

7th Program Progress Performance Report
for
National University Rail (NURail) Center:
Tier 1 University Transportation Center



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US DOT OST-R Tier 1 University Transportation Center

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Table of Contents

1. Accomplishments	2
a. What was accomplished under these goals?	2
b. How have the results been disseminated?	4
c. What do you plan to do during the next reporting period to accomplish the goals and objectives? ..	5
2. Products	7
a. Journal publications:	7
b. Books or other non-periodical, one-time publications:	7
c. Other publications, conference papers and presentations:	8
d. Website(s) or other Internet site(s):	8
e. Technologies or techniques:	9
f. Inventions, patent applications and/or licenses:	9
g. Other products (i.e. databases, audio/video products):	9
3. Participants and Other Collaborating Organizations	10
a. What other organizations have been involved as partners?	10
b. Additional collaborators:	11
4. Impact	11
a. What is the impact on the development of the principal discipline(s) of the program?	11
b. What is the impact on other disciplines?	12
c. What is the impact on the development of transportation workforce development?	12
d. What is the impact on physical, institutional and information resources at the university or other partner institutions?	13
e. What is the impact on technology transfer?	13
f. What is the impact on society beyond science and technology?	14
5. Changes/Problems	14
a. Changes in approach and reasons for change	14
b. Actual or anticipated problems or delays and actions or plans to resolve them	14
c. Changes that have a significant impact on expenditures	14
d. Significant changes in use or care of human subjects, vertebrate animals and/or biohazards	14
e. Change of primary performance site location from that originally proposed	14

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 objectives are to provide the transportation community with significant research results and a new generation of well-educated leaders who will foster smart, strategic and sustainable investments serving the traveling public, facilitating freight movement across a multi-modal network and bringing equitable economic benefits to the nation. The original NURail Grant (number DTRT12-G-UTC18) has closed and all researchers are now utilizing funds from Grant DTRT13-G-UTC52.

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

NURail Consortium

- Between October 1, 2016 and March 31, 2017 the NURail website had almost 4,700 unique visits and over 9,400 page loads.
- Preparation began for the NURail Center Annual Meeting, which will be held as part of the Midwest Rail Conference in Kalamazoo, MI on Western Michigan University's Campus on August 15 – 17, 2017. The theme of the conference is "Midwest Connections: Passenger and Freight Rail Look to the Future".
- Steve Landry from Michigan Technological University was presented with the NURail Student of the Year for Grant DTRT13-G-UTC52 award on January 7, 2017 during the CUTC Awards Banquet at the 96th Transportation Research Board Meeting in Washington, D.C.

University of Illinois Urbana-Champaign

- Hay Seminar Series: Hosted five on-campus seminars from industry experts that were also broadcast online. Total both online and in person attendees for the seminars was over 550 participants.
- Schedule Flexibility and Railway Line Capacity (Line Capacity): Additional simulations completed to investigate the capacity consumption of different combinations of scheduled and flexible trains for varying levels of schedule flexibility (project Task 3). Draft papers submitted to two conferences.
- Capacity of Hump Classification Yards (Yard Capacity): Input data for the initial factorial experiment (Task 2) developed and the corresponding scenarios currently being simulated. Access gained to the Belt Railway of Chicago hump yard model.
- Shared Rail Corridor Adjacent Track Accident Risk Analysis (Shared Rail Corridor Risk): Conducted a fault tree analysis to thoroughly develop the framework of adjacent track accidents, identifying all possible factors contributing to the occurrence of such accident, and a formula for estimating the risk of adjacent track accidents was derived using the fault tree.
- Numerical Investigation of Impact Load Effects on Railroad Track Systems (Load Effects): Data analyzed for both light rail and heavy rail transit systems, and

- compared to existing data from heavy haul freight systems. Data obtained on Amtrak's North East Corridor for a variety of freight and passenger rolling stock types, which will be analyzed in subsequent phases of the project.
- Improving Track Substructure Designs and Settlement due to Complex Dynamic Loads from High-Speed Passenger and Freight Trains (Track Substructure): Field load-deformation time history data were analyzed from Amtrak Northeast Corridor. An analytical model of track substructure under multiple moving loads was established and successfully validated with field data for high speed ACELA train passage.

