United States Department of Transportation
FY 2020 Annual Modal Research Plans

FEDERAL RAILROAD ADMINISTRATION

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Executive Summary

The mission of Federal Railroad Administration's (FRA) Office of Research, Development and Technology (RD&T) is to ensure the safe movement of people and goods by rail through research and the development of innovative technologies and solutions. RD&T achieves this goal through 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.

FRA's RD&T program is founded on an understanding of safety risks in the industry. Through threat identification and risk analysis, RD&T identifies opportunities to reduce the likelihood of accidents and incidents. In addition, FRA seeks to limit the consequences of hazardous events should they occur. Key research and development strategies include stakeholder input and engagement and partnerships with other organizations, such as the Association of American Railroads (AAR) and the American Short Line Regional Railroad Association (ASLRRA). RD&T strategically prioritizes research and conducts 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 automation solutions to improve the safety of America's railways.

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

1. Hazardous Material (HazMat) Transportation
2. Track and Structures
3. Rolling Stock Equipment and Components
4. Highway-Rail Grade Crossing and Trespassing
5. Human Factors
6. Train Control and Communication
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. One example is the Autonomous Track Geometry Measurement System (ATGMS) project, where FRA identified and worked to address the need for automated track inspection. The project spanned a 15-year period (2002-2017)—from proof of concept to deployment and commercialization. Sustained funding from RD&T enables pursuit of specific research needs. In doing so, FRA

initially bears the costs and risks for research that the railroad industry is unable to pursue, but that lead to innovative solutions that may not have otherwise been realized.

Research Program Summaries:

Hazardous Material Transportation
The hazardous materials research program fosters innovation throughout the industry, helping to develop new regulations and design standards that improve the safety and integrity of tank cars and other packages carrying hazardous materials. Hazardous materials research aids the continuing growth of new research programs that satisfy the needs of 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 also a common cause of derailments.

Rolling Stock Equipment and Components
Research efforts in the Rolling Stock Equipment and Components program area 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 209,000 highway-rail grade crossings exist in the approximately 140,000 miles of track that make up the United States railroad system. In 2018, 272 individuals died at railroad crossings. This figure increased from 232 in 2013, 262 in 2014, 237 in 2015, 255 in 2016, and 271 in 2017. 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 the U.S. Nationally, more than 400 trespass fatalities occur each year, the vast majority of which are preventable.

Human Factors
FRA's Human Factors program conducts research to improve railroad safety and organizational culture. Program areas include research on fatigue and distraction to address individual and team behavior; and developing technology, automation, and systems design to minimize the potential for human errors.

Train Control and Communication
The Train Control and Communication program conducts research to improve train operation systems safety and reduce accidents and incidents at grade crossings and prevent trespassing. This is accomplished through the research, development, and testing of Positive Train Control (PTC) technologies, automation, communication, and sensors, and providing trespassing countermeasures and best practices to communities and stakeholders. Results of this research and development directly support the development of technology and safety standards to improve railroad operation safety, as well as provide scientific research and data to support FRA regulations and rulemaking.

Train Occupant Protection
The Train Occupant Protection program conducts research on structural crashworthiness and interior safety of locomotives and intercity and commuter rail cars. The research focus is to improve the survivability of rail passengers and crewmembers in accidents.

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 Testing Facilities and 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 role in research, development, and testing of rail infrastructure and equipment.

Chapter 1. Introduction / Agency-Wide Research Approach

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

RD&T's Program Managers (PMs) use many tools to provide decision points for evaluating project progress and relevance. Each vendor submits monthly/bi-monthly/quarterly progress reports that provide research progress including research status and significant accomplishments. PMs work with vendors, industry stakeholders and subject matter experts throughout the research life cycle. This collaboration provides a wealth of knowledge to assess the progress of research activities and facilitate the transfer of technology. Using this knowledge and insight from program metrics and industry commitment, PMs conduct assessments of research projects' progress and their continued viability and 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 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.

