United States Department of Transportation
Annual Modal Research Plans

FEDERAL RAILROAD ADMINISTRATION

MAY 1, 2018

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Executive Summary

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology (RD&T) mission is to ensure the safe, efficient, and reliable movement of people and goods by rail. We achieve this goal through basic and applied research, and development of innovations and solutions. Safety is the Department of Transportation's (DOT) primary strategic goal and, thus, the principal driver of FRA's RD&T program. FRA's RD&T program also contributes to other DOT strategic goals because safety-focused projects typically yield solutions affecting infrastructure, innovation, and accountability goals. The RD&T program also has an important role to play in workforce development by addressing workforce challenges.

FRA's RD&T program is founded on an understanding of safety risks in the industry. Through threat identification and risk analysis FRA identifies opportunities to reduce the likelihood of accidents and incidents, and to limit the consequences of hazardous events should they occur. Key research and development strategies include stakeholder input and engagement partnerships with other researchers, such as the Association of American Railroads (AAR) and the American Short Line Railroad Association (ASLRRA). Additionally, research projects are strategically prioritized and conducted through cost-effective procurement. Current high priority issues for FRA include: Positive Train Control (PTC), grade crossing safety, trespass prevention, autonomous vehicles, safe transportation of energy products, automation technology, and predictive analytics. Three of the five high priority projects include machine learning or automation solutions to improve the safety of America's railways.

FRA's RD&T program consists of 10 critical program areas, which include:

1. Hazardous Material (HazMat) Transportation
2. Track and Structures
3. Rolling Stock
4. Highway-Rail Grade Crossing and Trespassing
5. Human Factors
6. Train Control
7. Train Occupant Protection
8. Track/Train Interaction
9. Testing Facilities and Equipment
10. Railroad Systems Issues

Aligned with DOT's Office of the Assistant Secretary for Research and Technology (OST-R) research objectives, FRA research identifies and addresses safety issues across the railroad industry, including high-risk, and long-term research. An example of this is the Autonomous Track Geometry Measurement (ATGMS) project where FRA identified the need for automated inspection and over a 15-year period (2002–2017) from proof of concept to deployment and commercialization. The sustained funding of FRA's research and development mission enables pursuit of specific research needs. This allows FRA to initially bear the costs and risks for research that the railroad industry is unable to pursue. The results of which lead to innovative solutions that may not have been otherwise realized.

Research Program Summaries:

Hazardous Material Transportation

The Hazardous Materials (HazMat) research program fosters innovation throughout the industry, helping with the development of new regulations and design standards that improve the safety and integrity of tank cars and other packages carrying hazardous materials. It aids the continuing growth of new research programs that satisfy the need of the industry and government.

Track and Structures

Strategic priorities for the Track and Structures program include: developing track inspection technologies; developing computer modeling capabilities; expanding the use of autonomous inspection methods; and developing new techniques for monitoring difficult to detect safety issues. Failure of track and infrastructure is the second leading cause of train derailments in the United States. Atypical interaction between moving vehicles and the track is a common cause of derailments.

Rolling Stock

Research efforts in the Rolling Stock program focus on the development and improvement of equipment defect detection and control. Both wayside and on-board detection and control systems offer diverse platforms for such research and demonstration.

Highway-Rail Grade Crossing and Trespassing

Approximately 212,000 highway-rail grade crossings exist in approximately 140,000 miles of track that make up the United States' railroad system. In 2017, 273 individuals died at railroad crossings. This figure is up from 255 in 2016, 236 in 2015, 262 in 2014, and 232 in 2013. FRA issues and enforces regulations on grade crossing safety and sponsors research aimed at reducing grade crossing accidents and fatalities. FRA also promotes education and awareness of grade crossing and trespassing to reduce incidents and prevent fatalities. Trespassing along railroad rights-of-way is the leading cause of rail-related deaths in America. Nationally, more than 400 trespass fatalities occur each year, the vast majority of which are preventable.

Human Factors

The objectives of FRA's Human Factors RD&T program is to improve the safety of rail transportation. Human Factors research is focused on conducting pilot trials and studies to improve safety and the organizational culture in railroad organizations; research on fatigue, distraction and ergonomics to address individual and team behavior; and developing technology, automation, and systems design to minimize the potential for human errors.

Train Control and Communication

Train control, which cuts across virtually all the RD&T program elements, includes the use of sensors, computers, and digital communications to collect, process, and disseminate information to improve the safety, security, and operational effectiveness of railroad. FRA and the railroad industry are working on the development of Intelligent Railroad Systems that would incorporate new sensor, computer, and digital communications technologies into train control, braking systems, grade crossings, and defect detection.

Train Occupant Protection

The Train Occupant Protection program conducts research on structural crashworthiness and interior safety of locomotives and intercity and commuter rail cars with the aim of improving the survivability of rail passengers and

crewmembers in accidents. The goal of this research program is to promote and improve the safety of the national passenger rail transportation system.

Track/Train Interaction

The Track/Train Interaction program addresses the safety implications arising from the dynamic interaction between track and train. This program supports the development of performance-based safety standards and industry guidelines for vehicle/track interaction safety and ride quality.

Testing Facilities and Equipment

The RD&T Facilities and Test Equipment program addresses the acquisition, upgrading, and maintenance of FRA-owned facilities and equipment required to accomplish the whole spectrum of railroad research objectives and projects. FRA oversees the DOT Transportation Technology Center (TTC) in Pueblo, CO, located on 52 square miles of land leased from the State of Colorado. Since its dedication as the High-Speed Ground Test Center in 1971, it has played an important part in research, development, and testing of rail infrastructure and equipment.

High Priority Research Projects for FY 2019:

Track Research Program - Priority Research Project 1: Track Support and Substructure:
Quantification of Track Instabilities due to Ballast Movement using Integrated Sensor Networks (SmartRock/iBeacon)
$186,000

The objective of this research is to develop a sensor network consisting of data broadcasting technology that will provide abnormal track instability data that can be automatically acquired from a moving platform (geometry car). This data will provide the railroad industry the enhanced capability to detect instabilities in track infrastructure providing the means to adapt and correct for these abnormalities and instabilities and improve safety.

Activities for FY19 include:

- Revenue service (actual train) testing of iBeacons with Amtrak
- Using a hirail vehicle, with scientists onboard and along the test track, test data collection in real time
- Based on success of hirail data collection, test data collection capabilities on locomotives
- Development and testing of the iBeacon system to be installed within a locomotive, providing real-time communication between SmartRocks and locomotives

Who else is researching this issue?
No one else is researching this issue.

Have we invested in this topic in the past and what have we learned to date?
Past research efforts have focused on the successful development of the SmartRock. RD&T has learned through the analysis of previous SmartRock collected data, that it is possible to quantify and set threshold values on the ballast stability (i.e., ballast failure mechanism and criteria) based on ballast particle contact and movement characteristics.

Quantification of the ballast failure mechanism and criteria together with advanced sensors and communication protocols allowing for real time communication with moving locomotives, are building blocks of a future "real-time ballast stability evaluation and monitoring program," which will enhance the understanding of ballast particle movement and track safety. Future efforts will focus on the development of the iBeacon system to be installed within a locomotive and provide real-time communication between SmartRocks and locomotives.

Alignment with DOT Strategic Goals
The project aligns with the DOT Strategic Goals of Safety, Innovation, Infrastructure, and Accountability.

Expected total project cost and expected funding for FY 2019
Total project cost is estimated at $323K over 2 years. Year 1 ($186K), Year 2 ($137K)

Is there a non-Federal financial contribution? If so, how much?
Yes, there is a non-Federal financial contribution estimated at $49K.

Rolling Stock – Priority Research Project 2: Rolling Stock Component Safety:
Brake System Behavior – Very Long Trains (VLT) $250,000

Major Class I railroads in the U.S. have begun operations that involve VLTs. The railroad industry uses VLTs to enhance economic competitiveness through better use of fuel, locomotive power, and rail cars, without having to add extra crew. However, VLTs may pose safety risks related to operations and train handling. Locomotive engineers are trained and familiar with running trains at normal length. Initiation of brakes and application of sufficient propulsion based on terrain and environment is based on adequate specialized training and experience. The required braking forces and resulting stopping distances for normal length trains is very different for VLTs. Brake propagation down the train line, in-train forces, track grade, track curvature, rail conditions (i.e., wet, lubricated, or dry) all affect the capability of a train to be stopped and handled appropriately and safely.

Why should we pursue (or invest in) this research?
There is an urgent need to better understand the different operating environments and requirements for VLTs. FRA's RD&T investment in this project will identify significant issues pertaining to the safe operation of VLTs as affected by air brake use. Recent accidents involving VLTs in rural areas, like West Virginia, require FRA to research safety issues related to VLT. As VLTs are increasingly used, FRA investment in this research ensures the timely implementation of effective strategies aimed at improving the safety of rail transportation for the American public through conducting analytical simulations of long trains using the Train Energy and Dynamics Simulator (TEDS) under varying operating and train make-up configurations.

Who else is researching this issue?
No one else is researching this issue.

Have we invested in this topic in the past and what have we learned to date?
Foundational research using simulations began in 2018 to better understand the issues surrounding braking of VLT.

Objectives, activities, and what is the problem being addressed?
This research investigates significant issues pertaining to safe operation of VLT as affected by automatic air brake use. The research outcome will help stakeholders understand how the increase of air brake signal propagation time for a VLT impacts the application and release of brakes on the cars in the consist (a set of railcars forming a train), and identify any resulting issues. This effort will also allow FRA to identify and better understand how air brake system leakage in VLT affects the brake pipe and brake cylinder pressure on cars located near the rear end of the train, especially in consists that do not use distributed power.

In 2019, research will begin with instrumentation and testing of a VLT in revenue service. Real world data on operations and braking of these trains over different routes, with and without distributed power over varying conditions of the rail (i.e., wet, icy, lubricated, dry, etc.) will be gathered in the main research effort. This will entail precisely placing locomotives at intermediate points throughout the consist. Initiating the project in the fall of 2019 will allow for test operations during various weather conditions resulting in complete data gathering as related to various rail conditions.

Knowledge will be gained on brake cylinder pressure recharge times in VLT, and if an issue, quantification of the recharge time after full service or emergency braking operations for VLT. It will also allow for, investigation of the capability of the current locomotive air compressor capacity to supply air to charge a train. With the results and recommendations of this research, FRA will address potential requirements and standards to modify current air brake and handling operations of VLT.

Alignment with DOT Strategic goals
The three DOT Strategic Goals met through this research are Safety, Innovation, and Infrastructure. Benefits include improved safety standards, lower operating costs, reduced railroad accidents and fatalities, and improved service life for rolling stock equipment.

Expected total project cost and expected funding for FY 2019
The expected total project cost is $421,761 and expected funding in FY19 is $250,000.

Is there a non-Federal financial contribution? If so, how much?
The railroads will provide in-kind contributions by loaning railroad equipment and the air brake manufacturers will provide their technical assistance.

Train Control and Communication – Priority Research Project 3: Positive Train Control (PTC) Research:
Note: PTC research includes multiple contracts with three priority contracts discussed as part of Project 3.

A. Railroad Crossing Violation Warning System (RCVW) $850,000

The Railroad Crossing Violation Warning System uses the connected vehicle infrastructure and grade crossing status to determine if a vehicle is about to violate the active grade crossing warning (i.e., flashing lights and bells) and about to crash into the crossing barrier and/or the train. The system warns the driver of this potential, and if no action is taken, the onboard system will automatically stop the vehicle short of the crossing gate.

Development started in FY 2017, and a successful demonstration of the prototype system was demonstrated in FY 2018 with potential for improvement and transfer and commercialization.

Why should we pursue (or invest in) this research?
It is necessary for railroad systems and traffic control infrastructure to communicate with approaching vehicles to facilitate their safe and consistent navigation of highway-rail grade crossings. Significant agency and private sector cooperation is required to achieve connection. Government investment is necessary at this early stage because the risk is high and business case analyses are not compelling for private investment.

Who else is researching this issue?
No one specifically is researching this issue. Automotive manufacturers are researching and providing similar automated safety systems; however, suppliers and automotive manufactures are providing in-kind support and some matching funds.

Have we invested in this topic in the past and what have we learned to date?
Yes, FRA has proved the viability of the technology and successfully demonstrated a prototype system.

Objectives, activities, and what is the problem addressed?
RD&T's objectives:
- Develop integrated solutions for connected-automated vehicle systems, railroads, and grade crossing infrastructure.
- Develop minimum connected infrastructure requirements for supporting safe navigation of grade crossings.
- Support large scale field operation tests and model deployments to foster innovation and collaboration.

This project specifically addresses the following issues within this environment:

- Reducing fatalities and accidents at grade crossings
- Improving communication between railroad systems and traffic control to facilitate safe and consistent navigation of highway-rail grade crossings
- Strengthening coordination between government safety agencies and private developers

FY19 Activities:
- Refining RCVW algorithms for consistent performance under challenging scenarios
- Evaluating diverse data stream requirements for safety critical operation
- Field testing and performance evaluation

Alignment with DOT Strategic Goals
RCVW supports DOT Strategic Goals by improving Safety at grade crossings by enabling autonomous and connected vehicles to safely negotiate grade crossings.

Expected total project cost and expected funding for FY 2019
The planned project total cost is $2,000,000. The planned funding for FY 2019 is $850,000.

Is there a non-Federal financial contribution? If so, how much?
Yes. Suppliers and automotive manufactures are providing in-kind support through cost-free participation in the project stakeholder and technical advisory groups. Some matching funds in the form of equipment donation and support from highway infrastructure suppliers and connected vehicle equipment manufacturers have been pledged.

B. GradeDec $25,000

Meeting the Office of Management and Budget (OMB) and U.S. DOT requirements for benefit-cost analysis of infrastructure investments, GradeDec.Net is the railroad industry standard for highway–rail grade crossing investment analysis. Class I railroads, U.S. DOT, State DOTs, metropolitan planning organizations, and transportation researchers rely on GradeDec for benefit-cost analysis, especially for grade crossing closure and separation. It is an online tool located on the FRA website and helps over 1,400 users address grade crossing safety and transportation network management issues. Twenty States and multiple jurisdictions depend upon the established reliability of GradeDec.Net.

GradeDec.Net measures the benefits and costs of safety, travel time, vehicle operating costs, and environmental benefits of grade crossing investments. GradeDec users can evaluate a single crossing or all crossings along a railroad corridor or within a geographic region. State DOTs can identify the most dangerous crossings on a passenger rail corridor or within a metropolitan area, county, or the entire State.

Why should we pursue (or invest in) this research?
This project supports FRA's mission to reduce accidents at highway-rail grade crossings. It encourages the use and development of cost-effective and innovative signaling technologies. GradeDec.Net is the only infrastructure benefit-cost analysis tool provided by U.S. DOT. It is used by the general public, the railroad industry, and State and local governments.

Who else is researching this issue?
National Academies of Science, Transportation Research Board (TRB), State DOTs, university engineering departments, and metropolitan planning organizations. These organizations and their consultants use GradeDec as

part of their research efforts to improve safety and efficiency on the U.S. These parties provide FRA suggestions to improve and update GradeDec. These researchers also conduct separate research projects to customize GradeDec.

Have we invested in this topic in the past and what have we learned to date?
Yes, FRA has invested in grade crossing research and GradeDec in the past. Current research finds that driver risk increases in highly congested areas. More tools are needed to help States implement pre-emptive signaling, especially on rail corridors governed by PTC systems.

Objectives, activities, and what is the problem being addressed?
The objective of GradeDec is to reduce traveler delay and bottlenecks and improve safety at grade crossings by allowing GradeDec users to evaluate pre-emptive signaling systems at heavily-traveled highway-rail at-grade crossings. Users will have the option to invest in the most cost-effective technologies to redirect highway traffic away from congested grade crossings during peak travel times. Activities include GradeDec updates and improvements and two on-site workshops in response to State DOT requests.

Alignment with DOT Strategic Goals
This project aligns with the DOT Strategic Goals of Safety, Infrastructure, and Accountability. GradeDec supports DOT Strategic Goals by improving safety and supporting economic growth. GradeDec is used to identify high-risk crossings and to manage highway delay and bottlenecks.

Expected total project cost and expected funding for FY 2019
Total project costs for web hosting, database management, software maintenance, and updates since 2002 is $790,000. Expected funding for FY 2019 is $25,000.

Is there a non-Federal financial contribution? If so, how much?
FRA does not have an estimate of railroad financial contribution at this time. In-kind labor will be provided as the following software services: testing, coding, and recommendations for improvements.

C. Generalized Train Movement Simulation (GTMS) $75,000

The GTMS is an online, web-based risk assessment modeling tool developed by FRA RD&T. It is designed to model train movement in highly complex railroad operating environments; simulate multiple braking algorithms including adaptive braking; generate and manage records of time, position, and speed of each train; and quantify network and dispatcher-induced train delay for all trains by train type. FRA uses GTMS in cooperation with the Class I railroads to evaluate the effects of PTC systems on accident risk and railroad network capacity. FRA uses GTMS to estimate the costs and benefits of new safety regulations.

State DOTs and their consultants use GTMS to evaluate the capital costs of adding or increasing passenger rail service on freight rail lines. GTMS is an open source tool available to the public upon request. Expert users are able to modify the software code to replicate unique operating practices considered private and confidential.

Why should we pursue (or invest in) this research?
GTMS is used to evaluate the economic costs and benefits of FRA's Office of Railroad Safety (RRS) regulations, to estimate the impact of adding or increasing passenger rail service on freight rail lines, and to estimate the risk associated with implementing upgrades to PTC systems.

Who else is researching this issue?

FRA RRS, AAR, the TTC, university engineering departments, and Class I railroads. AAR, all seven Class I railroads, and university engineering departments have established GTMS accounts to conduct research on the effects of PTC on railroad network capacity. Since GTMS is open source, Class I railroads intend to customize it to model secure and sensitive information (e.g., operation plans and communication systems). FRA RRS plans to use GTMS to evaluate the safety impact new PTC technologies.

Have we invested in this topic in the past and what have we learned to date?
GTMS now imports track infrastructure files and its open-source code allows users to modify the software to account for unique attributes of their system.

Objectives, activities, and what is the problem being addressed?
This project will quantify railroad risk under any conceivable signaling system, estimate the impact of PTC communication-based failures on railroad network capacity, and measure system random access memory Reliability, Availability, and Maintenance (RAM) metrics. All seven Class I railroads have access to GTMS open-source code as an executable file or as an online secure user account. FRA RRS plans to use GTMS to evaluate proposed changes to PTC systems intended to further reduce the risk of PTC preventable accidents.

Currently, GTMS input and output is at the subdivision level. Additional work in FY19 will allow users to link multiple subdivisions to form an entire railroad division. GTMS updates and revisions will customize the dispatcher algorithm to meet multiple optimization strategies.

Alignment with DOT Strategic Goals
This project aligns with the DOT Strategic Goals of Safety, Infrastructure, and Accountability.

Expected total project cost and expected funding for FY 2019
Total project cost for research, software development, web hosting, database management, and 24-hour database server support, updates, and maintenance is $4 million. Estimated FY 2019 cost is $75,000.

Is there a non-Federal financial contribution? If so, how much?
The Class I railroads will contribute to future development and maintenance of this tool. FRA does not have an estimate of railroads financial contribution at this time. In-kind, labor will be provided as the following software services: testing, coding, and recommendations for improvements.

Train Control and Communication - Priority Research Project 4: Grade Crossing Safety and Trespass Prevention: Investigating the Use of Artificial Intelligence in Railroad Systems $200,000

This research will investigate the use of artificial intelligence and data analytics to help researchers determine environmental and human factors that cause people to trespass on railroad right-of-way (ROW).

Why should we pursue (or invest in) this research?
Trespass is the main cause of accidents that occur on the railroads' ROW. The results of this FRA research project would not only increase the level of confidence in the detection of railroad trespassers, but also provide potential cost savings to the railroads and its partners, and increase public safety. There are methods to detect trespassers using live video, but no effective way to recognize a trespasser with a high level of confidence. While video recording devices installed on locomotives record all events happening ahead of the train, there is always a possibility of error in detecting a trespasser. Machine learning algorithms to be researched and investigated through this project could provide the missing gap in active trespass detection.

Who else is researching this issue?
Some universities have started considering video analytics (Massachusetts Institute Technology, Rutgers University, and University of South Carolina, among others). While this area of research is still at a very early stage of development, it is anticipated that FRA will collaborate with both the Class I railroads, universities and private sector to develop the appropriate algorithms.

Have we invested in this topic in the past and what have we learned to date?
FRA has considered big data mining to analyze accident statistics and trends, but no research has been undertaken with respect to video learning.

Objectives, activities, and what is the problem being addressed?
The objective of this research is to develop a machine learning algorithm capable of analyzing video from several sources and detect whether there is a trespass occurring or has been recorded without knowledge by the train crew. Cameras are installed on locomotives and on several locations along the ROW (e.g., stations, grade crossings, among others). There is a need, however, to have the ability to recognize when a trespass event occurs.

This is a brand-new project with deliverables to be determined based on the proposals received. The high-level objectives are described above. The project is currently being advertised through the Broad Agency Announcement (BAA).

Alignment with DOT Strategic Goals
This project supports DOT Strategic Goals of Safety, Innovation, and Accountability.

Expected total project cost and expected funding for FY 2019
$200,000 is the expected initial amount for FY2019. However, additional funds will be needed depending on proposals and how the project unfolds in future years.

Is there a non-Federal financial contribution? If so, how much?
Non-Federal funding will be determined as the proposals are evaluated and selected.

Human Factors –Priority Research Project 5: Automation, Operating Personnel Information Management and Control:
Note: Automation, Operating Personnel Information Management and Control research includes multiple contracts with two priority contracts discussed as part of Project 5.

A. Monitoring Engineer Fatigue (MEFA) System $179,580
Across all transportation modes, fatigue impacts performance. According the National Transportation Board (NTSB) "Fatigue can be just as deadly in transportation as alcohol and drug impairment, and fatigued drivers and operators regularly cause accidents." Degraded engineer performance is a significant contributor to most major accidents in the rail industry, with engineers missing wayside signals, having reduced situation awareness, or falling asleep while operating the locomotive. This performance level is often due to simple human error that is most often immediately corrected, but when an engineer is fatigued, the likelihood of corrective action decreases and the risk for a major accident increases.

FRA will develop the Monitoring Engineer Fatigue (MEFA) system as a means of improving locomotive operational safety. MEFA is an in-cab, passive monitoring system of motion sensors and intelligent software capable of detecting and signaling when a locomotive engineer is less vigilant due to fatigue. The system relies on multiple

physiological and behavioral cues from the sensors to infer the engineer's level of fatigue. MEFA will consist of a critical fail-safe monitoring system that existing Alerter systems do not have.

Why should we pursue (or invest in) this research?
The current detection and intervention method is the standard locomotive Alerter system, which monitors for frequent engineer interaction with the locomotive control panel. If there is no activity registered within a randomized period of time, the Alerter will activate a loud audio alert believed to be sufficient enough to wake up an engineer.

Although this system is reasonably effective given its simplicity, the Alerter does not account for whether the engineer is truly mentally engaged, MEFA will fill this gap. This technical approach to Alerter systems in locomotives has not been taken previously, and if MEFA is successfully developed and deployed, should drastically reduce the rail accident rate due to fatigue.

Who else is researching this issue?
No one else is researching this approach to fatigue and locomotive Alerter systems

Have we invested in this topic in the past and what have we learned to date?
The issue of fatigue monitoring and alertness in vehicle operations has been broadly researched, across modes. FRA defined and demonstrated fatigue and its degrading effects on human performance in simulators. FRA studies have documented fatigue-related degradation of performance in locomotive crews, dispatcher operations, and maintenance of way workers.

Objectives, activities, and what is the problem being addressed?
Fatigue is a degrading effect on human performance, thereby producing operational errors leading to accidents. The objective of this research is to develop a prototype passive monitoring system to detect a fatigued or asleep operator and take action. It is a fail-safe device intended to be more reliable than the existing Alerter system. Research activities include:

Activities:
- Selection of sensors for behavioral monitoring
- Development of software algorithms that provide the "intelligent" or decisional interface
- Integrating and testing the system with locomotive crew in FRA's Cab Technology Integration Laboratory (CTIL)
- Successful demonstration of the prototype in CTIL would lead to integration and testing in an actual locomotive. Actual locomotive testing is not arranged or funded at this time.

Alignment with DOT Strategic Goals
This research aligns with the transportation "safety" strategic goal and is part of FRA's automation and fatigue research project areas. Both research areas that are a high priority for DOT.

Expected total project cost and expected funding for FY 2019
The expected total cost if all phases are executed over an approximate 2-year period of performance is $394,618. Expected funding for FY 2019 is $179,580 for Phase 2 of 3 phases.

Is there a non-Federal financial contribution? If so, how much?
Non-federal contribution from the Aurora-MIT team is "at least $25,000" according to the cost proposal from Aurora Flight Sciences' and partner the MIT Man-Vehicle Laboratory (MVL).

B. Augmented Reality Head-Up Display (HUD) FY 2019 2nd task $ $500,000

Two behaviors are prominently related causal or contributing to major train accidents: locomotive crew distraction and loss of situational awareness. FRA is conducting research on an innovative approach to providing vehicle and environmental information to the crew where visual focus is maintained outside the locomotive cab.

Objectives, activities, and what is the problem being addressed?
This study will determine the relative utility of three different types of display in representative operational situations:

- A traditional wide field-of-view HUD
- A novel form of HUD with augmented reality features (containing symbolic representation of visual cues in the environment)
- Existing head-down operating display

This HUD provides information on the environment overplayed on the HUD. Train drivers operate by vision, focusing on all the visual cues on the track and in the environment. This study will address distraction and situational awareness challenges.

Have we invested in this topic in the past and what have we learned to date?
FRA has completed preliminary work in HUD to determine if RD&T could create a HUD in the simulator environment for further testing and research. The work effort has been divided into three major tasks to be completed over a period of 2 years which will lead to the design, development, and empirical evaluation of a prototype HUD in FRA's CTIL simulator. During FY 2019, Task 1 will be funded. Task 1 consists of the display design and feasibility assessment whereby there will be a HUD literature review, task modeling, iterative design modifications and a technical feasibility study of conformal (view adjusting) display technology.

Alignment with DOT Strategic Goals
This project aligns to DOT Strategic Goals Safety and Innovation.

Expected total project cost and expected funding for FY 2019
The expected total project cost is $1M as proposed in the BAA response. AAR has significant interest and support in the application in HUD technology (in writing). The Brotherhood of Locomotive Engineers and Trainmen (BLET) and International Association of Sheet Metal, Air, Rail, and Transportation Workers (SMART) support research on HUDs (in writing).

*Is there a non-Federal financial contribution? If so, how much***?**
This project does not include non-Federal funding.

BAA with MIT-GE Global Research

High Priority Completed Projects in FY 2017 or FY2018

Completed Priority Research Project 1: Autonomous Track Geometry Measurement System (ATGMS)

Objectives and activities
Autonomous Track Geometry Measurement System (ATGMS) technology was developed to enable high quality track geometry data collection without the need for traditional manned geometry railcars. The technology leverages advancement in sensor and communications technology to create a fully autonomous data collection system that transmits safety critical data directly to decision makers. The outcomes of this project include:

- Eliminated the need for direct human supervision of geometry data collection,
- Reduced life cycle costs of geometry measurement operations,
- Reduced interference with revenue operations,
- Increased inspection frequencies and productivity,
- High quality data, available remotely.

Alignment with DOT Strategic Goals
ATGMS aligns with the DOT Strategic Goals of Safety, by improving field inspection capabilities and knowledge of track geometry information, and Innovation by leveraging advancements in senor, power control, and communications technologies to produce a fully autonomous inspection system.

What was learned?
The ATGMS project has demonstrated that significant operational and efficiency improvements can be realized through focused application of advanced, commercially available technologies. This project has transformed the way in which the railroad industry collects track geometry data.

What were the research outputs/outcomes?
Physical outputs of the program include ATGMS installed on the DOTX225 and DOTX226 boxcars (each FRA-owned rail car has a car number designation that begins with DOTX). These ATGMS-equipped rail boxcars are currently used by FRA RRS as part of its mission to ensure rail safety. FRA RD&T developed ATGMS technology is experiencing wide-spread commercialization and may soon become the rail industry's predominant method to collect track geometry data. FRA's contractor has built/sold ATGMS's, based on the FRA design, to Metro North Railroad and several Class I railroads including: CSX, Norfolk Southern, and Union Pacific.

Does further research need to be done? If yes, for what purpose?
No significant additional research is planned at this time.

Will non-Federal stakeholders contribute to further research? If yes, how much?
This is not applicable.

What was the total cost?
The total cost of the project was approximately $5,000,000.

Were non-Federal dollars leveraged? If so, how much?
Non-Federal dollars were leveraged as part of this development project. There is not an accounting of all the non-Federal dollars that supported the development of the ATGMS technology. Many railroads contributed towards the success of this project. Railroads provided access to vehicles and equipment for system development and installation, testing support through complementary train moves, invaluable technical feedback on system design and data products. In addition, the FRA contractor commercialized, at their own expense, the FRA prototype into a viable product. The research project was recently completed and the final report is currently in the initial stages of FRA review.

Completed Priority Research Project 2: Fiber Optic Broken Rail Detection

Objectives and Activities
The objective of this project was to evaluate the performance of a fiber optic-based broken rail detection system. The goal was to research and investigate the potential for a fiber optic-based system to replace the functionality of a track circuit.

Real-world tests were conducted on revenue-like trains at the TTC. The tests were conducted throughout several phases, to extract cumulative results and create expectations for revenue service railroads. The fiber optic Distributed Acoustic Sensing (DAS) broken rail detection evaluation was conducted in three phases. In the first phase, vendors set up and calibrated their systems at the TTC, which consisted of configuring the fiber optic test bed, installing and integrating the DAS broken rail detection systems with the test bed, and calibrating the systems once integrated. The second phase consisted of data gathering and analysis during normal operations at the TTC Facility for Advanced Service Testing (FAST). The third phase involved data gathering and analysis from additional testing at varying train speeds.

Alignment with DOT Strategic Goals
This project aligned with DOT Strategic Goals of Safety by increasing the accuracy and timeliness of broken rail detection, Innovation by automating system operations and performance, and Accountability reducing the regulatory burden.

What was learned?
While fiber optic technology can perform some of the functions of track circuits to a limited degree, the technology needs to improve significantly before fiber optic replacement of track circuits is a serious consideration. The evaluation of the DAS systems shows that improvement is needed in both the rail break detection accuracy and the reduction of false alarms, as well as improvement in performance at lower speeds.

What were the research outputs/outcomes?
A defined understanding of the limitations of fiber optics sensing technology. Analysis of the collected data revealed that the technology is in its infancy and must be progressed to efficiently add to the capability of current technologies such as track circuits. There are still a considerable number of undetected broken rails and substantial false alarms that must be addressed prior to being considered a viable alternative to current technology.

Does further research need to be done? If yes, for what purpose?
No, further research does not need to be done.

Will non-Federal stakeholders contribute to further research? If yes, how much?
There is a significant interest in the railroad community to expand this research. FRA, Transportation Technology Corporation, Inc. (TTCI), and the Fiber Optic Acoustic Detection (FOAD) advisory group (AG) met with the vendors at the AAR Annual Review to discuss the technology, progress, limitations and future development.

The FOAD AG has been active and will continue to review the progress and potential applications of this technology. There is no additional fiber optic technology development or analysis scheduled for FRA funding at this time. Certain North American railroads are currently engaged in further research, but the exact level of activity is unclear.

What was the total cost?
$766,323

Were non-Federal dollars leveraged? If so, how much?
No non-Federal dollars were leveraged.

Section 1 – Program Descriptions, FY 2019

FY 2019 RD&T Program Funding Details

RD&T Program Name	FY 2019 Pres. Budget ($000)	FY 2019 Basic ($000)	FY 2019 Applied ($000)	FY 2019 Development ($000)	FY 2019 Technology ($000)
Railroad Systems Issues	$4,871*		$4,050	$821	
Track Research	$9,179		$7,109	$2,070	
Rolling Stock	$10,322*		$8,182	$2,140	
Train Control & Communication	$8,086		$6,306	$1,780	
Human Factors	$6,042*		$4,780	$1,262	
Totals	**$38,500**		**$30,427**	**$8,073**	

*Amounts include earmarks for Short Line Safety Institute ($2,500) in Human Factors, Safe Transportation of Energy Products ($2,000) in Rolling Stock and Research with Universities on Intelligent Railroad Systems ($1,000) in Railroad Systems Issues.

* *The total amount does not include $2,100 for facilities per instructions for the report. The total amount includes earmarks. All carryover amounts are included in the Project Spend Plan.

FY 2019 RD&T Program Budget Request by DOT Strategic Goal

RD&T Program Name	FY 2019 Pres. Budget ($000)	SAFETY ($000)	INFRA-STRUCTURE ($000)	INNOVATION ($000)	ACCOUNT-ABILITY ($000)
Railroad Systems Issues	$4,871*	$4,871*			
Track Research	$9,179	$9,179			
Rolling Stock	$10,322*	$10,322*			
Train Control & Communication	$8,086	$8,086			
Human Factors	$6,042*	$6,042*			
Totals	**$38,500**	**$38,500**			

*Amounts include earmarks for Short Line Safety Institute ($2,500) in Human Factors, Safe Transportation of Energy Products ($2,000) in Rolling Stock and Research with Universities on Intelligent Railroad Systems ($1,000) in Railroad Systems Issues.

* *The total amount does not include $2,100 for facilities per instructions for the report. The total amount includes earmarks. All carryover amounts are included in the Project Spend Plan.

Although all funding is listed under the Strategic Goal of Safety, funding for research addresses the other Strategic Goals. For example, Grade Crossing research addresses not only Safety, but Infrastructure and Innovation. Additionally, Automated Track Inspection Technology addresses Safety, Accountability and Innovation.

Research, Development, and Technology
Funding Request $40,600,000

Program Description/Activities:

The Railroad Systems Issues (RSI) research program directs the entire Research, Development, and Technology (RD&T) program towards the goals set forth by the Department of Transportation (DOT), the Office of the Assistant Secretary for Research and Technology (OST-R), the Federal Railroad Administration (FRA), and the Office of Railroad Policy and Development (RPD). The RSI research program defines the strategy to meet DOT's, OST-R's, FRA's, and RPD's goals and, and assures these goals are met. The principal focus and goal of the RD&T program is safety. FRA's RD&T program yields solutions that contribute to all DOT goals to advance infrastructure, innovation and accountability, while maintaining a safety focus.