University of Illinois Chicago

- College of Engineering (COE) - Implemented a viscoelastic model for damping into a coupled multibody-finite element code and applied the model to examining bridge approaches. Examined contact forces, stresses, and displacement under the rails in ballast and subgrade. Examined a simplified model of a bridge approach slab and showed that such a slab might reduce stress and deformation under a bridge approach. By gradually increasing the slab thickness, can further reduce the effects.
- College of Urban Planning and Public Affairs (CUPPA) - Draft of the value capture research report completed January 2017. Literature Review summary remains to be completed. Existing version of the report includes case studies of major transit projects and virtual roundtable of a handful of transit agencies concerning their current and future practices related to value capture.

Massachusetts Institute of Technology

- Major accomplishments are concerned with graduate thesis work. MIT has two active thesis research projects: Daniel Mascoop is performing research on Major HSR Terminals and Taka Hidema on Texas High-speed Rail. Presentations given at TRB, journal articles being prepared and research reports written.

Michigan Tech University

- Completed NURail – Tier 1 contract with Michigan Department of Transportation (cofounded with NURail).
- Completed one undergraduate student project: *Peshekee Yard Development and Site Improvement Design – Phase 1*, and started another one for *Sawyer International Airport Transportation Improvements*.
- Submitted (and were accepted) four papers to Joint Rail Conference 2017.
- Secured two undergraduate fellowships for grade crossing research; Aaron Dean (MEEM) - *Undergraduate Research Internship Program (URIP); Effectiveness of Using SHRP2 Naturalistic Driving Study Data to Study Driver Behavior at Highway-Rail Grade Crossings* and Darian Reed (CEE) – *Summer Undergraduate Research Fellowship; Valuation of Methods to Record Head Orientation in Driving Simulator and In-Vehicle Study Environments*
- Supported two K-12 activities
 - a. Western UP Stem festival
 - b. Transportation Engineering After School event

University of Kentucky

- Developed an accurate method of measuring trackbed pressures (magnitude and distribution) at the tie/ballast interface for various operating conditions.
- Continued imbedding pressure cells within ties to ascertain pressure distributions at open-track sites near special track works.
- Continued to update “Railroad (Engineering) and Facilities Design and Analysis” Class at University of Kentucky.
- Developed 3D sandbox for VR applications and teaching K-12 and college.

University of Tennessee, Knoxville

- Dr. Huang’s research group finished laboratory testing of both timber and steel crossties and participated in field testing of the tie-track system at Flat Rock, KY and Mascot, TN with Dr. Jerry Rose from the University of Kentucky. Research team presented results at the 96th Transportation Research Board (TRB) Annual Meeting held in Washington, D.C. January 8-12, 2017. Based on the results from the laboratory testing, one paper has been written and accepted to be published on ASCE’s Journal of Transportation Engineering, Part A: Systems.
- Dr. Ma’s research group carried out theoretical analysis based on the data from previous experiments and mechanical modeling. This analysis specially focused on the constraint effect of the rail track structure on the displacement behavior of the bridge pier top. This is necessary to prepare critical parameters for the following small-scale shake table testing.

b. How have the results been disseminated?

NURail Consortium

- Two final project reports were posted on the NURail website and sent to the document repositories as required by the UTC Deliverables and Requirements document.

University of Illinois Urbana-Champaign

- Line Capacity: Research presentation made at INFORMS annual meeting in November 2016. Paper describing research accepted for presentation at the International Association of Railway Operations Research conference in Spring 2017. A second paper abstract describing research accepted for presentation at the International Heavy Haul Association conference in Fall 2017.
- Yard Capacity: Summary of initial progress on project presented to railway practitioners on campus in February 2017.
- Shared Rail Corridor Risk: Paper submitted and presented at the TRB annual conference and paper accepted in the Journal of Transportation Research Record.
- Load Effects: Results shared with at least two Class I railroads and two transit agencies. Presentation given at 2017 Joint Rail Conference in Philadelphia. Journal paper under development to develop new impact factors prediction equations.