Consistent funding of research and development activities is essential to the progress of the railroad industry and its efforts to modernize and improve safety. The cessation of RD&T funding would have a devastating impact on railroad safety operations and a significant impact on the economy, infrastructure, and environment. Without investing in safety research, the Office of Railroad Safety (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 RD&T is required to understand the safety implications of change. RD&T staff collaborate with the RRS to maintain the efficacy of technical standards. If RD&T did not receive funding or had its funding decreased, the economic impact to the railroad industry would extend beyond that of the people, small businesses, universities, education supports, and facilities directly involved with research activities, reaching those affected by the absence of new technology and innovations.

Private industry invests in research; however, the results may not be shared across the industry. Companies may opt to retain results for profit that could otherwise benefit the industry and the public. Driven by profits, innovation would lag, research would increase the value of intellectual property rights, and private industry would only do the minimum to meet the safety technical standards set by government policy. If the Federal Government did not invest in railroad research and development, the public would not have an independent assessment of railroad safety issues.

Research Portfolio Information

FRA RD&T developed a Research Portfolio Information Action Plan to conduct an annual review and update of the FRA USDOT Research Hub. OST requires this annual review to maintain up-to-date content in the FRA USDOT Research Hub. The Action Plan includes a step-by-step process that aligns with the OST Annual

Review Cycle. (Pending OST approval, the annual process is subject to change to quarterly, tentatively effective the second quarter or FY 2019.) As of July 2019, the annual refresh process is still in development. RD&T has engaged the OST-R Research Hub point of contact and will respond quickly to the new process once completed.

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

USDOT Research Hub – The following data fields, as defined by the Research Hub data dictionary, need to be reviewed and updated:

Field Name	Field Description
Project Title	Name of project
Project Description	Short description of the project
Program	Name of the research program (if any) funding the project
Contract/Grant Number	Contract/grant or other funding agreement identifier
Status	Project status (active or completed)
Period of Performance (POP) Start Date	Contract/grant start date
POP End Date	Contract/grant end date
Amount of Funding	Amount of funding allocated to the project
Performer	Name of the performer (research vendor)

The FRA USDOT Research Hub annual update process steps include:

Steps	Process
Steps 1-2	OST Database Administrator submits the USDOT 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 and provide updates/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 USDOT Research Hub.

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

Ongoing and continuous updates to the ROSA-P include: updates to reports, research results, and summary descriptions of project outputs and outcomes/impacts.

FRA High-Level Publishing Process:

Steps	Process
Step 1	RD&T Division Chiefs and Program Managers send the Technical Editors the Technical Reports, research results, and summary descriptions of project outputs.

Steps	Process
Step 2	RD&T Technical Editors prepare the reports and research results then send email notifications with the website for publication to the FRA Web Team. (Frequency is weekly or monthly.)
Step 3	The FRA Web Team receives an email from the Technical Editors. The Web Team generates the publication notification which includes ROSA-P updates.
Step 4	RD&T Technical Editors send email communication with the website for publication to the following: • Division Chief • Program Manager • RD&T Director • Strategic Communications • Public Affairs • National Transportation Library (NTL) • Transportation Research Board's Research-in-Progress (RiP) database • U.S. DOT ROSA-P • Transportation Research International Documentation (TRID) database
Step 5	RD&T Technical Editors send social media post(s) to Public Affairs to notify the public about the new FRA publication.
Step 6	FRA Public Affairs posts notices to FRA Facebook and Twitter accounts.

Technical Reports and Research Results are presented at industry meetings to share accomplishments and findings with stakeholders.

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, OST-R, FRA, and the Office of Railroad Policy and Development (RPD) goals for the upcoming fiscal year. RD&T utilizes a competitive procurement process across all 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)

In general, RD&T divisions use a competitive acquisition approach to execute multi-phase research projects. However, in later phases of the research, divisions use a non-competitive (sole source) acquisition approach to conduct research projects, as the research requires special expertise and specific knowledge of the work that has been performed. In such cases, it is advantageous to the government's return on investment (ROI) (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 divisions. Work products produced by the Volpe Center are respected and widely adopted by the rail industry.

In FY 2020, RD&T will increase its use of the BAA to invest in research related to intelligent railroad systems (IRS.). Each division has included research topics in the RD&T BAA to promote open competition. The divisions will review and select research topics for investment in FY 2020 and in some cases FY 2021 if a multi-year contract is required. BAA proposals are reviewed, and award recommendations are made in the fourth quarter of the fiscal year.