Economic Impact of Regulatory Reform:

RD&T conducts research to improve railroad safety and provides data to support the activities of the Office of Railroad Safety (RRS) including their regulatory reform efforts. Essentially, RD&T lays the foundation for regulatory reform and promotes decisions that are data driven. Research conducted by FRA decreases the cost of complying with regulations. For example, innovations in automation resulting from FRA research allow the railroads to decrease the economic burden of inspection allowing the railroads to inspect more of the rail network for a lower cost. This reduction in burden is realized by reduced labor hours and track time, reduced equipment failure, or improved infrastructure, all resulting in fewer incidents. To maximize research resources, RD&T collaborates with RRS to align and prioritize project selection to focus research in areas of high concern and impact in support of regulatory reform.

RD&T conducts research that addresses the improvement of the Code of Federal Regulations (CFR*) Title 49 Part 213 Track Safety Standards; Part 215 Railroad Freight Car Safety Standards; Part 225.12 Rail Equipment Accident/Incident Reports alleging employee human factor as cause; Part 228 Hours of Service of Railroad Employees; Appendix F Part 229 Recommended Practices for Design and Safety Analysis; Part 231 Railroad Safety Appliance Standard; Part 232 Brake System Safety Standards for Freight and Other Non-Passenger Train and Equipment; End-of-Train Devices; Part 234 Grade Crossing and Signal System Safety; Part 236 Subpart I Positive Train Control Systems; Part 238 Passenger Equipment Safety Standards; Part 239 Passenger Train Emergency Preparedness; Part 270 System Safety Program; Part 924 Highway Safety Improvement Program;* and *Appendix E Part 236 Human Machine Interface (HMI) Design.*

In addition to addressing CFR 49, FRA established the Grade Crossing and Trespassing Task Force and a working group that is currently drafting a notice of proposed rulemaking (NPRM)for Locomotive Recording Devices. FRA working groups create forums where stakeholders across the industry address safety concerns. Working groups allow FRA to gain direct industry input. Collaboration may lead to research projects or industry standards that directly address the needs of the industry, including barriers to adoption and the cost of implementation for new and emerging technology.

Economic Impact of Permitting Reform:

RD&T's research does not address the economic impact of permitting reform.

Performance-Based Regulations and Safety:

RD&T research programs address performance-based regulations across multiple research areas.
The Track Research program focuses its efforts in developing the scientific basis for removing prescriptive-based regulations and moving toward performance-based regulations. The Rolling Stock program staff are engaging stakeholders across the industry to address performance-based regulations as they relate to research including tank cars, hazardous materials, wheel failures, high-speed rail, and glazing systems to reduce fatalities. The Human Factors research program is researching new performance-based regulations that may increase the sharing and use of data. Each research program is working with RRS and other transportation modes to research best practices and new approaches to improving safety.

Potential Impact of Asset Recycling:

Research activities include the acquisition of tank cars and tank car pieces resulting from derailments. These tank cars and pieces are acquired from the railroads after an incident and moved to the TTC for further research and analysis to determine the potential causes of the incident. At the completion of the research, tank cars and pieces are sold as scrap materials.

Potential Impact of Value Capture:

RD&T's research does not address value capture.

Improving the Mobility of Freight:

Each RD&T research program improves the mobility of freight on America's railways. RD&T's research efforts help improve infrastructure and introduce innovations that contribute to improving the mobility of freight. Research by the Track Research and Rolling Stock programs to prevent the derailment of trains significantly affect mobility. Rolling Stock's research on early detection of rail wheel defects reduces the risk of an accident caused by that type of defect. Positive Train Control (PTC) research conducted by Train Control and Communication allows for the faster delivery of people and goods by rail. Research on very long trains conducted by the Rolling Stock and Human Factors research programs supports the economic competitiveness of railroads while maintaining safe operations, improving the mobility of freight by identifying risks and developing strategies for mitigating those risks.

Feasibility of Micro-Transit:

RD&T's research does not address micro-transit.

Improving Mobility for Underserved Communities:

RD&T structures research to address high priority problems wherever they may occur. Although RD&T programs impact short lines and grade crossings, which have a higher concentration in rural areas, programs have not historically been geographically focused. Autonomous inspection programs conducted by the Track Research program included short lines to identify high risk derailment locations. PTC research is improving the safety of all communities including rural and underserved communities. RD&T's research will inform FRA of rural and underserved area unique concerns and challenge which will aid project prioritization and planning to consider these challenges in the future. The Research with Universities on Intelligent Railroad Systems project will provide

preference towards projects that implement technology in rural areas (see the Program/Activities section) to improve the mobility of underserved communities.

Cybersecurity:

Train Control and Communication's research includes cybersecurity. TTC's cybersecurity focus is securing the communication and ensuring authentication of sender and receiver of the PTC communication. Multiple PTC research efforts address security which includes "cybersecurity."

Federal Role/Continued Relevance:

Aligned with DOT OST-R research objectives, FRA research identifies and addresses safety issues across the railroad industry, including high-risk, and long-term research. The sustained funding of FRA's research and development mission enables pursuit of safety specific research needs. This allows FRA to initially bear the costs and risks for research that the railroad industry is unable to pursue. The results of which lead to innovative solutions that may not otherwise materialize.

FRA's program managers (PMs) use many tools to provide decision points for evaluating project progress and relevance. Each vendor provides monthly/bi-monthly/quarterly progress reports that provide deliverables, milestones, and research progress including research status and significant accomplishments. PM's work with vendors, industry stakeholders and subject matter experts throughout the research life cycle. This collaboration and interaction provides a wealth of knowledge to assess the progress of research activities and facilitate the technology transfer. Using this knowledge and that gained from program metrics and industry commitment, the PM conducts assessments of research projects' progress and their continued viability or relevance. FRA RD&T formalizes research priorities and accounts for the assessments of PMs, industry commitment, administration priorities and the Technology Readiness Level (TRL) of evolving technology to determine if the research warrants continued support.

FRA's extensive synergy with industry stakeholders and external research partners delivers accelerated information sharing and technology transfer, to achieve safety goals. To guide FRA's investments, RD&T sets forth a research agenda defined by a clear set of priorities to investigate current and future safety issues.

The relevance of Government funding of R&D research is clear and substantial. Without this investment, significant safety related research would not occur and the benefits would not be realized.

Consistent funding of R&D activities is essential to the progress of the railroad industry and its efforts to modernize and improve safety. The cessation of R&D would have a devastating impact on railroad safety operations and undetermined impact on the economy, infrastructure, and environment. Without investing in safety research, RRS would lack contextual data or information to define safety requirements to address accidents and trends. As technologies and systems evolve, technical standards need to adapt and R&D is required to understand the safety implications of changes. Efficacy of technical standards are maintained by the scientific research of RD&T staff in collaboration with RRS. The economic impact would exceed that of the people, small business, universities, education supports and facilities directly involved with research activities, reaching those affected by the absence of new technology and innovations.

Even though the private industry may invest in research, the results would not be freely transferred within the industry, allowing companies to retain results for profit that could otherwise benefit the industry and the public.

Driven by private profits, innovation would lag, research would increase intellectual property rights, and the private industry would only do the minimum to meet the safety technical standards set by government policy.

Impact of Additional Funding:

In the 2017 AMRP, RD&T planned to spend over $40M on research and activities to improve railroad safety in FY18 and FY19. RD&T's 2018 AMRP and President's Budget reflected a reduction in funding translating to a reduction of investment. RD&T reprioritized projects through stakeholder engagement and DOT research priorities to meet the President's Budget. The additional $21.1M requested in this update of the FY19 AMRP will have the following impact on RD&T's research program and railroad safety improvement.

- RD&T will be able to expedite research timelines, returning to original research scope and plans.
- RD&T will have funding to address more DOT and OST-R priorities, aligning research to OST-R's research topic areas.
- RD&T will have the capability to add additional projects to RD&T's project list, investing in research needs pushed to future fiscal years. As part of FRA's new investments, RD&T will create a new partnership with private industry and universities that includes an investment of $2M/year from FRA and nearly $900K from AAR.
- The additional funding will also help RD&T better respond to RRS needs. RD&T has already committed to a new partnership with RRS, Railroad Information Sharing Environment (RISE) to promote the sharing of data to improve safety.

Statutory Requirements:

Railroad Research and Development is statutorily mandated in the budgets prepared by the President, House and Senate of the U.S. RD&T's research and outcomes are aligned directly to the statuary requirements. The Short Line Safety Institute grant is managed by FRA's Human Factor's division to improve the safety culture of Class II and Class III railroads. FRA has been working with the ASLRRA and the Short Line Safety Institute since funding was provided for this investment. The Rolling Stock division manages Tank Car research to improve the safe transport of energy/hazardous materials on America's railroads. The Railroad Systems Issues division created a contracting vehicle for administering and managing funding to universities on intelligent railroad systems. The Human Factors and Train Control and Communication divisions conduct research in grade crossing (GX) and trespassing.

RD&T utilizes statutory requirements to establish investment priorities. Priorities described in the (Senate/House) reports urge FRA to prioritize investments in the development of technologies designed to verify the functional performance of complex electronic systems such as:

- PTC,
- Electronically controlled pneumatic (ECP) brakes,
- Automated train control,
- Passenger door control,
- Train communications,
- Train environmental control, and
- Railcar signs.

Investments throughout the five divisions explore solutions to each of these priority areas, with the exception of ECP brakes, which, per Congress, is no longer a priority. All RD&T divisions address automation issues which aligns

with this recommendation. GX and trespassing are also a priority for RD&T as it is a priority for FRA RRS (their statutory requirement is also included below). Each division's section reviews activities and outcomes relative to these statutory requirements.

RD&T is collaborating with FRA RRS which has a statutory requirement to identify and study the causal factors that lead to trespassing incidents on railroad property and develop a national strategy to prevent trespasser accidents, including milestones, timelines, and metrics to define success. The House and Senate Committees on Appropriation directs FRA to submit the trespassing prevention strategy to the Committee no later than August 1, 2018. The Committee expects FRA to implement the national strategy to prevent trespasser accidents within the recommended timelines.

Program Alignment with Strategic Goals:

RD&T strategically aligns its research with DOT, OST-R, FRA, and RPD goals and strategic plans, with a focus on improving the safety of America's railways. Many of RD&T's research projects yield additional benefits in the areas of innovation, infrastructure, and accountability. As the railroad industry evolves with emerging technology, FRA has been a leader for decades, researching innovative solutions to improve the safety of moving goods and people in America. All five divisions of RD&T conduct research in automation technology to help understand how to best utilize new technologies and minimize the human error associated with automation. Projects conducted by the Track Research, Train Control and Communication (TCC), and Rolling Stock divisions improve the infrastructure of America's railroads to improve safety. RD&T continues its research into the industry's workforce development efforts to support the infrastructure of America's railroads. Project evaluations conducted by the Human Factors division support RD&T's goals of accountability and helped gain insight on how RD&T will mature its performance measurement and evaluation efforts. RD&T works closely with FRA RRS to provide the basis for science-based requirements, standards, and recommendations that have been tested in real-world environments with the help of companies and organizations who will adopt and use the technology.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

RD&T projects focus on problems impacting all urban, suburban, and rural communities. FRA structures research to address high priority problems wherever they may occur, responding to incidents that may take place during a fiscal year, with a long-term vision on improving safety. Although RD&T programs impact short lines and grade crossings which have a higher concentration in rural areas, programs have not historically been geographically focused. RD&T will consider rural communities as part of program planning in the future. The Research with Universities on Intelligent Railroad Systems project will provide preference towards projects that implement technology in rural areas (see the Program/Activities section).

Program Objectives:

While rail safety has improved over the last 10 years with the downward trend of accidents, FRA is still focused on improving the safety of railways for the American public and rail workers. RD&T's main objective is to reduce incidents and accidents involving America's railroads, to save lives, and reduce environmental hazards. Some of the problems FRA is solving include:

- Reduction of accidents caused by human error.
- Reducing track-related derailments.
- Reducing incidents and accidents related to grade crossing and trespassing.
- Investigating automation and technology

RD&T achieves its objective through continuous stakeholder engagement throughout a project's research, technology transfer, and acquisition life cycles. FRA's RD&T program objective is to promote innovation and facilitate leadership across the railroad industry in the exploration and use of technology and automation to advance the railroad safety culture. Anticipating the increased impact of technology and automation on the railroad industry for over a decade, RD&T's objective has been to better understand the benefits and impacts of technology on safety and workforce development. RD&T has prioritized research in technology, like PTC systems and issues, to provide needed solutions to the technology's development, implementation and integration issues.

RD&T addresses market failure by pursuing solutions to safety problems and striving to decrease the number of incidents and accidents, save lives and reduce property damage. Working with internal stakeholders like FRA's RRS, RD&T is able to react quickly to industry needs and address safety issues as they evolve.

Research Collaboration Partners:

RD&T utilizes stakeholder input to establish research needs and priorities. PMs are members of industry organizations and regularly engage stakeholders at meetings throughout the year to remain current on the issues and needs of the railroad industry. RD&T research collaboration partners include the railroads, labor, manufactures/suppliers, universities, non-profits, private industry, city/State/Federal government DOTs, and DOT Operating Administrations (OAs). Each RD&T research program will detail some of their partners. RD&T is considering tracking stakeholder input.

Partner Detail

Partner Name	Contribution	Benefit of Partnership
Universities across the United States	Expertise and research	Subject matter expertise and workforce development
American Public Transportation Association	In-kind contribution; subject matter expertise, data	Provide data on noise emissions design features
Class I Railroads	In-kind contribution; subject matter expertise	Provide locomotive engine, duty cycle data; support testing activities
American universities	Subject matter expertise	Subject matter expertise
Railroads	Access to rail facilities	Subject matter expertise
ASLRRA	Subject matter expertise	Subject matter expertise

Benefits Detail

Beneficiary	Benefit(s) Received
FRA RRS	Improved safety standards/recommendations Improved science to improve standards and requirements in support of EPA's revisions to noise emissions limit for trains
Rail industry	Improved safety standards/recommendations Lower operating costs Improved visibility for railroad workers and grade crossings Reduced railroad accidents and fatalities Reduced regulations
Small businesses, and University research centers	Improved railroad research resources and capabilities.
Class I Railroads	Standardized matrix to determine most efficient technology for improved energy and efficiency of locomotive engines

Acquisition/Assistance:

RD&T begins its acquisition process by engaging internal and external stakeholders to understand industry concerns, priorities, needs, and safety issues. RD&T establishes research priorities and defines its acquisition plan

considering internal and external priorities, and aligning priorities with DOT, FRA, and RPD goals for the upcoming fiscal year. RD&T utilizes a competitive procurement process across all the divisions.

RD&T works with the FRA Office of Acquisitions to initiate various funding vehicles across the department, including:

- Broad Agency Announcement (BAA)
- Indefinite Delivery/Indefinite Quantity (IDIQ)
- Full and open competition
- Sole Source
- Inter-Agency Agreement (IAA)
- Small Business Innovative Research Program (SBIR)

All RD&T divisions use a non-competitive (sole source) acquisition approach to conduct multi-phase research projects and for research that requires special expertise. In these cases, it is advantageous to the government's return on investment (i.e., no additional cost for educating and bringing a new contractor up to speed on the development already done). Sole source agreements are also used to increase partnerships with small businesses and universities. Sole source agreements are justified on a case by case basis. IAAs are established with the Volpe National Transportation Systems Center (Volpe Center) because of its technical expertise and existing relationships within the rail industry. The Volpe Center provides specialized support to RD&T's divisions. Work products produced by the Volpe Center are respected and adopted by the rail industry.

RD&T divisions fund research using an incremental approach to accommodate limited funding and limited availability of resources. Divisions utilize both single year and multi-year contracts and grants for projects. Research that is limited in scope or undertaken to answer questions related to a well-defined technical issue is often limited to one year or less. Multi-year acquisitions are used to provide incremental funding for research projects, especially when developing new technologies, and to allow for decision-making and potential redirection, as necessary, as the research progresses. As part of RD&T's decision-making process, PMs assess the viability of research and determine if research should continue at various stages of the research and development life cycle.

RD&T divisions benefit from in-kind contributions (e.g., subject matter expertise, track time, data sharing, and equipment) from their collaboration partners. These contributions are not only desirable for their inherent value but also guide researchers to develop practical technology that will function well in practice. Some divisions benefit from partners providing non-federal funding; however, this is not a requirement for RD&T research. Examples of RD&T's non-federal funding can be found in the following sections detailing the research program of each division.

Technology Transfer (T2):

Partnerships and stakeholder engagement form the foundation of RD&T's technology transfer (RDT2) methodology. Each division works closely with stakeholders throughout the R&D life cycle and the T2 life cycle to increase user adoption of research products/services. Over the past decade, RD&T has not seen an increase in budgetary dollars, requiring the divisions to begin working on user adoption prior to the start of research efforts.

Each division works with stakeholders to understand adopter (industry and stakeholder) needs and barriers to adoption. RD&T PMs work internally and externally to identify and address barriers to adoption. A major mitigation strategy used by FRA is to create partnerships across the industry to increase the likelihood of adoption. RD&T PMs are the subject matter experts (SMEs) in their areas of research. As the SMEs in their area, each PM

works with stakeholders (internal and external) in the industry to understand and develop new technology. RD&T PMs and their research partners work early in the research process to begin communicating the value and benefit of RD&Ts research products.

Most research conducted by RD&T is Technology Readiness Level (TRL) 1–5. TRL is a measure of the maturity of research. It helps FRA RD&T track progress from basic research (Levels 1–3) to applied research (Level 4–5), development (Level 6–8), and eventual implementation (Level 9).[1] These early levels (1–5) are the foundation for creating technology that is eventually adopted by the industry, showing evolution from modeling and proof of concept to prototype creation and testing in a lab or, sometimes, a real-world environment. RD&T determines expected TRL during acquisition planning and project prioritization based on stakeholder (internal and external) input, risk strategy and budgetary limits. RD&T's acquisition plan establishes resourcing and timelines for each project. Starting in FY19, RD&T will formalize its T2 methodology by piloting technology transfer plans throughout the divisions. RD&T will create program level T2 plans for each division. Plans will consider all program areas and include:

- Business Case
- Operational Need
- TRL Assessment
- Resource Strategy
- Risk Assessment
- Communications/Stakeholder Engagement Strategy
- Integration Strategy

As T2 plans are implemented, the identification of specific transfer activities will be performed throughout the research project life cycle. Stakeholder engagement is critical at all stages of research to ensure industry involvement, to maximize all resource streams and enhance wide adoption of new technologies.

Activities to directly support technology development and implementation (Technology Readiness) are integrated with the research project life cycle with a continuum of planning, engaging stakeholders, identifying resources and executing research activities. Consequently, performance of T2 activities occurs throughout the research life cycle and can be measured through the level of stakeholder engagement, commitment and adoption. Therefore, many research and project management activities can be, at least in part, attributable to T2 maturity efforts.

RD&T T2 related spend plans will be approximately $576K in FY19. T2 implementation costs include:

- Stakeholder Engagement
    - Industry Conferences, Meetings, Presentations/Demonstrations
    - Workshops, Committees and Summits
        - Right-of-Way Fatality & Trespass Prevention Workshop
        - Grade Crossing Workshop
- Communications
    - Support for publications and reports

Generally, RD&T's stakeholders are the railroad carriers, the labor unions, the railroad manufacturers, universities, FRA RRS, Federal Transit Administration (FTA), Pipeline and Hazardous Material Safety Administration (PHMSA),

[1] https://www.transportation.gov/sites/dot.gov/files/docs/research-and-technology/283896/novelsurfacetransportationmodes-web.pdf

Federal Highway Administration (FHWA), and the American public (each research program will address these categories specifically). These stakeholder groups benefit from RD&T's research through information sharing and transparency; development and testing of innovative technology; workforce development; safety recommendations; improved safety culture; safety tools; improved infrastructure; safety training; research risk mitigation; exploration of automation and the impact of automation on transportation; and safer transportation of goods and passengers throughout America's railroads. The beneficiaries of RD&T's research are the internal and external stakeholders especially the American public. RD&T's main goal is to prevent incidents and accidents on America's railways to prevent injury, loss of life and property damage.

Internal stakeholders, like RRS, provide safety data to RD&T leveraged for research and utilize RD&T research to support safety standards and requirements. RRS' use of RD&T research has improved the safety of American railways and decreased fatalities over the last 10-years. External stakeholders (e.g., railroads and labor unions) provide insights, trends, data used to begin and prioritize research. These same stakeholders participate in research either by providing expertise or equipment, providing feedback during research projects or as participants for research studies. Internal and external stakeholders consume RD&T research, implementing training, standards, or adopting RD&T equipment. A good example of the success of RD&T's technology transfer efforts is the success of the research with ATGMS. Numerous ATGMS systems have been built, or are under construction. FRA expects that ATGMS will soon become the rail industry's predominant method to collect track geometry data.

Most of RD&T's research projects include the production of Technical Reports and Research Results which are published on FRA's eLibrary at the conclusion of research, making the work accessible to the railroad industry's stakeholders and the American public. Some RD&T contracts include funding for vendors to present RD&T research at industry meetings with FRA permission. Information regarding RD&T's work can also be found on OST-R's Research Hub. RD&T will begin to publish research to the National Transportation Library (NTL) as part of its publishing process in FY19 to ensure material is widely available and searchable to increase the dissemination of FRA's reports. In an effort to increase production of tangible research outputs, FRA restructured its technical report review process in 2017 to decrease the time it takes to publish research material. FRA PMs begin to share research accomplishments and findings with stakeholders during the R&D life cycle during industry meetings so that the industry can benefit immediately from information and lessons learned.

In 2017, RD&T's produced two new products[2], filed two patents[3], worked with 16 small business and over 117 collaboration partners, published 29 Technical Reports/Research Results, and conducted 117 in-person webinars or presentations. In 2018, RD&T plans to increase the production of research outputs through its improved publishing process.

FRA RD&T has developed a Research Portfolio Information Action Plan to conduct an annual review and update of the FRA DOT Research Hub and US DOT Repository and Open Science Access Portal (ROSA-P) databases. This annual review is required by OST to maintain up-to-date content in the FRA USDOT Research Hub and ROSA-P databases. The Action Plan includes a step-by-step process that aligns with OST Annual Review Cycle (pending OST approval the annual process is subject to change to quarterly, tentatively effective 2nd Quarter FY19).

[2] Helping Train Engineers Think Ahead: Methods of Providing Situational Awareness (GE) and Simulator of Human Operator Workload (SHOW) (Duke University).
[3] A Method for Detection of Rail Breaks on Occupied Blocks to Support Reduced Train Spacing (TTCI – AAR) and Flexible Operator Location System (TTCI – AAR).

Monitoring and conducting the Research Hub updates will be the responsibility of the RD&T Program Office point of contact, with support from Director, Division Chiefs, and Program Managers.

US DOT Research Hub **-** The following data fields, as defined by the Research Hub data dictionary, need to be reviewed and updated**:** Project Title, short Description of the Project, program through which it is funded, Contract/Grant number (or other funding agreement identifier), Status:(active or completed), period of performance (POP) Start Date, POP End Date, amount of funding allocated to the project, and vendor (performing organization).

The FRA DOT Research Hub annual update process steps include:

Steps	Process
Steps 1-2	OST Database Administrator submits the US DOT Research Hub data export Excel spreadsheet to the RD&T Program Office POC.
Step 3	The Program Office POC sends an email communication to the Division Chiefs and PMs, with instructions and timeline to complete the review.
Step 4	Division Chiefs and PMs conduct a review, provide updates and corrections in the SharePoint collaboration tool within 90 days. ***(Please note the first time will be a one-time clean-up effort, future updates will have a shorter turn-around time)***
Step 5	Division Chiefs and PMs will confirm completion of review and provide updates to RD&T Program Office POC.
Step 6	RD&T Program Office POC will send the updated Excel spreadsheet to OST Database Administrator. The OST Database Administrator will upload updates to the FRA DOT Research Hub.

Data Collection Criteria: Baseline date parameter includes all projects that are either Active/Closed from 2014–2020. (Approved by OST Research HUB Database Administrator).

US DOT Repository and Open Science Access Portal (ROSA-P) – The data fields to be reviewed and updated include: Ongoing and continuous updates to the ROSA-P include: updates to reports, research results and summary descriptions of project outputs and outcomes/impacts.

The ongoing ROSA-P update process steps include:

Steps	Process
Step 1	RD&T Division Chiefs and Program Managers send the Technical Editor the final deliverable reports, research results and summary descriptions of project outputs.
Step 2	RD&T Technical Editor prepares the reports and research results then sends email notifications with the URL for publication to the FRA Web Team. (Frequency is weekly or monthly.)
Step 3	The FRA Web Team receives an email from the Technical Editor. The Web Team generates the publication notification.

Step 4	RDT Technical Editor sends email communication with the URL for publication to the following: • Division Chief • Program Manager • RD&T Director • Strategic Communications • Public Affairs • National Transportation Library • Transportation Research Board • US DOT Repository and Open Science Access Portal (ROSA-P)

RD&T is establishing a baseline for measuring the performance of its T2 activities in FY18. RD&T published 110 publications between October 1, 2015, and March 30, 2018. Using this timeframe as a baseline, RD&T will establish the following:

eLibrary Metrics
- Total Traffic to eLibrary FY18
- Total Traffic to RD&T Research FY18
- Total Traffic to Special Project Areas
- Traffic by Region/Classification

Utilizing this information as a baseline, RD&T is establishing following goals to measure the effectiveness of T2 in FY19 and FY20:
- Increase Traffic to eLibrary
- Increase Access to RD&T Research
- Increase Traffic to Special Project Areas
- Access to Research Hub
- Access to NTL
- Conduct In-Person/Webinar Presentations
- Traffic by Region/Classification

Evaluation/Performance Measurement:

RD&T established two vehicles for evaluating project performance and to assess the manner and extent to which programs achieved their intended objectives. In compliance with the Government Performance and Results Act (GPRA) and the GPRA Modernization Act of 2010, the RD&T program performs project evaluations specifically designed to:
- Guide and strengthen RD&T's program execution.
- Facilitate the collection of feedback to improve project performance.
- Assess achievement of target audience needs.
- Assess and drive the transfer of technology to the private sector.

RD&T's external project evaluation "program" determines the effectiveness of research programs and their intended impact. The results inform project performance improvements and increase the Return on Investment (ROI) on funding. Initially, RD&T required each division to conduct a pilot project evaluation, with the intent to

improve FRA's ability to assess the impact on improving rail safety resulting from RD&T research projects. Each division selected projects for external evaluation and RD&T conducted both formative (proactive) and summative (retroactive) evaluations comprised of four evaluation categories (context, input, impact and implementation).

In 2015, RD&T sponsored an external evaluation conducted by the Transportation Research Board (TRB) titled "Transportation Research Board Special Report 316 Evaluation of the Federal Railroad Administration Research and Development Program." The evaluation encompassed each research division, focusing on research projects, communication, stakeholder engagement, strategic planning, and priority setting and evaluation. FRA used the evaluation to address each TRB recommended area for improvement. RD&T plans to support another TRB evaluation (FY 2020) and will concurrently implement internal processes to improve FRA's accountability to the American public.

To improve the effectiveness of performance management, RD&T conducted project evaluation training for each division in 2018. The training provided a basic evaluation skillset for each RD&T PM. As part of the evaluation program, RD&T tracks project data and leverages information to make data driven decisions. RD&T remains committed to using performance measurements to improve research and development throughout the life cycle process, with the goal of standardized performance measurement across the organization.

An effective performance management approach promotes the use of information learned through evaluations to inform and influence project planning, strategy, technology transfer, and stakeholder engagement. As best practices for measuring performance are deployed throughout RD&T (FY 2019–FY 2020), a full range of projects will be systematically evaluated. Technical evaluation support will implement an evaluation framework, standards, procedures, and templates as identified in the "FRA Evaluation Implementation Plan" and the "FRA Manual for Research, Development and Technology (RD&T) Program and Project Evaluation." As the performance measurement framework and methodology is developed, RD&T will implement the following tools and techniques:

- A framework based on DOT's, OST-R's, FRA's and RPD strategic goals and objectives for categorizing research into tiers so that appropriate measurement and evaluation methodology can be used to provide the right information at the right time for the right purpose.
- A workflow map of the research life cycle used in RD&T with a corresponding set of evaluative questions and performance measures that will be used for each phase to demonstrate progress, efficiency and effectiveness.
- A balanced set of performance measures with definitions and data collection plans.
- An established baseline for data measures.
- A guide that provides an understanding of the basic evaluation questions and key metrics to use throughout the research process.
- The handbook that includes two types of tools sample templates and descriptions of methods for assessing research impact.
- An applied project, whereby the information from the Quick Reference Guide and Handbook will be used on a specific project.

Starting in FY19, FRA will measure performance for the DOT Strategic Goal Innovation.

Development of Innovation
- Increase Dissemination of DOT-Funded Research Reports (OST)
- Increase Production of Tangible DOT-Funded Research Outputs (OST)
- Increase DOT Technology Transfer Activity (OST)

Deployment of Innovation

- Increase Tangible Production of DOT-Funded Research (OST)

RD&T began tracking data with FRA's OST-R Technology Transfer Report 2017. As discussed in the T2 section, RD&T will establish baseline metrics using data from FY18 to track performance against the Innovation performance goals. RD&T will track page views and downloads of published materials in addition to the following data to measure progress:

- Collaborative relationships
- Technical publications made available to public
- In-person or webinar presentations delivered to foster technology transfer
- Technical publication downloads – NTL
- Workshops or demonstrations to foster technology transfer
- Total number of small businesses supported
- Number of new inventions disclosed
- Number of patent applications filed

RD&T has commissioned the development of a project evaluation program, scheduled to be rolled out next quarter, that will implement the processes, tools and training to support the evaluation of program performance as an integral part of managing research projects. The program will include guidance to facilitate the development of performance metrics to include how they are collected and analyzed. The performance metrics will be used to evaluate research programs. This will include both research and development metrics and those more specific to T2 activities and progress.

An initial analysis of evaluation guidance and tools has been conducted and will be used as a foundation for developing and implementing the RD&T evaluation process. Next steps include finalization of the process steps, development of tools, guides and templates. Training and coaching will also be provided to help develop essential skills to ensure program success.

Designating Performance Metrics:
R&D Metrics – Division Chiefs and PMs lead the effort to define measures of R&D success for each project (e.g., Cost, ROI, Timing, Relevance, and Results). These metrics include measures specific to the research being conducted in addition to the traditional project related metrics. Targets and milestones are established and are an integral part of managing the research project.

T2 Metrics – PMs and stakeholders define measures reflecting technology readiness and industry adoption (e.g., Stakeholder participation, commitment, contribution, adoption levels). Based on the current readiness level and the anticipated objectives of the research project, targets and measures are established to monitor the progress of the research and the impact on the readiness of the technology for commercial adoption.

Evaluating Program Effectiveness:
Activities - Research project leaders will collect, analyze and report RD&T and T2 measures as part of their project management plans. Evaluations will occur by design and reports of effectiveness and benefits will be established for each program/project. The RD&T evaluation program will provide the means to systematically assess effectiveness against the established measures and objectives to determine course corrections or continued program support.

Resources – The Project Evaluation Program is currently under development to provide RD&T the training, guides, and tools to conduct evaluation as an integral part of project management of research projects. Project Evaluation

processes will incorporate defining of T2 activities and associated costs. Data analysis will inform future projects and approaches as well as measuring the effectiveness of the program. External evaluation of research programs and the evaluation process will also continue as previously evidenced by the TRB report.

Railroad Systems Issues

Funding Request $4,871,000

Program Description/Activities:

The principal focus and goal of the RSI program is safety; however, the program's activities contribute to all DOT goals to advance infrastructure, innovation and accountability, while maintaining a safety focus. The RSI research program develops, facilitates, manages and supports the following areas: RD&T's research strategy; safety risk analysis; performance-based regulations; non-regulatory recommendations; railroad environmental issues; locomotive efficiency; project evaluation; Transportation Research Board's (TRB's) independent evaluation recommendations; workforce development; RD&T related technology transfer and travel; operations, maintenance, and equipment at the Transportation Technology Center (TTC) facilities in Pueblo, CO; and contractor support.

The RSI research program activities are tailored to address relevant railroad issues spanning the spectrum from safety to workforce development. RD&T collaborates with academia, the private sector and rail industry, in addition to working with other DOT modes and federal agencies. Activities include:

Rail Safety Innovations Deserving Exploratory Analysis (IDEA) $400,000

The TRB initiated this effort in conjunction with FRA to address safety needs within the railroad industry. The focus of this project is to solicit new innovation and technology in rail. The Rail Safety IDEA committee members meet once a year (usually in December) and discuss all submitted proposals (about 15–18 are received annually) to select the most promising two to three proposals to be funded.

The Rail Safety IDEA program is sole sourced to the TRB, which has been successfully conducting the program since 2001. TRB is the only entity with the capability of carrying out this program because it is an independent non-profit entity that has no affiliation with railroad providers, manufacturers, or suppliers. It also has no affiliation with the universities and small companies (usual candidates for winning IDEA projects). This makes TRB a unique organization for being fully independent, with no bias on behalf of any organization.

Anticipated Activities:

- Monitor existing projects.
- Review and select new projects.
- Collaborate with the TRB committee.
- Fund and launch new research.

Expected Outcomes:

With multiple activities each year, the outcomes vary based on the selected projects and duration of research. In 2018, the focus is on:

- Improve the railroad's ability to detect broken rails.
- Develop better technology for railroad bridge inspections and improved bridge safety.
- Improve rail welds, thus minimizing broken rail and its related derailments.

Project Selection $95,065

RD&T prioritizes its research investments annually. This process utilizes a software package (DecisionLens Software) as part of this effort. This project includes the activities and costs associated to maintaining the license

for the prioritization software and executing the prioritization process. RD&T conducts prioritization activities to effectively manage its budget and ensure that stakeholder and industry needs are included in the investment planning process. DOT priorities and safety priorities, especially those provided by the FRA RRS, are a major input into the process.

As part of technology transfer efforts, RD&T staff engages with both internal and external stakeholders throughout the research and development life cycle. An integral part of engagement includes collaborating with stakeholders to understand research needs and safety issues that require additional data, information, and solutions. Stakeholder research needs become an input into RD&T's prioritization process to increase industry adoption by meeting the industry's safety needs and addressing current and future safety problems. Throughout the research and development life cycle, RD&T staff evaluates the progress and usefulness of the research data and products in collaboration with research partners and other stakeholders. RD&T considers research progress and TRL as an input into their prioritization process.

RD&T developed the Safety Risk Model (SRM) to analyze safety risk across the railroad system. The model uses data from FRA's Rail Accident/Incident Reporting System (RAIRS) to calculate the likelihood of accidents occurring by the consequences when they occur. The SRM provides RD&T insight into where research investment may have influence on improving safety. The SRM is an input to the prioritization process.

Prioritization of research is accomplished using DecisionLens Software which includes the following inputs:
- Research Needs – Stakeholder research needs/requests, industry problems and safety trends.
- Selection Criteria – RD&T establishes selection criteria which could vary year to year. Criteria includes TRL, DOT and FRA strategic alignment and risk.
- Weights – In collaboration with stakeholders, RD&T staff develops weighting for project prioritization each year, especially input from RRS.

