with multiple Class I railroads and transit agencies. Presentations given at the 2018 Joint Rail Conference in Pittsburg, 2018 International Crosstie and Fastening System Symposium in Urbana, and the 2018 AREMA Conference in Chicago. Journal paper developed and submitted for review focusing on a revised understanding of the flexural demands on crossties, and the lack of linearity between wheel loads and bending moment demands.
- *Concrete Crossties* - A draft presentation highlighting results from previous, similar tests was developed for an Industry Partner's meeting.
- *Resilient Materials* - A draft presentation highlighting results from previous, similar tests was developed for an Industry Partner's meeting.

University of Illinois Chicago

- *Substructure Behavior* - One publication is in preparation. One Master's thesis has been completed.
- *Chicago Transit* - Results posted on the UTC website through a news story and abstract with links to the complete report. The news story was disseminated to local transportation and planning media as well as planning organizations.

  Abstract: https://utc.uic.edu/research/the-history-of-the-city-of-chicago-central-area-transit-circulation-efforts/

  News Story: https://utc.uic.edu/incremental-approach-may-have-given-green-light-to-proposed-1990s-chicago-central-area-circulator-project/

Michigan Tech University

- Several publications/presentations were completed during the reporting period (Details below.)

University of Kentucky

- Presented a poster at the AREMA 2018 meeting in Chicago in September.
- Paper presented at the 2018 Joint Rail Conference in Pittsburgh in April.
- Summary of trackbed pressure research presented at the TRB Summerail ’18 meeting in Chattanooga in August.

c. What do you plan to do during the next reporting period to accomplish the goals and objectives?

University of Illinois Urbana-Champaign

- *Line Capacity* - The two journal papers currently in press will be consolidated with previous conference papers to form a final project report.
- *Yard Capacity* - Conduct analysis of simulation output to quantify capacity relationships and effects associated with different operating parameters. This work will be advanced into a draft dissertation during the next reporting period. This work will be presented at the INFORMS Annual Meeting in November 2018. Research abstracts have been submitted to several international conferences.
- *Terminal Capacity* - Use the integrated AnyLogic intermodal terminal model to execute the simulations in the experiment design. This work will be presented at the INFORMS Annual Meeting in November 2018. Research abstracts have been submitted to several international conferences.
- *Shared Corridor* - Prepare a draft to submit to an academic journal for the completed refined train presence model. Develop another model for network level train collision probability analysis.
- *Grade Crossing* - Finalize the report and get it published.
- *Load Effects* - Continue to process remaining data from transit field, largely from Metra / UPRR site in Chicago. Compare data to static design loads of railcars and previously developed metrics for predicting dynamic and impact loads.
- *Track Substructure* - Complete the improvement of current analytical track model by implementation of nonlinear properties of track substructure and use it for simulations of different dynamic loading conditions as well as track substructure. Consolidate the previous conference paper and current results into a journal paper for submission.
- *Load Effects* - Continue to analyze and disseminate results from the analysis of field data. Compare data to static design loads and bending moments of railcars and previously developed metrics for predicting dynamic and impact loads and bending moments. Ultimately, propose new design considerations for AREMA to take into account these non-linear effects.
- *Concrete Crossties* - Continue to run cyclic tests on full-scale crossties. Cast additional prisms for cyclic testing in and out of water. Initiate testing of prisms. Complete calibration of laboratory equipment to ensure accuracy of all results over the next year. Present results from this work, as well as past work on the same topic, in multiple venues (AREMA C30, UIUC RailTEC IP Meeting, TRB, JRC, etc.
- *Resilient Materials* – Will continue to run shake down tests. Initiate revenue service tests. Present results at relevant venues (AREMA C30, TRB, etc.)