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 1 year or less. Multi-year acquisitions are used to provide incremental funding for research projects, especially when developing new technologies. In addition, multi-year contracts 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 R&D life cycle.

RD&T divisions benefit from in-kind contributions (e.g., subject matter expertise, track time, data sharing, 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&T research products.

RD&T determines expected TRLs 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. RD&T will formalize its T2 methodology by piloting program-level T2 plans this year. 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 and maximize all resource streams and wide adoption of new technologies.

Activities that 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 $550K in FY 2020. T2 implementation costs include:

- Stakeholder Engagement
  - Industry conferences, meetings, presentations/demonstrations (e.g., international suicide conference, Union of International Railways Grade Crossing Awareness Day)
  - Workshops, committees and summits
  - Community meetings
- Communications
  - Support for publications and reports

Generally, RD&T's stakeholders are the railroad carriers, labor unions, railroad manufacturers, universities, FRA RRS, Federal Transit Administration (FTA), Pipeline and Hazardous Material Safety Administration (PHMSA), Federal Highway Administration (FHWA), Intelligent Transportation Systems – Joint Program Office (ITS-JPO), and the American public (each research program will address these categories specifically). These stakeholder groups benefit from RD&T 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 the Office or Railroad Safety (RRS), provide safety data for RD&T research. Subsequently, RRS uses 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, labor unions) provide insights, trends, and data used to begin and prioritize research. These same stakeholders participate in research by providing expertise or equipment, providing feedback during research projects or as participants for research studies. Internal and external stakeholders consume RD&T research; they implement training, establish standards, and adopt equipment suggested in RD&T research and development. A good example of the success of RD&T's technology transfer efforts is ATGMS research. 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—published on FRA's eLibrary at the conclusion of research. This provides accessibility to the railroad industry's stakeholders and the American public. Some RD&T contracts include funding for vendors to present, with FRA permission, RD&T research at industry meetings. 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 NTL as part of its publishing process to ensure material is widely available and searchable and increase the dissemination of FRA reports. FRA PMs have already begun to share research accomplishments and findings with stakeholders during the R&D life cycle at industry meetings so that the industry can benefit immediately from information and lessons learned.

In 2017, RD&T produced 2 new products[1], filed 2 patents[2], 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 increased the production of research outputs through an improved publishing process. RD&T published 41 Technical Reports, 17 Research Results and 14 additional documents in 2018.

RD&T is establishing a baseline for measuring the performance of its T2 activities. 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
- Total Traffic to RD&T Research
- Total Traffic to Special Project Areas
- Traffic by Region/Classification

Utilizing this information as a baseline, RD&T is establishing the following goals to measure the effectiveness of T2 in FY 2019 and FY 2020:
- 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
- Increase Publishing of FRA Research

Data Management:

The Foundations for Evidence Based Policymaking Act of 2018 codifies the need for data to be more accessible both to the Department as well as the public. This increased access to data is intended to enable evidence based policy making and improve transparency. As part of an intermodal collaboration across the Department, all new projects funded in 2020 under the research plan will be examined to identify if they are producing data and whether or not the data can be shared. To meet this end, FRA shall work with its partners in the other modes through the Data Work Group to establish consistent guidance:
- To establish standard data management plans to be incorporated into their research processes,
- To develop methods to register new research products in a timely manner under one of the existing Department catalogs (e.g. data, transportation.gov, ITS JPO Data Hub, or equivalent modal catalog)
- To work with partners in the modes to identify the technical assistance needed for project managers and awardees to effectively adhere to the above guidance

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

Evaluation/Performance Measurement

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 research investment decisions.

RD&T's external project evaluation efforts determine the effectiveness of research programs and their intended impact. The results inform project performance improvements and opportunities to increase ROI on funding.

- Initially, RD&T required each division to conduct a pilot project evaluation, designed to improve FRA's ability to assess the impact on improving rail safety resulting from RD&T research projects.
- 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."
- RD&T has started another TRB evaluation in FY 2020, and will concurrently implement internal processes to improve its accountability to the American public.