During FY 2018 the DecisionLens model was significantly modified and is currently under review, test and assessment to determine if the prioritization tool will more accurately represent FRA R&D requirements and better aligned with DOT Strategic Goals.

Anticipated Activities:
- Update the safety risk model to guide the RD&T project safety risk decisions and improve efficiency in project spending.
- Update the portfolio prioritization methodology.
- Prioritize RD&T's research portfolio.

Expected Outcomes:
- Optimize the prioritization methodology/process.
- Prioritize investments.

Program Support $981,321
This project provides technical editing, analyst and management support to RSI. FRA research produces various deliverables as part of RD&T T2 process and FRA works with technical editors to publish this content. Program management/analyst/subject matter experts provide project, program and portfolio management support.

Anticipated Activities:
- Review papers, reports, results and other material.

- Edit papers, reports, results and other material.
- Program, project and portfolio management support.

Expected Outcomes:
- Edited and published RD&T material.
- Strategic planning, tracking, and management of RD&T's portfolio, information and data.

Project Evaluation $72,500
The focus of this project is to educate and train PMs about project evaluation techniques, develop performance measures, improve project progress, and reduce cost. PMs and external parties will evaluate projects conducted by the five RD&T divisions to measure success, improve project performance and railroad safety.

Anticipated Activities:
- Continue project evaluation training.
- Create project evaluation tools.
- Continue implementation of RD&T's project evaluation methodology.
- Conduct project evaluations.
- Optimize RD&T's performance management metrics.

Expected Outcomes:
- Increase maturity of project evaluation practices.
- Standardize performance measurement.
- Standardize project evaluation.
- Establish performance measurement baseline.

Transportation Technology Center (TTC) $200,000
The primary objectives of this funding are to maintain the one of a kind infrastructure at the TTC to accommodate the testing and evaluation of intelligent railroad systems technologies and to provide FRA with the type and quality of facilities and equipment needed to meet its missions in safety, infrastructure, innovation, and accountability. Focused on enhancing railroad safety, the TTC drives national research, development and application of new technology for railways, suppliers, governments, and others involved in rail transportation. Other government agencies utilize the TTC:
- Since 1985, the Security and Emergency Response Training Center at the TTC has been training first responders to handle hazardous materials accidents.
- The Transportation Security Administration (TSA) has created the Surface Technology Security Training Center located at the TTC, providing training to Department of Homeland Security (DHS) inspectors and other federal, state and local security partners.
- DHS has been an active user of the facility. DHS is conducting the assessment of Threat Risk for Rail Car Blast Scenarios project and numerous railroad operations and safety training. DHS is also pursuing development of the underground rail station and tunnel security training facility.
- The Federal Transit Administration and the Department of Defense are also involved in utilizing the facility.

RSI provides project evaluation funding to RD&T projects including the TTC. Every year, the TTC conducts an evaluation and assessment of equipment and facilities. The TTC has a variety of track conditions, types of construction, and test bed configurations to test a large variety of track equipment, vehicles, operating conditions and material types. Engineering services are needed to visually inspect and make an evaluation of track condition with respect to designated class of track, including components (i.e., ties (wood/concrete), rail fasteners, rail, rail

joints, ballast, subgrade, switches, signals, crossings, special track work, etc.,) referred to herein after as the "railroad system", interview TTCI personnel associated with track maintenance and conditions of the TTC track infrastructure for historical and background information, and review construction drawings for age, alignment, and detail for use in determining quantity, current value, replacement value, capital investments and repair needs.

Anticipated Activities:
- Detailed in Track Research's section.

Expected Outcomes:
- Detailed in Track Research's section.

Railroad Systems Issues $598,344
This project conducts research focused on safety with secondary strategic alignment to innovation, infrastructure and accountability in the railroad industry.

Anticipated Activities:
- Continued documentation of HSR Design Guidance Manual to accommodate varying train types and operational conditions.

Expected Outcomes:
- Basic aerodynamic concepts.
- Aerodynamic impact criteria.
- Aerodynamic evaluations.
- Documentation methodology.

Workforce Development (WFD) $155,000
This research provides support and domain expertise in the areas of railroad WFD to adequately identify suitable approaches for both the management and capture of rail workforce-related trends, and respond to DOT data calls. This research increases the awareness of railroad industry WFD issues by establishing and/or participating in forums and research efforts to foster and support industry collaboration. As part of this effort, FRA has an interest in the workforce development in the railroad industry and impacts of automation.

Anticipated Activities:
- Participate in the DOT Education and Workforce Development Community of Practice on behalf of FRA.
- Conduct and publish a railroad industry workforce assessment (known as the Modal Profile).
- Capture and analyze data on trends, skill gaps, skill demands, training opportunities, industry best practices, and cross-modal efforts.

Expected Outcomes:
- Updated Modal Profile published.
- Research results of workforce development published.
- Continued stakeholder engagement.

Energy and Emissions $40,000
Investigate alternative energy and propulsion and emissions reduction technologies for rail equipment, improving the transportation of goods and people. This research area focuses on supporting activities related to real-world

demonstration of alternative fuels, technologies that can reduce harmful exhaust gases, and improvement in standards for noise emissions to ensure implementation of high speed rail across the nation.

Anticipated Activities

- Update the High-Speed Rail (HSR) Noise Standards and Regulations Research to include requirements from FRA National Environmental Policy Act and HSR Noise Guidance documents and procedures.

Expected Outcomes

- Provide FRA RRS with improved science to drive standards and requirements development, and support compliance in support of emissions limit for both passenger and freight equipment.

Locomotive Engine Efficiency Safety Research $100,000

The goal of this research is to investigate innovative locomotive engine technologies to ensure the safe and efficient transportation of goods and people. Areas of focus for this research program include; reduction in fuel consumption, improvement in engine component life, and improvement in the efficiency of older, less efficient locomotives. Research is conducted in collaboration with Class I railroads to demonstrate and develop prototype systems. This research area addresses the DOT Strategic Goal of Safety and Innovation and the DOT RD&T Critical Transportation Topics of promoting safety, and preserving the environment.

If FRA does not participate in these initial technology assessment, FRA will not have the knowledge and expertise to effectively work with the railroads to review and approve any submittal for safe use of such fuels. Even though there are Federal standards for hydrogen transportation in rail, the unique characteristics of such fuel will require comprehensive gathering of base knowledge to ensure the Federal standards are adequate for transportation in fuel tenders. There is no precedence for safe transportation of this type of energy as a fuel or commodity because it has not been done.

For additional details, please refer to the Locomotive Engine Efficiency OST-B Project Research Questionnaire.

Anticipated Activities:

- Assess technological innovation such as locomotive waste heat recovery systems using high-pressure heat exchangers in a real-world environment.
- Development and prototype demonstration of hybrid systems such as battery technology, and heat exchangers for improved efficiency.

Expected Outcomes:

- Knowledge of the performance of locomotive engine systems to improve efficiency while maintaining safety.
- Fostering relationships with the rail private sector.
- Ensure that emerging, innovative locomotive engine efficiency improvement technologies are safe.

Accessibility $260,000

Investigate universal and inclusive designs for accessibility onboard passenger trains. FRA is in a unique position to collaborate with stakeholders (other Federal agencies, disability advocacy groups, passenger rail operators, and equipment manufacturer and industry groups) to ensure that new standards for accessibility are feasible and safe; balancing the requirements of the law with the capability of the equipment.

Anticipated Activities:

- Identify available technologies that can improve communication and travel experience for passengers with disabilities.
- Investigate the impact of new requirements for accessible onboard passenger rail equipment, as related to safety, usability and efficiency.
- Testing of wheeled mobility devices onboard passenger equipment including 49 CFR Parts 37 and 38 that require a standard 30" x48" space for people using wheeled mobility devices.

Expected Outcomes
- Implementation of procurement specification standards for equipment.
- Understanding of the performance of wheeled mobility devices, occupant located in standard accessible seat location, and various alternative designs and layout for improved accessibility.
- Investigate and develop innovative safety technologies that improve emergency preparedness features of passenger rail equipment.
- Ensure that passenger rail onboard crewmembers are sufficiently trained to perform safety and life-saving functions for passenger during emergencies.

Research with Universities on Intelligent Railroad Systems$1,000,000*
This project will utilize funding from FY17 Appropriation (H.R. 244-610) and FY18 (see Statutory Requirements section) provided to RD&T to support university research on intelligent railroad systems. FRA will use a broad agency announcement (BAA) to solicit basic and applied technology research projects that will support DOT and FRA goals to advance automation and connected vehicle technology adoption in the rail industry. The BAA was produced in collaboration with the Intelligent Transportation Systems – Joint Program Office (ITS-JPO). FRA will review proposals with a preference for projects that advance these technologies for rural applications. Program objectives within this project include:
- Enabling safer vehicles and roadways
- Enhancing mobility
- Limiting environmental impacts
- Promoting innovation
- Supporting transportation connectivity

*This funding has been provided by Congress for the Research with Universities on Intelligent Railroad Systems in FY17 and FY18, in addition to the total budget for FRA RD&T. If Congress chooses NOT to fund the $1M additional funds, this activity will not be executed in 2019.

Anticipated Activities:
- Publish the BAA
- Review university proposals
- Select prospective research projects
- Fund and begin selected projects

Expected Outcomes:
- Focus on advanced technology, automation, and connected vehicle technologies
- Projects that advance these technologies for rural application
- Intelligent transportation systems
- Workforce development

*Office of Railroad Safety Support $850,000**

All RD&T divisions support RRS by providing SME consultation, research, data, and tools to improve railroad safety and reduce accidents and incidents. RRS works closely with RD&T to provide insight into research needs throughout the fiscal year. RD&T needs the ability to support requests for research and expertise for time sensitive safety issues. RD&T plans to support the following RRS requested initiatives:

- Railroad Information Sharing Environment (RISE) Developmental Evaluation Support
- Periodic requests from RRS

Anticipated Activities:

- Partner with RRS and industry on RISE
- Conduct research of urgent safety issues
- Provide SME support to RRS

Expected Outcomes:

- Establishment and implementation of a program similar to Federal Aviation Administration's Aviation Safety Information Analysis and Sharing (ASIAS) at FRA.
- Analysis of safety risks and identifying mitigations to those risks.

Note: This funding will come from multiple divisions to support their research. The Human Factors division is planning on funding approximately $850K to initiatives supporting the Office of Railroad Safety.

Public, Private, and University Cooperative Research Agreement $118,770 (Totaling $2,000,000 from all divisions)

The Public, Private and University Cooperative Research Agreement is a collaboration of the Association of American Railroads (AAR) to provide research opportunities to American academic institutions and it attracts and funds proposals that have the potential of improving safety and performance in railroad systems in the following areas: Track, Rolling Stock, Train Control & Communication, and Human Factors.

Annually, the Public, Private and University Cooperative Research Agreement committee members will review and determine research themes that the railroad industry needs to address through this Agreement. These research themes will drive research topics. Through this Agreement, research topics will be announced and reviewed and the most promising proposals will be selected for funding.

All selected proposals have the ultimate goals of improving railroad safety and performance, enhancing the infrastructure conditions and services by stimulating economic growth, productivity and workforce development, and serving the nation with reduced regulatory burden and greater efficiency, effectiveness and accountability.

This effort includes cost share arrangement with AAR contributing approximately $800K annually and the railroad industry's significant in-kind support.

Anticipated Activities:

- Publish the request for proposals
- Review university proposals
- Select prospective research projects
- Fund and begin selected projects

Expected Outcomes:

The expected outcomes align with the DOT Strategic Goals of Safety, Innovation, Infrastructure, and Accountability. Expected outcomes include:

- Projects that focus on advanced technology, automation, and connected vehicle technologies
- Projects that advance these technologies for rural application
- Workforce development

Note: This funding will come from multiple divisions to support their research.

Statutory Requirements:

Railroad Research and Development is statutorily mandated in the budgets prepared by the President, House and Senate of the U.S. The RSI research program is funded with discretionary funds.

RD&T is collaborating with FRA RRS which has a statutory requirement to identify and study the causal factors that lead to trespassing incidents on railroad property and develop a national strategy to prevent trespasser accidents, including milestones, timelines, and metrics to define success. The Committee directs FRA to submit the trespassing prevention strategy to the House and Senate Committees on Appropriation no later than August 1, 2018. The Committee expects FRA to implement the national strategy to prevent trespasser accidents within the recommended timelines.

Program Alignment with Strategic Goals:

RSI strategically aligns its research with DOT, OST-R, FRA, and RPD goals and strategic plans, with a focus on improving the safety of America's railways. Many of RD&T's research projects yield additional benefits in the areas of innovation, infrastructure, and accountability. As the railroad industry changes due to disruptive technology, FRA has been a leader for decades, researching innovative solutions to improve the safety of moving goods and people in America. RSI continues its research into the industry's workforce development efforts to support the infrastructure of America's railroads. Project evaluations conducted by the RSI division support RD&T's goals of accountability and helped gain insight on how RD&T will mature its performance measurement and evaluation efforts. RSI works closely with FRA RRS to provide the basis for science-based requirements, standards, and recommendations that have been tested in real-world environments with the help of companies and organizations who will adopt and use the technology.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

RSI will consider rural communities as part of program planning in the future. The Research with Universities on Intelligent Railroad Systems project will provide preference towards projects that implement technology in rural areas (see the Program/Activities section).

Program Objectives:

FRA's RSI research program improves railroad safety by evaluating risks and prioritizing RD&T projects to reduce safety risk and achieve DOT, OST-R, FRA, and RPD goals. RSI's objective is to determine strategic research needs

and priorities through collaboration with internal and external partners and stakeholders, considering real time safety issues requiring subject matter expertise or long-term research solutions.

While rail safety has improved over the last ten years with the downward trend of accidents, FRA is still focused on improving the safety of railways for the American public and rail workers. RD&T's main objective is to reduce incidents and accidents involving America's railroads, to save lives, and reduce environmental hazards. Some of the problems FRA is solving include:

- Reduction of accidents caused by human error
- Reducing track-related derailments
- Reducing incidents and accidents related to grade crossing and trespassing
- Investigating automation and technology

RSI achieves its objective through continuous stakeholder engagement throughout a project's research, technology transfer, and acquisition life cycles. FRA's RD&T program objective is to promote innovation and facilitate leadership across the railroad industry in the exploration and use of technology and automation to advance the railroad safety culture. Anticipating the increased impact of technology and automation on the railroad industry for over a decade, RSI's objective has been to better understand the benefits and impacts of technology on safety and workforce development. RSI has prioritized research in technology to provide needed solutions to the industry. RSI addresses market failure by pursuing solutions to safety problems and striving to decrease the number of incidents and accidents, save lives and reduce property damage.

Research Collaboration Partners:

RSI utilizes stakeholder input to establish research needs and priorities. PMs are members of industry organizations and regularly engage stakeholders at meetings throughout the year to remain current on the issues and needs of the railroad industry. RSI research collaboration partners include the railroads, labor, manufactures/suppliers, universities, non-profits, private industry, city/State/Federal government DOTs, and DOT OAs. RSI is considering tracking stakeholder input.

Partner Detail

Partner Name	Contribution	Benefit of Partnership
Transportation Research Board	TRB collaborates with DOT modes to improve innovation and technology within the transportation industry. Free membership.	FRA RD&T receives bi-annual review of its research, stakeholder engagement, strategic planning, priority setting, and evaluation work, and recommendations on how it can improve. Free registration, for all FRA members, to attend the TRB annual conference. Free membership to receive TRB publications, and Free FRA booth at the TRB annual exhibit.
Universities across the United States	Expertise and research	Subject matter expertise and workforce development
Amtrak	In-kind contributions; subject matter expertise, Peer Review	Provide data on noise emissions design features
California High Speed Rail Association	In-kind contribution; subject matter expertise	Provide data on noise emissions design features
American Public Transportation Association	In-kind contribution; subject matter expertise, data	Provide data on noise emissions design features

Partner Name	Contribution	Benefit of Partnership
US Environmental Protection Agency	Guidance on current regulatory environment; subject matter expertise	Input and feedback on the boundaries of the tool as it relates to the new noise emissions limits
Class I Railroads	In-kind contribution; subject matter expertise	Provide locomotive engine, duty cycle data; support testing activities
American universities	Subject matter expertise	Subject matter expertise
Railroads	Access to rail facilities	Subject matter expertise
Private industry	Product commercialization	Subject matter expertise
AAR	Subject matter expertise	Subject matter expertise

Benefits Detail

Beneficiary	Benefit(s) Received
FRA RRS	Improved safety standards/recommendations Improved science to improve standards and requirements in support of EPA's revisions to noise emissions limit for trains
Rail industry	Improved safety standards/recommendations Lower operating costs Improved visibility for railroad workers and grade crossings Reduced railroad accidents and fatalities Reduced regulations
General public	Reduced railroad accidents and fatalities High speed rail transportation, safer rail travel, reduced noise emission The Manual will encompass both the open and tunnel environments for high speed trains and increase the safety of passengers, train crews, track workers, and the general public
Small businesses, and University research centers	Improved railroad research resources and capabilities.
Rail Equipment Suppliers and Manufacturers	Standardized matrix to determine cost of noise emission mitigation technology for high speed rail
Class I Railroads	Standardized matrix to determine most efficient technology for improved energy and efficiency of locomotive engines
EPA	Improved guidelines for noise emissions limits
High-speed rail operators	Design Guidance Manual will permit quantifying and mitigating the aerodynamic effects of high speed trains.

Acquisition/Assistance:

The RSI program establishes research priorities and defines its acquisition plan considering internal and external priorities, and aligning priorities with DOT, FRA, RPD, and RD&T goals for the upcoming fiscal year. The RSI program works with the FRA Office of Acquisitions to initiate various funding vehicles, for both single year and multi-year contracts, across the division. RSI uses the following acquisition methods for awarding contracts and grants:

- Broad Agency Announcement (BAA)
- Indefinite Delivery Indefinite Quantity (IDIQ)
- Full and open competition solicitations
- Sole source acquisition
- Small Business Innovative Research Program (SBIR)

The RSI program uses a non-competitive acquisition approach for continued research or follow-up research, unsolicited proposals, and for research that requires special expertise in a timely manner. Most research projects are funded in a phased approach to accommodate limited funding and limited availability of other resources. A sole source award is made for unsolicited research ideas that have merit and is aligned with the strategic research goals.

To provide robust scientific data to RRS for decision-making, Inter-Agency Agreements are established with the Volpe Center because of its technical and project evaluation expertise, and its existing relationships with the rail industry used to obtain needed data.

The RSI program utilizes both single year and multi-year acquisitions for projects. Multi-year acquisitions are used to provide incremental funding for research projects, and to allow for decision-making and potential redirection, as necessary, as the research progresses.

The RSI program always seeks to leverage non-Federal funds to support its activities. Cost-sharing, matching funds, and in-kind contributions are mechanisms used to leverage the resources of non-Federal stakeholders and partners.

Technology Transfer (T2):

RSI works closely with stakeholders throughout the R&D life cycle and the T2 life cycle to increase user adoption of research products/services. PMs work with internal (e.g., FRA Office of Railroad Safety, other OAs) and external stakeholders (e.g., Class I and short line railroads, labor unions, equipment manufacturers, State DOTs) to understand their needs and how the research will affect their eventual adoption of the technology or policy change. RD&T PMs and their research partners work together early in the research process to communicate the value and benefit of RD&T's research products.

Engagement provides benefits to all stakeholders as well as FRA. Across the division's research projects, FRA and its partners share information, develop and test new technology and safety tools, improve safety culture, and contribute to the safe transportation of goods and passengers across America's railroads. RSI also publishes Technical Reports and Research Results in the FRA eLibrary, which are available to the American public. PMs also present their research at numerous industry meetings both nationally and internationally.

Evaluation/Performance Measurement:

The RSI research program participates in external project evaluations that help all divisions improve performance and increase ROI of government funding.

In 2019, RSI program will work with other RD&T divisions to implement internal processes to improve FRA's accountability to the American public based on the recommendations from these groups and skills learned in the training. PMs will work to implement the evaluation framework, standards, procedures, and templates identified in the "FRA Evaluation Implementation Plan" and the "FRA Manual for Research, Development and Technology (RD&T) Program and Project Evaluation." For more information about these efforts, see the Evaluation/Performance Measurement section in the Research, Development and Technology section.

Starting in FY19, FRA will measure performance for the DOT Strategic Goal Innovation.

Development of Innovation

- Increase Dissemination of DOT-Funded Research Reports (OST)
- Increase Production of Tangible DOT-Funded Research Outputs (OST)
- Increase DOT Technology Transfer Activity (OST)

Deployment of Innovation

- Increase Tangible Production of DOT-Funded Research (OST)

RD&T began tracking data with FRA's OST-R Technology Transfer Report 2017. As discussed in the T2 section, RD&T will establish baseline metrics using data from FY18 TO track performance against the Innovation performance goals. RD&T will track page views and downloads of published materials in addition to the following data to measure progress:

- Collaborative Relationships
- Technical Publications made available to public
- In-person or webinar presentations delivered to foster technology transfer
- Technical Publication downloads – NTL
- Workshops or demonstrations to foster technology transfer
- Total Number of Small Businesses supported
- Number of new inventions disclosed
- Number of patent applications filed

Track Research
Funding Request $11,279,000

Program Description/Activities:

The Track Research program prepares for the future of rail transportation through applied research, development, and demonstration. As new technologies continue to emerge, and train axle loads and speeds increase, the timely development of technical information, data, and expertise is crucial to provide a basis on which to make decisions about issues affecting the safe operation of rail vehicles on U.S. track. The Track Research program supports the goals and objectives of the DOT/FRA administration; conducts safety related research for new and in-service railroad system investments; develops and demonstrates new track condition assessment technologies; and coordinates research teams between railroads, universities, technology leaders, and the government. There are three primary research areas included in the program: track structures and components, track and train interaction safety, and operation of research assets, including the DOT TTC facility.

Performance-Based Regulations and Safety:

The Track Research program focuses efforts in developing the scientific basis for removing prescriptive-based regulations and moving toward performance-based regulations. Under the Vehicle and Track Interaction program, computer modeling has been developed to evaluate the current track safety thresholds and the corresponding track forces. The results of this modeling will provide the facts needed to relax or change the current minimum safety thresholds. Additional activities include developing testing technologies that measure the performance of the track structure and the dynamics of train cars, and relate that performance to derailment risk.

Track research addresses the improvement of *CFR 49 Part 213 Track Safety Standards* and *Part 231 Railroad Safety Appliance Standards.* By using computer based modeling to determine current track safety thresholds, regulators are able to adjust current and future regulations that pertain to track safety. This helps to lessen the regulatory burden on railroads and provides more precise regulations in the future, which ultimately has the potential to lead to larger safety benefits. Furthermore, by examining the dynamics of train cars and how they relate to derailment risk, regulations can be designed that more effectively reduce the risk of derailments due to the train car dynamics.

Improving the Mobility of Freight:

Current efforts of the Track program focus on preventing derailments of trains. Train derailments significantly affect the average velocity of the train and freight throughput, cost of operations, and customer service. One method of decreasing derailments currently used by the industry is frequent track inspections; however, track inspections take track-time and many hours of railroad personnel. The FRA track autonomous inspection program is an effort to improve the quality and coverage of inspections using automated means. The results of this program decrease the amount of track inspection time by using revenue service trains as the inspection vehicle and advanced analytics to process the data to determine the safety risk associated with data collected. This decreases the time and cost associated with the inspection process and increases safety with the improved capability to detect defects and prioritize track repair. Decreasing derailments can significantly improve the mobility of freight over our nation's railroads.

The research conducted by RD&T improves *CFR 49 Part 213 Track Safety Standards*. Given the large number of track miles that exist on the rail network, an autonomous inspection program would allow FRA and the railroads to

inspect larger portions of the network at a reduced cost. This reduction in economic burden for the railroads is realized through reduced track-time for track inspections, and more efficient allocation of railroad personnel man hours. Furthermore, the advanced analytics collected have the potential to more effectively and efficiently determine track deficiencies, reducing the risk of track related accidents, including derailments. From a productivity standpoint, being able to quickly identify and fix track related defects allows the rail network to operate more fluidly and reduces the cost of delays caused by derailments.

Improving Mobility for Underserved Communities:

The autonomous inspection program recently conducted testing on many Short Line, Regional, and Class I railroads in cooperation with the American Short Line and Regional Railroad Association (ASLRRA). A new coordinated method was used linking Short Lines with an autonomous inspection car in freight service. Using a specialized car over their track, a Short Line received a list of high risk locations that could cause a derailment that should be addressed with maintenance and repair. The Short Lines are typically located in underserved communities.

In FY 2019, the Track Research program will conduct the following activities:

- Rail Performance and Integrity - Initiate the design of the first prototype **Autonomous Internal Rail Flaw Inspection Device**. This advanced technology allows internal rail defect inspection under revenue service trains at speed to improve operational efficiencies and increase the timeliness of safety-critical condition data. It is based on the non-contact passive rail techniques currently under development.
- Track Inspection Technology and Processes - Continue development, and start the implementation, of a **Change Detection Machine Vision System** that automates data analysis of track inspections to determine safety related changes to the track structure, and reports this information to stakeholders with limited human intervention.
- Rail Performance and Integrity - Prototype an **End of Train Broken Rail Detection Device**. Rails often break under trains but do not lead to immediate derailment until further damage occurs at the fracture. This project uses uniquely coupled technologies (e.g., laser, accelerometer, and vision) to identify broken rail discontinuities and alert railroad operating authorities before the next train arrives.
- Track Buckling and Panel Shift - Prototype a **Reference Free Measurement of Rail Force Device**. Effective management of thermal stresses in rail is critical to preventing rail buckles and pull a part. The objective of this research is to develop a prototype that can accurately measure the absolute stress state of rail without disturbing the track structure and without prior knowledge of the zero-stress state (neutral temperature) of the rail.
- Track Inspection Technology and Processes/Track Predictive Analytics - Initiating the development of **Predictive Analytic Evaluation Tools** utilizing mathematical, statistical, and signal processing tools for predicting track structure and substructure behavior through a multi-year joint research initiative with Amtrak. This effort will produce models that can be used to predict adverse track conditions which will, in turn, help railroads/Amtrak to plan maintenance and capital investments more effectively, prevent track downtimes, and, most importantly, prevent safety-related issues.
- Vehicle Track Performance - Construct a **Precision Anomaly Curved Test Track** at the TTC. This curved track section, in addition to the existing tangent section, will be used to assess track geometry measurement system performance on curved track, and verify their accuracy to measure curvature and all track geometry parameters on curved track section. The other benefit will be to aid calibration and validation of vehicle models that are used for simulation of vehicle/track performance.

- Track Support and Substructure - Conclude the **Ballast Research Testing Program** and determine track geometry degradation rates as they relate to ballast fouling levels and moisture content. Develop guidance for the FRA RRS enforcement of fouled ballast locations having degraded track geometry conditions.
- Track Inspection Technology and Processes - Coordinate the evaluation of **Unmanned Aerial Vehicle (UAV) Technology** through cooperative programs with industry to demonstrate safety improvements by leveraging UAV technologies for more efficient and effective track inspections.
- Track Inspection Technology and Processes - Implement **Innovative Track Inspection Technologies** such as Ground Penetrating Radar (GPR), light detection and ranging (LIDAR), Vertical Track Deflection, nuclear magnetic resonance, and others that have significant potential to improve track safety, especially if the data products were closely integrated with traditional track inspection systems such as Gage Restraint Measurement Systems (GRMS) and Track Geometry Measurement Systems (TGMS).
- Track Support and Substructure - Quantify track instabilities due to ballast movement using **Integrated Sensor Networks**. Track structure fails due to "abnormal" ballast particle movement at locations such as rail joints, turnouts, diamonds, and switches under both freight and high-speed passenger traffic. iBeacon, a data broadcasting technology, will be integrated into a sensor network called SmartRocks, a ballast motion sensor previously developed by FRA, to measure track health automatically when passing by with a revenue service train.
- Vehicle Track Performance - Continue **Vehicle/Track Modeling, Simulation, and Validation** to better understand derailment causes and make improvements to simulation methodologies and software to assess, evaluate, and qualify new equipment prior to revenue service operation.
- Wheel/Rail Interface **- Wheel/Rail Surface Defect Assessment** to understand how wheel/rail surface defects grow, root causes of rolling contact fatigue (RCF), and how to prevent these defects from forming using a full-scale test rig developed by FRA and industry.

Track and Structures – Rail Performance and Integrity $1,449,456

Rail integrity derailments and accidents cost the United States and its railroads about $50 million per year,[4] more than any other track defect. FRA works with the railroads in committees, conferences, and the Rail Safety Advisory Committee (RSAC) to understand the current state of Rail Performance and Integrity in the country and what can be done to improve it.

The scope of this project was to be extended over a longer period of time to meet the reduced proposed President's Budget. With full funding of $1.5M, this project can be expedited and be completed on schedule.

Anticipated Activities:

- Partner with a willing service provider to initiate a unique automation of detection protocol for ultrasonic rail inspection that FRA research has developed.
- Develop the first prototype flash thermography technology to detect rail base defects.
- Gather rail defect donations from at least three Class 1 railroads, characterize these defects, and add them to the FRA rail defect library at TTC for the entire research community to utilize in developing better detection systems.
- Develop Laser Doppler Vibrometer rail measurement for non-contact rail integrity testing.
- Develop acoustic based rail vibration measurement for non-contact rail integrity testing.
- Field test a patented rail head repair technology to prove it is more robust than current methods.

[4] FRA Database

- Develop a more cost effective and smaller rail flaw three-dimensional (3D) image scanner.

Expected Outcomes:
- Initiated unique automation of detection protocol for ultrasonic rail inspection
- Developed prototype of flash thermography technology to detect rail base defects
- Updated FRA rail defect library at the TTC
- Laser Doppler Vibrometer rail measurement for non-contact rail integrity testing
- An acoustic based rail vibration measurement for non-contact rail integrity testing
- Tested rail head repair technology with results to prove it is more robust than current methods
- A cost effective and smaller rail flaw 3D image scanner.

Track and Structures – Track Inspection Technology and Processes $2,103,599
This research addresses inspection technology and processes to improve track safety and decrease derailments in the nation through:

- Enhanced risk analysis capabilities via improved data collection, management, and integration
- Intelligent synchronization and preparation of datasets for predictive applications using fast and reliable algorithms that automatically align and process multiple sources of frequently used track-measurement data.
- Identification of high-risk track segments with respect to rail-related defect growth in the nation's rail network using new risk measures
- Prediction of the probability of broken rails and, the derailment consequences, through innovative predictive analytics applications
- Effective mitigation of track-related derailment risk through optimized preventative maintenance strategies based on risk-management practices
- Development of data-driven technologies and innovations aimed at real-time decision making
- Development of automated track change detection technologies to enhance track inspection effectiveness

Anticipated Activities:
- Develop algorithms for the automated, real-time analysis of track-related data in preparation for the prediction of track degradation rates.
- Complete work on the artificial intelligence (AI)-driven decision-support tool for evaluating track segments for the risk of rail-related defects and derailments.
- Finalize the development of a prototype track change detection system.

Expected Outcomes:
- Improved capabilities for real-time analysis of track-related data
- Completed AI-driven decision-support tool for evaluating track segments for the risk of rail-related defects and derailments.
- Prototype of track change detection system

Track and Structures – Track Support & Substructure $1,355,000
The goal of this research is to prevent derailments caused by track support and subgrade issues through improved understanding of track support and substructures.

Anticipated Activities:
- Develop techniques to detect potential failure and evaluate field conditions of ballast and subgrade.

- Develop characterization and further understanding of ballast mechanistic behavior and properties.
- Continue development of Vertical Track Deflection Measurements to provide a structural indication of the track support structure with large deflection indicating weakness in the track support layers.
- Continue refinement of GRMS technology to identify potential track strength weakness at the rail tie interface.

Expected Outcomes:
- New techniques to detect potential failure and evaluate field conditions of ballast and subgrade.
- Improved understanding of ballast mechanistic behavior and properties.
- Developed Vertical Track Deflection Measurements.
- Improved GRMS technology to identify potential track strength weakness at the rail tie interface.

Track and Structures – Track Buckling and Panel Shift $760,000

Track Buckling and Panel Shift derailments and accidents cost the United States and its railroads about $14 million per year.[5] This research addresses issues to improve the safety and reduce derailments.

Anticipated Activities:
- Develop first generation prototypes to measure rail stress without a zero reference.
- Develop specifications and plans for a rail stress and rail neutral temperature test bed at TTC.
- Study and document how track maintenance and construction can influence rail neutral temperature and track buckling prevention.
- Upgrade a track buckling prediction web application that can be utilized by FRA, industry, and researchers.

Expected Outcomes:
- Prototypes to measure rail stress without a zero reference.
- Detailed specifications and plans for a rail stress and rail neutral temperature test bed at the TTC.
- Improved knowledge regarding how track maintenance and construction influences rail neutral temperature and track buckling prevention.
- Web application to improve predictions of track buckling.

Facilities and Equipment - Transportation Technology Center (TTC) $1,239,438

This funding supports RD&T Facilities and Equipment programs, which play an important role in supporting rail transportation technology, development, testing, standards-development, and training.

Anticipated Activities:
- Building improvements required by changes in building codes, regulations, technology, and testing demands.
- Infrastructure upgrades for infrastructure that has reached or is nearing the end of useful life, has become obsolete, and/or is uneconomical to upgrade.

Expected Outcomes:
- Building upgrades that meet building codes, regulations, new technology, and new testing improvements.
- Upgraded infrastructure to enhance testing capabilities.

Track and Structures – Bridge and Structures $0

[5] FRA Database

Two significant problems hinder the use of displacements in bridge condition assessment:

1. Collection of displacements in railroad bridges is limited currently to infrequent situations.
2. The industry has not established standards for acceptable displacement limits. Current limits regarding displacements are oriented toward design. New limits need to be developed that better relate to the different levels of service expected for railroad bridges during their life.

Anticipated Activities:
This project will address the industry standards for acceptable displacement limits by:
- Optimizing and porting the reference-free displacement estimation algorithms to the next generation wireless sensor node, the Xnode.
- Collecting critical data about bridges for the same type but in different conditions.
- Developing recommendations about service limit states of each bridge type using railroad bridge displacements.
- Developing a graphical user interface (GUI) for efficient decision making.
- Documentation and technology transfer.

Expected Outcomes:
- Development of industry standards for acceptable displacement limits.
- Updated reference-free displacement estimation algorithms.
- Enhanced critical data about bridges for the same type but in different conditions.
- Recommendations about service limit states of each bridge type using railroad bridge displacements.
- A GUI for efficient decision making.
- Research documentation and technology transfer data.