- Track Substructure: Interim report describing current progress submitted in January 2017. Paper on analytical modeling of track substructure accepted for publication and presentation at the upcoming ASCE T&DI ICRT Chengdu 2017 conference.

University of Illinois Chicago

- COE: A paper is in submission.

Massachusetts Institute of Technology

- Results disseminated through TRB presentations, journal articles (in prep) and research reports. Major milestone reached with submission of eight final reports in March reflecting the three-year program with JR East. Results reinforce research conducted as part of NURail since MIT's NURail research is HSR-oriented too. Useful synergies abound among all MIT's HSR-oriented research projects.

Michigan Tech University

- Several publications/presentations completed during the reporting period. Details in section 2 below.

University of Kentucky

- Presented three posters at TRB.
- Published three papers in TRB proceedings.
- Published one civil engineering master's project report.
- Presented at a TRB Workshop.

University of Tennessee, Knoxville

- Huang: Research team presented results at 96th TRB Annual Meeting. One journal paper accepted for publishing in ASCE's Journal of Transportation Engineering, Part A: Systems. Part of a Ph.D. dissertation is based on the results from this study.

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

NURail Consortium

- The NURail Annual Meeting will be held as part of the Midwest Rail Conference in Kalamazoo, MI on Western Michigan University's Campus on August 15 – 17, 2017. The theme of the conference is "Midwest Connections: Passenger and Freight Rail Look to the Future".

University of Illinois Urbana-Champaign

- Line Capacity: Results will be presented at the 2017 IAROR and IHHA conferences. Additional simulations will be conducted to determine the relationship between schedule flexibility, train speed and distribution of running times on a corridor. Final experiment will investigate if decreasing train speed to achieve structured operations can achieve a higher network velocity than running faster flexible trains.

- Yard Capacity: Complete simulations for the initial factorial experiment (Task 2).
- Shared Rail Corridor Risk: Continue to develop and refine quantitative models for train intrusion and train presence on adjacent track in intrusion scenarios, which are part of the overall risk management framework of adjacent track accident on shared rail corridors.
- Load Effects: Continue to process data from WILD sites and field data from UIUC-installed experimental sites on intercity passenger rail and commuter rail transit systems. Compare data to static design loads of railcars and previously developed metrics for predicting dynamic and impact loads. Ultimately, will propose new mode-specific equations for predicting load environment.
- Optimal Planning of Rail Grinding Activities in Large-scale Networks: Focus on developing advanced mathematical models and solution techniques for the rail grinding scheduling problem. 1) Conduct intensive literature review to understand current practice on rail grinding scheduling, and 2) Develop model formulations and solution algorithms that can handle various real-world constraints and business rules.
- Track Substructure: Results will be presented at the ASCE T&DI ICRT Chengdu 2017 conference in July. Continue to develop/improve current analytical track model to study behavior of track substructure under dynamic loadings with consideration of 3-D soil wave propagation.

University of Illinois Chicago – COE

- COE: Apply model to examine vibrations effects in nearby buildings. Should be able to model accelerations in buildings using the models, and use code values to assess occupant comfort.
- CUPPA: Work with researchers to get the value capture research report completed in Second Quarter 2017.

Massachusetts Institute of Technology

- Continue current plan working with *Taka Hidema* and *Daniel Mascoop* on their master's theses.

Michigan Tech University

- Complete *Life Cycle Assessment (LCA) of Ore Transportation Route/Mode Alternatives for Eagle Mine* research project.
- Conduct inaugural Midwest Rail Conference.
- Complete on-going student project.
- Conduct 2017 Summer Youth Program in Rail and Intermodal Transportation.
- Present papers at the Railway Interchange 2017 and Grade Crossing Research Workshop.