To improve the effectiveness of performance management, RD&T will conduct additional project evaluation training in FY 2019 to continue to grow project evaluation skills and implement new tools. As part of the evaluation practice, RD&T will track project data and leverage information to make data-driven decisions. RD&T remains committed to using performance measures 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. 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.

FRA will measure performance for T2 as part of the DOT Strategic Goal Innovation.
Development of Innovation:

- Increase the Development of Innovations in Transportation (DOT)

Metric: Increase the Development of Innovations in Transportation		**2018**	**2019**	**2020**
Research Laboratory Utilization Rates	Targets	Increase	Increase	Increase
	Actuals	85%	N/A	N/A
Research Outcomes Made Publicly Available in Research Hub	Targets	N/A	Baseline	Increase
	Actuals	N/A	N/A	N/A
Technical Reports Made Publicly Available in the National Transportation Library	Targets	N/A	Baseline	Increase
	Actuals	N/A	N/A	N/A

Deployment of Innovation:

- Increase Effectiveness of Technology Transfer (DOT)

Metric: Increase Effectiveness of Technology Transfer		**2018**	**2019**	**2020**
Technologies Toward Implementation (Pilots and Demonstrations)	Targets	N/A	N/A	N/A
	Actuals	N/A	Baseline	Increase
Success Stories (Evidence of Societal Benefits)	Targets	10	13	15
	Actuals	12	N/A	N/A

PMs and stakeholders define metrics relating to T2, including TRL 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.

RD&T began tracking data with FRA's input to the OST-R Technology Transfer Report 2017. As discussed in the T2 section, RD&T will establish baseline metrics using data from FY 2018 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 commissioned the development of a project evaluation practice that will be rolled out in the second and third quarters of FY 2019, that will implement the processes, tools and training to support the evaluation of program performance as an integral part of managing research projects. Training and coaching

will also be provided to help RD&T staff develop essential skills to ensure program success. The tools will include guidance to facilitate the development, collection, and analysis of performance metrics.

The performance metrics will be used to evaluate research programs. This will include RD&T metrics, traditional project-related metrics, and those more specific to T2 activities and progress. Division Chiefs and PMs lead the effort to define measures of success for each project (e.g., cost, ROI, timing, relevance, results). Targets and milestones are established and are an integral part of managing the research project.

Evaluating Program Effectiveness:
Activities – PMs and research partners 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 practice (tools, training, and coaching) 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. 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.

Chapter 2. High Priority Project Descriptions

Railroad Systems Issues - High Priority Project 1: Biennial Peer Review and Evaluation of FRA's RD&T Program

Why should we pursue (or invest in) this research?

The Senate Appropriations Committee asked the TRB to conduct a peer review of FRA's Research and Development (R&D) program (now called RD&T), which focuses on research in support of safety regulations. FRA has committed to commissioning an independent peer review and evaluation, periodically, to make sure the RD&T program is on track and consistent with the overall objectives of FRA/DOT, and to benefit and implement valuable recommendations of the review committee. Due to the specific and special nature of this program, it can only be funded by FRA, according to the request of the Senate Appropriations Committee.

Who else is researching this issue?

No one; this evaluation is specific to RD&T.

Have we invested in this topic in the past and what have we learned to date?

Yes, RD&T has conducted this program in the past. The last time was in 2013-2015; the final report for the TRB review and evaluation was published in 2015 (TRB Special Report 316). The report offered some valuable recommendations that are considered in the current ongoing research. The table below details the history of TRB reviews.

DATE	ACTIVITY
1998-2001	Conceived for review of R&D and Next Generation High Speed Rail (HSR) programs
2002-2005	Re-scoped as "Committee for Review of the FRA Research, Development, and Demonstration Programs"
2005-2007	Renewed (additional term)
2007	1st and 2nd meetings of new Committee (FRA HQ and TTCI, Pueblo)
2010	6th meeting, letter report 03/2011
2012	Letter report, 05/2012
2015	TRB Special Report 316 (2015) describing review of "case studies"
2019	Renewed (new term, new members)

Objectives, activities, and what is the problem being addressed?

TRB will create an ad-hoc committee to conduct an expert review and evaluation of the FRA Office of RD&T to assess RD&T products and services to the agency and railroad industry.