Track and Structures – On-Track Research and Testing $227,344
This research improves track safety and decreases derailments on America's railways. The goal is to eliminate fatalities and serious injuries on heavy axle load (HAL) mainlines by:
- Identifying and mitigating potential infrastructure-related risk factors.
- Understanding the failure modes associated with heavier tonnage and higher axle-load operations exhibited in the HAL environment.
- Ensuring the safety and effectiveness of new and innovative technologies and maintenance strategies by way of thorough evaluation and testing in real-world conditions with a variety of operating, structural, and environmental considerations.
- Establishing an early warning of future track component and/or wheel failure associated with the implementation of new, untried track designs, products, materials, and strategies.
- Development and timely implementation of new and innovative technologies and maintenance strategies with partner Class I railroads.
- Ensuring track infrastructure is planned, constructed, and maintained using best operations and risk; management practices for HAL through provision of critical research and technical assistance.

Anticipated Activities:
- Continue investigation of relationship between degraded ballast conditions and the integrity of track as a system.
- Evaluate the effectiveness of the ultrasonic impact treatment (UIT) to improve weld strength through lab and controlled-environment testing.
- Finalize process/procedure for mapping rail-related defects for use of railhead-repair welds (RHRW).

Expected Outcomes:

- Data results on relationship between degraded ballast conditions and the integrity of track as a system.
- Evaluation results of effectiveness of the UIT to improve weld strength through lab and controlled-environment testing.
- Finalized process/procedure to map rail-related defects for use of RHRW.

Track and Structures – Tie and Fastener Performance and Integrity $805,000

This research will improve track safety and decrease derailments caused by Tie and Fastener Performance through:

- Improved design and testing standards for engineered-polymer composite (EPC) ties and fastening systems and identification of root causes of EPC tie-related failures.
- Development and timely incorporation of data-driven recommended practices for EPC tie use.
- Ensuring track infrastructure is planned, constructed, and maintained using best operations and risk management practices through provision of critical research and technical assistance.

Anticipated Activities:

- Initiate modeling and in-track testing of instrumented EPC ties to evaluate the thermal effects on track gage and stress/load environment.

Expected Outcomes:

- Test results of modeling and in-track testing of instrumented EPC ties, evaluating the thermal effects on track gage and stress/load environment.

Track-Train Interaction – Vehicle Track Performance $1,209,915

This research will improve track-train safety through understanding of the interaction and forces between vehicle and track, and how the vehicle performs under different operational conditions traversing different track anomalies.

Anticipated Activities:

- Design of a precision test track section for track geometry measurement systems testing, validation, and vehicle performance over known anomalies.
- Support FRA in qualification of new equipment and evaluate equipment and track performance
- Testing and validation of new developed track geometry measurement system.

Expected Outcomes:

- Precision test track section designs.
- Qualified and evaluated new equipment and track.
- Tested and validated new track geometry measurement system.

Track-Train Interaction – Wheel-Rail Interface $700,000

Improve the understanding of forces at the wheel-rail interface, and influence of wheel/rail profile and lubrication practice, to better understand performance and derailment causes and wheel/rail surface damage.

Anticipated Activities:

- Study forces at the contact interface by use of the Rolling Fatigue Test Simulator (RCFS) to determine root causes of RCF.
- Identify factors contributing in RCF (e.g., friction, forces, wheel/rail profile, and track input).

Expected Outcomes:
- Improved knowledge of forces at the contact interface and root causes of RCF.
- Knowledge of contributing factors leading to RCF (e.g., friction, forces, wheel/rail profile, and track input).

Track – Train Interaction – Vehicle-Track Modeling, Simulation and Validation $400,000
This research improves knowledge and understanding of how to model and simulate different operating condition and components, to understand interactions and forces between vehicle and track.

Anticipated Activities:
- Develop procedures for both model building and model validation.
- Develop procedures to include advanced friction models that examine the effects of falling friction, speed, and third body layer on wheel-rail contact forces, three-dimensional contact geometry.
- Test and model coil springs used in vehicle suspension.
- Build vehicle and track models for various equipment and operating practices to be used for derailment investigations or developing safety procedures.

Expected Outcomes:
- Model building and model validation procedures.
- Advanced friction model procedures.
- Improved understanding of coil springs used in vehicle suspension.
- Vehicle and track models for derailment investigations and developing safety procedures.

Rail Joints and Welds Research $275,000
FRA conducts research on rail welding and joining to improve overall rail integrity in both jointed and continuously weld track. Rail weld and joint failures are a leading cause of derailments. FRA efforts are targeted at improving the reliability of these critical components to ensure rail safety, by developing solid state robotic welding techniques.

New technologies can be applied to these areas of track to improve safety and reliability. This research effort is conducted with significant in-kind support from railroads and industry suppliers that supplements FRA's limited research funds. This advanced research would not be possible without this support, however, FRA's leadership provides a conduit to maximize and align the research efforts.

Anticipated Activities:
- In FY19 FRA will continue the development of two technologies that will positively impact rail reliability and safety.
  Repair, install, and in-service performance monitoring of an AMS frog.
- Develop an automated, pre-weld grinding procedure and test and demonstrate the new attachment technique at DOT's TTC and in revenue service tracks owned by participating railroads.

Expected Outcomes:
- Develop and demonstrate solid state, robotic welding techniques to repair worn switch frogs.

- Develop and demonstrate new technology to attach signal wires to rail that eliminates the variability in weld quality and the undesirable metallurgical changes that result from the current CAD-WELD technology used throughout the industry.

Minimum Safety Requirements $334,248
FRA conducts research to improve the understanding of interaction and forces between vehicle and track influence of track geometry, vehicle suspension, and vehicle or track design. Based on this information, recommendations are provided on minimum standards designed to reduce risk of derailment.

Expected outcomes:
- Establishing track geometry parameters to improve safe operation of trains.
- Development of measurement techniques and tools for measuring accurate track geometry.
- Development of measurement techniques and requirements for measuring rail and maintaining proper rail shape.
- Defining safe track geometry for operation at lower speed

Activities:
- Continue the design and construction of a cart that can be used to measure track geometry very accurately and easily on the precision slab track at the TTC
- Simulation and analysis of vehicle performance over combination track geometry parameters and assessing derailment risk.

Public, Private, and University Cooperative Research Agreement $420,000 (Totaling $2,000,000 from all divisions)
See Railroad Systems Issues for description, activities, and expected outcomes.

Statutory Requirements:

Railroad Research and Development is statutorily mandated in the budgets prepared by the President, House and Senate of the U.S. The Track Research program is funded with discretionary funds.

Program Alignment with Strategic Goals:

The FRA RD&T Track Research program supports the goals and objectives of the DOT, OST-R, FRA, and RPD administrations. This program's fundamental mission is to improve railroad safety. It provides the scientific and engineering basis for improved industry guidelines and Federal safety standards. It develops new technologies and transfers this technology to the industry through coordinated research and demonstrations. This includes new and advanced inspection approaches that, after implementation, provide an improved situational awareness of the railroad system infrastructure.

These technologies focus railroad maintenance activities on the locations that have the highest risk for derailments. They incorporate innovative, science-based approaches to evaluate the overall stress state of the railroad such as longitudinal rail stress, the underlying cause of sun kinks, and rail pull-parts. Highly portable tools that measure the rail stresses will allow the railroads to monitor track condition and prioritize the maintenance needed to prevent derailments.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

In all inspection system projects conducted, the FRA research team continuously works on autonomous approaches to permit testing of the track structure using non-contacting, low maintenance sensors under revenue service vehicles at track speeds. This approach turns every train pass into a track system evaluation. The result is earlier detection of defects and trending of defect development without interference in train operations. This keeps average train velocities high over the system, improving mobility of passengers and freight. Throughout the program, FRA collaborates with the railroad industry to develop and implement these new technologies and practices to improve overall rail system safety.

Rural communities are directly impacted by the outcome of this research as it affects short line railroads (i.e., small business railroad entities), which operate 29% of freight rail in the U.S.[6] Short line railroads provide critical transportation services for rural markets, such as farming and ranching. By preventing derailments through better control of track-train interaction forces and accelerations, the Track Research program reduces the risk of rail related HazMat spills and contamination of rural and urban areas affecting local air or water quality.

Program Objectives:

The Track Research program aims to prevent high-consequence derailments that result in the loss of human life and significant damage to property and communities by:

- Identifying, understanding, and mitigating track-related failure modes that pose significant risk to safe HAL operations and changes in track designs and/or materials.
- Ensuring the safe and effective implementation of new and innovative technologies and maintenance strategies intended to mitigate adverse effects of HAL operations on track infrastructure.
- Developing procedures for vehicle and track simulation building and validation.
- Providing guidelines for FRA RRS, railroad industry, and consultants on how to build, model, and simulate different vehicle or track components to understand the fundamentals of vehicle/track interaction and reduce derailment risk.
- Increasing the inspection frequency of railroad bridges.
- Predicting, detecting, and preventing rail defects that lead to train derailments.
- Ensuring the safe and effective implementation of EPC ties and their fastening systems through the development of data-driven recommended practices.
- Preventing track buckles.
- Predicting adverse conditions and safety-related issues in the track infrastructure long before they become problematic.
- Understanding how changes in track infrastructure condition, operations, and/or regulations can affect the potential risk for track-related derailments.
- Increasing safety by reducing track support caused derailments.
- Supporting research partners in derailment investigations.

[6] Source: American Short Line and Regional Railroad Association

- Supporting research partners and the railroad manufacturing community in vehicle qualification and evaluation testing.
- Understanding the root cause of RCF in wheels and rails and developing methodologies, techniques, and inspection tools to identify problematic conditions before they become a safety threat.

FRA needs to invest in this research as it has the responsibility for conceptualizing and demonstrating the effectiveness of technology solutions that improve safety and where safety regulations may or may not already exist. The private sector is not motivated to invest in research in areas where it is already compliant with existing federal regulations and industry standards, even when those regulations and standards do not yield the maximum possible safety. The railroad industry is focused on overall railroad system efficiency. Preventing derailments is a component to this efficiency. However, a significant cost goes into track inspection, planned maintenance, and spot repair that is needed to prevent derailments.

Research Collaboration Partners:

FRA works closely with universities, suppliers, and the railroad industry, including the AAR and individual railroads. These entities contribute to the success of projects through in-kind support in the form of access to relevant data, on-track support, intellectual resources, and, in some cases, supporting funds. Within the context of this specific topic area, documented partnerships with Class I railroads:

- Allow for access to mainline revenue service track for field testing.
- Maintenance-of-way (MOW) personnel for installation and maintenance of test equipment/components.
- On-track support for field verification and measurements.
- Relevant data and technical guidance for extracting necessary information from these datasets.

Suppliers provide donations of essential track components and materials for evaluation and testing purposes.

Partner Detail

Partner Name	Contribution	Benefit of Partnership
American Short Line and Regional Railroad Association (ASLRRA)	In-kind support activities: manufacturing support, access to railroads and materials, expert analysis	More realistic testing than in a laboratory
Canadian National Railroad (CN)	In-kind support activities: manufacturing support, access to railroads and materials, expert analysis	More realistic testing than an average laboratory set up
Genesee and Wyoming Railroad	In-kind support activities: manufacturing support, access to railroads and materials, expert analysis	Critical samples for research and expert advice
Western NY and Pennsylvania Railroad (WNYP)	In-kind support activities: manufacturing support, access to railroads and materials, expert analysis	Professional laboratory results without having to pay for new laboratory equipment
Indiana and Southern Railroad (ISRR)	In-kind support activities: manufacturing support, access to railroads and materials, expert analysis	Real world testing
Toledo, Peoria, & Western Railway (TZPR)	In-kind support activities: manufacturing support, access to railroads and materials, expert analysis	Real world testing
Illinois and Midland Railroad (IMRR)	In-kind support activities: manufacturing support, access to railroads and materials, expert analysis	Realistic rail defects for validating new detection technologies

Partner Name	Contribution	Benefit of Partnership
Indiana and Ohio Railway (IORY)	In-kind support activities: manufacturing support, access to railroads and materials, expert analysis	More realistic testing than in a laboratory
BNSF – Burlington Northern Santa Fe Railway	Track materials for test bed	More realistic testing than an average laboratory set up
ArcelorMittal	Rails and expertise	Critical samples for research and expert advice
Edison Welding Institute (EWI)	Test facilities and data collection	Professional laboratory results without having to pay for new laboratory equipment
Massachusetts Bay Transportation Authority (MBTA)	Real world on track testing grounds and equipment	Real world testing
Three Class I Railroads	Donations of rail defects	Real world testing
Norfolk Southern	Test location and track time	Realistic testing environment
University of California, San Diego (UCSD)	Expertise and materials from the rail force test bed	Materials and expertise
Association of American Railroads (AAR)	Relevant data, on-track support, intellectual resources, and, in some cases, supporting funds	Materials, expertise and funding
Rutgers University	In-kind support	Subject matter expertise
Amtrak	Data, track time, intellectual resources, and in some cases supporting funds	Materials, expertise and funding
New Jersey Transit Authority	Data, track time, intellectual resources, and in some cases supporting funds	Materials, expertise and funding
Metro North	Provide data, track time, intellectual resources, and in some cases supporting funds	Materials, expertise and funding
American Public Transportation Association (APTA)	Data, track time, intellectual resources, and in some cases supporting funds	Materials, expertise and funding
Transportation Technology Center, Inc. (TTCI)	Transportation research, development, security, training, and test activities, reliability, and productivity	Testing and training expertise and support.

Benefits Detail

Beneficiary	Benefit(s) Received
General public	Increased safety and more efficient train operations.
Rural and urban communities	Improved safety, infrastructure and reduced environmental impact
Rail industry	Improved safety, and operational efficiencies.
Other transportation modes	Increased exposure of adaptive technologies to improve safety and operations.

Acquisition/Assistance:

The Track Research program establishes research priorities and defines its acquisition plan considering internal and external priorities, and aligning priorities with DOT, FRA, RPD, and RD&T goals for the upcoming fiscal year. The Track Research program utilizes a competitive procurement process as often as possible.

The Track Research program works with the FRA Office of Acquisitions to initiate various funding vehicles, for both single year and multi-year contracts, across the division, including:

- Broad Agency Announcement (BAA)
- Indefinite Delivery/Indefinite Quantity (IDIQ)
- Full and open competition
- Sole Source
- Inter-Agency Agreement (IAA)
- Small Business Innovative Research Program (SBIR)

The Track Research program benefits from in-kind contributions (e.g., subject matter expertise, track time, data sharing, and equipment) from its collaboration partners. A list of these partners, the contributions they make to the Track Research program's projects, and how that benefits FRA, can be found in the next section. These contributions are not only desirable for their inherent value but also guide our researchers to develop practical technology that will function well in practice. The Track Research program also benefits from partners providing non-federal funding on the following projects:

Track Research receives $325,000 in supporting funds from AAR for *HAL Research and In-Track Testing* on an annual basis.

Technology Transfer (T2):

The Track Research division works closely with stakeholders throughout the R&D life cycle and the T2 life cycle to increase user adoption of research products/services. PMs work with internal (e.g., FRA RRS, other OAs) and external stakeholders (e.g., Class I and short line railroads, labor unions, equipment manufacturers, and State DOTs) to understand their needs and how the research will affect their eventual adoption of the technology or policy change. RD&T PMs and their research partners work together early in the research process to communicate the value and benefit of RD&T's research products.

Engagement provides benefits to all stakeholders as well as FRA. Across the division's research projects, FRA and its partners share information, develop and test new technology and safety tools, improve safety culture, and contribute to the safe transportation of goods and passengers across America's railroads. The Track Research division also publishes Technical Reports and Research Results in the FRA eLibrary, which are available to the American public. PMs also present their research at numerous industry meetings both nationally and internationally.

- Collaborative research with contractors has resulted in the development and adoption of recommended practices by the railroad industry and continues to be a driving force for the development of new industry procedures and processes.
- The developed precision anomaly tangent track is used by the industry to evaluate their geometry measurement systems. It is anticipated that the new curved track section will enhance and complete the evaluation regimes.
- The developed knowledge about wheel/rail contact and factors contributing to RCF can help railroads and manufacturers to develop better operation practice and develop better wheel/rail profile or material.
- The developed knowledge about vehicle/track modeling, simulation and validation can help railroads and manufacturers to develop better operation practice and develop better vehicles for operation at higher speeds or higher axle loads.

Evaluation / Performance Measurement:

The RD&T program supports evaluation on behalf of all divisions. The Track Research division participates in these external project evaluations that help all divisions improve performance and increase ROI of government funding.

In 2014, the Track Research division selected Track Buckling project "Evaluation of Neutral Temperature (NT) and Incipient Buckling Detection System for Continuously Welded Rail (CTW)" as part of RD&T's pilot project evaluation effort, and, later, participated in the TRB's evaluation focusing on research projects, communication, stakeholder engagement, strategic planning, priority setting and evaluation. The Track Research division PMs participated in this year's project evaluation training aimed at providing a basic evaluation skillset for each RD&T PM.

In 2019, the Track Research division will work with other RD&T divisions to implement internal processes to improve FRA's accountability to the American public based on the recommendations from these groups and skills learned in the training. PMs will work to implement the evaluation framework, standards, procedures, and templates identified in the FRA Evaluation Implementation Plan and the FRA Manual for Research, Development and Technology (RD&T) Program and Project Evaluation. For more information about these efforts, see the Evaluation/Performance Measurement section in the Research, Development and Technology section.

Starting in FY19, FRA will measure performance for the DOT Strategic Goal Innovation.
Development of Innovation

- Increase Dissemination of DOT-Funded Research Reports (OST)
- Increase Production of Tangible DOT-Funded Research Outputs (OST)
- Increase DOT Technology Transfer Activity (OST)

Deployment of Innovation

- Increase Tangible Production of DOT-Funded Research (OST)

RD&T began tracking data for FRA's OST-R Technology Transfer Report 2017. As discussed in the T2 section, RD&T will establish baseline metrics using data from FY18 TO track performance against the Innovation performance goals. RD&T will track page views and downloads of published materials in addition to the following data to measure progress:

- Collaborative relationships
- Technical publications made available to public
- In-person or webinar presentations delivered to foster technology transfer
- Technical publication downloads – NTL
- Workshops or demonstrations to foster technology transfer
- Total number of small businesses supported
- Number of new inventions disclosed
- Number of patent applications filed

Rolling Stock Research
Funding Request $10,322,000

Program Description/Activities:

The Rolling Stock Research program performs research activities relating to critical transportation topics that promote rail safety, improve rail infrastructure, and mobility of goods and passengers, as well as topics that focus on preserving the environment. The Rolling Stock Research program conducts research to reduce railroad accidents and incidents due to rolling stock related causes as well as research to reduce fatalities and injury severity to passengers and crew members involved passenger train accidents and incidents. The Rolling Stock Research program produces solutions contributing to all DOT Strategic Goals: Safety, Infrastructure, Innovation, and Accountability. The goals of this program are accomplished through the research areas described.

Performance-Based Regulations and Safety:

The Rolling Stock research program is working on multiple performance-based regulations efforts. The program has established partnerships with other DOT modes, the railroad industry, law enforcement and state and local governments. Each of the three Rolling Stock program areas has multiple efforts creating performance-based regulations.

Rolling Stock is collaborating with the Office of Railroad Safety (formerly the Rail Safety Advisory Committee's Engineering Task Force) to develop performance-based regulations to enable the introduction of high-speed Tier III passenger equipment designed to foreign standards in the U.S. The program is working with the Office of Railroad Safety and the Rail Safety Advisory Committee's Hazardous Materials Task Force to develop performance-based regulations for the transportation of hazardous materials by rail (to be incorporated in CFR 174). The program is working with the Association of American Railroads (AAR) to develop industry standards for construction, repair, and maintenance of tank cars used to transport hazardous materials in North America. Ongoing research on tank car impact testing is aimed at developing performance-based requirements for construction, modification, improvement, and maintenance of tank cars, addressing NTSB Safety Recommendations to FRA.

Rolling Stock PMs collaborate with the American Public Transportation Association (APTA) to revise existing standards and develop new safety standards as part of the Passenger Rail Equipment Safety Standards (PRESS) reactivation effort sponsored in part with FRA funds. Ongoing research on glazing system integrity is aimed at developing performance-based requirements for glazing retention during passenger train accidents in which vehicles derail and roll on their sides. Loss of glazing securement has resulted in numerous fatalities and injuries and is the subject of an NTSB Safety Recommendation to FRA. Rolling Stock is developing a reliable framework for a wheel life model to explain wheel fatigue to understand and mitigate wheel failures.

Potential Impact of Asset Recycling:

Rolling Stock research activities include the acquisition of tank cars and tank car pieces resulting from derailments. These tank cars and pieces are acquired from the railroads after an incident and moved to the TTC for further research and analysis to determine the potential causes of the incident. At the completion of the research, tank cars and pieces are sold as scrap materials.

Improving the Mobility of Freight:

The Rolling Stock program is conducting research to improve mobility of freight by identifying rolling stock related risks and developing strategies for mitigating those risks. One of the methods used by this program to reduce risk is simulations. The Train Energy and Dynamics Simulator (TEDS) computer software is capable of performing longitudinal train dynamics simulations to conduct safety and risk evaluations, energy consumption studies, accident/incident investigations, train operations studies, ride quality evaluations, safety of train make-up, new equipment design and current equipment evaluations. Application of TEDS to challenges facing the freight industry can lead to improved safety, efficiencies of operation, and improved mobility.

Research demonstrating the efficacy of advanced wayside detectors offers the ability to identify defective bearings, brakes and other components before total failure occurs. Wayside detection can better inform the condition of the rolling stock equipment and components and make more cost efficient general repairs to their equipment. The program is working with the Office of Railroad Safety to review the Class I railroads waiver from regulatory 1,000-mile brake inspection to consider using wayside detectors in their operations to flag inappropriate hot or cold wheels. The waiver request would allow the railroads to travel greater distances before requiring inspection of the brakes. A process for evaluating wayside detection technology implementation plans was developed, which could expedite implementation of such technologies leading to improved detection of safety critical defects, increased operational safety, and improved mobility.

Rolling Stock is conducting an assessment of the operational safety of very long trains. Understanding the braking and power distribution requirements, as well as train handling needs for such trains, is the focus of this research. This research will improve mobility of freight by identifying risks and developing strategies for mitigating those risks; thereby promoting more efficient movement of freight in the U.S.

Improving Mobility for Underserved Communities:

Rolling Stock is reviewing proposals for Consolidated Rail Infrastructure and Safety Improvements (CRISI) grants which are targeted at rural communities. It is not clear that Rolling Stock will manage any of the grant(s) identified for award.

Hazardous Materials (HazMat) Transportation
The HazMat Transportation research program fosters innovation throughout the industry, helping development of new regulations and design standards that improve the safety and integrity of tank cars and other packages carrying hazardous materials continuing growth of new research programs that satisfy the need of the industry and government.

HazMat Collaboration with Pipeline and Hazardous Materials Safety Administration (PHMSA)

The Pipeline and Hazardous Materials Safety Administration (PHMSA) is responsible for all HazMat regulations, to include those that pertain to the movement of HazMat via the rail network. While the HazMat program does not directly address the economic impact of regulatory reform, its research addresses the improvements of PHMSA HazMat regulations. Rolling Stock research that leads to the development of new tank car designs or that improves the safe transportation of HazMat material has large economic benefits. The cost of a HazMat release has the potential to be in the billions of dollars, depending on where it happens and what HazMat is released. Reducing this risk ensures that the occurrences of HazMat releases are minimal and the costs associated with a release are low. Additionally, due to the economic benefit of transporting goods over the rail network, research into safer tank cars and improvements to the safe transportation of HazMat potentially allow for different types of HazMat to be

considered for transportation over the rail network (e.g., Liquefied Natural Gas (LNG)). The inclusion of various types of HazMat on the rail network has the potential to bring lower costs to shippers while at the same time ensuring that the public's safety is maintained.

The program manager of the Rolling Stock HazMat research program collaborates across the DOT transportation modes to conduct research. The Rolling Stock HazMat research program specifically collaborates with PHMSA to address the safe transportation of hazardous materials packages by rail and reduce the duplication of research efforts. RD&T conducts research pertaining to bulk packaging traveling by rail, such as: tank cars, rail cars, and intermodal tanks. PHSMA concentrates research on non-bulk packaging, including cylinders, drums, cardboard boxes, and bottles that can travel on any mode of transportation. Both PHSMA and FRA RD&T collaborate to prevent duplication of research, especially on topics that overlap their agreed upon research responsibilities. For example, FRA RD&T collaborates with PHMSA and the Maritime Administration (MARAD) to ensure the safety of containers and tank cars intended to transport LNG. RD&T meets bi-monthly with PHMSA to discuss research (current and future), attends meetings and conferences with PHMSA, and informs PHMSA of inspections.

Some research areas require RD&T and PHSMA to work together on research projects, addressing all packages that can transport hazardous materials, in the case of intermodal tanks, PHMSA and FRA collaborate on fire and impact research, since these tanks can be transported by any mode of transportation. This cooperation includes sharing budgets on some research efforts. This joint research decision prevents duplication of research. The frequent communication between the OAs ensures that FRA is sharing information so that research results can be beneficial to both modes and has prevented the duplication of effort between the modes.

HazMat – Tank Car Research $153,000
This research develops and improves the packages that carry hazardous materials, helping to reduce the release of material during rail accidents and incidents.

Anticipated Activities:
- Full-scale dynamic crash test on two tank cars to evaluate performance and validate computer models.
- Fire test on an International Organization for Standardization (ISO) tank to evaluate the survivability under fire conditions.

Expected Outcomes:
- Provide FRA with information on the crashworthiness and puncture resistance of different tank cars used in transportation of hazardous materials.
- Determine cars' behavior and failure modes under accident and normal transportation conditions.
- Provide a foundation for modifying, eliminating, or creating standards by leading research and capturing the results.
- Disseminate this information to the rail and tank car industry so it can be used for tank car designs.

HazMat – Structural Integrity $400,000
The goal of this project is to understand the performance and durability of safety equipment, and protective systems for tank cars and portable tanks. This research area focuses on study of the current fleet, identifying problems with current equipment and packages.

Anticipated Activities:
- Studies for FY19 include a man way cover closure tightness test and a coupling impact test to better understand the operational environment and forces exerted on tank cars during switching operations.
- Additional studies are identified by the data collected during safety and tank car inspections.

Expected Outcomes:

- Provide RD&T and FRA RRS with information on the performance and durability of safety equipment for tank cars and portable tanks so DOT has the required information to justify, modify, eliminate, and create safety standards.

HazMat – Accident Consequence Reduction $437,505

This research will study the loading and unloading practices of hazardous material to improve the operating practices and securement of the package for safe transportation and reducing non-accident releases.

Anticipated Activities:

- Investigate accidents involving hazardous materials packages.
- Conduct forensic analysis on equipment.
- Procure and store equipment for further investigation.

Expected Outcomes:

- Better understanding of how failures occur and how to best prevent or manage the consequences of such failures through improved equipment design and protection.
- Help FRA evaluate and document damage to railroad tank cars, study and capture the results of the liquid/vapor release flow on pressure relief devices, and improve resistance to failures that cause hazardous material release during train accidents.

Rolling Stock Equipment and Components (RSEC)

Research efforts in the Rolling Stock Equipment and Components (RSEC) program area focus on development and improvement of equipment defect detection and control. Both wayside and onboard detection and control systems offer diverse platforms for such research and demonstration.

RSEC research addresses the improvements of *CFR 49 Part 231 Railroad Safety Appliance Standards and CFR 49 Part 213 Track Safety Standards.* The ability to monitor and detect defects within RSEC has the potential to bring about productivity and safety benefits. When defects are detected early, such as a defect pertaining to the wheel of the equipment, the risk of an accident caused by that type of defect decreases. Early detection of defects can lead to a decrease in some defect caused accidents. The inclusion of both wayside and onboard detection helps to ensure that defects are detected and allows for better information to be sent to the railroads regarding the exact nature of the defect. Additionally, wayside and onboard detection, can inform the condition of the RSEC and leading to more cost efficient general repairs to their equipment.

RSEC – Rolling Stock Component Safety $2,732,637

The research comprised in this project proactively prevent above-track equipment and component failures (e.g., situational hazard prevention), and provide the analytical and technical basis to develop equipment safety standards while also improving safety, reliability, and respectability of rail equipment, technologies, and material.

Anticipated Activities:

- Evaluate and test equipment and components for increased integrity to withstand damage and failure that could increase risks and lead to accidents and incidents.
- Research methods to measure the predictability of equipment health and component wear life.
- Collaborate and support the demonstration and implementation of wayside and onboard monitoring and inspection of equipment and components to help ensure safe train operations.

Expected Outcomes:

- Research, development, and technology transfer of components and systems that reduce the risk of rail incidents and accidents and increase the safety of the nation's rail transportation network.
- Reduce the likelihood of derailments from equipment failures and mitigate the consequences should derailments occur through these or other causes. Strategic priorities include investigation of the effectiveness of wayside and onboard monitoring systems to detect equipment defects and analysis of component failure modes to identify necessary improvements in materials and construction methods.
- Design, develop, and demonstrate prototypes of effective wayside and onboard technologies that can provide component health monitoring.

RSEC – Rolling Stock Maintenance & Inspection $953,474

The focus of this research is to evaluate and demonstrate the effectiveness and efficiency of automated inspection and maintenance procedures and equipment. This project will demonstrate the ability to develop, monitor, control, and evaluate integrated advanced components to detect defects in real-time, predict and prevent future failures, improve rolling stock capabilities and performance, and improve overall rail operational safety. Developing a system for powering many advanced detection devices on freight trains will increase safety and security, and improve the efficiency of freight railroad operations. Technologies developed to detect defects on rolling stock equipment, and predict future failures that may be prevented, will substantially improve railroad safety. These investments keep the U.S. rail sector growing and improving to keep up with the latest efficiency and safety standards.

Benefits of this research include improved safety requirements, lower operating costs for railroads, reduced railroad accidents and fatalities, improved equipment service life for equipment, and increased safety, security and efficiency of freight railroad operations.

Anticipated Activities:

- Evaluate and demonstrate advanced equipment and inspection and maintenance procedures.
- Demonstrate the ability to develop, monitor, control, and evaluate integrated advanced components.
- Develop a system to power advanced devices and systems.
- Develop a reliable framework for a wheel life model.
- Develop technologies to detect defects on rolling stock equipment and predict failures.

Expected Outcomes:

- A system to power advanced detection devices.
- Technologies to detect defects on rolling stock equipment and preventable failures.
- An explanation of wheel fatigue to help mitigate wheel failure.
- Quantify the effects of tread braking on wheel damage mechanisms and fatigue life.
- Develop and conduct vehicle dynamics simulations.
- Demonstrate results that could be used by industry and universities to make improvements to railroad safety through systematic, basic research.

RSEC – Train Handling & Operating Practices $1,470,846

This research will develop simulation scenarios to evaluate different network and capacity related parameters with ECP brakes and PTC technologies, and compare these to the conventional signaling and braking applications. Simulation scenarios include network topology, traffic type, ECP scenarios, and PTC scenarios (with and without ECP scenarios).

This research will also focus on developing effective methodologies/models for evaluating the economic benefits of improving railroad network velocity and capacity. These tools will be critical in demonstrating the benefits of technologies such as ECP brakes, PTC, higher speed operations, and shared corridors.

This research is in line with FRA's mission to improve safety and performance, and prevent derailments that cause injury and loss of life. Derailment prevention is a major safety issue. It is in FRA's best interest to enhance the economic benefits of improving railroad network velocity and capacity. The rail industry will benefit from this research through improved safety requirements, lower operating costs, reduced railroad accidents and fatalities, and overall improved railroad performance.

Anticipated Activities:

- Develop simulation models to evaluate network and capacity related parameters with ECP brakes and PTC technologies, and compare to conventional signaling and braking applications.
- Evaluate the economic and safety benefits of improving railroad network velocity and capacity.
- Develop effective methodologies/models for evaluating the economic benefits of improving railroad network velocity and capacity. These tools will be critical in demonstrating the benefits of technologies such as ECP brakes, PTC, higher speed operations, shared corridors, etc.
- Technical support and coordination are provided to develop regulations and industry standards to promote the safe interaction of rail vehicles with the track over which they operate. Technical support includes, but is not limited to, conducting analyses, simulation studies designed to examine vehicle response to track geometry irregularities, reviews of vehicle qualification and revenue service test data, and consideration of international practices.

Expected Outcomes:

- Establish optimal train operating practices, improve equipment and component design, promote fuel conservation, and improve ride quality.
- Support the Engineering Task Force (ETF) II Inspection, Testing and Maintenance (ITM) Working Group of the Rail Safety Advisory Committee (RSAC).
- Support of American Public Transportation Association (APTA) Mechanical Group in revising and updating various standards including the Truck Equalization Standard.
- Support to the FRA Office of Railroad Safety related to testing and evaluation of equipment.
- Develop methods for condition monitoring and inspection of critical suspension components.

Train Occupant Protection (TOP)

The Train Occupant Protection program will carry out research on structural crashworthiness and interior safety of locomotives in intercity and commuter rail cars, with the aim of improving the survivability of rail passengers and crewmembers in accidents. The goal of this research program is to promote and improve the safety of the national passenger rail transportation system.

Research by the TOP program improves *CFR 49 Part 238 Passenger Equipment Safety Standards* and *CFR 49 Part 239 Passenger Train Emergency Preparedness.* The structural crashworthiness of the locomotive is paramount for crewmembers. Improving the crashworthiness of the locomotive and train cars decreases the risk of a fatality in the event of an accident. Fatalities represent a large economic cost, both in the loss of human life and the economic loss of human productivity. A reduction in fatalities presents a relatively large benefit, especially on passenger rail service, where large numbers of individuals could be involved.

TOP – Locomotive Crashworthiness and Occupant Protection $1,252,825

Research in this area will develop improved strategies and designs for rail rolling stock to reduce injuries and fatalities resulting from rail accidents (i.e., collisions and derailments). FRA needs to invest in this research to support its missions of improved safety, performance, and mitigation of the consequences of collisions and derailments that cause injury and loss of life. Crashworthiness and Occupant Protection continue to be major safety issues as evidenced by several recent, high-profile collisions and derailments.

Anticipated Activities:

- Research activities focus on conceptualizing, analyzing, designing, and demonstrating the effectiveness of engineering improvements to rail vehicle crashworthiness.

Expected Outcomes:

- Reduced fatalities and injuries to train crews, passengers, and the public.

TOP – Glazing Standards $0

In the last 44 years, at least 25 fatalities have been attributed to ejection through rail car window openings during passenger train accidents. The research in this area will comprehensively describe all the engineering requirements placed on glazing systems, survey existing glazing systems design strategies used throughout the world, and assess the effectiveness of these designs in meeting all of the engineering requirements. In addition to functioning as a window, glazing systems are also expected to be impact resistant, provide emergency egress, provide emergency access, be fire resistant, and provide occupant containment.

FRA needs to invest in this research as it has the responsibility for conceptualizing and demonstrating the effectiveness of technology solutions that improve safety and where safety regulations may or may not already exist. The private sector is not motivated to invest in research in areas where it is already compliant with existing federal regulations and industry standards, even when those regulations and standards do not yield the maximum possible safety.