University of Illinois Chicago

- *Substructure Behavior* - Reformulating the nonlinear settlement problem

Michigan Tech University

- Finalize final report and submittals on the research project "Evaluation of Driver Behavior at Railroad-Highway Grade Crossings Using Naturalistic Driving Study Data", co-funded with the Federal Railroad Administration.
- Develop draft final report for "Log Movement in the Superior Region – Rate and Capacity Based Analysis of Modal Shares", co-funded collaboratively by the Michigan Economic Development Corporation, Michigan Department of Transportation, Michigan Department of Agriculture, Michigan Tech and NURail.
- Presented paper at TRB Annual Meeting.
- Initiate coordination for 2019 Michigan Rail Conference and 2019 Summer Youth Program in Rail and Intermodal Transportation.

University of Kentucky

- Continuing planning for the installation of trackbed pressure cells at a soft support/muddy track site to measure the magnitudes and distributions of trackbed pressures for revenue train operations.
- Prepare a series of instrumented ties for installation in the trackbed.
- Assemble strain gages for measuring strain in the rail for various degrees of soft support track and trackbed pressures.

University of Tennessee, Knoxville

- Models will be calibrated and verified using the experimental data. Dissertation will be completed.

2. Products

a. Journal publications:

University of Illinois Urbana-Champaign

- Dick, C.T., I. Atanassov, F.B. Kippen and D. Mussanov. 2018. Relative train length and the infrastructure required to mitigate delays from operating combinations of normal and over-length freight trains on single-track railway lines in North America. *Journal of Rail and Rapid Transit*. (In Press).

- Dick, C.T., D. Mussanov and N. Nishio. 2018. Transitioning from flexible to structured heavy haul operations to expand the capacity of single-track shared corridors in North America. *Journal of Rail and Rapid Transit*. (In Press).

- Bastos, J.C., J.R. Edwards, M.S. Dersch, and B. Andrawes. 2018. Laboratory analysis of track gauge restraining capacity of center cracked railway concrete sleepers with various support conditions. Engineering Failure Analysis, 94 (2018) 354-363.

- Edwards, J.R., A.A. Cook, M.S. Dersch and Y. Qian. 2018. Quantification of Rail Transit Wheel Loads and Development of Improved Dynamic and Impact Loading Factors for Design. Journal of Rail and Rapid Transit, Part F, DOI: 10.1177/0954409718770924

- Quiros Orozco, R.J., J.R. Edwards, Y. Qian and M.S. Dersch. 2018. Quantification of Loading Environment and Flexural Demand of Prestressed Concrete Crossties under Shared Corridor Operating Conditions. Accepted: Transportation Research Record: Journal of the Transportation Research Board, In Press.

- Edwards, J.R., A.E. Canga Ruiz, A.A. Cook, M.S. Dersch and Y. Qian. 2018. Quantifying Bending Moments in Rail Transit Concrete Sleepers. Journal of Transportation Engineering, Part A: Systems, 144(3): 04018003.

Michigan Tech University

- Ko, S., Lautala, P. T., *Optimal Level of Woody Biomass Co-Firing with Coal Power Plant Considering Advanced Feedstock Logistics System*. Agriculture 8(6), 74. Luzianky: International Journal of the National Agricultural and Food Centre. doi:10.3390/agriculture8060074

- Ko S., Lautala P., *Advanced Woody Biomass logistics for Co-firing in existing Coal Power Plant: Case Study of the Great Lakes States*, Transportation Research Record, the National Academies, Washington, DC, January 7-11, 2018 https://doi.org/10.1177/0361198118797806

- Jeon, M., Landry, S., Lautala P., Nelson, D., *Design and Assessment of In-Vehicle Auditory Alerts for Highway-Rail Grade Crossings*, Transportation Research Part F: Psychology and Behaviour (under revision, 2018)

- Lautala P., Dick T., *Railway Engineering Education Symposium: Evolving to Rebuild a Growing Rail Academic Community*, Transportation Research Record: Journal of the Transportation Research Board, No. 2608, 2017, pp. 96–104. http://dx.doi.org/10.3141/2608-11

University of Tennessee, Knoxville

- Rose, J.G., Clarke, D.B., Liu, Q., and Watts, T.J., "Application of Granular Material Pressure Cells to Measure Railroad Track Tie/Ballast Interfacial Pressures," Transportation Research Record: Journal of the Transportation Research Board, 2018 (in press).

b. Books or other non-periodical, one-time publications:

NURail Consortium

- Four project final reports were written.