University of Kentucky

- Continue both laboratory and in-track testing for the next few months.

University of Tennessee, Knoxville

- Huang: Research team plans to give more presentations about results and to write more conference and journal papers.

- Ma: Detailed plan for small shaking table testing will be determined based on current analytical study. Then testing will be carried out.

2. Products

a. Journal publications:

University of Illinois Urbana-Champaign

- Lin, C-Y., M.R. Saat and C.P.L. Barkan. 2016. Fault tree analysis of adjacent track accidents on shared-use rail corridors. *Transportation Research Record: Journal of the Transportation Research Board*. 2546: 129-136; DOI 10.3141/2546-16.
- Hou, W., Tutumluer, E., Huang, H., Boler, H., and D. Mishra. “Analytical Model of Ballasted Track Bridge Approach Validated with Field Measurements.” Accepted for presentation and Publication at the ASCE T&DI International Conference on Rail Transportation (ICRT), July 10-12 2017, Southwest Jiaotong University, Chengdu, China.

Michigan Tech University

- Lautala PT, 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. DOI: 10.3141/2608-11.

University of Kentucky

- Liu, Q., T. Wang and R. Souleyrette, “A 3D Evaluation Method for Rail-Highway Hump Crossings,” *Journal of Computer-Aided Civil and Infrastructure Engineering*. 5 December 2016, DOI: 10.1111/mice.12244.

University of Tennessee, Knoxville

- Song, W., X. Shu, B. Huang, Y. Sun, H. Gong, D. Clarke, “Laboratory Evaluation of Pressure Distribution under Steel and Timber Crossties In Railway Track,” *ASCE Journal of Transportation Engineering, Part A: Systems* (accepted and in print).

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

Massachusetts Institute of Technology

- Year 2 Report to Masdar Institute.
- Eight reports to JR East reflecting three years of research overlapping with NURail.

Michigan Tech University

- SPR-1650 - National University Rail Transportation Center (NURail) Tier 1, Final Report, February, 2017, http://www.michigan.gov/mdot/0,4616,7-151-9622_11045_24249-406488--,00.html

c. Other publications, conference papers and presentations:

NURail Consortium

- Final reports were written for the following projects:
 - NURail2015-UIC-R15 - Efficient Goods Movement / Off Peak Delivery Pilot Project
 - NURail2016-UKY-R11 - Study behavior of track in bridge transition zones (Phase 2).

University of Illinois Urbana-Champaign

- Mussanov, D. and C.T. Dick. 2016. Operational Schedule Flexibility and Infrastructure Investment: A Capacity Trade-off on Single Track Railways. Presented at the 2016 INFORMS Annual Meeting, Nashville TN, November 2016.
- Edwards, J.R., A. Cook, M. Dersch, M. Csenge, Y. Qian, and A. Canga. 2017. Quantification of Impact Factors: Results from Rail Transit Systems. Presented at the 2016 Joint Rail Conference (JRC), Philadelphia PA, April 2017.

Michigan Tech University

- Lautala P., Dick T., Railway Engineering Education Symposium: Evolving to Rebuild a Growing Rail Academic Community, Transportation Research Board 96th Annual Meeting of the National Academies, Washington, DC (paper and poster presentation).
- Dean, A., *Effectiveness of Using SHRP2 Naturalistic Driving Study Data to Study Driver Behavior at Highway-Rail Grade Crossings*, Michigan Tech Undergraduate Research Symposium, March 17, 2017.

University of Kentucky

- Wang, T. and R. Souleyrette. "Rail-Highway Grade Crossings: Multi-vehicle Accelerometer-based Rideability Measures." *Proceedings of the 96th Annual Meeting of TRB*, Washington, DC, Jan. 2017. 17 pages.
- Wang, T. and R. Souleyrette. "Rail-Highway Grade Crossings: Isolating Rideability Effects of Condition and Design." *Proceedings of the 96th Annual Meeting of TRB*, Washington, DC, Jan. 2017. 13 pages.