Anticipated Activities:

- Perform full-scale testing to investigate the performance of alternative means of protecting the rubber gasket that holds passenger car windows in place. These gaskets are often ripped from the side of the train during derailments.
- Test novel approaches for gasket protection to assess their efficacy in maintaining the structural integrity of the windows attachment.

Expected Outcomes:

- Identify candidate protection strategies most likely to mitigate window loss in derailments. The focus will be on methods that can potentially be retrofit on existing passenger equipment to foster wider adoption by passenger car builders.

TOP – Fire Safety Research $260,000

This work will evaluate cost-effective, alternative methods and criteria for passenger rail equipment fire safety. The FRA requirements for fire safety performance were developed over 20 years ago. Newer innovative technologies, evaluation methods, and industry standards have been developed within this timeframe. This research allows FRA to review the current requirements for equivalency with newer standards, possibly allowing for the application of newer industry standards.

Anticipated Activities:

- Validate fire dynamics models that can be used to predict the behavior of different types of material.

- Conduct small-scale and large-scale tests of passenger rail car interior materials to determine fire safety performance.

Expected Outcomes:
- Validation of fire dynamics models that can be used to predict the behavior of different types of material and components used in passenger rail car interiors.
- Alternative techniques for showing compliance with Federal requirements for material flame and smoke performance.
- The output from this research will assist FRA in decision-making as to the compliance of passenger rail equipment.

TOP – Emergency Preparedness Research $0

This project will investigate and develop innovative safety technologies that improve emergency preparedness and egress features of passenger rail equipment. The Emergency Preparedness Research program supports initiatives that ensure passenger rail equipment and onboard crewmembers' training is modern, progressive, and effective.

Anticipated Activities:
- Develop and demonstrate tools and techniques that ensure passenger rail crewmembers are sufficiently trained to perform safety and life-saving functions for passengers during emergencies. The research tools can be used to better design or access design of equipment for rapid and easy egress.

Expected Outcomes:
- Scientific-based data on the efficacy of ingress and egress from passenger rail equipment under various accident scenarios such as an inclined, emergency lighting, or smoked filled rail car. Data will be collected on time to enter and exit the rail car.
- Define minimum safety standards for passenger rail equipment.
- Collect data in a transparent manner in collaboration with the private sector, and ensure findings are shared across all interested stakeholders.

TOP – Cab Displays, Controls, & Environment $220,000

This project will improve cab/locomotive visibility at night, provide extra alerting for track workers and attempting trespassers, provide extra visibility/alerting when approaching grade crossings, unify an optimized cab display across all railroad providers, increase freight and passenger rail safety, and reduce operating and maintenance costs for locomotives.

Anticipated Activities:
- Improve locomotive cab displays, control, and visibility at night. In this phase (Phase 1) of the light-emitting diode (LED) sample testing, FRA will validate whether all LED samples submitted by locomotive headlight and auxiliary light suppliers are following all applicable standards and codes. Samples that satisfy the requirements set forth in Phase 1 will be eligible for Phase 2: subjective field testing for LED sample fixtures.

Expected Outcomes:
- Provide guidance for the target luminance of LED fixtures in the "dim" setting.
- Improve train control and visibility.
- Reduce fatalities and injuries to train crews, passengers, track workers, and the general public.

Liquified Natural Gas (LNG) - Natural Gas Safety Research $35,713

This research will investigate innovative safety technologies that will improve the transportation and use of natural gas, both liquefied (LNG) and compressed (CNG), in the rail sector. The research provides the FRA RRS with the scientific basis for decision-making and development of standards and requirements.

Anticipated Activities:

- Continue initiatives for the planned grade-crossing impact load case on an LNG fuel tender.
- Finalize collision dynamics model of grade-crossing impact.
- Develop the industry specifications for LNG and CNG fuel tenders.
- Assess equipment that is in prototype services, or those that have accumulated over 1,000,000 miles of revenue service, for the effectiveness of their safety features.

Expected Outcomes:

- Develop fundamental knowledge on the performance of safety design features of natural gas fuel tenders and transportation tank cars and ISO tanks
- Identify and apply risk criteria for review of applications for shipment of LNG. The research area will yield needed information on the crash environment and performance of industry specified tenders.
- Develop a knowledge base on the performance of the safety design features of tank cars and ISO tanks under accident scenarios. This provides FRA with the scientific knowledge needed to support development of performance-based requirements over current prescriptive standards, allowing for more innovation in the design of rail equipment. The FRA RRS must make decisions based on scientifically defensible safety/risk assessments.
- Provide FRA the tools it needs to support the PHMSA and conduct its business as it relates to the safety of natural gas research.

Safe Transportation of Energy Products (STEP) $2,000,000*

This project will assess the operational safety risks associated with hazardous material unit trains, and will focus on determining if unit train operation of hazardous materials presents any unique or additional risks compared with 1) unit train operations of non-hazardous materials or 2) mixed-freight operations involving the same hazardous materials as currently or planned for transportation in unit trains. FRA will develop a risk model for quantifying risks associated with the operation of hazardous material unit trains and on risk mitigation.

As part of this project, FRA will continue providing engineering support in the research, design, fabrication, and test planning of ISO tank and tank car fire testing and the structural performance of these equipment used as fuel tenders and energy products as commodity transport.

*This funding is an earmark provided annually by Congress for Safe Transportation of Energy Products (STEP). This is in addition to the total budget for FRA RD&T. If Congress chooses NOT to fund the $2M earmark, this activity will not be executed in 2019.

Anticipated Activities:

- Provide engineering support in research, design, development, and test planning.
- Test ISO tank and tank cars.
- Collaborate with PHMSA.

Expected Outcomes:

- Understand the risk related to the transportation of different hazardous materials in different train configurations.
- Understand the risk related to the transportation and use of energy products (LNG, ethanol, etc.).
- Develop a risk model for quantifying risks and risk mitigation for hazardous material on unit trains.

Public, Private, and University Cooperative Research Agreement $406,000 (Totaling $2,000,000 from all divisions)
See Railroad Systems Issues for description, activities, and expected outcomes.

Statutory Requirements:

Rolling Stock research program is part of FRA's statutory requirement; it is the program that manages the tank car research.

Program Alignment with Strategic Goals:

FRA's RD&T Rolling Stock Research program focuses on improving railroad safety. It provides the scientific and engineering basis for improved industry and Federal standards and improved safety enforcement and compliance using those standards. Through the program, FRA collaborates with the railroad industry to develop and implement new technologies and practices to improve overall rail system safety. The Rolling Stock Research program, in collaboration with the rail industry, is aimed at reducing derailments due to equipment failures, minimizing the consequences of derailments, and minimizing hazardous material accidental releases

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

This program inherently has a significant impact on rural communities in that improving equipment and operating practices reduces the risk of rail-related HazMat spills, and the hazardous materials research minimizes the consequences of the releases that may affect rural communities.

Program Objectives:

FRA's Rolling Stock Research program improves railroad safety through evaluating risks and prioritizing RD&T projects to reduce safety risks, and to achieve DOT, OST-R, FRA, and RPD goals. The Rolling Stock division's objective is to determine strategic research needs and priorities through collaboration with internal and external partners and stakeholders, considering real-world safety issues requiring subject matter expertise or long-term research solutions.

The Rolling Stock research program conducts research that is critical to the rail industry and the American public. This program helps mitigate potential risks of unexpected failures occurring in rolling stock that can cause delays and disruptions to transport services or even result in derailment accidents. This program's research helps determine criticality and methods for identifying, analyzing, and evaluating potential failure modes. FRA invests in technology that is innovative and has a lower technology readiness level than the private sector can justify. This investment keeps the U.S. rail sector growing and improving to keep up with the latest efficiency and safety standards. FRA also undertakes research-partnering with railroads and other interested parties, which results in successful demonstrations subsequently adopted by the industry.

Research Collaboration Partners:

The Rolling Stock Research program is subject to continuous input and review from industry stakeholders. PMs are active contributors to industry committees and meetings overseen by the AAR, APTA, American Society of Mechanical Engineers (ASME), and others. Input from industry stakeholders at these meetings is solicited and appropriately addressed in ongoing research efforts. Program staff also publish research results for peer review in technical journals, both domestically and internationally.

For example, Fire Safety research will be coordinated with AAR's Locomotive Equipment Engineering and Tank Car Committees, APTA, National Fire Protection Association (NFPA) and presented at other industry forums. Research results will be disseminated for review and implementation by the FRA RSAC; AAR; APTA Passenger Rail Equipment Safety Standards Committee; NFPA via committee meetings and conferences such as the Joint Rail Conference, the APTA Rail Conference, the International Heavy Haul Association Conference, the Fire Protection in Rolling Stock Conference; and others.

Partner Detail

Partner Name	Contributions	Benefits of Partnership
Tank cars owners	In-kind contributions include tank cars, valves, engineering consultation.	Equipment, subject matter expertise
Tank car shops	In-kind contributions include tank cars, valves, engineering consultation.	Equipment, subject matter expertise
Sharma & Associates, Inc.	Data analysis, test support, actual testing, resources and modeling. In-kind equipment contribution.	Subject matter expertise
Transportation Technology Center	Data analysis, test support, actual testing, resources and modeling. In-kind equipment contribution.	Subject matter expertise
Class I freight railroads	Donations of railcars for using in testing (including destructive testing).	Equipment, subject matter expertise
Passenger rail equipment manufacturers and component suppliers	Donations of equipment or components (e.g., window glazing samples, prototype seats, passenger workstation tables).	Equipment for testing
Passenger and commuter railroads	Donations of railcars for using in testing (including destructive testing).	Equipment for testing
Passenger and freight industry associations	Donations of railcars for using in testing (including destructive testing).	Equipment for testing
BNSF Railroad	Access to bearing/wheel Shop facilities, operator time, allow sample collection. In-kind contributions of $6,000.	Equipment/material
Norfolk Southern Railroad	Access to bearing/wheel shop facilities, operator time, allow sample collection. In-kind contributions of $6,000.	Equipment/material
Progress Rail	Access to bearing/wheel shop facilities, operator time, allow sample collection. In-kind contributions of $6,000.	Equipment/material
Union Pacific Railroad	Access to bearing/wheel shop facilities, operator time, allow sample collection. In-kind contributions of $6,000.	Equipment/material

Partner Name	Contributions	Benefits of Partnership
Indiana North Eastern Railroad	In-kind contributions of $6,000: Provide labor and access to their cars and locomotives for test installation and feedback.	Equipment, subject matter expertise
Metropolitan Transportation Authority (MTA) (Metro-North Railroad and Long Island Railroad)	In-kind contribution: Provide access to their data and operational information, allowing us access to data that is difficult to gather, which can be then be used to evaluate the safety efficacy of these wayside systems.	Data
Railway and industrial specialties	In-kind contribution: Access and data on wheel failure types and defect details, allowing for accurate modeling of defects.	Data
Penn Machine Company (potential)	In-kind contribution: Design data on wheels, and access to wheel replacement data to help validate wheel life model.	Data
Siemens and Alstom	In-kind support (personnel, facilities, equipment) may be provided to perform tests which may be necessary as part of new equipment qualification.	Facilities
LED manufacturers Railroads	In-kind contribution which include Halogen and tungsten light samples. Meeting participation; technology requirements; in-kind support.	Material for testing
TTC, American Public Transportation, AAR, and TTCI	Passenger rail equipment manufacturers (e.g., Siemens, Alstom, Stadler) have donat window glazing for our ballistics test program.	Equipment for testing

Benefits Detail

Beneficiary	Benefit(s) Received
FRA RRS	Improved safety recommendations and innovative solutions
Rail industry FRA RRS Tank car owners Tank car manufacturers Leasers tank car shops	FRA will acquire: • In-depth knowledge of the performance of tank cars and the different service equipment of tank cars and portable tanks • In-depth knowledge of the crashworthiness of different types of tank cars and the failure modes to improve the performance of HazMat packages
General public	• Reduced railroad accidents and fatalities • Lower operating costs • Reduced railroad accidents and fatalities • Improved service life for its rolling stock equipment • Improve railroad performance
Small businesses, and university research centers	Improve their railroad research resources and capabilities

The Rolling Stock Research program benefits from the expertise, experience, and contributions of its stakeholder partners. Non-governmental partners provide cash contributions, donations of equipment and components, data, oversight, and peer review to rolling stock research initiatives.

Rolling Stock Research Partners are Members of the following Organizations	
American Railway Association (ARA)	University of Nebraska
American Public Transportation Association (APTA)	Southwest Research Institute
Pipeline and Hazardous Materials Safety Administration (PHMSA)	Sandia National Laboratories
National Railroad Passenger Corporation (Amtrak)	Friedrich Research
Southeast Pennsylvania Transportation Authority (SEPTA)	Transport Canada
Transportation Technology Center Inc. (TTCI)	U.S. Access Board
Progress Rail	Next Generation Equipment Committee
General Electric Transportation Services	Volpe National Transportation Systems Center
Trinity Rail	TRB
Chart Industries	U.S. Environmental Protection Agency (EPA)
Michigan Technical University	U.S. Department of Energy (DOE)
Oregon State University	National Transportation Safety Board (NTSB)
	California Department of Transportation

Acquisition/Assistance:

The Rolling Stock Research program establishes research priorities and defines its acquisition plan considering internal and external priorities and aligning priorities with DOT, FRA, RPD, and RD&T goals for the upcoming fiscal year. The Rolling Stock Research program works with the FRA Office of Acquisitions to initiate various funding vehicles, for both single-year and multi-year contracts, across the division. The Rolling Stock Research program uses the following acquisition methods for awarding contracts and grants:

- Broad Agency Announcement (BAA)
- Indefinite Delivery Indefinite Quantity (IDIQ)
- Full and open competition solicitations
- Sole source acquisition
- Small Business Innovative Research Program (SBIR)

The Rolling Stock Research program uses a non-competitive acquisition approach for continued research or follow-up research, unsolicited proposals, and for research that requires special expertise in a timely manner. Most research projects are funded in a phased approach to accommodate the limited funding and availability of other resources. A sole source award is made for unsolicited research ideas that have merit and is aligned with the strategic research goals.

To provide robust scientific data to the Office of Railroad Safety for decision-making, Inter-Agency Agreements (IAA) are established with the Volpe Center because of its technical and modeling expertise and its existing relationships with the rail industry used to obtain needed data. The Volpe Center provides specialized support to the Rolling Stock Research division for the investigation of passenger train accidents and incidents. Personnel from the Volpe Center travel to accident sites and provide on-the-ground support to National Transportation Safety Board (NTSB) investigators and local FRA inspectors when needed. Work products produced by the Volpe Center are readily accepted and respected by the rail industry. Volpe is also a source for computational simulations**.**

The Rolling Stock Research program utilizes both single-year and multi-year acquisitions for projects. Multi-year acquisitions are used to provide incremental funding for research projects, and to allow for decision-making and potential redirection, as necessary, as the research progresses.

The Rolling Stock Research program always seeks to leverage non-Federal funds to support its activities. Cost-sharing, matching funds, and in-kind contributions are mechanisms used to leverage the resources of non-Federal stakeholders and partners.

Technology Transfer (T2):

The Rolling Stock research program works closely with stakeholders throughout the R&D life cycle and the T2 life cycle to increase user adoption of research products/services. PMs work with internal (e.g., FRA Office of Railroad Safety, other OAs) and external stakeholders (e.g., Class I and short line railroads, labor unions, equipment manufacturers, state DOTs) to understand their needs and how the research will affect their eventual adoption of the technology or policy change. RD&T PMs and their research partners work together early in the research process to communicate the value and benefit of RD&T's research products.

Engagement provides benefits to all stakeholders as well as FRA. Across the division's research projects, FRA and its partners share information, develop and test new technology and safety tools, improve safety culture, and contribute to the safe transportation of goods and passengers across America's railroads. The Rolling Stock research program also publishes Technical Reports and Research Results in the FRA eLibrary, which are available to the American public. PMs also present their research at numerous industry meetings both nationally and internationally.

The Train Energy and Dynamics Simulator (TEDS) is a software tool designed and developed for studying train safety, operations, and dynamic performance, and can be used for modeling train performance under a wide variety of rolling stock, track/terrain, and operating configurations. The tool has been validated extensively under a variety of real-world and laboratory settings. Railroads, railcar builders, systems suppliers, academic institutions, consultants, and agencies (e.g., NTSB), can use TEDS to study train operations, performance, and safety. Having developed and validated the tool, FRA remains a primary user and stakeholder. The software is maintained by the FRA contractor who developed TEDs.

In 2016, TEDS was made available to the general public. This was announced through professional industry magazines (*Railway Age* and *Progressive Railroading*) and professional conferences arranged by the ASME Rail Transportation Division. Research papers on the use and application of TEDS continue to be presented at industry forums and conferences. A paper on the validation of TEDS was presented at the ASME Joint Rail Conference in Pittsburg, PA on April 18-20, 2018. Twenty-one parties have expressed interest in TEDS; there are seven current users. Discussions are underway with other potential users of future software.

In 2019 and beyond, FRA will continue to make TEDS available to interested parties, including railroad industry entities, universities and research institutions, and other government agencies. Support provided includes hosting the software on a secure private server, conducting user training and providing support for resolving issues in the use and interpretation of results.

Beneficiaries:

- Railroads can optimize train makeup and train operations. For example, the tool can be used to determine optimum number and placement of locomotives, safe train handling practices, and fuel consumption studies. Car builders and systems supplier may benefit by using TEDS to design and optimize the systems they are supplying, such as brake systems, coupler/draft systems, etc.
- Institutions with a safety mandate can benefit from the use of TEDS for a variety of safety studies, including investigations of train incidents and derailments.

Regarding the effectiveness of TEDS, FRA and NTSB have used TEDS to investigate train derailments and evaluate various air brake systems and their impact on train handling and operation safety. The Transport Safety Board of Canada is conducting internal studies, and the Canadian National Research Council is conducting proprietary studies. There have been no intellectual property activities associated with this research effort. This research is in the Research Hub, but does not yet appear in the National Transportation Library.

The past 3 years of funding for TEDS is as follows:
2016: $130,000, 2017: $67,000, and 2018: $80,000 (projected)

Evaluation/Performance Measurement:

The Rolling Stock Research program participates in these external project evaluations that help all divisions improve performance and increase ROI of government funding.

In 2014, the Rolling Stock research program selected the Locomotive Efficiency area to be evaluated under the project "Evaluation of Rail Energy, Environment and Engine-Efficiency Technology Research Program" as part of RD&T's pilot project evaluation effort, and, later, participated in the TRB's evaluation, focusing on research projects, communication, stakeholder engagement, strategic planning, priority setting, and evaluation. Rolling Stock Research program PMs participated in this year's project evaluation training, aimed at providing a basic evaluation skillset for each RD&T PM.

In 2019, the Rolling Stock research program will work with other RD&T divisions to implement internal processes to improve FRA's accountability to the American public based on the recommendations from these groups and skills learned in the training. PMs will work to implement the evaluation framework, standards, procedures, and templates identified in the "FRA Evaluation Implementation Plan" and the "FRA Manual for Research, Development and Technology (RD&T) Program and Project Evaluation." For more information about these efforts, see the Evaluation/Performance Measurement section in the Research, Development, and Technology section.

Starting in FY19, FRA will measure performance for the DOT Strategic Goal Innovation.
Development of Innovation:

- Increase Dissemination of DOT-Funded Research Reports (OST)
- Increase Production of Tangible DOT-Funded Research Outputs (OST)
- Increase DOT Technology Transfer Activity (OST)

Deployment of Innovation

- Increase Tangible Production of DOT-Funded Research (OST)

RD&T began tracking data for FRA's OST-R Technology Transfer Report 2017. As discussed in the T2 section, RD&T will establish baseline metrics using data from FY18 to track performance against the Innovation performance

goals. RD&T will track page views and downloads of published materials in addition to the following data to measure progress:

- Collaborative relationships
- Technical publications made available to public
- In-person or webinar presentations delivered to foster technology transfer
- Technical publication downloads – NTL
- Workshops or demonstrations to foster technology transfer
- Total number of small businesses supported
- Number of new inventions disclosed
- Number of patent applications filed

Train Control and Communication
Funding Request $8,086,000

Program Description/Activities:

The Train Control and Communication (TCC) research program focuses on improving railroad operation safety through the development and testing of train control and communication systems and grade crossing safety technologies. The program also conducts pilot studies, creates prototypes, and demonstrates safety and security systems, including intelligent rail systems, blocked crossings, and trespass prevention.

TCC Collaboration with Intelligent Transportation Systems Joint Programs Office (ITS-JPO)

The TCC research program collaborates with the Intelligent Transportation Systems Joint Program Office (ITS-JPO) on multiple efforts. TCC meets regularly with ITS-JPO (once or twice per month, based on research needs) to address safety issues within the railroad industry and reduce the duplication of research efforts. Currently, RD&T is collaborating with ITS-JPO on automated behavior related to grade crossings (GX) to determine how to protect people in connected vehicle scenarios. TCC received $1.5M in funding over a 3-year period from ITS-JPO in a research collaboration on the Railroad Crossing Violation and Warning System (RCVW) to develop a concept of operations and safety scenarios.

RD&T is researching and developing technologies that will leverage existing PTC system functionality to enable automated train operation and safe negotiation of grade crossings by automated vehicles. These research activities include evaluation of sensor technologies, communication system requirements, and system safety analyses. In August 2018, FRA engaged approximately 30 stakeholders across all modes of transportation to discuss a comprehensive review of automation systems, safety system designs, and direction. FRA will document, discuss, and evaluate stakeholder ideas and feedback and schedule follow-up meetings. FRA will sponsor multiple stakeholder interactions to review stakeholders' proposed designs prior to structuring research and development of systems that will be implemented alongside existing PTC systems. This process will help improve technology transfer and reduce barriers to adoption.

RD&T also collaborates with ITS-JPO through the Office of the Assistant Secretary for Research and Technology (OST-R) to discuss strategy and planning. Frequent communication with ITS-JPO allows FRA to share information so that research results can be beneficial to ITS-JPO, and has prevented the duplication of effort on research.

Improving the Mobility of Freight:

Train Control and Communication's research in PTC is improving the mobility of freight. PTC allows for the faster delivery of people and goods, increasing the frequency of railway operations while keeping operations safe and intact. Improved communications allow the railroads to manage dispatch differently, increasing the number of cars during operations, thus increasing frequency and speed of delivery. The industry utilizes several variables to determine railroad schedules (e.g., car type, typology, track layout, stopping time, accelerating time, etc.) and PTC enhancements allow the industry to maximize these benefits to increase rail network capacity.

Improving Mobility for Underserved Communities:

Train Control and Communication's research in PTC is improving the mobility of freight for all communities.

PTC Congressional Mandate Deployment:

Deployment of PTC by the railroads was outside the scope of the FRA's Office of RD&T. Enforcing and monitoring the deployment of the PTC technology has been handled by FRA's Office of Railroad Safety. The deployment has been successful, as noted in OST's memorandum December 31, 2018:

- The 41 railroads required by Congress to implement PTC by December 31, 2018, have submitted documentation that they assert is sufficient to meet the statutory requirements for system activation or the statutory requirements to qualify for an alternative schedule ("extension") for up to 2 additional years to complete full implementation.
- As of the third quarter of 2018, the percentage of track segments completed is 94% for freight railroads and 77% for passenger. This compares to 20% for freight and 13% for passenger as of the third quarter of 2016. 2018 yielded many positive results and highlighted great collaboration between industry and government. However, significant work remains to be done in order to ensure additional field testing, interoperability, and full implementation arrive as soon as possible.
- Four railroads have self-reported that they fully implemented an FRA-certified and interoperable PTC system on all of their required main lines: the Port Authority Trans-Hudson (PATH), North County Transit District, Portland & Western Railroad, and the Southern California Regional Rail Authority (Metrolink).

Cybersecurity:

Train Control and Communication's research focus includes securing communication and ensuring authentication of senders and receivers of PTC communication.

Positive Train Control (PTC) Research $5,972,763

The PTC research program conducts research to improve system safety and reduce railroad accidents. This is accomplished through the research, development, and testing of modern digital technology to integrate command, control, communications, and information systems for controlling train movements with safety, security, precision, and efficiency. This system was mandated by the Rail Safety Improvement Act (RSIA) of 2008, to be deployed by 2015 on approximately 100,000 miles of high-density mainline tracks.

PTC relies on real-time wireless digital communication schemes between trains, control centers, and wayside infrastructure to maintain up-to-date train positions, movement authority transmission/reception, and temporary speed restrictions. Global positioning systems, inertial navigation systems, or radio frequency transponders are used to track the movement and location of the trains. Databases and information processing equipment are also used for various decision-making functions. By employing all these technologies, trains can be continuously monitored to ensure they comply with the movement authorities and speed limits, resulting in the following benefits:

(1) Prevent train-to-train collisions.
(2) Prevent over-speed derailments.
(3) Protect roadway workers.
(4) Ensure switch positions are correct for safe movement.

In addition, back office computer systems integrate data collected from PTC systems to update other IT systems, like scheduling, to optimize train operation and management.

The Train Control and Communication program's research improves *49 CFR Part 236 Subpart I Positive Train Control Systems*. PTC has the potential to provide large safety benefits to the railroad industry as well increase the overall productivity of the rail network. PTC is designed to stop several human factor-type accidents from occurring. Furthermore, research and investments into PTC technology have the potential to lay the groundwork for the integration of autonomous systems within the railroad industry. Research into PTC technology not only has the potential to help shape autonomous rail systems but also to improve PTC so that it can be implemented cheaper and more effectively. This improvement will allow for railroads to voluntarily install the system, which currently has the potential to be limited due to the high cost associated with implementation.

PTC Technology $2,522,763

This research addresses problems associated with PTC development, deployment, and long-term evolution and maintenance. It supports the design and development of innovative systems to ensure PTC interoperability and reliability.

Anticipated Activities:

- Design PTC-integrated work zone protection technologies.
- Railroad wireless spectrum use analysis and planning.
- Investigation of potential rail communication security enhancement techniques.
- PTC reliability and availability improvements.
- PTC automated braking performance improvement.

Expected Outcomes:

- Safer and more reliable PTC systems that contribute positively to railroad operational efficiencies.

PTC Interoperability $0

Interoperability is the requirement that all railroads have the ability to work anywhere on the North American railroad network. If railroads are not interoperable, all rail traffic must stop and transition between carriers at each individual railroad boundary. This would be extremely inefficient and costly.

Interoperability is a requirement of Rail Safety Improvement Act of 2008 (RSIA '08), as all railroads must have the ability to use the national network and transport goods and people on all lines. Multiple efforts are reviewed for viability, including radiofrequency spectrum allocation, infrastructure enhancements and modifications, and monitoring and analysis of the network. Interoperability will alleviate the regulatory burden requiring FRA to check the interoperability between different railroads and will lead to the development of an automated system that will ensure interoperability.

Anticipated Activities:

- Engage stakeholders to develop interoperability specifications, lifecycle management, verification of interoperability between differing PTC systems, applications, and integration of products and processes into the national PTC network.

Expected Outcomes:

- Produce publicly available, finalized technology specifications to encourage the private sector to further develop and deploy. Since this will be an open standard; it will create a competitive marketplace, increasing economic competition and workforce development.
- All railroads are expected to accept these developments for implementation at the earliest opportunity and finalize any individual railroad requirements.

PTC Next Generation $2,850,000

This research will identify and develop the methods, facilities, equipment, and capabilities required for providing ongoing industry PTC support. Research will focus on providing additional functionality, improving reliability, and supporting integration with other technologies, all of which will support the objectives of improving safety and throughput. Multiple areas of consideration are under review for potential development, including signaling, communications, and infrastructure enhancements to reduce PTC burden and improve safety.

Anticipated Activities:

- Work with industry, vendor, and academic support to develop a spectrum of potential solutions, ranging from improving conventional train control and management methods to developing and implementing an advanced train control and management system architecture along with an associated migration plan.

Expected Outcomes:

- Improve the safety and capacity of the railroads with concepts such as moving block operations, automated train movements, connected vehicles, and variants thereof. North American railroads are actively engaged in the development and implementation of these cutting-edge technologies.
- It is anticipated that AAR and its member railroads will implement future technological advances upon development for safety and efficiency enhancements.

Intelligent Transportation Systems (ITS) $600,000

Facilitate collaboration between railroads and automotive industry stakeholders to develop coordinated solutions for automated transportation systems. Accelerated development of connected and autonomous road vehicles must be mirrored by railroad investment in rail automation and highway-rail grade crossing technologies.

RD&T's research of ITS improves *49 CFR Part 234 Grade Crossing Safety* and *Part 924 Highway Safety Improvement Program*. Most highway-grade crossing regulations, especially those pertaining to the interactions of highway users, fall under FHWA or Federal Motor Carriers Safety Administration (FMCSA). The regulations that FRA puts forth on highway-grade crossings, in general, pertain to the requirements that the railroads must maintain regarding the safety devices and general upkeep of highway-rail grade crossings. However, as the auto industry is pursuing autonomous vehicles, those vehicles will need to interact with highway-rail grade crossings and research needs to be conducted. Odds are that the current highway-rail grade crossing safety system will need to be altered to better communicate with autonomous vehicles so that the vehicles are "informed" of the position of the gates as well as informed about oncoming trains. A potential benefit that could come from the inclusion of autonomous vehicles at highway-rail grade crossings is the reduction of accidents caused by highway drivers moving around safety devices or by highway drivers misjudging the distance of an oncoming train and continuing to move through the crossing.

Anticipated Activities:

- Develop open standards and practices for automated rail operations and highway-rail grade crossing systems.
- Research innovative technologies important to rail ITS.
- Develop prototype and reference architectures.
- Support model deployments and evaluation of connected safety systems.

Expected Outcomes:

- Significant improvements in grade crossing safety and highway-rail transportation integration
- Coordinated deployment of automated vehicles and connected infrastructure systems

Grade Crossing Safety and Trespass Prevention $1,778,357

The Grade Crossing Safety and Trespass Prevention research program conducts research to improve system safety and reduce railroad accidents and incidents at grade crossings. This is accomplished through the research, development, and testing of safety technologies and providing trespassing countermeasures and best practices to communities and stakeholders. Results of this research and development directly supports the development of technology and safety standards to improve railroad operation safety as well as providing scientific research and data to support FRA regulations and rulemaking.

RD&T's Grade Crossing and Trespass Countermeasures research improves *49 CFR Part 234 Grade Crossing Safety*. FRA has some regulations that deal with trespassers on railroad property and has recently formulated a task force to look into possible mitigation strategies to reduce the number of trespasser violations occurring each year. As it is not economically feasible to surround the entire rail network with fencing, nor would that deter all trespassing violations, a more cost-effective strategy needs to be developed. The task force will help to develop those strategies.

FRA's Grade Crossing and Trespassing Task Force is looking at identifying areas that have high concentrations of trespassing and grade crossing violations and identifying what factors might be contributing to the high occurrences. If any patterns in trespassing can be established, then there is a potential that the number of fatalities in high-risk areas could be decreased through the use of pointed deterrence/prevention methods. The cost of trespassing is not only the life of the trespasser but also the psychological effect on the engineer/conductor of the locomotive who hit the trespasser as well as any delays that might ensue as the incident is investigated.

RD&T's research of ITS improves 49 *CFR Part 234 Grade Crossing Safety* and *Part 924 Highway Safety Improvement Program*. Most highway-grade crossing regulations, especially those pertaining to the interactions of highway users, fall under FHWA or FMCSA. The regulations that FRA puts forth on highway-grade crossings, in general, pertain to the requirements that the railroads must maintain regarding the safety devices and general upkeep of highway-rail grade crossings. However, as the auto industry is pursuing autonomous vehicles, those vehicles will need to interact with highway-rail grade crossings and research needs to be conducted. Odds are that the current highway-rail grade crossing safety system will need to be altered to better communicate with autonomous vehicles so that the vehicles are "informed" of the position of the gates as well as informed about oncoming trains. A potential benefit that could come from the inclusion of autonomous vehicles at highway-rail grade crossings is the reduction of accidents caused by highway drivers moving around safety devices or by highway drivers misjudging the distance of an oncoming train and continuing to move through the crossing.

Trespass Countermeasures $0
Trespassing is the leading cause of accidents that happen on a railroad. The purpose of this research area is to investigate and evaluate new technologies and their applications to mitigate the risk of accidents on railroad track due to trespassing.

Anticipated Activities:
- Install, test, and evaluate augmented train horn in an operational railroad environment.
- Evaluate a trackside wireless detection net for pedestrian safety.
- Investigate the use of Artificial Intelligence (AI) that can be employed in detecting trespassers.

Expected Outcomes:
- New technologies and solutions are expected to be then evaluated, tested, and implemented in a railroad environment leading to technology transfer and an increase in public safety.

Intelligent Transportation Systems $0

This work will help facilitate collaboration between railroads and automotive industry stakeholders to develop coordinated solutions for automated transportation systems. Accelerated development of connected and autonomous road vehicles must be mirrored by railroad investment in rail automation and highway-rail grade crossing technologies.

Anticipated Activities:

- Develop open standards and practices for automated rail operations and highway-rail grade crossing systems.
- Research innovative technologies important to rail ITS.
- Develop prototype and reference architectures.
- Support model deployments and evaluation of connected safety systems.

Expected Outcomes:

- Significant improvements in grade crossing safety and highway-rail transportation integration
- Coordinated deployment of automated vehicles and connected infrastructure systems

Grade Crossing Technology $1,105,000

This project will investigate, analyze, and test new technologies to improve public safety at grade crossings. Grade crossings, along with public railway station platforms, are the locations where the railroad is most exposed to interaction with other modes of transportation, as well as the public. Most accidents reported to FRA occur at grade crossings.

Anticipated Activities:

- Evaluate the effectiveness on the drivers' behavior of flashing lights installed on the surface of the pavement of a roadway when approaching a railroad grade crossing.
- Evaluate how low-cost pavement markings at railroad grade crossings can effectively warn a driver not to stop on the railroad tracks.
- Evaluate the effectiveness of LED-enhanced "Do Not Stop on Tracks" (R8-8) signs on reducing traffic queuing at highway-rail grade crossings.
- Use AI algorithm (AIA)/machine learning capabilities to help identify potential collisions at grade crossings, detect trespass events, and possibly prevent suicide attempts.

Expected Outcomes:

- Technology transfer and implementation by railroad carriers (in cooperation with state and local governments) of products and practices evaluated under this research area.

Grade Crossing Pedestrian Safety $60,000

This research will evaluate the effectiveness of technologies and infrastructure improvements that can mitigate the risk of accidents at grade crossings where pedestrians are involved.

Anticipated Activities:

- Evaluate the effectiveness of grade separations that can be either roadways with pedestrian paths—or dedicated pedestrian underpasses or overpasses.
- Evaluate new types of pedestrian gates (known as "gate skirts") that can aid in preventing pedestrians crossing the tracks when a train is approaching.