University of Illinois Urbana-Champaign

- Final report: Optimal Planning of Rail Grinding Activities in Large-scale Networks

University of Illinois Chicago

- S Masurekar. *3D FEM and MBS Coupled Model of Railroad System to Investigate the Vibrations in Surrounding Building Structures.* MS Thesis. University of Illinois at Chicago. 2018

University of Illinois Chicago

- News Story: https://utc.uic.edu/incremental-approach-may-have-given-green-light-to-proposed-1990s-chicago-central-area-circulator-project/

Michigan Tech University

- Salim, A., *Evaluation Of Driver Behavior At Highway-Railroad Grade Crossings Based On Environmental Conditions And Driver Demographics,* MS Report, Michigan Technological University, Summer, 2018
- Final Report: Life Cycle (LCA) and Life Cycle Cost (LCCA) Analysis of Freight Transportation Alternatives to Copperwood Mine Project
- Final Report: Life Cycle Assessment (LCA) of Ore Transportation Route/Mode Alternatives for Eagle Mine

Rose-Hulman

- Final Report for: Railroad Engineering: Hands-On Experience

University of Kentucky

- Comparisons of Railway In-Track Tie/Ballast Interfacial Impact Pressure Measurements with Wheel/Rail Surface Impact Load Detector –NURail 2016-UKY-R12e, April.

c. Other publications, conference papers and presentations:

University of Illinois Urbana-Champaign

- Dick, C.T. 2018. Influence of Traffic Complexity on Railway Hump Classification Yard Capacity. Presented at: TRB Summerail Conference, Chattanooga, TN, August 2018.

University of Illinois Chicago

- News Story: https://utc.uic.edu/incremental-approach-may-have-given-green-light-to-proposed-1990s-chicago-central-area-circulator-project/

Michigan Tech University

- Landry S., Jeon M., Lautala P., Dean A, and Nelson D., *How Do Drivers Behave At Highway-Rail Grade Crossings – Comparison Of Data From Actual And Virtual Environments*, American Railway Engineering and Maintenance of Way Association (AREMA) 2018 Annual Conference, Chicago, IL, September 16-19, 2018.
- Landry, S., Wang, Y., Lautala, P., Nelson, D., & Jeon, M. (2018). *Driver behavior at simulated railroad crossings*. Proceedings of the 20th International Conference on Human-Computer Interaction (HCII2018), NV, USA, July 15-20.
- Salim, A., Lautala, P., Jeon, M., Nelson, D., *Using Naturalistic Driving Study Data to Investigate Driver Behavior at Highway-Rail Grade Crossings*, ASME/ASCE/IEEE 2018 Joint Rail Conference, Pittsburgh, PA, April 18-20, 2018.

University of Kentucky

- "Crosstie/Ballast Interfacial Pressure Measurement and Analyses" -- 12th Annual TRB Rail Freight Transportation Meeting, Summerail 2018, Chattanooga, Tennessee, August 2018.
- "Relationships between Wheel/Rail Surface Impact Loadings and Correspondingly Transmitted Tie/Ballast Impact Pressures for Revenue Train Operations" -- Proceedings of the 2018 Joint Rail Conference, Paper JRC 2018-6184, American Society of Mechanical Engineers, April 2018.
- "Crosstie/Ballast Pressure Measurement and Analysis" -- Annual Meeting of the American Railway Engineering and Maintenance-of-Way Association, Chicago, Illinois, September 2018.

University of Tennessee, Knoxville

- Student Travis Watts presented tie pressure project results at the TRB SummeRail conference in Chattanooga, TN August 1, 2018.

d. Website(s) or other Internet site(s):

University of Illinois Urbana-Champaign

- NURail consortium website: http://www.nurailcenter.org/index.php

Michigan Tech University

- Michigan Rail Conference, http://www.rail.mtu.edu/mrc2018
- 2018 Summer Youth Program Web site; http://rail.mtu.edu/event/rail-intermodal-transportation-summer-youth-program-2018
- Railroad Night XIV, http://rail.mtu.edu/event/railroad-night-2018

e. Technologies or techniques:

- Nothing to report.

f. Inventions, patent applications and/or licenses:

- Nothing to report.

g. Other products (i.e. databases, audio/video products):

- Nothing to report.