University of Tennessee, Knoxville

- Song, W., X. Shu, B. Huang, Y. Sun, D. Clarke, "Laboratory Evaluation of Pressure Distribution under Steel and Timber Crossties In Railway Track," 96th Transportation Research Board (TRB) Annual Meeting, Washington, D.C., January 8-12, 2017.

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

University of Illinois Urbana-Champaign

- UIUC maintains the NURail Center website: <http://www.nurailcenter.org/index.php>. To enrich our outreach effort, each month in 2016 we released a new short video with

a member of our NURail leadership team answering one of a variety of questions about the railroad industry.

University of Illinois Chicago

- CUPPA: Previous NURail funded studies posted on the Urban Transportation Center website continue to generate downloads. From January 2016 to April 2017, these results include:
 - Pedestrian Cyclist Safety at CTA Grade Crossings: 420 views
 - Online Accessibility Tool: 244 views
 - Environmental Assessment of Rail Infrastructure: 231 views
 - Truck to Rail Mode Shift: 162 views
 - Off Peak Delivery: 73 views
 - Value Capture Best Practices: 43 views

Massachusetts Institute of Technology

- Much of MIT's work appears on the website: <http://web.mit.edu/hsr-group/index.html>

Michigan Tech University

- Midwest Rail Conference, <http://www.rail.mtu.edu/event/mrc2017>
- 2017 Summer Youth Program Web site; <http://rail.mtu.edu/event/rail-and-intermodal-transportation-2017>

e. Technologies or techniques:

University of Illinois Chicago

- COE: Implemented a viscoelastic model into their coupled finite element model, and developed a scheme to determine the viscous stresses.

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 Name	Location of the Organization	Partner's Contribution to the Project	Name (First and Last)
Masdar Institute of Science and Technology	Abu Dhabi, UAE	Complementary funding for related research on HSR	Prof. Rita Sousa
JR East	Tokyo, Japan	Complementary funding for related research on HSR	Masaki Ogata, Vice Chairman
NS	Norfolk, VA	funding	NS Corporate Partnership
Nichols Foundation	Jacksonville, FL	funding	Gerald Nichols
UIUC	Urbana, IL	collaboration	Tim Stark
Univ. of Tennessee	Knoxville	collaboration	Baoshan Huang
University of Kentucky	Lexington, KY	Ran field testing	Dr. Jerry Rose
Norfolk Southern	Knoxville, TN	Provided test site	Mr. Les Hall
Belt Railway of Chicago	Chicago IL	In-kind support of base case for yard simulations	Nick Chodorow
Amtrak	Philadelphia, PA	In kind support, provision of WILD data	Steven Melniczuk
MetroLink	St. Louis, MO	In kind support, access to infrastructure for experimentation	Chuck Clemins
MTA New York City Transit Authority	New York, NY	In kind support, access to infrastructure for experimentation	Antonio Cabrera
Michigan Dept. of Transp.	Lansing, MI	Matching funds/ project oversight	Nikkie Johnson
FRA	Washington, DC	Cofunded project	Starr Kidida
Sawyer International Airport	Marquette, MI	Senior Design sponsor	Steve Shanton
Marquette County	Marquette, MI	Senior design advisor	Eric Anderson
JM Longyear	Marquette, MI	Undergraduate project support	Jake Hayrynen
Eagle Mine	Marquette, MI	Graduate Research project support	Matt Johnson

b. Additional collaborators:

Name (First and Last)	Company, University, or Organization Name	Location	Contribution to the Project
Dan Lau	Dept. of Electrical Engineering, and Visualization Center, Univ. of Kentucky	Lexington	contributed his time, technology and resources to 3D rail crossing project; also developed 3D sandbox
David Clarke	Center for Transportation Research, UTK	Knoxville, TN	Funded purchase of additional sensor equipment for project
Steve Schlickman	University of Illinois at Chicago	Chicago, IL	Principal Investigator
Jordan Snow	University of Illinois at Chicago	Chicago, IL	Researcher

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 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.
- 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 grade crossing areas safer for the people living in the area.
- Shared corridor project will advance our understanding on how to most efficiently and effectively manage risk on shared rail corridors thereby providing guidance for tactical and strategic operational control, infrastructure and vehicle design and maintenance, and public (FRA) and private sector policy making.
- 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.