Expected Outcomes:

- Recommendations to local and state governments for the planning and construction of grade separations. Results from the evaluation of pedestrian treatments are expected to be considered by the railroads in cooperation with local communities.

Grade Crossing Modeling and Simulation $170,000

This project will evaluate scenarios of possible safety improvements at grade crossings without the actual need to perform field testing. Modeling consists of simulating traffic and pedestrian scenarios to understand what safety improvements can be effective at a grade crossing. Traffic simulations will also be evaluated to understand several implications that could result from a safety improvement.

Anticipated Activities:

- Understand the position of the Emergency Notification System (ENS) warning sign at grade crossings using the grade crossing simulator.
- Improve GradeDec.Net, the FRA-developed highway-rail grade crossing investment analysis tool used to identify the most cost-effective investments to improve safety and reduce highway congestion at grade crossings.

Expected Outcomes:

- Continue improvements to GradeDec.Net, which helps users estimate the costs and benefits of grade crossing investments by comparing the reduced costs of fatalities, injuries, and property damage from possible incidents, reduced travel times, and reduced emissions to the construction costs.

Grade Crossing and Trespass Outreach and Education $443,357

This research will develop and disseminate educational tools to the public, including local and state governments, law enforcement agencies, and schools, among others. The purpose of the tools is to provide awareness of the risk of accidents that may occur at grade crossings when appropriate behavior is not observed.

Anticipated Activities:

- Provide support to a Law Enforcement Strategies for Reducing Trespassing Pilot Grant Program. Specifically, the Grant Program will award up to $150,000 to law enforcement agencies with the purpose of understanding the effectiveness of the presence of police officers along the railroad ROW to prevent trespassing activities.
- Disseminate rail ROW trespass prevention outreach materials. Also, conduct final tests on a mobile application that was developed in FY18. The application will be used to educate high school students to the dangers of grade crossings and trespassing.
- Objectives are to inform drivers about any violations at a grade crossing and provide an informative sheet on the implications of violating a grade crossing warning system.
- Organize a workshop by mid-2019. This workshop will continue the collaboration effort among several national and international stakeholders on trespass and suicide issues.

Expected Outcomes:

- Improved public safety through the further dissemination and reception of educational and training aids.
- Prove the effectiveness of deploying police officers along the railroad.
- Formation of an international working group on trespass prevention.

Public, Private, and University Cooperative Research Agreement $334,880 (Totaling $2,000,000 from all divisions)

See Railroad Systems Issues for description, activities, and expected outcomes.

Statutory Requirements:

Railroad Research and Development is statutorily mandated in the budgets prepared by the President, House and Senate of the U.S. The TCC program is funded with discretionary funds. The program meets the annual funding appropriation act's requirement to conduct train control and communications research. The TCC Research program meets the FAST Act Section 11404 requirement to evaluate the potential of Positive Train Control to improve safety at grade crossings.

Program Alignment with Strategic Goals:

This program supports DOT's Safety and Innovation strategic goals by developing and helping to deploy innovative technologies to improve railroad operation safety and efficiency, affecting all communities. Technology helps improve rail services of moving people and goods, which has a significant positive impact on the U.S. economy as a whole and rural communities' accessibility to participate in economic activities. This program also supports the Accountability goal in its role in reducing regulatory burden.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

Historically, "rural community impact" has not been a criterion for measuring the TCC Division's research and development portfolio. The TCC Division will develop metrics for assessing the impact of its research on rural communities. The following shows how each TCC research area aligns to DOT goals and impacts rural communities.

PTC research aligns with DOT Strategic Goal of Safety by creating more reliable and effective PTC safety systems. FRA's research increases the timeliness and efficiency of communications between interoperable railroads. PTC's safety goals include increasing the safety at highway-rail grade crossings to reduce the incidents and fatalities that occur yearly. PTC research also aligns secondarily to the DOT Strategic Goal of Innovation. Automation systems operation and performance are a large part of FRA's research program to increase the efficiency of PTC. FRA is leading the industry to facilitate the development of a PTC system that meets regulatory requirements and provides operational benefit to railroads. As part of this effort, TCC is working with FRA RRS to reduce the regulatory burden as part of the DOT Strategic Goal of Accountability.

GX and trespasser research aligns with DOT Strategic Goal of Safety. The main goal of this research is to reduce the number of incidents on the railroads at grade crossings. Work in this area also meets secondary DOT Strategic Goals of Innovation and Infrastructure. TCC trespassing and GX research tests and implements new methods to warn the public of the presence of trains and recognizing trespassers with the aid of AI. Many incidents occur at highway-rail grade crossings in rural communities resulting in loss of life or property. This program strives to mitigate those impacts.

Program Objectives:

FRA's TCC Research program is aimed at reducing train-to-train collisions and train collisions with objects on the line and at grade crossings. Each research area has its own goals and issues it is trying to solve.

PTC Technology - The goal is to assist railroads in meeting the Congressional mandate for PTC while maintaining safe and efficient rail operations. As a critical safety system, PTC must be highly reliable, interoperable, and secure. The government must work with U.S. railroads to ensure the requirements of RSIA '08 are satisfied while maintaining the value of this critical national transportation system.

PTC Interoperability - The goal of this research area is to work with railroads to define standards for interoperability between the North American railroads. Interoperability is a requirement of RSIA '08, as all railroads must have the ability to use the national network and transport goods and people on all lines. FRA, in conjunction with multiple revenue service railroads, has taken the initiative to develop the initial infrastructure of an interoperability system between differing versions of PTC between railroads.

PTC Next Generation - If PTC technology is not improved, it is safe to assume that inefficiencies will continue to cripple capacity, which will in turn increase the cost of shipping people, goods, and services throughout the network. Future train control must improve capacity and maintain safe rail operations through innovative technological advances. There are multiple concepts that need to be explored, developed, and tested to determine if they are viable for implementation into revenue railroad service.

To achieve the intended safety benefits, the PTC system must maintain a high level of availability. Additionally, because PTC can slow and stop trains, it is critical to keep the system running smoothly and dependably, to avoid delays and disruptions to the flow of the nation's critical railroad traffic. The best possible tools and methods are needed so that system problems can be anticipated and prevented or else quickly detected, diagnosed, and fixed before they have a significant impact on safety and traffic flow.

Intelligent Transportation Systems - This program aims to facilitate stakeholder coordination and invest in technology development to keep rail on pace with highway vehicle connectivity and automation. The market failure that may occur is the broad deployment of automated highway vehicles (i.e., cars and trucks) that may not be able to safely negotiate all types of highway-rail grade crossings.

Trespass Countermeasures - More than 70% of casualties on a railroad are due to trespass activities on railroad property. The goal of this research area is to develop, test, and validate methods and means to reduce the number of casualties. Without this research, the number of accidents on railroad property due to trespass will likely not decrease.

Grade Crossing Technology - The mission of the railroads is to operate a failsafe system. FRA's mission is to assist the railroads in providing a safe environment. One of the weakest areas in a railroad environment are grade crossings. This is where most accidents involving injuries and deaths occur. Technologies developed in this research area provide ways and tools to decrease this weakness.

Grade Crossing Pedestrian Safety - When a grade crossing warning device activates, vehicles and pedestrians sometimes try to go around the gates or "beat the train." This research area's objective is to develop and test solutions that help prevent pedestrians from crossing the tracks in the presence of a moving train, leading to fewer incidents and accidents.

Grade Crossing Modeling and Simulation - Simulation and modeling offer a non-invasive and non-destructive method to predict traffic trends and accident reduction in a controlled environment. Often, a new solution cannot be tested and evaluated in the real world, as it may result in excessive investments. This helps mitigate those costs.

Grade Crossing and Trespass Outreach and Education - Education and awareness are the best tools to have the public understand and be aware of the risks involved when near a railroad property. Increasing education will help decrease incidents and accidents.

Research Collaboration Partners:

The research and development activities accomplished in the TCC research program are in partnership with government and non-government groups to target the research to solve rail transportation safety issues and needs. These partnerships benefit from technical and financial collaboration for a more efficient and effective research program. Multiple railroads are contributing in-kind support of the development of requirements, testing, and providing technical guidance and intellectual resources. In-kind support of non-governmental agencies can contribute 20% or more of a project's value when considering hourly wages, travel, and overhead.

Stakeholder input is a critical driver of TCC's research planning. The following is a list of contributors that help drive TCC's research:

- Periodic evaluation by a special committee of the TRB
- Coordination with the AAR research program through the AAR's Train Control, Communications and Operations Committee
- Program staff participation in the FRA's RSAC meetings
- Program staff presentation of research results for peer review at industry meetings and in technical journals

Partner Detail

Partner Name	Contribution	Benefit of Partnership
Volpe National Transportation Systems Center	Engineers and scientists at the Volpe Center conducted R&D for FRA on grade crossing safety and trespass prevention.	Access to subject matter expertise
FHWA	FRA collaborates with these partners on intelligent transportation systems research.	Stronger products through engagement with highway and automaker stakeholders
Federal Motor Carriers Safety Administration (FMCSA)	FRA collaborates with these partners on intelligent transportation systems research.	Stronger products through engagement with freight and trucking stakeholders
Intelligent Transportation Systems – Joint Program Office	FRA collaborates with these partners on intelligent transportation systems research.	Coordinated multimodal development
AAR	Rail industry coordination and project advisory group support; subject matter expertise.	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
BNSF	System software development and supplier contracts; field test data and subject matter expertise.	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
Norfolk Southern	Subject matter expertise	Solutions that integrate seamlessly with railroad operations; enhanced technology transfer success

Partner Name	Contribution	Benefit of Partnership
Union Pacific	Field test data and subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
CSX	Subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
Amtrak	Field test data and subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
Alaska Railroad	Subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
Kansas City Southern	Subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
Canadian National	Subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
Wabtec Railway Electronics	I-ETMS system development and insight; subject matter expertise; modifications to braking algorithm	Better product deploy ability
Meteorcomm	PTC 220MHz radio design and testing data; subject matter expertise	Better product deploy ability
Metrolink	Field test data and subject matter expertise	Better product deploy ability
Sound Transit	Field test data and subject matter expertise	Better product deploy ability
Metra	Field test data and subject matter expertise	Better product deploy ability
North County Transit	Field test data and subject matter expertise	Better product deploy ability
FarmRail	Right of way access; subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
OKDOT	Subject matter expertise	Better product deploy ability
MTA	Subject matter expertise	Better product deploy ability
Town of Bedford, NY	Subject matter expertise	Better product deploy ability
Town of Belmont, MA	Subject matter expertise	Better product deploy ability
Massachusetts Bay Transportation Authority (MBTA)	Right of way access; subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
Brunswick Police Department	Police Department facilities; subject matter expertise	Better product deploy ability
Monarch Media	Software development; subject matter expertise	Better product deploy ability
PanAm Railways	ROW access; subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
City of Orlando	Cameras and instillation	Better product deploy ability

Partner Name	Contribution	Benefit of Partnership
SunRail	ROW access; subject matter expertise	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.

Benefits Detail

Beneficiary	Benefit(s) Received
FRA RRS	Improved safety regulations and innovative solutions
Large Railroads	Reduced PTC operational impact, workforce health & safety, specialized test facilities. Efficiency, increased safety, infrastructure development, reduced regulatory burden. Roadway worker protection
Small Railroads	Reduced cost of PTC deployment and maintenance. Efficiency, increased safety, infrastructure development, reduced regulatory burden. Roadway worker protection
American Public	Increased safety, improved transportation infrastructure, economic benefit, fewer accidents, reduced congestion and fuel related environmental impacts
Universities	Publicly available research and data sets
SunRail	Innovative solutions, increased safety
Metropolitan Transportation Authority (MTA)	Innovative solutions, increased safety
MBTA	Innovative solutions, increased safety
Oklahoma Department of Transportation (OKDOT)	Innovative solutions, increased safety
Town of Belmont, MA	Innovative solutions, increased safety
Town of Bedford, NY	Innovative solutions, increased safety
PanAm Railway	Innovative solutions, increased safety
Town of Brunswick	Innovative solutions, increased safety
City of Orlando	Innovative solutions, increased safety
Highway motorists	Reduced delay and accident risk
Long-distance and short haul trucks	Reduced travel time and supply chain logistics costs
FHWA	Innovative solutions, increased safety
Local communities	Innovative solutions, increased safety
FTA	Innovative solutions, increased safety
State DOTs	Innovative solutions, increased safety
Labor Organizations	Increased Safety of employees
Railroad workers	Increased on track worker safety

Acquisition/Assistance:

The TCC program establishes research priorities and defines its acquisition plan considering internal and external priorities, aligning priorities with DOT, FRA, RPD, and RD&T goals for the upcoming fiscal year. The TCC program utilizes a competitive procurement process as often as possible.

The TCC program works with the FRA Office of Acquisitions to initiate various funding vehicles, for both single-year and multi-year contracts across the division, including:

- Indefinite Delivery/Indefinite Quantity (IDIQ)
- Full and open competition
- Sole source

- Inter-Agency Agreement (IAA)

The TCC program benefits from in-kind contributions (e.g., subject matter expertise, track time, data sharing, and equipment) from its collaboration partners. A list of these partners, the contributions they make to the TCC program's projects, and how that benefits FRA can be found in the next section. These contributions are not only desirable for their inherent value but also guide our researchers to develop practical technology that will function well in practice.

Technology Transfer (T2):

The TCC program works closely with stakeholders throughout the R&D life cycle and the T2 life cycle to increase user adoption of research products/services. PMs work with internal (e.g., RRS, other OAs) and external stakeholders (e.g., Class I and short line railroads, labor unions, equipment manufacturers, state DOTs) to understand their needs and how the research will affect their eventual adoption of the technology or policy change. RD&T PMs and their research partners work together early in the research process to communicate the value and benefit of RD&T's research products.

Engagement provides benefits to all stakeholders as well as FRA. Across the division's research projects, FRA and its partners share information, develop and test new technology and safety tools, improve safety culture, and contribute to the safe transportation of goods and passengers across America's railroads. The TCC program also publishes Technical Reports and Research Results in the FRA eLibrary, which are available to the American public. PMs also present their research at numerous industry meetings both nationally and internationally.

The TCC program area measures project performance by how it does in advancing the technology and how effective the technology is in addressing or solving the particular need for which the research is done. Also, adoption and commercialization are other metrics used to measure program performance. TCC's aim in partnering with stakeholders in developing new safety technologies is to ensure adaption, as technologies that are not embraced and adopted by the railroad industry are not worth pursuing.

Beneficiary	Benefit(s) Received	Safety, Strategic, or Project Goal Addressed
Large Railroads	Reduced PTC operational impact, workforce health & safety, specialized test facilities	Roadway worker protection
Small Railroads	Reduced cost of PTC deployment and maintenance	Roadway worker protection
American Public	Increased safety, improved transportation infrastructure, economic benefit, fewer accidents	Public safety, state of good repair
Academia	Publicly available research and datasets	Public safety, infrastructure, workforce development

Evaluation / Performance Measurement:

The RD&T program supports evaluation on behalf of all divisions. The TCC program participates in these external project evaluations that help all divisions improve performance and increase ROI of government funding. In addition, the TCC program uses the Technical Advisory Group (TAG) to make sure research progress is on the right path, and to clear any obstacles.

The TCC program participated in the TRB's evaluation, focusing on research projects, communication, stakeholder engagement, strategic planning, priority setting, and evaluation. TCC program PMs participated in this year's project evaluation training aimed at providing a basic evaluation skillset for each RD&T PM.

In 2019, the TCC program will work with other RD&T divisions to implement internal processes to improve FRA's accountability to the American public based on the recommendations from these groups and skills learned in the training. PMs will work to implement the evaluation framework, standards, procedures, and templates identified in the "FRA Evaluation Implementation Plan" and the "FRA Manual for Research, Development and Technology (RD&T) Program and Project Evaluation." For more information about these efforts, see the Evaluation/Performance Measurement section.

Starting in FY19, FRA will measure performance for the DOT Strategic Goal Innovation.
Development of Innovation:

- Increase Dissemination of DOT-Funded Research Reports (OST)
- Increase Production of Tangible DOT-Funded Research Outputs (OST)
- Increase DOT Technology Transfer Activity (OST)

Deployment of Innovation

- Increase Tangible Production of DOT-Funded Research (OST)

RD&T began tracking data for FRA's OST-R Technology Transfer Report 2017. As discussed in the T2 section, RD&T will establish baseline metrics using data from FY18 TO track performance against the Innovation performance goals. RD&T will track page views and downloads of published materials in addition to the following data to measure progress:

- Collaborative relationships
- Technical publications made available to public
- In-person or webinar presentations delivered to foster technology transfer
- Technical publication downloads – NTL
- Workshops or demonstrations to foster technology transfer
- Total number of small businesses supported
- Number of new inventions disclosed
- Number of patent applications filed

Human Factors Research
Funding Request $6,042,000

Program Description/Activities:

FRA's Human Factors (HF) Research program aims to reduce railroad accidents caused by human error. The HF Division conducts research and development activities related to safe rail operations and the safe integration of people with technology. Areas of research within the HF division include rail trespass and suicide prevention; technology, automation, and systems design; fatigue; project evaluation; highway-rail grade crossing; and support of the Short Line Safety Institute (SLSI).

FRA RD&T takes a non-regulatory approach to human factors for safety and efficiency in the railroad industry. By implementing established research practices and education-oriented guidance/tools for the rail industry, attention to human factors is encouraged rather than regulated.

Human Factors' Research supports the Office of Railroad Safety. RD&T's Grade Crossing and Trespass Countermeasures research improves *49 CFR Part 234 Grade Crossing Safety*. FRA has regulations that apply to trespassers on railroad property and has recently formulated a task force to consider possible mitigation strategies to reduce the number of trespasser violations that occur each year.

FRA's Grade Crossing and Trespassing Task Force is looking at identifying areas that have high concentrations of trespassing and grade crossing violations and seeing what factors might be contributing to the high frequency. If any patterns in trespassing can be established, then there is a potential that the number of fatalities in high-risk areas could be decreased through the use of pointed deterrence/prevention methods. The cost of trespassing is not only the life of the trespasser but also the psychological effect on the engineer/conductor of the locomotive who hit the trespasser as well as any delays that might ensue as the incident is investigated.

Human Factors Research also improves *49 CFR Parts 228 Hours of Service of Railroad Employees* and *270 System Safety Program*, which address short line safety and fatigue issues. Human Factors' work in both areas improves safety culture to reduce incidents and fatalities.

Performance-Based Regulations and Safety:

The Human Factors Research program is collaborating with the Office of Railroad Safety to consider performance-based regulations to improve safety culture within the railroad industry. One of the programs RD&T is reviewing is a successful Federal Aviation Administration (FAA) program. FAA's Aviation Safety Information Analysis and Sharing (ASIAS) system promotes the exchange of safety information to continuously improve safety. The program connects approximately 185 data and information sources (including commercial air carriers, general aviation operators, manufactures, and maintenance organizations) across government and industry, including voluntarily provided safety data. RD&T is reviewing the program and meeting with stakeholders (e.g., AAR, ASLRRA, Amtrak, labor unions) to determine whether and how FRA can implement a similar program.

Improving the Mobility of Freight:

The Human Factors Research program is collaborating with the Rolling Stock research program to investigate the safety of very long trains (VLTs). Railroads use VLTs to enhance economic competitiveness through the better use of fuel, locomotive power utilization, and additional rail cars—without adding extra crew. As part of this research,

HF will be advising the research of human factors issues that may be associated with the operation and handling of VLTs.

Rail Trespass and Suicide Prevention $370,000
This research seeks to better understand the two leading causes of rail-related death in the U.S. Hundreds of people lose their lives every year on train tracks due to trespassing or suicide.

Anticipated Activities:
- Conduct pilot studies with rail carriers implementing strategies to mitigate trespass and suicide.
- Evaluate the effectiveness of these strategies and disseminate the results in the FRA eLibrary.
- Use geographic information system (GIS) mapping capabilities to work with stakeholders to understand their trespass/suicide problem and create an internal database to map suicide and trespass casualties.
- Conduct and sponsor a trespass research needs workshop to solicit ideas on prospective new or expanded initiatives, strategies, and research projects.

Expected Outcomes:
- Improve understanding of the causal factors behind why individuals contemplating suicide consider this method to end their lives.
- Identify countermeasures to prevent accidents attributable to trespassing and suicide.
- Identify and plan new efforts to support FRA rail trespass and suicide prevention.
- Track media reports of suicide and trespass incidents on ROWs.
- Better understanding of how to improve cause of death determinations for rail fatalities.

Automation, Operating Personnel Information Management, and Control $800,750
HF wants to help ensure that the rail industry moves from a manual, analog operating environment to a more automated digital environment, where automation is designed and implemented in a manner that:
- Utilizes a systematic, organization-wide approach to implementing new technologies and modernizing existing systems for safe and efficient use by operating personnel
- Does not degrade safety by introducing new forms of error with its use

Poorly designed and implemented automated systems have been causal or contributing to many major accidents across transportation modes, particularly in aviation.

HF addresses the prudent integration of people with automation technology by conducting research on automation and manpower, personnel, human factors engineering, safety, and training. These are the primary aspects where automation intersects with human behavior and human operational requirements. Application of research results in this area by the industry will yield better performing human-machine collaborative systems.

Anticipated Activities:
- Display prototype development and preparation for simulator study (approximately 30 participants).
- Develop the algorithm for the classification of different fatigue states (includes machine learning).
- Prototype the heads-up display (HUD), integrating the HUD into Cab Technology Integration Laboratory (CTIL) designing experiments, and prepare for the study in CTIL.

Expected Outcomes:

- Produce a concept to inform design of future locomotive control systems for inexperienced operators and increasing levels of automation. This is important to reducing human error by new and inexperienced operators.
- Develop machine-learning capability to determine operator state of fatigue.
- Develop a prototype ready for a CTIL human in the loop study (approximately 8 participants).

Fatigue $385,728.98

This project provides tools for fatigue monitoring that detect sleep-deprived operators and then "safe" the system, understand workload factors and their contribution to fatigue, and create fatigue prediction models to help personnel work scheduling to significantly reduce the number of fatigue-related accidents and incidents.

Across transportation modes, the requirement for around-the-clock operations and maintenance of safe and efficient operations is taxing on limited operating personnel. Errors and accidents caused by operating personnel fatigue continue to occur, amounting in significant loss of life and property. Fatigue brought on by sleep apnea and other medical and lifestyle issues complicate this potential risk factor.

Anticipated Activities:

- Collect background information on contributing factors to fatigue and the impact these factors have on locomotive crew commute performance and safety will be documented and summarized.

Expected Outcomes:

- The information produced by the literature review will be used to identify existing gaps in research, particularly related to the railroad industry, that need to be assessed and targeted by a survey.

Project Evaluation $252,000

Project evaluations of government-funded research projects use rigorous methods to assess the extent to which, and ways, programs goals are met. Project evaluations tell what is working and why, or why not. It is necessary to study or evaluate the effects of safety interventions and technology in the scheme of overall safety programs to determine if implemented solutions are making a difference in railroad safety.

Anticipated Activities:

- Conduct formative and summative evaluation activities for SLSI. Activities include: a systematic review of all assessment reports to identify safety trends across Class II and Class III railroads, a formative evaluation of the follow-up safety culture assessment process, and a summative evaluation of SLSI's Implementation Phase for 2016-2017.
- Disseminate and analyze results from a needs assessment survey about railroad workers' preferred methods of receiving information, including the technologies they use to access information.
- Survey results will inform the development of safety education programs (e.g., online safety courses), and can be utilized to improve communication of safety information to railroad workers.

Expected Outcomes:

GPRA and the GPRA Modernization Act of 2010 require federal agencies to assess the manner and extent to which their programs achieve intended objectives. Consistent with the GPRA directive, FRA RD&T conducts project evaluations to:

- Meet FRA RD&T accountability requirements.
- Guide and strengthen FRA RD&T programs.
- Facilitate knowledge diffusion and technology transfer.

- Obtain input, feedback, and data regarding industry and government-supported programs.
- Build FRA RD&T evaluation capacity.
- Contribute to improving railroad safety.

Highway-Rail Grade Crossing $713,171.02

This research studies GX to understand the underlying causes and human behaviors that result in pedestrians and vehicles being struck by oncoming trains at grade crossings. Driver behavior accounts for up to 94 percent of vehicle crossing accidents for the U.S. railroad system. Thus, efforts to decrease human errors are critical.

It is an FRA goal and priority to significantly improve grade crossing safety and reduce grade crossing accident frequencies. The HF division will conduct technical research and apply innovative technologies, study accident statistics and occurrences, and sponsor industry conferences and workshops to determine top research needs. Enforcement alone is not effective. Research in technology, infrastructure, grade crossing environments, and other areas is necessary to improve grade crossing safety and reduce grade crossing accident frequencies.

Anticipated Activities:

- Examine the extent to which drivers understand Emergency Notification System signs at grade crossings, and determine whether orientation (i.e., horizontal or vertical) affects the signs' visibility.
- Use a driving simulator to examine the effects of in-vehicle auditory alerts on driver behaviors at grade crossings.

Expected Outcomes:

- Better understand the causal factors behind why individuals violate warning signals at grade crossings.
- Reduce safety risk by reducing both the likelihood of accidents occurring and the consequence should they occur.
- Develop grade crossing technology that considers human behavior in its design and minimizes the potential for human errors.

*Short Line Safety Institute $2,500,000**

HF provides program monitoring of and support for SLSI. Since FY15, FRA RD&T has received $2 million from Congress specifically for SLSI. Since FY 2014, FRA has partnered with SLSI to develop, pilot test, and implement an innovative safety culture assessment process. Recommendations resulting from the safety culture assessment process have provided Class II and III railroads—small railroads with limited resources to support safety training and education—with information and actionable processes that can be implemented to operate at an increasingly high level of safety.

Small railroads do not have the resources (i.e., budget or personnel) to conduct these activities on their own. SLSI serves all Class II and Class III railroads, not just railroads that are members of the ASLRRA.

*This funding is an earmark grant provided annually by Congress for the Short Line Safety Institute. This is in addition to the total budget for FRA RD&T. If Congress chooses NOT to fund the $2M earmark, this activity will not be executed in 2019.

Anticipated Activities:

- Conduct no-cost safety culture assessments on Class II and Class III railroads.
- Develop and pilot test a follow-up process to measure safety culture shift.

- Provide no-cost training and education to Class II and Class III railroads on the topics of safety and safety culture.
- Develop and disseminate outreach/safety communications materials that railroads can use onsite with employees.

Expected Outcomes:
- SLSI helps small railroads operate more safely by assessing safety culture, recommending how to improve it, and providing leadership, training, and education about safety culture.
- SLSI's goals are to reduce the risk of accidents and incidents in the short line and regional railroad industry by improving safety and safety culture.

Vigilance, Attention, and Distraction $50,000
The goal of this research project is to understand ways to improve factors that affect vigilance and sustained attention. Research in this area includes conducting studies to learn more about cognitive and behavioral elements that affect human sustained attention and vigilance. Railroad operation requires operators to manage and understand information provided by multiple systems while keeping an eye on track and signals. The problems this research is solving include:
- Loss of operator focus and distraction
- Accidents caused by human error

This project would also address a priority of OST-R, as noted in the updated Strategic Plan (pages 10-11).

Anticipated Activities:
- Collaborate with industry to research roadway worker fatalities related to adjacent track and train approach warnings.

Expected Outcomes:
- Reduce accidents caused by distraction.
- Improve operator decision making and performance.

*Office of Railroad Safety Support $250,000**
All RD&T divisions support the Office of Railroad Safety (RRS) by providing subject matter expertise consultation, research, data, and tools to improve railroad safety and reduce accidents and incidents. RRS works closely with RD&T to provide insight into research needs throughout the fiscal year. RD&T needs the ability to support requests for research and expertise for time sensitive safety issues. RD&T plans to support the following RRS requested initiatives:
- Railroad Information Sharing Environment (RISE) developmental evaluation support
- Periodic requests from RRS

Anticipated Activities:
- Partner with RRS and industry on RISE.
- Conduct research of urgent safety issues.
- Provide SME support to RRS.

Expected Outcomes:
- Establish and implement of a program similar to Federal Aviation Administration's Aviation Safety Information Analysis and Sharing (ASIAS) at FRA.

- Analyze safety risks and identify mitigations to those risks.

Note: This funding will come from multiple divisions to support their research. The Human Factors division is planning on funding approximately $850K for initiatives supporting the Office of Railroad Safety.

Public, Private, and University Cooperative Research Agreement $720,350 (Totaling $2 million from all divisions)
See Railroad Systems Issues for description, activities, and expected outcomes.

Statutory Requirements:

The rail Human Factors Research program is not statutorily mandated as it is for the aviation mode through the Federal Aviation Administration. FY 2018 bill language in reference House Report 115-237 and the Senate Report 115-138 address specific human factors research areas related to the development of next generation (NexGen) and other system development programs. Though not mandated, FRA, as the result of major accident investigations, recognizes the importance of human factors to safety and seeks to research and apply solutions to reduce the risk of more accidents where human factors have a causal or contributing role. FRA foresight about the potential for human factors-related accidents is key to good safety management and an extremely important element of any systems safety management plan.

Class II and Class III (short line) safety is statutorily mandated by the budgets, approved by the President, Congress and Senate. The HF research program manages the SLSI funding in collaboration with SLSI and ASLRRA. The project and outcomes were defined in the Program Activities section of HF.

Program Alignment with Strategic Goals:

The HF research program aligns with the DOT Strategic Goal *Safety* and the DOT Critical Transportation Topic *Promoting Safety*. Successful execution of FRA's mission requires research and development activities aimed at improving railroad safety, efficiency, security, and capacity. Human errors account for more than one-third of all train accidents in the U.S. railroad industry. Data does not allow causal linkages between FRA's HF research program and accident/incident reduction. However, if human factors continue to be a common probable cause of rail accidents, FRA must continue to investigate new technologies and programs that help reduce human error and improve safety in the industry.

The division provides direction to the rail industry on a spectrum of safety issues that are rooted in human behavior and human performance (e.g., distraction, failure to perform correct procedure, design-induced human error, and error due to workload). Approximately 38 percent of rail accidents and incidents include human factors as a causal or contributing factor.

The HF research program is also vital in helping to meet DOT strategy to collaborate with stakeholders to improve safety, as evidenced by the Confidential Close Call Reporting system (C3RS). The Human Factors division conceived, initiated, developed, and pilot-tested the program before transitioning it to FRA RRS for industry implementation.

HF's automation research program is cited in the DOT Strategic Plan as an example of a contributing program and initiative to conduct research on advanced technology to promote transportation safety and efficiency. HF's automation research is conducted to improve human reliability and reduce human error when automated technology is inserted into the rail network. The division invests in research and development activities to inform the safe integration of people with technology, particularly as the implementation of automated systems gains traction in the rail domain. Investment in human factors rail automation will enable more scientific and

technological innovation to occur which in turn will promote safer operations, economically better-performing railroads, and economic growth.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

The HF division has an impact on rural communities, most notably through the following project areas: Grade Crossing Safety, Trespasser and Suicide Prevention, and SLSI. The HF division expects that its research on the underlying causes and circumstances of accidents and incidents will have a positive impact on reducing the accident and incident rates in rural areas. This information, in turn, will help FRA decide the appropriate measures to take to improve safety.

In 2015, passive grade crossings (i.e., crossings that indicate to a roadway user that there is a crossing, but do not indicate whether a train is approaching) comprised 46 percent of all grade crossings in the U.S. Generally, passive crossings and lower traffic volumes are prevalent in rural areas. Passive crossings are almost 10 times more risky than active crossings. Therefore, grade crossing research, especially grade crossing research focused on passive crossings, affects rural communities.[7]

The vast majority of trespassing accidents occurred in counties with low population densities—counties that are mostly rural.[8] Rural areas are also a common characteristic of the majority of rail trespass fatalities involving intoxicated individuals, individuals riding all-terrain vehicles along the ROW, and individuals using a handheld device prior to the strike. The continued investment in HF's trespass and suicide prevention research will affect rural communities as safety resolutions are developed and implemented.

The SLSI helps Class II and Class III railroads perform at an increasingly high level of safety in the rural areas where they operate. Safe operations on Class II and Class III railroads have a number of public benefits. By reducing traffic on highways and rural roads, these small railroads reduce public maintenance costs, while mitigating congestion and emissions and conserving fuel. Rail transportation is also less risky than highway transportation, and FRA-funded programs like SLSI are helping to ensure this continues. For large areas of rural America, Class II and Class III railroads are the only way shippers can stay connected to the national network, helping businesses and employment stay local.

Since FY14, SLSI has conducted 45 safety culture assessments on Class II and Class III railroads, reaching 4,282 railroad employees. SLSI plans to conduct 24 safety culture assessments in 2018. Over 3,300 railroad employees have participated in SLSI's training programs and webinars

Historically, "rural community impact" has not been a criterion for measuring the HF Division's research and development portfolio. The Human Factors Division will develop metrics for assessing the impact of its research on rural communities.

Program Objectives:

[7] *Data Analysis of Grade Crossing Incidents.* Accessed at https://www.fra.dot.gov/eLib/details/L01325 on March 23, 2018.
[8] *Trespass Event Risk Factors*. Accessed at https://www.fra.dot.gov/eLib/details/L16047 on March 22, 2018.

The HF division's research program is focused on improving railroad safety and reducing rail accidents caused by human error. Research in the following areas provides specific examples of the main goal or problem the Human Factors division is trying to solve.

Highway-Rail Grade Crossing: Driver behavior accounts for up to 94 percent of accidents at highway-rail grade crossings, and grade crossing accident rates have plateaued over recent years. In 2016, 2,031 at-rail-crossing incidents were reported, leading to 296 fatalities and 809 injuries. Thus, efforts to decrease human error at grade crossings are critical.

Railroad Trespass and Suicide Prevention: HF research solves the two leading causes of rail-related death in the U.S.: trespass and suicide. Suicide was not historically considered alongside efforts to decrease trespassing and grade crossing deaths. Hundreds of people lose their lives every year on train tracks due to trespassing or suicide. FRA is trying to identify and study the causal factors that lead to trespassing incidents on railroad property.

Fatigue: The Human Factors division is addressing one of NTSB's Most Wanted List problems by trying to solve fatigue-related issues.[9] Employees in the railroad industry are susceptible to the risk of injury and property damage caused by human fatigue and loss of attentiveness due to around-the-clock operations. HF seeks to develop interventions and solutions to mitigate the effect of irregular work hours, long shifts, and the unpredictability of on-duty times associated with the U.S. rail industry.

Automation, Operating Personnel Information Management, and Control: Automation is increasingly important as the rail industry moves to increase the level of automation in rail systems to enhance safety and efficiency. A top priority mandated by Congress is the implementation of PTC. FRA will assist with this process by providing guidance, education, and technical demonstration through its research efforts. Additional research to assess new concepts for the human-machine interface in locomotives and other systems will also be undertaken as resources allow, so that the industry may address crew distraction and situation awareness issues.