3. Participants and Other Collaborating Organizations

a. What other organizations have been involved as partners?

Organization or University Name	Location	Contribution to the Project	Name (First and Last)
Norfolk Southern Corporation	Atlanta, GA	In-Kind Support, Corporate Partner Funds	Philip Merilli
Belt Railway of Chicago	Chicago IL	In-kind support of base case for yard simulations	Nick Chodorow
Central South University, China	Changsha, China	Research collaboration on numerical modelling	Jianfeng Mao
Norfolk Southern Corp.	Knoxville	In-kind support	Les Hall
GEOKON, Inc.	Lebanon, NH	Test equipment	Mr. Tony Simmonds
Federal Railroad Administration	Washington, DC	Co-funded project	Starr Kidda
Michigan Dept. of Transp.	Lansing, MI	Co-funded project	Nikkie Johnson
Lake State Railway Company	Saginaw, MI	Senior design sponsor	Sean Pengelly
Michigan Economic Development Corporation/Alger County	Lansing, MI	Co-funded project	Peter Van Steen (Alger)
Amtrak	Philadelphia, PA	In kind support, provision of WILD data	Steven Melniczuk
MetroLink	St. Louis, MO	In kind support, access to infrastructure of experimentation	Chuck Clemins
MTA New York City Transit Authority	New York, NY	In kind support, access to infrastructure of experimentation	Antonio Cabrera
Union Pacific Railroad	Chicago, Metra	In kind support, access to infrastructure of experimentation	Antonio Buelna

Chicago Transit Authority (CTA)	Chicago, IL	In kind support, access to infrastructure of experimentation	Planning for late 2018
Vossloh North America (Formerly Rocla Concrete Tie)		Supplying ties	
LB Foster		Supplying ties for Amtrak Philadelphia, PA project	
CXT Concrete Ties		Supplying ties for Amtrak Philadelphia, PA project	
Getzner		Supplying under tie pad materials	
Progress Rail Services		Supplying under tie pad materials	

b. Additional collaborators:

Name (First and Last)	Company, University, Organization Name	Location	Contribution to the Project
Mike Handler	L.B. Foster (Salient Group)	Dublin, OH	Review Test Plan and Provide Data
Qingjie Liu	East China Jiaotong University	Nanchang, China	Review Test Plan and Contribute to Data Analysis

4. Impact

a. What is the impact on the development of the principal discipline(s) of the program?

University of Illinois Urbana-Champaign

- *Terminal Capacity* - Terminal capacity constraints are a major issue for the railroads. With major investments in new hump yard projects underway, design and sizing of new yards and terminals is a growing need for the rail industry. Research on interaction between yard and mainline capacity will allow railroad practitioners to make better capital investment decisions to maximize the overall capacity of the rail network through properly balanced investments in mainline and yard projects. Similarly, research to better understand the factors that control intermodal facility capacity will allow railroads to make prudent investments in new and expanded terminals to handle the fast-growing intermodal rail traffic market sector.

- *Grade Crossing* - Grade crossing project study directly supports the USDOT Strategic Goals on safety. Finding of the study will help improve the safety at highway-railroad crossings. Also indirectly supports the USDOT Strategic Goals of Economic Competitiveness and Livable Communities by improving safety and reducing delay for motor vehicles and trains, as well as making the grade crossing areas safer for the people living in the area.
- *Load Effects* - Numerical investigation project supports the DOT goals for safety and state of good repair by providing a better understanding of how railroad track components may deteriorate and from that identifying areas where designs can be improved to mitigate high impacts loads entering the track structure.
- *Shared Corridor* - The risk assessment of adjacent track accidents is a crucial step towards an integrated risk assessment and management on shared-use rail corridors. The result of the study provide a risk management took for project manager, policy maker and risk manager of a shared-use corridor projects to better understand the potential risk and allocate risk mitigation resources more efficiently and effectively.