University of Illinois Chicago

- COE: Models can be used to evaluate bridge approach mitigation strategies, which can reduce costs for track owners. Vibration analysis will help in the design of methods to reduce vibrations in nearby buildings, improving occupant comfort and potentially the life of the system.
- CUPPA: Establish more awareness regarding effective value capture practices. In many cases, transit agencies use value capture methods without fully pursuing coordination between their own planners, other taxing authorities, and private entities that will eventually pay the levies associated with value capture.

Massachusetts Institute of Technology

- The kinds of issues MIT is researching are inherently interdisciplinary in content and approach. So while we advance the field of transportation, it is done in a context of a deeper understanding of regional economics, land use planning, engineering systems and other related fields.

Michigan Tech University

- Increased use of student projects is slowly changing the principles how we educate our students.

University of Kentucky

- Imbedded sensors will provide data for better design and prediction of performance of track structures.

b. What is the impact on other disciplines?

University of Illinois Chicago – COE

- COE: 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 structures.
- CUPPA: Results of report could build more awareness for effective value capture strategies within the public and private sectors, along with transit agencies.

Michigan Tech University

- Most activities (student projects, rail conference, summer youth program) are not designed for a specific discipline.

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

University of Illinois Chicago

- COE: Working with one MS student on the project and one PhD student graduated during this period (Ahmed El-Ghandour).
- CUPPA: Increased use of value capture could lead to transportation expansion and improvement projects, which could lead to jobs in planning, engineering and construction.

Michigan Tech University

- Total of 31 civil engineering and surveying students are involved in the completed and on-going undergraduate student projects.

University of Kentucky

- Educating undergraduate and graduate students in civil engineering is the principal impact.

University of Tennessee, Knoxville

- Part of a Ph.D. dissertation is based on the results from this study.

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

University of Illinois Chicago

- COE: Developing software packages that can be used by partner institutions for analysis.
- CUPPA: Value capture research could inspire other researchers to pursue similar studies by other colleges and departments, such as Engineering, Public Health and Business.

Michigan Tech University

- Rail Learning site is slowly becoming a warehouse for rail related conference recordings.

e. What is the impact on technology transfer?

University of Illinois Chicago

- CUPPA: Both public and private sectors can use findings from value capture research; governments, transit agencies and developers can apply findings and incorporate into future projects. Media interest in the topic of value capture should remain strong as governments and transit agencies will continue to seek alternative sources for project funding.

Michigan Tech University

- Materials at Rail Learning site are available for large audiences:
<http://rail-learning.mtu.edu/>

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

University of Illinois Urbana-Champaign

- Proper investments in mainline and yard 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 improves safety and reduces delay for motor vehicles and trains, as well as making the grade crossing areas safer for people living in the area.

University of Illinois Chicago

- COE: Ultimately, models will be used to reduce maintenance costs, reducing the costs of shipping. Vibration analysis will increase occupant comfort in buildings near railways.
- CUPPA: Value capture is another way to fund transit; increased transit options enhance mobility and help people reach jobs, schools, parks and other destinations.

Michigan Tech University

- Midwest Rail Conference is an avenue for larger understanding of rail transportation and attracts participants from outside industry.

5. Changes/Problems

a. Changes in approach and reasons for change

Massachusetts Institute of Technology

- New thesis projects are now included as described earlier (Mascoop, Hidema). This extends the scope beyond Penn Station in NYC to include St. Pancras, London and Las Vegas, NV, promising to create a richer set of results (Mascoop). In addition, another HSR case in Texas expands the geographic scope and also enriches our research findings (Hidema).

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.