Short Line Safety Institute: The HF division's support of SLSI addresses a Congressional directive for FRA to help Class II and Class III railroads improve safety and safety culture. Research and experience show that when safety culture is strong, accidents are less frequent and less severe.[10] FRA rules and requirements are the bare minimum for achieving safe operations. To conduct a fully safe rail operation, each railroad needs to improve safety culture.

Project Evaluation: Conducting project evaluations is a prudent business practice. Employing improvement-oriented project evaluation is the essence of professional service and responsibility. Moreover, the sound evaluation of government-funded research helps ensure program success and holds contractors conducting government-funded research accountable for efficient and effective use of resources to serve the public good.

Across the rail industry there is a distinct lack of attention to human and human factors requirements in design and development to improve safety and efficiency. Failure to include human factors requirements in the systems development of new technology, for example, will result in railroads acquiring more risk-prone systems. The HF research program attempts to fill the gap in attention to human factors by providing the rail industry with

[9] NTSB's 2017-2018 "Most Wanted" list: https://www.ntsb.gov/safety/mwl/Pages/default.aspx
[10] *Safety Culture: A Significant Influence on Safety in Transportation*. Accessed at https://www.fra.dot.gov/eLib/details/L18784 on March 23, 2018.

education, guidance, and technology across four project areas: automation, operator performance (fatigue), sponsorship and development of SLSI, and project evaluation.

Human Factors rail research should be funded by the government to ensure that results are shared across the industry and with other industry modes of transportation addressing the same human factors issues in their respective modal industries. Researchers contracted by FRA independently conduct research according to the scientific method, which ensures high quality and lack of bias.

Research Collaboration Partners:

The American public's and stakeholders' input is critical for the HF division to execute its research programs. While no metrics are used in tracking input, HF PMs work with stakeholder groups to address the needs of the various groups. Stakeholders for the division include rail carriers, labor unions, trade groups, and nonprofit organizations, which provide:

- Data for analysis
- Feedback on the feasibility of technology transfer (i.e., implementing a research project that, through a project evaluation, FRA demonstrated to be effective on a wide-scale basis)
- Subject matter expertise and feedback on project evaluation findings

Stakeholder input has impacted research and research outcomes:

- *Railroaders' Guide to Healthy Sleep* website (https://www.railroadersleep.org/) was developed specifically for stakeholders in the railroad industry. This website provides scientifically credible information about sleep and wellness specific to the needs of railroaders.
  - A project evaluation demonstrated that the website's information is effective at reaching the target audience of railroaders.
  - A Stakeholder Review Panel, comprised of representatives from labor, industry, and trade organizations, reviews all content produced on the website.
- FRA RD&T (HF and TCC divisions) sponsor the Trespassing and Grade Crossing Research Needs workshops every 2 years. Attendees are trespass and grade crossing experts from industry, universities, and state and local government. These workshops provide an opportunity for industry stakeholders to gather and discuss needs, issues, concerns, and priorities. FRA is able to share research findings to help support adoption activities and gain insight into research needs to begin T2 and acquisition planning.
  - At the 2017 Grade Crossing Research Needs Workshop,[11] FRA committed to implementing the high-priority research needs that stakeholders identified in this workshop.
  - FRA sponsored a Trespass Prevention Research Needs Workshop in 2015 and anticipates holding another Trespass Prevention Research Needs Workshop in fall 2019.

[11] A summary of the 2015 Trespass Prevention Workshop proceedings is in *2015 Right-of-Way Fatality and Trespass Prevention Workshop*. Accessed at https://www.fra.dot.gov/eLib/details/L18704 on April 2, 2018. A summary of the 2017 Grade Crossing Research Needs Workshop published eLibrary DOT/FRA/ORD-19-05.

Partner Detail

Partner Name	Contribution	Benefit of Partnership
DOT Human Factors Coordinating Committee (HFCC)	Share Human Factors research/information with each DOT mode.	As noted in the *U.S. Department of Transportation Strategic Plan for FY 2018-2022* (p. 34), the DOT HFCC "serves as a collaborative, multimodal team with Federal Government-wide liaisons to address crosscutting human factors issues in transportation." The HFCC includes representatives from every DOT OA with a human factors program. An engineering psychologist from FRA RD&T is the Chair of the HFCC for 2018-2020.
DOT Safety Council	HF provides financial support to the DOT Safety Council.	As mentioned in the *U.S. Department of Transportation Strategic Plan for FY 2018-2022* (p. 16), the DOT Safety Council provides leadership and establishes a departmental commitment to improving transportation safety through improved safety culture. The DOT Safety Council is composed of the heads of each DOT operating administration, their senior safety officers, and senior officials from the Office of the Secretary (OST).
FRA RRS	Subject matter expertise, collaboration, and recommendations	HF PMs work closely with their counterparts in FRA RRS. As a primary customer, FRA RRS's research needs and priorities helps shape the division's research plan.
FRA RRS's Grade Crossing Task Force	Subject matter expertise, collaboration, and recommendations	HF PM is a member of FRA RRS's Grade Crossing Task Force.
TCC (RPD-33)	Collaboration, subject matter expertise, stakeholder engagement	Work closely with TCC PMs, conduct jointly sponsored research projects. HF and TCC provide an engineering and human factors approach to GX and trespassing research.
Union Pacific (UP)	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
Metra	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
New Jersey Transit	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
Amtrak	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations

Partner Name	Contribution	Benefit of Partnership
Keolis/MBTA	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
Long Island Rail Road	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
SEPTA	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
Caltrain	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
Metrolink	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
BNSF	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
BLET	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
International Association of Sheet Metal, Air, Rail, and Transportation Workers (SMART)	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement/understanding of human error situations
ASLRRA	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement
AAR	Subject matter expertise, collaboration, data, and recommendations	Stakeholder engagement
City of Orlando, Florida	Rights-of-way access	Partnered with FRA to study ROW incursions on railroad tracks and photo enforcement at grade crossings
Short Line Safety Institute	Subject matter expertise, collaboration, data, and recommendations	Improved safety culture
Massachusetts Institute of Technology (MIT),	Subject matter expertise, collaboration, data, and recommendations	HF automation expertise
Duke University	Subject matter expertise, collaboration, data, and recommendations	HF automation expertise
Michigan Technological University	Subject matter expertise, collaboration, data, and recommendations	HF expertise
University of Connecticut	Subject matter expertise, collaboration, data, and recommendations	Project evaluation expertise

Benefits Detail

Beneficiary	Benefit(s) Received
FRA RRS	Improved safety requirements, standards, recommendations
Rail industry	Improved safety and safety culture Lower operating costs Improved visibility for railroad workers and grade crossings Reduced railroad accidents and fatalities Improved training for railway workers
General public	Reduced railroad accidents and fatalities Proper implementation of technology to improve safety especially related to grade crossing and trespassing prevention
Small businesses and university research centers	Improved railroad research resources and capabilities Workforce development opportunities

Acquisition/Assistance:

HF establishes research priorities and defines its acquisition plan considering internal and external priorities and aligns priorities with DOT, FRA, OST-R, and RD&T goals for the upcoming fiscal year. The HF division utilizes a competitive procurement process as often as possible.

The HF division works with the FRA Office of Acquisitions to initiate various funding vehicles for both single-year and multi-year contracts across the division, including:

- Broad Agency Announcement (BAA)
- Indefinite Delivery/Indefinite Quantity (IDIQ)
- Full and open competition
- Sole source
- Inter-Agency Agreement (IAA)
- Small Business Innovative Research Program (SBIR)

HF benefits from in-kind contributions (e.g., subject matter expertise, track time, data sharing, equipment) from its collaboration partners. A list of these partners, the contributions they make to HF's projects, and how that benefits FRA, can be found in the next section. These contributions are not only desirable for their inherent value but also guide our researchers to develop practical technology that will function well in practice. HF also benefits from partners providing non-federal funding on the following projects:

- ASLRRA contributed $250,000 matching funds in FY14 to help develop SLSI.
- National University Rail Center (NURail) University Transportation Center (UTC) consortium contributed $112,000 to the Michigan Tech research study *Driver Behavior at Highway-Rail Grade Crossings Using NDS Data and Driving Simulators.*
- GE Global Research is contributing $247,553 toward *Design and Evaluation of a Robust Manual Locomotive Operating Mode as* part of a BAA.

The HF division sponsors research on rail suicide, using an IAA with Volpe because of their rail suicide expert on staff. This individual leads several projects that require extremely specialized expertise. Examples of this research[12], which is executed under a noncompetitive IAA, are the *Suicide Countermeasure Pilot Projects*.
HF directed grants to two organizations to help develop SLSI as a result of ASLRRA, creating SLSI in response to a January 2014 letter from the DOT Secretary Anthony Foxx. The accident at Lac Megantic, Quebec had occurred the previous year, and Secretary Foxx asked ASLRRA to take action to improve safety and safety culture on Class II and Class III railroads.

Technology Transfer (T2):

HF works closely with stakeholders throughout the R&D life cycle and the T2 life cycle to increase user adoption of research products/services. PMs work with internal (e.g., FRA Office of Railroad Safety, other OAs) and external stakeholders (e.g., Class I and short line railroads, labor unions, equipment manufacturers, state DOTs) to understand their needs and how the research will affect their eventual adoption of the technology or policy change. RD&T PMs and their research partners work together early in the research process to communicate the value and benefit of RD&T's research products.

Engagement provides benefits to all stakeholders as well as FRA. Across the division's research projects, FRA and its partners share information, develop and test new technology and safety tools, improve safety culture, and contribute to the safe transportation of goods and passengers across America's railroads. The HF division also publishes Technical Reports and Research Results in the FRA eLibrary, which are available to the public. PMs also present their research at numerous industry meetings, both nationally and internationally.

In each contracted research activity, there are clauses requiring the researcher to disclose to FRA any invention resulting from this sponsored activity. With further research activity, a patent could result. For example:

- HF sponsors applied research at Duke University to prototype a decision-modeling tool to examine the impact of the application of new technologies on rail dispatcher workload. Duke has filed an invention disclosure with the university and FRA. This model can be used fora variety of job position and technology insertion. As the model undergoes continued validation through data collected at rail dispatch centers, a working software model is already available on the Duke University Humans and Autonomy Lab website. The model still requires substantial validation.
- HF-sponsored automation research through General Electric Global Research has resulted in disclosure of an invention that describes methods of providing locomotive operators with enhanced situational awareness through remote video feeds and communications with other equipment made available through displays or voice radio. This method provides information about the track environment (e.g., grade crossings) in addition to simple signal status.
- Participating in TRB and ASLRRA conferences and regional meetings.

Evaluation/Performance Measurement:

The RD&T program supports evaluation on behalf of all divisions. The HF division participates in these external project evaluations that help all divisions improve performance and increase Government funding ROI.

[12] https://www.volpe.dot.gov/rail-suicide-prevention

In 2012, the HF division began its pilot evaluation effort, and, later, participated in the TRB's evaluation, focusing on research projects, communication, stakeholder engagement, strategic planning, priority setting, and evaluation. HF PMs participated in this year's project evaluation training aimed at providing a basic evaluation skillset for each RD&T PM.

In 2019, the HF division will work with other RD&T divisions to implement internal processes to improve FRA's accountability to the American public based on the recommendations from these groups and skills learned in the training. PMs will work to implement the evaluation framework, standards, procedures, and templates identified in the "FRA Evaluation Implementation Plan" and the "FRA Manual for Research, Development and Technology (RD&T) Program and Project Evaluation." For more information about these efforts, see the Evaluation/Performance Measurement section in the Research, Development, and Technology Strategic Plan.

The HF division conducts project evaluations of some of its funded research (see table below). These evaluations help the division improve the development, utilization, impact, and overall effectiveness of its R&D products, tools, and processes.

HF has conducted two types of program evaluations in the past: formative and summative. Formative evaluations provided ongoing feedback to a project as it was developed. That is, the object of the evaluation used systematic feedback to strengthen its program activities in real time. The HF division's summative evaluations provide retrospective assessments and reporting of program outcomes—intended and unintended—to support data-driven decision making, formulations of evidence-based policies, and public accountability.

Project	Type of Evaluation	Outcomes & Deliverables
RD&T Program Evaluation Capacity Building	Formative	Independent consultants provide ongoing technical evaluation advisory and educational support to FRA RD&T program managers. The Human Factors division intends to use guidance from the consultants to build evaluation capacity in its staff. Once trained, staff will embed program evaluation methods in their R&D programs through education, sharing best practices and exemplar studies.
Amtrak Evaluation	Summative	Independent evaluation of Amtrak's Safe-2-Safer (S2S) safety program. Evaluation provides information to Amtrak about how to improve its program and increase its effectiveness and impact. Deliverables are Research Results reports published in FRA eLibrary.
BNSF Evaluation	Summative	Independent evaluation of BNSF's safety initiatives. Collected information about the initiatives' roll-out and impact on safety at BNSF. Deliverables are Research Results and Technical Reports published in the FRA eLibrary.
SLSI Evaluation	Formative and Summative	Independent evaluation to assess the progress and efficacy of the SLSI's initiatives and processes. Deliverables are briefs provided to SLSI, presentations at industry conferences, and Research Results and Technical Reports published in the FRA eLibrary.
Confidential Close Call Reporting System (C3RS) Evaluation	Formative and Summative	Deliverables include independent evaluation of FRA's C3RS program. Evaluation provided formative and summative evaluations of the C3RS demonstration project.

		Deliverables are Research Results and Technical Reports published on the FRA eLibrary and presentations at TRB.
SOFA/FAMES Evaluation Support	Formative	Support of FRA-sponsored working groups comprised of FRA, labor, and rail carriers. Evaluation support provides guidance on these groups' processes and procedures (i.e., how to analyze findings from incident reports and extract lessons learned). Deliverables include feedback to the working groups and development of procedures for systematically analyzing incident reports.

Starting in FY19, FRA will measure performance for the DOT Strategic Goal Innovation.
Development of Innovation:

- Increase dissemination of DOT-funded research reports (OST).
- Increase production of tangible DOT-funded research outputs (OST).
- Increase DOT technology transfer activity (OST).

Deployment of Innovation:

- Increase tangible production of DOT-funded Research (OST).

RD&T began tracking data for FRA's OST-R Technology Transfer Report 2017. A s discussed in the T2 section, RD&T will establish baseline metrics using data from FY18 to track performance against the Innovation performance goals. RD&T will track page views and downloads of published materials in addition to the following data to measure progress:

- Collaborative relationships
- Technical publications made available to public
- In-person or webinar presentations delivered to foster technology transfer
- Technical publication downloads—NTL
- Workshops or demonstrations to foster technology transfer
- Total number of small businesses supported
- Number of new inventions disclosed
- Number of patent applications filed

Section 2: Program Descriptions, FY 2020
Railroad Systems Issues

Program Description/Activities:

The Railroad Systems Issues (RSI) research program directs the entire Research, Development and Technology (RD&T) program toward the goals set forth by the Department of Transportation (DOT), the Office of the Assistant Secretary for Research and Technology (OST-R), the Federal Railroad Administration (FRA), and the Office of Railroad Policy and Development (RPD). The RSI research program defines the strategy to meet DOT, OST-R, FRA, and RPD goals and assures these goals are met. The principal focus and goal of the RD&T program is safety. FRA's RD&T program yields solutions that contribute to all DOT goals to advance infrastructure, innovation, and accountability—while maintaining a safety focus.

The RSI research program develops, facilitates, manages, and supports the following areas: RD&T research strategy; safety risk analysis; performance-based regulations; non-regulatory recommendations; railroad environmental issues; locomotive efficiency; project evaluation; Transportation Research Board's (TRB's) independent review recommendations; workforce development; RD&T-related travel; operations, maintenance and equipment at the Transportation Technology Center (TTC) facilities in Pueblo, Colorado; and contractor support.

The RSI research program activities are tailored to address relevant railroad issues spanning the spectrum from safety to workforce development. RD&T collaborates with academia, the private sector, and the rail industry—in addition to working with other DOT modes and federal agencies. Activities include:

Rail Safety Innovations Deserving Exploratory Analysis (IDEA)
TRB initiated this effort in conjunction with FRA to address safety needs within the railroad industry. The focus of this project is to solicit new innovation and technology in rail. The Rail Safety IDEA committee members meet once a year (usually in December) and discuss all submitted proposals (about 15-18 are received annually) to select the most promising 2 to 3 proposals to be funded.

The Rail Safety IDEA program is sole-sourced to the TRB, which has been successfully conducting the program since 2001. TRB is the only entity with the capability of carrying out this program because it is an independent non-profit entity that has no affiliation with railroad providers, manufacturers, or suppliers. It also has no affiliation with the universities and small companies (usual candidates for winning IDEA projects). This makes TRB a unique organization for being independent and unbiased on behalf of an organization. Each research effort selected has a unique timeframe, generally lasting 1 to 2 years.

Anticipated Activities:
- Monitor existing projects.
- Review and select new projects.
- Collaborate with the TRB committee.
- Fund and launch new research.

Expected Outcomes:
With multiple activities each year, the outcomes vary based on the selected projects and duration of research. In 2020, the focus is on:
- Starting new research and completing existing research (based on timelines)

- Delivering an innovative solution to the railroad industry; technology transfer of 2020, 2019, and 2018 efforts.

Project Selection
RD&T prioritizes its research investments annually. This process utilizes a software package (DecisionLens) as part of this effort. This project includes the activities and costs associated to maintaining the license for the prioritization software and executing the prioritization process. RD&T conducts prioritization activities to effectively manage its budget and ensure that stakeholder and industry needs are inputs to the investment planning process. RD&T conducts project selection activities to ensure stakeholder input is considered as part of the planning process. Safety priorities, especially those provided by the FRA RRS, are a major input into the process.

Anticipated Activities:
- Update the safety risk model to guide the RD&T project safety risk decisions and improve efficiency in project spending.
- Update the portfolio prioritization methodology.
- Prioritize RD&T research portfolio.

Expected Outcomes:
- Optimize the prioritization methodology/process.
- Prioritize investments.

Program Support
This project provides technical editing, analyst, and management support to RSI. FRA research produces various deliverables as part of RD&T T2 process, and FRA works with technical editors to publish this content. Program management/analyst/subject matter experts provide project, program, and portfolio management support.

Anticipated Activities:
- Review papers, reports, results, and other material.
- Edit papers, reports, results, and other material.
- Provide program, project, and portfolio management support.

Expected Outcomes:
- Edited and published RD&T material.
- Strategic planning, tracking, and management of RD&T's portfolio, information, and data.

Project Evaluation
The focus of this project is to educate and train program managers (PMs) about project evaluation techniques, develop performance measures, improve project progress, and reduce cost. PMs and external parties will evaluate projects conducted by the five RD&T divisions to measure success, improve project performance and railroad safety. Project evaluation processes will help RD&T better manage funding and meets the DOT Strategic Goal of Accountability. RD&T has benefited from project evaluation efforts in previous fiscal years, improving the benefit of solutions delivered. This funding supports RD&T's project evaluation maturity (see Performance Measurement RSI section).

Anticipated Activities:
- Continue project evaluation training.
- Create project evaluation tools.

- Continue implementation of RD&T project evaluation methodology.
- Conduct project evaluations.
- Optimize RD&T's performance management metrics.

Expected Outcomes:
- Increase maturity of project evaluation practices.
- Standardize performance measurement.
- Standardize project evaluation.
- Establish performance measurement baseline.

Transportation Technology Center (TTC)
The primary objectives of this funding are to maintain the one-of-a-kind infrastructure at TTC to accommodate the testing and evaluation of intelligent railroad systems technologies and to provide the FRA with the type and quality of facilities and equipment needed to meet its missions in safety, infrastructure, innovation, and accountability. Focused on enhancing railroad safety, TTC drives national research, development, and application of new technology for railways, suppliers, governments, and others involved in rail transportation. Other government agencies also utilize TTC:
- Since 1985, the Security and Emergency Response Training Center at TTC has been training first responders to handle hazardous materials accidents.
- The Transportation Security Administration (TSA) has created the Surface Technology Security Training Center at TTC, providing training to Department of Homeland Security (DHS) inspectors and other Federal, State, and local security partners.
- DHS has been an active user of the facility. DHS is conducting the assessment of Threat Risk for Rail Car Blast Scenarios project and numerous railroad operations and safety training. DHS is also pursuing development of an underground rail station and tunnel security training facility.
- The Federal Transit Administration and the Department of Defense are also involved in utilizing the facility.

Anticipated Activities:
- See Track Research section.

Expected Outcomes:
- See Track Research section.

Railroad Systems Issues
This project conducts research focused on safety with secondary strategic alignment to innovation, infrastructure, and accountability in the railroad industry. The problem addressed by this project will be selected based on industry need.

Anticipated Activities:
- Continued innovative research to improve America's railways

Expected Outcomes:
- Technology transfer of RSI efforts

Workforce Development (WFD)
Provide support and domain expertise in the areas of railroad WFD to adequately identify suitable approaches for both the management and capture of rail workforce-related trends, and respond to DOT data calls. This research

increases the awareness of railroad industry WFD issues by establishing and/or participating in forums and research efforts to foster and support industry collaboration.

Anticipated Activities:
- Participate in the DOT Education and Workforce Development Community of Practice on behalf of FRA.
- Conduct and publish a railroad industry workforce assessment (known as the Modal Profile).
- Capture and analyze data on trends, skill gaps, skill demands, training opportunities, industry best practices, and cross-modal efforts.

Expected Outcomes:
- Updated Modal Profile published.
- Research results of workforce development published.
- Continued stakeholder engagement.

Energy and Emissions
Investigate alternative energy and propulsion and emissions reduction technologies for rail equipment, improving the transportation of goods and people. This research area focuses on supporting activities related to real-world demonstration of alternative fuels, technologies that can reduce harmful exhaust gases, and improvement in standards for noise emissions to ensure implementation of high-speed rail across the nation.

Anticipated Activities:
- No activities are planned for FY20.

Expected Outcomes:
Provide FRA RRS with improved science to drive standards and requirements development, and support compliance in support of emissions limit for both passenger and freight equipment.

Locomotive Engine Efficiency Research
The goal of this research is to investigate innovative locomotive engine technologies to ensure the safe and efficient transportation of goods and people. Areas of focus for this research program include: reduction in fuel consumption, improvement in engine component life, and improvement in the efficiency of older, less efficient locomotives. Research is conducted in collaboration with Class I railroads to demonstrate and develop prototype systems. This research area addresses the DOT Strategic Goal of Safety and Innovation and the DOT RD&T Critical Transportation Topics of promoting safety, and protecting the environment.

Anticipated Activities:
- Assess technological innovation, such as locomotive waste heat recovery systems, using high-pressure heat exchangers in a real-world environment.
- Develop and prototype demonstration of hybrid systems, such as battery technology and heat exchangers, for improved efficiency.

Expected Outcomes:
- Deployment of a prototype fuel cell technology in railroad application for propulsion

Accessibility
Investigate universal and inclusive designs for accessibility onboard passenger trains. FRA is in a unique position to collaborate with stakeholders (e.g., other Federal agencies, disability advocacy groups, passenger rail operators,

equipment manufacturer and industry groups) to ensure new standards for accessibility are feasible and safe, balancing the requirements of the law with the capability of the equipment.

Anticipated Activities:
- Identify available technologies that can improve communication and travel experience for passengers with disabilities.
- Investigate the impact of new requirements for accessible on-board passenger rail equipment, as related to safety, usability, and efficiency.

Expected Outcomes:
- Implementation of procurement specification standards for equipment

*Research with Universities on Intelligent Railroad Systems**
This project will utilize funding from FY19 if funding is provided to RD&T to support university research on intelligent railroad systems. This project will start funding research in FY18. FRA will use a broad agency announcement (BAA) to solicit basic and applied technology research projects that will support DOT and FRA goals to advance automation and connected vehicle technology adoption in the rail industry. The BAA was published in collaboration with the Intelligent Transportation Systems – Joint Program Office (ITS-JPO). FRA reviews proposals with a preference for projects that advance these technologies for rural applications. Program objectives within this project include:
- Enabling safer vehicles and roadways
- Enhancing mobility
- Limiting environmental impacts
- Promoting innovation
- Supporting transportation connectivity

*This funding is an earmark grant provided by Congress for the Research with Universities on Intelligent Railroad Systems annually. In addition to the total budget for FRA RD&T. If Congress chooses NOT to fund the $2M earmark, this activity will not be executed in 2019.

Anticipated Activities:
- Publish the BAA.
- Review university proposals.
- Select prospective research projects.
- Fund and begin selected projects.

Expected Outcomes:
- A focus on advanced technology, automation, and connected vehicle technologies
- Projects advancing these technologies for rural application
- Intelligent transportation systems
- Workforce development

Public, Private, and University Cooperative Research Agreement
The Public, Private and University Cooperative Research Agreement is a collaborative effort with the Association of American Railroads (AAR) to provide research opportunities to American academic institutions, attracting and funding proposals with the potential to improve safety and performance in railroad systems in the following areas: track, rolling stock, train control and communication, and human factors.

Annually, the Public, Private and University Cooperative Research Agreement committee members review and determine research themes that the railroad industry needs to address through this Agreement. These research themes will drive research topics. Through this Agreement, research topics will be announced and reviewed and the most promising proposals will be selected for funding.

All selected proposals have the ultimate goals of improving railroad safety and performance; enhancing the infrastructure conditions and services by stimulating economic growth, productivity and workforce development; and serving the nation with reduced regulatory burden and greater efficiency, effectiveness, and accountability.

This effort includes a cost-share arrangement, with AAR contributing approximately $800K annually and the railroad industry's significant in-kind support.

Anticipated Activities:
- Publish the request for proposals.
- Review university proposals.
- Select prospective research projects.
- Fund and begin selected projects.

Expected Outcomes:
The expected outcomes align with the DOT Strategic Goals of Safety, Innovation, Infrastructure, and Accountability. Expected outcomes include:
- Projects that focus on advanced technology, automation, and connected vehicle technologies.
- Projects that advance these technologies for rural application.
- Projects that focus on workforce development.

Note: This funding will come from multiple divisions to support their research.

*Office of Railroad Safety Support $850,000**
All RD&T divisions support the Office of Railroad Safety (RRS) by providing subject matter expertise (SME) consultation, research, data, and tools to improve railroad safety and reduce accidents and incidents. RRS works closely with RD&T to provide insight into research needs throughout the fiscal year. RD&T needs the ability to support requests for research and expertise for time sensitive safety issues. RD&T plans to support the following RRS-requested initiatives:
- Railroad Information Sharing Environment (RISE) Developmental Evaluation Support
- Periodic requests from RRS

Anticipated Activities:
- Partner with RRS and industry on RISE.
- Conduct research of urgent safety issues.
- Provide SME support to RRS.

Expected Outcomes:
- Continue the implementation of RISE.
- Analyze safety risks and identify mitigations to those risks.

Program Alignment with Strategic Goals:

RD&T strategically aligns its research with DOT, OST-R, FRA and RPD goals and strategic plans, with a focus on improving the safety of America's railways. Many of RD&T's research projects yield additional benefits in the areas of innovation, infrastructure, and accountability. As the railroad industry changes due to advancements in technology, FRA has been a leader for decades, researching innovative solutions to improve the safety of moving goods and people in America. All five RD&T divisions conduct research in automation technology to help understand how to best utilize new technologies and minimize human errors associated with automation. Projects conducted by the Track Research, Train Control and Communication (TCC), and Rolling Stock divisions improve the infrastructure of America's railroads to improve safety. FRA RD&T's Railroad Systems Issues program continues its research into the industry's workforce development efforts to support the infrastructure of America's railroads. Project evaluations conducted by RD&T divisions support accountability and help gain insight on how RD&T will mature its performance measurement and evaluation efforts. RD&T works closely with FRA RRS to provide the basis for science-based requirements, standards, and recommendations that have been tested in real-world environments with the help of companies and organizations who will adopt and use the technology.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

RD&T projects focus on problems affecting urban, suburban, and rural communities. FRA structures research to address high priority problems wherever they may occur, responding to incidents that may take place during a fiscal year, with a long-term focus on improving safety. Although RD&T programs impact short lines and grade crossings which have a higher concentration in rural areas, programs have not historically been geographically focused. RD&T will consider rural communities as part of program planning in the future. The Intelligent Railroad Systems project emphasizes research that benefits rural areas.

Section 2: Program Descriptions, FY 2020
Track Research

Program Description/Activities:

The Track Research program prepares for the future of rail transportation through applied research, development, and demonstration. As new technologies continue to emerge, and as train axle loads and speeds increase, the timely development of technical information, data, and expertise is crucial to provide a basis on which to make decisions about issues affecting the safe operation of rail vehicles on U.S. track. The Track Research program supports the goals and objectives of the DOT/FRA administration; conducts safety-related research for new and in-service railroad system investments; develops and demonstrates new track condition assessment technologies; and coordinates research teams between railroads, universities, technology leaders, and the Government. There are three primary research areas included in the program: track structures and components, track and train interaction safety, and operation of research assets, including the DOT TTC facility. In FY 2019, the Track Research program will conduct the following activities:

Track and Structures – Rail Performance and Integrity
This research builds upon the FY 2019 first-generation prototype with the second-generation prototype of flash thermography technology for the detection of base defects.

Activities:
- Continue to gather rail defect donations from at least three Class I railroads, characterize these defects, and add them to the FRA rail defect library at TTC for the entire research community to utilize in developing better detection systems.
- Refine toward commercialization a unique automation of detection protocol for ultrasonic rail inspection.
- Building upon FY 2018 and FY 2019 efforts, develop a second-generation prototype for Laser Doppler Vibrometer rail measurement for non-contact rail integrity testing.
- Fabricate first commercial grade prototype for acoustic-based rail vibration measurement for non-contact rail integrity testing.
- Develop first commercial-grade prototype for rail flaw 3-dimensional image scanner.

Outcomes:
- Updated FRA rail defect library at TTC for the entire research community.
- Refined automation of detection protocol for ultrasonic rail inspection.
- Second-generation prototype for Laser Doppler Vibrometer rail measurement for non-contact rail integrity testing.
- Prototype for acoustic based rail vibration measurement for non-contact rail integrity testing.
- Prototype for rail flaw 3D image scanner.

Track and Structures – Track Inspection Technology and Processes
This research automates the design of the track change detection system and develops models for combining track-related measures.

Activities:
- Developing mathematical/statistical models for combining multiple track-related measures (including ballast condition) to enhance predictive capability of each with respect to the condition of the overall track system.

- Initiating efforts to automate the previously developed prototype track change detection system.

Outcomes:
- Mathematical/statistical models for combining multiple track-related measures (including ballast condition) to enhance predictive capability of each with respect to the condition of the overall track system.
- Automated prototype track change detection system.

Track and Structures – Track Support & Substructure
This research seeks to prevent derailments caused by track support and subgrade issues.

Activities:
- Develop reliable and automated method to assess track fouling and the development of safety criteria through an understanding of subgrade failures.
- Develop characterization and further understanding of ballast mechanistic behavior and properties.
- Further develop Vertical Track Deflection Measurements to provide a structural indication of the track support structure with large deflection indicating weakness in the track support layers.
- Further refine GRMS technology to identify potential track strength weakness at the rail-tie interface.

Outcomes:
- Automated method to assess track fouling and the development of safety criteria through understanding of subgrade failures
- Improved understanding of ballast mechanistic behavior and properties
- Vertical Track Deflection Measurements to provide a structural indication of the track support structure with large deflection suggesting weakness in the track support layers
- Refinement of GRMS technology to identify potential track strength weakness at the rail tie interface

Track and Structures – Track Buckling and Panel Shift
This research builds upon the FY 2019 first-generation prototypes for measuring rail stress without a zero reference.

Activities:
- Develop second-generation prototypes to measure rail stress without a zero reference.
- Initiate build of a rail stress and rail-neutral temperature test bed at TTC building upon the specifications and plans developed under FY 2019 funding.

Outcomes:
- Prototypes to measure rail stress without a zero reference
- In-progress build of a rail stress and rail neutral temperature test bed at TTC building upon the specifications and plans developed under FY 2019 funding

Track and Structures – On-Track Research and Testing
This research seeks to conduct track research and testing to prevent derailments caused by track and structures.

Activities:
- Expand upon the test capabilities of the specialized test zone at TTC, focused on investigating the relationship between degraded ballast conditions and the integrity of track as a system.

- Further evaluate the effectiveness of the UIT to improve weld strength through revenue service testing at the megasite(s).
- Develop and evaluate the next-generation RHRW for rail-related defect removal through lab and controlled-environment testing.
- Initiate tests focused on the effects of cold weather on the integrity of the track system.

Outcomes:
- New test capabilities of the specialized test zone at TTC, focused on investigating the relationship between degraded ballast conditions and the integrity of track as a system.
- Report on the effectiveness of the UIT to improve weld strength through revenue service testing at the mega site(s).
- Advancement of next generation RHRW for rail-related defect removal through lab and controlled-environment testing.
- Test results on the effects of cold weather on the integrity of the track system.

Track and Structures – Tie and Fastener Performance and Integrity
This research builds upon the FY 2019 modeling and testing of instrumented EPC tiles.

Activities:
- Complete modeling and in-track testing of instrumented EPC ties to evaluate the thermal effects on (1) track gage and (2) stress/load environment.
- Finalize science-based recommended practices for the safe implementation of EPC tie in revenue service using the research results.

Outcomes:
- Completed modeling and in-track testing of instrumented EPC ties to evaluate the thermal effects on (1) track gage and (2) stress/load environment.
- Finalized science-based recommended practices for the safe implementation of EPC tie in revenue service using the research results.

Track-Train Interaction – Vehicle Track Performance
The goal of this research is to better understand how track and train interact and how infrastructure reacts with vehicles, given the industry trend toward higher loads or faster service.

Activities:
- Finish the design and start building a test bed that can validate the accuracy of track geometry measurement systems being used by FRA and the industry.
- Initiate development of tangible outcomes for some projects.
- Initiate construction of the curved test track.

Outcomes:
- Finished design and initiate building a test bed that can be used to validate the accuracy of track geometry measurement systems used by FRA and the industry.
- Developed tangible outcomes for some projects.
- Constructed curved test track.

Track-Train Interaction – Wheel-Rail Interface

The goal of this project is to continue research to understand the root cause of RCF and develop methodology, techniques, and inspection tools to identify the problematic conditions before they become a safety threat.

Activities:

- Development of tangible outcomes for some projects within this research program by the end of 2020
- Development of recommendations on third body layer influence and parameters—and operating conditions that can cause RCF

Outcomes:

- Developed tangible outcomes for some projects within this research program by the end of 2020.
- Recommendations on third body layer influence and parameters and operating conditions that can cause RCF.

Track-Train Interaction – Vehicle-Track Modeling, Simulation and Validation

Under the Vehicle-Track Modeling research area of this program, TR will continue the work on all the areas related to Vehicle-Track Modeling.