University of Illinois Chicago

- *Substructure Behavior* - Vibration analysis will help to determine whether buildings in different situations could be subject to significant vibrations from passing trains. In the case that they are, the models could be used in the design and evaluation of techniques to reduce vibrations in nearby buildings, improving occupant comfort and potentially the life of the system.

Michigan Tech University

- Student projects continue to change the principles how we educate our students. Summer Youth Program has had a positive effect on student recruitment. Michigan Rail Conference has become the main rail transportation stakeholder even in the state & Rail Day and Expo (and Railroad Night) on campus.

University of Kentucky

- To provide experimental test data applicable as input for rational structural design of railway trackbeds.
- To assess the relative damage to the track structure from increased pressures imparted to the track structure as a result of increased impact loadings to the rail.
- To utilize rational designs to provide safer and longer service lives for the railway trackbeds and correspondingly reduce trackbed maintenance costs.

b. What is the impact on other disciplines?

University of Illinois Chicago

- Developing numerical models that can be applied to a variety of dynamic systems including coupled finite element and multibody problems. Other applications specifically include vehicle/soil interaction and geotechnical modeling for soil structure interaction.

Michigan Tech University

- Most activities (student projects, rail conference, summer youth program, Rail Day) are designed for multiple discipline.

c. What is the impact on the development of transportation workforce development?

University of Illinois Chicago

- One MS student has graduated.

Michigan Tech University

- Total of 30+ civil engineering and surveying students are involved in the completed and on-going undergraduate student projects. Numerous more involved in the outreach activities.

d. What is the impact on physical, institutional and information resources at the university or other partner institutions?

University of Illinois Chicago

- Developing modeling techniques that can be used with other partner institutions or others to evaluate vibration-damping options.

e. What is the impact on technology transfer?

- Nothing to report.

f. What is the impact on society beyond science and technology?

University of Illinois Urbana-Champaign

- Proper investments in mainline, classification yard and intermodal facility capacity allow railroads to operate more efficiently, lowering supply chain costs and improving reliability of the transportation system, to the economic benefit of society.
- Grade crossing project indirectly supports the USDOT Strategic Goals of Economic Competitiveness and Livable Communities by improving the safety and reducing delay for motor vehicles and train, as well as making the grade crossing areas safer for the people living in the area.
- Reliable risk assessment tool provides better planning of shared-use rail corridors, allowing faster and more efficient train operations without compromising safety.

University of Illinois Chicago

- Vibration analysis will increase occupant comfort in buildings near railways. Ultimately, we can evaluate the most efficient and economical tools for mitigating vibrations.

Michigan Tech University

- Michigan Rail Conference is an avenue for larger understanding of rail transportation and attracts participants from outside industry. Summer Youth Program and Rail Day and Expo expand the visibility among students.

5. Changes/Problems

a. Changes in approach and reasons for change

NURail Consortium

- After the passing of NURail Partner and Co-PI, Joseph M. Sussman, the University of Illinois at Urbana-Champaign reached out to MIT to see if another MIT faculty member was interested in conducting research that supported the NURail objectives. At this point in time there is no interest in the opportunity so UIUC will start the process to de-obligated MIT's remaining funds so that it can be used elsewhere in the consortium.

University of Kentucky

- Had to experiment with different types and configurations of pressure cells to optimize and prove the adequacy of the system for accurately and consistently measuring tie/ballast interfacial pressures under typical revenue train operations. This phase of the study represents original research aimed at developing criteria for direct application to the railway engineering practice.

b. Actual or anticipated problems or delays and actions or plans to resolve them

- Nothing to report.

c. Changes that have a significant impact on expenditures

- Nothing to report.

d. Significant changes in use or care of human subjects, vertebrate animals and/or biohazards

- Nothing to report.

e. Change of primary performance site location from that originally proposed

- Nothing to report.