Activities:

- Continue to support the development of procedures for both model building and model validation.
- Continue to support the development of procedures to include advanced friction models that examine the effects of falling friction, speed, and third body layer on wheel-rail contact forces and 3-dimensional contact geometry.
- Support testing and modeling of vehicle suspension components.
- Support building of vehicle and track models for various equipment and operating practices to be used for derailment investigations or developing safety.
- Tangible outcomes for some projects within this research program can be expected toward the end of 2020. Completion of the model perform simulation to see the response of the vehicle to multiple track input.

Outcomes:

- Developed procedures for both model building and model validation.
- Developed procedures to include advanced friction models that examine the effects of falling friction, speed, and third body layer on wheel-rail contact forces and 3-dimensional contact geometry.
- Test results and modeling of vehicle suspension components.
- Progress toward building of vehicle and track models for various equipment and operating practices to be used for derailment investigations or developing safety.
- Development of tangible outcomes for some projects within this research program; completion of the model perform simulation to see the response of the vehicle to multiple track input.

Rail Joints and Welds Research

FRA conducts research on rail welding and joining to improve overall rail integrity in both jointed and continuously weld track. Rail weld and joint failures are a leading cause of derailments. FRA efforts are targeted at improving the reliability of these critical components to ensure rail safety by developing solid-state robotic welding techniques.

New technologies can be applied to these areas of track to improve safety and reliability. This research effort is conducted with significant in-kind support from railroads and industry suppliers that supplements FRA's limited

research funds. This advanced research would not be possible without this support; however, FRA leadership provides a conduit to maximize and align the research efforts.

Anticipated Activities:

- In FY19, FRA will continue the development of two technologies that will improve rail reliability and safety.
- Repair, install, and in-service performance monitoring of an AMS frog.
- Develop an automated, pre-weld grinding procedure and test, and demonstrate the new attachment technique at DOT TTC and on revenue service tracks owned by participating railroads.

Expected Outcomes:

- Develop and demonstrate solid-state, robotic welding techniques to repair worn switch frogs.
- Develop and demonstrate new technology to attach signal wires to rail that eliminates the variability in weld quality and the undesirable metallurgical changes that result from the current CAD-WELD technology used throughout the industry.

Public, Private, and University Cooperative Research Agreement

See Railroad Systems Issues for description, activities, and expected outcomes.

Program Alignment with Strategic Goals:

The FRA RD&T Track Research program supports the goals and objectives of DOT, OST-R, FRA and RPD administrations. This program's fundamental mission is to improve railroad safety. It provides the scientific and engineering basis for improved industry guidelines and Federal safety standards. It develops new technologies and transfers this technology to the industry through coordinated research and demonstrations. This includes new and advanced inspection approaches that, after implementation, provide an improved situational awareness of the railroad system infrastructure.

The goal of this research is to increase safety by reducing track support-caused derailments. Investment in On-Track Research and Testing ensures the timely implementation of effective strategies aimed at improving the safety of rail transportation for the American public by bolstering instrumental public-private partnerships that advance DOT Strategic and Organizational Goals.

These technologies focus railroad maintenance activities on the locations that have the highest risk for derailments. They incorporate innovative, science-based approaches to evaluate the overall stress state of the railroad such as longitudinal rail stress, the underlying cause of sun kinks, and rail pull-parts. Highly portable tools that measure rail stresses will allow the railroads to monitor track condition and prioritize the maintenance needed to prevent derailments.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

In all inspection system projects conducted, the FRA research team continuously works on autonomous approaches to permit testing of track structures using non-contacting, low-maintenance sensors under revenue service vehicles at track speeds. This approach turns every train pass into a track system evaluation. The result is earlier detection of defects and trending of defect development without interference in train operations. This keeps average train velocities high over the system, improving the mobility of passengers and freight. Throughout the

program, FRA collaborates with the railroad industry to develop and implement these new technologies and practices to improve overall rail system safety.

Rural communities are directly impacted by the outcome of this research as it affects short line railroads (i.e., small business railroad entities), which operate 29 percent of freight rail in the U.S.[13] Short line railroads provide critical transportation services for rural markets, such as farming and ranching. By preventing derailments through better control of track-train interaction forces and accelerations, the Track Research program reduces the risk of rail-related HazMat spills and contamination of rural and urban areas affecting local air or water quality.
The industry trend toward higher loads has stressed existing infrastructure where these loads are common and particularly the support structure, including ties and ballast. The application of high loads to new territory to satisfy transportation demands, such as a rise in crude oil by rail traffic volume, increases the risk of track support failure where the support materials are below the track surface and impossible to inspect visually.

Innovative technologies have been applied to quantify the condition of these materials, including advanced ground-penetrating radar and spectral analysis of surface waves. These technologies provide data on the condition of infrastructure, may expose failure risks, and are applicable to maintenance planning. By providing a history of the condition change over time, these technologies can be applied to ensure accountability of the industry to maintain proper track support for the high loads that drive the efficiency of the industry.

In addition to FRA, AAR, multiple Class I freight railroads, and Amtrak are actively involved with research endeavors aimed at improving track inspection technology and processes. AAR, Class I's, and Amtrak are also working on track support and substructure research.

FRA has invested in this research in the past and the results of such research are driving the technological roadmap for this program for the next 5–10 years. FRA is heavily invested in this research, and past results have benefitted railroad safety in the form of technologies such as GRMS, used to predict gage widening and track strength. Tangible outcomes for some projects within this research program can be expected toward the end of 2020.

[13] Source: American Short Line and Regional Railroad Association

Section 2: Program Descriptions, FY 2020
Rolling Stock Research

Program Description/Activities:

The Rolling Stock Research program performs research activities on critical transportation topics that promote rail safety and improve rail infrastructure and mobility of goods and passengers—as well as topics that focus on preserving the environment. The Rolling Stock Research program conducts research to reduce railroad accidents and incidents due to rolling stock-related causes as well as research to reduce fatalities and injury severity to passengers and crew members involved in passenger train accidents and incidents. The program produces solutions contributing to all DOT Strategic Goals: Safety, Infrastructure, Innovation, and Accountability. The goals of this program are accomplished through the following research areas:

HazMat – Tank Car Research

Tank car research aims to improve the packages that carry hazardous materials to reduce their release during rail accidents and incidents.

Anticipated Activities:

Conduct full-scale dynamic crash tests on a DOT 117 and DOT 113 tank cars to evaluate the performance of these tank cars, validate the computer models, and start the preparation for a fire test on a DOT 113.

Expected Outcomes:

The tank car research will provide FRA with information on the crashworthiness and puncture resistance of the different tank cars used in the transportation of hazardous materials as well as determining its behavior and failure modes under accident conditions and normal transportation conditions.

HazMat – Structural Integrity

Structural integrity research goals include understanding the performance and durability of safety equipment and protective systems for tank cars and portable tanks. This research area focuses on the study of the current fleet and identifying problems with current equipment and packages.

Anticipated Activities:

Studies will be identified from the data collected during the safety and tank car inspections. These include instrumented tank cars to record the operating environment in various train configurations and evaluation of new non-destructive techniques to identify cracks on tank cars.

Expected Outcomes:

By conducting this research, RD&T will provide the information on the performance and durability of safety equipment for tank cars and portable tanks so DOT has the required information to justify, modify, eliminate, and create safety standards.

HazMat – Accident Consequence Reduction

Accidence consequence reduction goals include studying the loading and unloading practices of hazardous materials to improve the operating practices and securement of packages for safe transportation and reduce non-accident releases.

Anticipated Activities:

Continue to investigate accidents involving hazardous material packages and test new steel for use on tank cars.

Expected Outcomes:
This research will help FRA evaluate and document the damage to railroad tank cars, study and capture the results of the liquid/vapor release flow on pressure relief devices, and improve resistance to failure during train accidents.

The research will enable FRA and stakeholders to better understand how failures occur and how to best prevent or manage the consequences of such failures through improved equipment designs and protection.

*Safe Transportation of Energy Products (STEP)**
This project will assess the operational safety risks associated with hazardous material unit trains, and will focus on determining if unit train operation of hazardous materials presents any unique or additional risks compared with 1) unit train operations of non-hazardous materials, or 2) mixed-freight operations involving the same hazardous materials planned for transportation in unit trains.

As part of this project, FRA will continue providing engineering support in the research, design, fabrication, and test-planning of ISO tank and tank car fire testing and the structural performance of equipment used as fuel tenders and energy products as commodity transport.

*This funding is an earmark provided annually by Congress for Safe Transportation of Energy Products (STEP). This is in addition to the total budget for FRA RD&T. If Congress chooses NOT to fund the $2M earmark, this activity will not be executed in 2020.

Anticipated Activities:
- Provide engineering support in research, design, development, and test-planning.
- Collaborate with PHMSA.

Expected Outcomes:
- Understand the risk related to the transportation of different hazardous materials in different train configurations.
- Understand the risk related to the transportation and use of energy products (e.g., LNG, ethanol).

RSEC – Rolling Stock Component Safety
Rolling Stock component safety research seeks to proactively prevent above-track equipment and component failures (i.e., situational hazard prevention), and provide the analytical and technical basis to develop equipment safety standards while also improving safety, reliability, and "respectability" of rail equipment, technologies, and material.

FRA needs to invest in this research as it is responsible for conceptualizing and demonstrating the effectiveness of technology solutions which improve safety. FRA undertakes research to design, develop, and demonstrate effective wayside and onboard technologies which can provide component health monitoring. Partnering with railroads and other interested parties results in successful demonstration of technologies which are subsequently adopted by the industry.

Strategic priorities include the investigation of the effectiveness of wayside and onboard monitoring systems to detect equipment defects and the analysis of component failure modes to identify necessary improvements in materials and construction methods.

Anticipated Activities:

- Continue to evaluate and test equipment and components for increased integrity to withstand damage and failure that could increase risks and lead to accidents and incidents.
- Research and consider methods to measure the predictability of equipment health and component wear life.
- Collaborate and support the demonstration and implementation of wayside and onboard monitoring and inspection of equipment and components to help ensure safe train operations.

Expected Outcomes

- Research, development, and technology transfer of components and systems that reduce the risk of rail incidents and accidents and increase the safety of the nation's rail transportation network.
- The research and development in this area aims to reduce the likelihood of derailments from equipment failures and to mitigate the consequences should derailments occur through these or other causes.

RSEC—Rolling Stock Maintenance & Inspection

The Rolling Stock maintenance and inspection research area goals are to evaluate and demonstrate the effectiveness and efficiency of automated inspection and maintenance procedures and equipment. The goal is also to demonstrate the ability to develop, monitor, control, and evaluate integrated advanced components to detect defects in real time, predict and prevent future failures, improve rolling stock capabilities and performance, and improve overall rail operational safety.

This research is important because FRA's mission is to improve safety and prevent derailments that cause injury and loss of life. Derailment prevention is a major safety issue. Developing a system for powering many advanced detection devices on freight trains will increase safety and security, and improve the efficiency of freight railroad operations. Developing technologies to detect the defects on rolling stock equipment, and predict future failures that may be prevented, will substantially improve railroad safety. These types of research investments keep the U.S. rail sector growing and improving to keep up with the latest efficiency and safety standards. FRA's systematic, basic research in this area provides results that could be used by industry and universities to make improvements to railroad safety.

Benefits of this research include improved safety regulations, lower operating costs, reduced railroad accidents and fatalities, improved equipment service life, increased safety and security, and improved efficiency for freight railroad operations.

Anticipated Activities:

- Continue to evaluate and demonstrate advanced equipment as well as inspection and maintenance procedures.
- Demonstrate the ability to develop, monitor, control, and evaluate integrated advanced components.
- Develop a system to power advanced devices and systems. Develop a reliable framework for a wheel life model.
- Develop technologies to detect defects on rolling stock equipment and predict failures.

Expected Outcomes:

The development of a system to power advanced detection devices, technologies to detect defects on rolling stock equipment and preventable failures, a reliable framework for a wheel life model to explain fatigue and help mitigate wheel failure, the quantification of the effects of tread braking on wheel damage mechanisms and fatigue life, and vehicle dynamics simulations.

RSEC—Train Handling & Operating Practices

Train handling and operating practices research is intended to develop simulation scenarios to evaluate different network and capacity-related parameters with ECP brakes and PTC technologies and to compare these to the

conventional signaling and braking applications. Simulation scenarios include network topology, traffic type, ECP scenarios, and PTC scenarios (with/without ECP scenarios).

This area of research will also focus on developing effective methodologies/models for evaluating the economic benefits of improving railroad network velocity and capacity. These tools will be critical in demonstrating the benefits of technologies such as ECP brakes, PTC, higher-speed operations, shared corridors, etc.

This research is in line with FRA's mission to improve safety and performance, and prevent derailments that cause injury and loss of life. Derailment prevention is a major safety issue. It is in the FRA's best interest to enhance the economic benefits of improving railroad network velocity and capacity. Developing an improved and reliable railroad network velocity and capacity will substantially improve railroad safety and performance. FRA invests in technology that is innovative and has a lower technology readiness level than the private sector can justify. This investment keeps the U.S. rail sector growing and improving to keep up with the latest efficiency and safety standards. FRA's systematic, basic research in this area provides results that could be used by industry and universities to make improvements to railroad safety.

The rail industry will benefit from this research through improved safety regulations, lower operating costs, fewer railroad accidents and fatalities, and overall improved railroad performance.

Anticipated Activities:

- Continue to develop simulation models to evaluate network- and capacity-related parameters with ECP brakes and PTC technologies and compare to conventional signaling and braking applications.
- Evaluate the economic and safety benefits of improving railroad network velocity and capacity.

Expected Outcomes:

- The rail industry will benefit from this research through improved safety regulations, lower operating costs, fewer railroad accidents and fatalities, and overall improved railroad performance.

TOP – Fire Safety Research

The fire safety research area is focused on evaluating cost-effective, alternative performance methods and criteria for passenger rail equipment fire safety through analysis and testing.

This research area addresses the DOT Strategic Goal of Safety and Innovation and the DOT RD&T Critical Transportation Topics of promoting safety, and preserving the environment.

Anticipated Activities:

- Computer simulations of the performance of rail car designs that are atypical for the current U.S. market using validated fire safety models.
- Additional activities include a feasibility study of integration of validated fire dynamic models with railEXODUS to evaluate fire growth and passenger egress based on rail car interior designs and an evaluation of the toxicity of materials.
- An update of industry standards in the promotion of cost efficiency will be conducted.

Expected Outcomes:

- The anticipated outcomes from this research area are the evaluation of alternative industry and equipment manufacturers' standards on fire safety of passenger rail equipment materials and components and the determination of equivalency of such standards to the current Federal regulations.

TOP – Emergency Preparedness Research

The emergency preparedness research area's goal is to investigate and develop innovative safety technologies that improve emergency preparedness and egress features of passenger rail equipment using state-of-the-art simulation tools.

It is part of FRA's mission to define minimum safety standards for passenger rail equipment. These research initiatives allow FRA to collect data in a transparent manner in collaboration with the private sector, and ensure findings are shared across all interested stakeholders. This research area addresses the DOT Strategic Goal of Safety and Innovation and the DOT RD&T Critical Transportation Topics of promoting safety, and preserving the environment.

Anticipated Activities:

- Research activities will focus on collecting data from training exercises by railroad employees and first responders using the Bi-level Passenger Vehicle Emergency Evacuation Simulation tool.
- Evaluate egress based on simulations using fire dynamics simulation and railEXODUS models.

Expected Outcomes:

- The research activities develop and demonstrate tools and techniques that can be used to guide the design of rail car interiors to ensure efficiency in egress as well as to ensure passenger rail crewmembers are sufficiently trained to perform safety and life-saving functions for passengers during emergencies.

TOP – Natural Gas Safety Research

The goal of natural gas safety research is to investigate innovative safety technologies that will improve the transportation and use of natural gas, both liquefied and compressed, in the rail sector. The research provides FRA RRS with the scientific basis for decision-making and development of standards and requirements. This research area addresses the DOT Strategic Goal of Safety and Innovation and the DOT RD&T Critical Transportation Topics of promoting safety, and preserving the environment.

Anticipated Activities:

- Anticipated research activities will focus on reviewing railroads' prototype revenue service operations plans of natural gas-fueled locomotives and transportation of natural gas as a commodity.

Expected Outcomes:

- Documentation of the effectiveness of industry-specified safety features of natural gas storage equipment after prolonged exposure in the rail environment
- Industry specification for CNG tender car
- Assessment of prototype dual-fuel locomotive with onboard CNG storage

TOP – Cab Displays, Controls, and Environment

The goals of this research area are: to improve cab/locomotive visibility at night, provide extra alerting for track workers and trespassers, provide extra visibility/alerting when approaching grade crossings, unify an optimized cab display across all railroad providers, increase freight and passenger rail safety, and reduce operating and maintenance costs for locomotives.

FRA needs to invest in this research area to support its missions of improved safety, performance, and mitigation of the consequences of collisions and derailments that cause injury and loss of life.

FRA invests in technology that is innovative and has a lower technology readiness level than the private sector can justify. This investment keeps the U.S. rail sector growing and improving to keep up with the latest efficiency and safety standards.

Anticipated Activities:

- Research activities focus on improving locomotive cab displays, developing an optimized cab display that could be unified across all railroad providers, and improving train control and visibility at night.
- Continued implementation of advanced, safe, and cost-effective LED headlights across all railroad providers.

Expected Outcomes:

- Expected outcomes from this research are better train control and visibility and fewer fatalities and injuries to train crews, passengers, track workers, and the general public.

Public, Private, and University Cooperative Research Agreement

See Railroad Systems Issues for description, activities, and expected outcomes.

Program Alignment with Strategic Goals:

FRA's RD&T Rolling Stock research program focuses on improving railroad safety. It provides the scientific and engineering basis for improved industry and Federal standards and improved safety enforcement and compliance using those standards. Through the program, FRA collaborates with the railroad industry to develop and implement new technologies and practices to improve overall rail system safety. The Rolling Stock research program, in collaboration with the rail industry, is aimed at reducing derailments due to equipment failures, minimizing the consequences of derailments, and minimizing accidental releases of hazardous materials.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

This program inherently has a significant impact on rural communities in that improving equipment and operating practices reduces the risk of rail-related HazMat spills; hazardous materials research minimizes the consequences of the release that may affect rural communities

Section 2: Program Descriptions, FY 2020
Train Control and Communication Research

Program Description/Activities:

The Train Control and Communication (TCC) research program focuses on improving railroad operation safety through the development and testing of train control and communication systems and grade crossing safety technologies. The program also conducts pilot studies, creates prototypes, and demonstrates safety and security systems, including intelligent rail systems, blocked crossings, and trespass prevention.

PTC Technology
Anticipated Activities:
This work will continue to assist railroads in meeting the congressional mandate for PTC while maintaining safe and efficient rail operations. FRA staff will work with railroad stakeholders to identify technology gaps and needs in the design, development, deployment, and evolution of PTC.

- PTC-integrated work zone protection technology deployment
- Railroad wireless spectrum use planning and optimization
- Rail communication security solution testing
- PTC reliability and availability improvement testing
- PTC automated braking system refinement

Expected Outcomes:
- Safer and more reliable PTC systems that contribute positively to railroad operational efficiencies.
- Greater number of track miles equipped.

PTC Interoperability
Anticipated Activities:
- Continue interoperability research to ensure compliance with the RSIA of 2008.
- Engage stakeholders to develop interoperability specifications, lifecycle management, verification of interoperability between differing PTC systems, applications and integration of products and processes into the National PTC network. These activities will evolve as PTC is rolled out on all railroads.

Expected Outcomes:
- Produce publicly available, finalized technology specifications to encourage the private sector to further develop and deploy. Since this will be an open standard, it will create a competitive marketplace, increasing economic competition and workforce development.
- All railroads are expected to accept these developments for implementation at the earliest opportunity and finalize any individual railroad requirements.

PTC Next Generation
Anticipated Activities:
- Work with industry, vendor, and university support to develop a spectrum of potential solutions, ranging from improving conventional train control and management methods to developing and implementing an advanced train control and management system architecture, along with an associated migration plan, are key steps toward achieving mitigation of PTC impacts.

Expected Outcomes:

- Improve the safety and capacity of the railroads with concepts such as moving block operations, automated train movements, connected vehicles, and variants thereof. North American railroads are actively engaged in the development and implementation of these cutting-edge technologies.
- It is anticipated that the AAR and its member railroads will implement future technological advances upon development for safety and efficiency enhancements. The evolution of PTC as a technology will continue to be an important element of the industry's strategy for the enhancement of safe and efficient rail transportation. If PTC technology does not continuously improve, inefficiencies will continue to cripple capacity, increasing the cost of moving people, goods, and services throughout the network.

Intelligent Transportation Systems (ITS)

Anticipated Activities:

- Continue collaboration between railroads and automotive industry stakeholders to develop coordinated solutions for automated transportation systems.
- Continue the development of standards and practices for automated rail operations and highway-rail grade crossing systems.
- Evaluate innovative technologies important to rail ITS.
- Test prototype and reference architectures.
- Monitor model deployments and evaluation of connected safety systems.

Expected Outcomes:

- Continued improvement in grade crossing safety and highway-rail transportation integration
- Coordinated deployment of automated vehicles and connected infrastructure systems

Trespass Countermeasures

Anticipated Activities:

- Evaluate a trackside wireless detection net for pedestrian safety.
- Investigate the use of Artificial Intelligence (AI) that can be employed in detecting trespassers.

Expected Outcomes:

- New technologies and solutions are expected to be then evaluated, tested, and implemented in a railroad environment leading to technology transfer and an increase to public safety.

Grade Crossing Technology

Anticipated Activities:

- Continue research on AI algorithms.
- Analyze and evaluate ways that such algorithms can be applied to the rail environment.

Expected Outcomes:

- Technology transfer and implementation by railroad carriers (in cooperation with State and local governments) of products and practices evaluated under this research area.

Grade Crossing Pedestrian Safety

Anticipated Activities:

- Continue evaluation of the effectiveness of grade separations that can be either roadways with pedestrian paths, or dedicated pedestrian underpasses or overpasses.

- Finalize the evaluation of new types of pedestrian gates (known as "gate skirts") that can aid in preventing pedestrians from crossing the tracks when a train is approaching.

Expected Outcomes:
- Recommendations to local and State governments for the planning and construction of grade separations. Results from the evaluation of pedestrian treatments are expected to be considered by the railroads in cooperation with local communities.

Grade Crossing Modeling and Simulation
Anticipated Activities:
- Continue GradeDec.Net improvements and detailed railroad traffic modelling.

Expected Outcomes:
- Continue improvements to GradeDec.Net, which helps users estimate the costs and benefits of grade crossing investments by comparing the reduced costs of fatalities, injuries, and property damage from possible incidents, reduced travel times, and reduced emissions to the construction costs.

Grade Crossing and Trespass Outreach and Education
Anticipated Activities:
- New tools potentially made available to law enforcement partners will be unmanned aerial vehicles (UAV).
- Continue to disseminate rail ROW trespass prevention outreach materials.
- Organize a workshop by mid-2019. This workshop will continue the collaboration effort among several national and international stakeholders on trespass and suicide issues.

Expected Outcomes:
- Improving public safety through further dissemination and reception of educational and training aids
- Proving the effectiveness of deploying police officers along the railroad
- Formation of an international working group on trespass prevention

Public, Private, and University Cooperative Research Agreement
See Railroad Systems Issues for description, activities, and expected outcomes.

Program Alignment with Strategic Goals:

This program supports the DOT's Safety and Innovation strategic goals by developing and helping to deploy innovative technologies to improve railroad operation safety and efficiency, affecting many communities. Technology helps improve transportation of people and goods through rail, which has a significant positive impact on rural communities' accessibility and the U.S. economy as a whole. This program also supports the Accountability goal in its role in the reduction of regulatory burden.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

Historically, "rural community impact" has not been a criterion for measuring the TCC division's research and development portfolio. The TCC division will develop metrics for assessing the impact of its research on rural

communities. The following section shows how each TCC research area aligns to DOT goals and impacts rural communities.

Section 2: Program Descriptions, FY 2020
Human Factors Research

Program Description/Activities:

FRA's HF Division aims to reduce railroad accidents caused by human error. The HF division conducts research and development activities related to safe rail operations and the safe integration of people with technology. Areas of research within the HF division include rail trespass and suicide prevention; technology, automation, and systems design; fatigue; project evaluation; highway-rail grade crossings; and SLSI support.

FRA RD&T takes a non-regulatory approach to human factors for safety and efficiency in the railroad industry. By implementing established research practices and education oriented for the rail industry, attention to human factors is encouraged rather than regulated.

Rail Trespass and Suicide Prevention

- Human Factors research on rail trespass and suicide addresses the two leading categories of rail fatalities in the U.S. Hundreds of people die every year on train tracks due to trespassing or suicide.
- HF should examine the human behaviors associated with rail trespass and suicide to increase rail safety and decrease the number of fatalities along the ROW.
- Rail carriers, consultants, and academics across the globe invest research dollars in studying trespass and suicide prevention. Fatalities along the ROW due to trespass and suicide are a universal; they can happen anywhere there is an active railroad.
- FRA has been tracking rail suicides in the U.S. since 2011 and learned that suicide prevention is something rail carriers can do effectively, with the right training. Also, FRA has learned that media reporting of rail suicides can trigger copycat events. FRA has identified that the common causal factors for trespassing are: shortest distance between two points, recreation (e.g., ATV riding), and criminal behavior (e.g., drug use, graffiti, theft). Intoxicants are often found in trespassers.
- Human Factors research on trespass and suicide prevention should continue indefinitely; as long as there are fatalities along ROWs that can be attributed to human error (e.g., distracted walking along the tracks with earbuds, photographing along the tracks and not paying attention to oncoming train, intentionally causing harm to oneself), FRA will need to continue to study mitigation strategies.

Anticipated Activities:

- Continue to conduct pilot studies with rail carriers that are implementing strategies to mitigate trespass and suicide.
- Evaluate the effectiveness of these strategies and disseminate the results in the FRA eLibrary.
- Update the FRA report that reviews known characteristics of victims of rail trespass and suicide in the U.S. (last version: *Defining Characteristics of Intentional Fatalities on Railway Right-of-Way in the United States, 2012-2014*).
- Assist FRA's Office of Railroad Safety in studying trespass prevention strategies proposed in the August 2018 report to Congress.

Expected Outcomes:

The outcome goals of the trespasser and suicide prevention research topic area are to:

- Better understand the causal factors behind why individuals contemplating suicide consider this method to end their lives.

- Identify countermeasures to prevent accidents attributable to trespassing and suicide.
- Identify and plan new efforts to support FRA rail trespass and suicide prevention.
- Track media reports of suicide and trespass incidents on the rights-of-way.
- Better understanding of how to improve cause of death determinations for rail fatalities.
- Create an internal database to map suicide and trespass casualties.
- Use GIS mapping capabilities to work with stakeholders to better understand their trespass/suicide problem to determine the most effective mitigation strategies.

Automation, Operating Personnel Information Management, and Control

HF addresses the prudent integration of people with automation technology by conducting research, particularly on automation and manpower, personnel, human factors engineering, safety, and training. These are the primary aspects where automation intersects with human behavior and human operational requirements. The application of research results in this area by the industry will yield better-performing man-machine collaborative systems.

Anticipated Activities:

- Studying the created prototype in CTIL (approximately 30 subjects)
- Validation of the fatigue state classification algorithm (includes machine learning)
- Conducting research of the HUD in CTIL

Expected Outcomes:

- Results of the study to include an initial assessment of the prototype's usability.
- Demonstration of the prototype in CTIL
- An assessment of the usability of the prototyped system

Fatigue

Employees in the railroad industry are susceptible to the risk of injury and property damage caused by human fatigue and loss of attentiveness due to around-the-clock operations. The Human Factors division seeks to develop interventions or solutions to mitigate the effect of irregular work hours, long shifts, and the unpredictability of on-duty times associated with the U.S. rail industry. Railroad workers need training, tools, and alertness to conduct their jobs properly and safely.

Anticipated Activities:

- Activities include survey distribution, follow-up focus groups, and data analysis.
- Communication and outreach to publicize the survey to stakeholder organizations to increase participation among the targeted sample.
- Focus group sessions with relevant representatives of the stakeholder organizations to explore in greater detail the responses from the survey.
- Descriptive analyses will be used to assess the commute times of locomotive engineers along with their opinions and perceptions of the factors affecting their fatigue and safety.
- A final report will be drafted.

Expected Outcomes:

Outcomes of the survey will reflect the opinions and perceptions of the workers (locomotive crew) most directly exposed to fatigue in locomotive operations and will help identify problems in this area.

Project Evaluation

- Project evaluations of government-funded research projects use rigorous methods to assess the extent to which, and ways, programs goals are met.
- Project evaluation of the SLSI will promote accountability in SLSI's programs. Evaluation by an independent, third-party organization provides unbiased evidence about the extent to which the SLSI's programs are (or are not) working as intended.
- FRA should continue to pursue this investment in project evaluation because it monitors the progress and success of the project and promotes accountability. The SLSI receives a directed grant from FRA to fund its programs; built-in project evaluation provides evidence that these funds are being spent on programs that improve the safety of small railroads.
- Only one organization provides project evaluation services to SLSI.
- FRA external project evaluation of the SLSI's processes and procedures have identified opportunities for it to improve and build on lessons learned from the pilot testing of the processes and procedures.
- Project evaluation of SLSI will continue as long as it receives funding from FRA.

Anticipated Activities:
- Continue formative and summative evaluations of SLSI's programs, including the safety culture assessment process and follow-up assessment process
- Develop one-pagers on the outcomes of SLSI's work, for distribution to Congress and the public.

Expected Outcomes:
The GPRA and the GPRA Modernization Act of 2010 require Federal agencies to assess the manner and extent to which their programs achieve intended objectives. Consistent with the GPRA directive, FRA RD&T conducts project evaluations to:
- Meet FRA RD&T accountability requirements.
- Guide and strengthen FRA RD&T programs.
- Facilitate knowledge diffusion and technology transfer.
- Obtain input, feedback, and data regarding industry and government-supported programs.
- Build FRA RD&T evaluation capacity.
- Contribute to improving railroad safety.

Highway-Rail Grade Crossing
- Driver behavior accounts for up to 94 percent of vehicle crossing accidents for the U.S. railroad system; thus, efforts to decrease human errors are critical. It is an FRA goal and priority to significantly improve grade crossing safety and reduce grade crossing accident rate.
- Human Factors research addresses human behavior at grade crossings and the extent to which individuals understand new technologies to notify them of an approaching train.
- If drivers do not understand a new technology that is implemented, grade crossing safety will not improve. Technology transfer and user adoption requires an understanding of the technology and user behavior.
- Rail carriers, consultants, and academics across the globe invest research dollars in studying grade crossing safety.
- FRA has invested in grade crossing research in the past. FRA has learned that there are limited safety benefits gained when new technologies are implemented without a complete understanding of how humans will interact with and react to that technology.
- Human factors research on grade crossing safety should continue indefinitely; as long as there are fatalities at grade crossings that can be attributed to human error, FRA will need to continue to study mitigation strategies.

Anticipated Activities:

- Examine trends in driver behavior at grade crossings and work with rail carriers to implement intervention strategies to improve safety at grade crossings.

Expected Outcomes:
- Better understand the causal factors behind why individuals violate warning signals at grade crossings.
- Improve safety by reducing the likelihood of accidents occurring and their severity should an accident occur.
- Develop grade crossing technology that considers human behavior in its design and minimizes the potential for human errors.

*Short Line Safety Institute **
- Human Factors provides program monitoring and support of SLSI. The SLSI addresses the safety of Class II and Class III railroads, which are small railroads in rural locations with limited resources for safety training and education.
- Funding for this project should continue because small railroads do not have the budget or personnel to conduct safety culture assessments, training, and education at their railroads.
- FRA receives earmarked funding specifically to support SLSI.
- HF has learned that Class II and Class III railroads are committed to a strong safety culture, but could use assistance with leadership development training.

*This funding is an earmark grant provided by Congress annually for the Short Line Safety Institute. In addition to the total budget for FRA RD&T. If Congress chooses NOT to fund the $2M earmark, this activity will not be executed in 2020.

Anticipated Activities:
SLSI will continue its core program areas:
- Conduct no-cost safety culture assessments on Class II and Class III railroads.
- Develop and pilot-test a follow-up process to measure safety culture shift.
- Provide no-cost training and education to Class II and Class III railroads on the topics of safety and safety culture.
- Develop and disseminate outreach/safety communications materials that railroads can use onsite with employees.

Expected Outcomes:
- SLSI helps small railroads operate more safely by assessing safety culture, recommending how to improve it, and providing leadership, training, and education about safety culture.
- SLSI goals are to reduce the risk of accidents and incidents in the short line and regional railroad industry by improving safety and safety culture.

Vigilance, Attention, and Distraction
The goal of this research project is to understand ways to improve factors that affect vigilance and sustained attention. Research in this area includes conducting studies to learn more about cognitive and behavioral elements that affect human sustained attention and vigilance. Railroad operation requires workers to manage and understand information provided by multiple systems while keeping an eye on track and signals. The problems this research is solving include:
- Loss of operator focus and distraction.
- Accidents caused by human error.

Anticipated Activities:

- Collaborate with industry to research roadway worker fatalities related to adjacent track and train approach warnings.

Expected Outcomes:

- Reduce accidents caused by distraction.
- Improve operator decision making and performance.

Public, Private, and University Cooperative Research Agreement

See Railroad Systems Issues for description, activities, and expected outcomes.

Program Alignment with Strategic Goals:

The HF Research program aligns with the DOT Strategic Goal *Safety* and the DOT Critical Transportation Topic *Promoting Safety*. Successful execution of FRA's mission requires research and development activities aimed at improving railroad safety, efficiency, security, and capacity. Human errors account for more than one-third of all train accidents in the U.S. railroad industry. Data does not allow causal linkages between FRA's HF research program and accident/incident reduction. However, if human factors continue to be a common probable cause of rail accidents, FRA must continue to investigate new technologies and programs that help reduce human error and improve safety in the industry.

The division provides direction to the rail industry on a spectrum of safety issues that are rooted in human behavior and human performance (e.g., distraction, failure to perform correct procedure, design-induced human error, error due to workload). Approximately 38 percent of rail accidents and incidents include human factors as a causal or contributing factor.

DOT Strategic Goal	DOT RD&T Critical Transportation Topic
Safety	Promoting safety

The HF division has an impact on rural communities, most notably through the following project areas: grade crossing safety, trespasser and suicide prevention, and SLSI. The HF division expects that its research on the underlying causes and circumstances of accidents and incidents will have a positive impact on reducing the accident and incident rates in rural areas. This information, in turn, will help FRA decide the appropriate measures to take to improve safety.

Historically, "rural community impact" has not been a criterion for measuring the HF division's research and development portfolio. The Human Factors division will develop metrics for assessing the impact of its research on rural communities.

[END]