The committee will evaluate each of the four major division areas (Track, Rolling Stock, Train Control and Communication, and Human Factors), including cross-division efforts and RD&T support functions (planning, evaluation, and management).

The TRB committee will deliver two letter reports:

- Letter report of RD&T evaluation findings and recommendations.

- Letter report of RD&T public event findings and recommendations.

Alignment with DOT Strategic Goals and/or DOT research priorities,

Congress funds FRA RD&T to contribute to the DOT's strategic goals, the principal of which is improving safety. Thus, the goal of this review and assessment is to provide strategic feedback to RD&T for program improvement and planning purposes with specific emphasis on: 1) validating FRA's process to identify new priorities for addressing emerging safety issues and trends, and 2) evaluating the feasibility, usefulness, effectiveness, and impact of RD&T products and services in railroad safety.

Expected total project cost and expected funding for FY 2020,

Total project cost is about $385,000. The current project was funded in FY 2018; therefore, no extra funds are expected in FY 2020.

Is there a non-Federal financial contribution? If so, how much?

No, there is not.

Railroad Systems Issues - High Priority Project 2: Public, Private, and University Cooperative Research Agreement

Why should we pursue (or invest in) this research?

The Public, Private and University Cooperative Research Agreement is a collaboration with the AAR to provide research opportunities to American academic institutions. 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 and communication, and human factors.

RD&T has increased its focus on technology for the last 5 years and plans to continue to strategically invest in technological innovation that can improve the safety of America's railroads. The Public, Private and University Cooperative Research Agreement's research topics will explore promising, innovative concepts and methods to improve safety and performance of railroads. This research will include projects that advance technology for rural application. This investment will keep the U.S. rail sector growing and improving with the latest efficiency and safety standards. Furthermore, FRA invests in technology that is innovative and has a lower technology readiness level than the private sector can justify. There is minimal incentive for the private sector to invest in fundamental research to improve rail safety.

Who else is researching this issue?

This question is not applicable to this research.

Have we invested in this topic in the past and what have we learned to date?

This question is not applicable to this research.

Objectives, activities, and what is the problem being addressed?

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 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.

Expected outcomes include:
- Projects on advanced technology, automation, and connected vehicle technologies.
- Projects advancing these technologies for rural application.
- Workforce development.

There are no active acquisitions related to this research.

Alignment with DOT Strategic Goals and/or DOT research priorities,

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

Expected total project cost and expected funding for FY 2020,

The total project cost for FY 2020 is $2M. RD&T will spend $1M.

Is there a non-Federal financial contribution? If so, how much?

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

Track Research - High Priority Project 3: Ballast Waiver Study

Why should we pursue (or invest in) this research?

The FRA Ballast Waiver project is a study centered on a waiver granted to the AAR for FRA TSS 213.103 Ballast, generally referred to as the ballast rule. The ballast rule attempts to describe the required functions of ballast to support a performance-based rule. But, with no structural condition measurements for track support, the indications of ballast that do not meet the required functions are made by visual observation. With the emerging measures of ballast conditions using ground-penetrating radar (GPR) and track deflection, a study of the changes in track support with ballast condition was conducted using track geometry changes as one safety-critical indicator of track support failure related to noncompliant ballast. This study requires industry support to provide track with suitable ballast conditions and revenue traffic to develop meaningful links between ballast and track geometry performance, i.e., track geometry degradation over time. FRA has an inherent role in this research, since the ballast rule is a fundamental structural requirement for track being considered for revision. Government resources, including autonomous track geometry measurements and ground-penetrating radar measurements, provide critical data that is not generally available to industry but necessary to uncover the links between track support and track structural performance. FRA investment in a single-pass structural evaluation system for track is providing the necessary data supporting this study.

Who else is researching this issue?

Track geometry degradation studies are currently being investigated by HyGround Engineering, a division of Loram. Class I railroads, such as CSX Transportation and Norfolk Southern, have expressed interest in participating in similar studies. Separate statistical studies have begun at the University of Delaware and there has been some discussion of starting a program at Texas A&M. However, solely statistical studies without structural condition-related data can only develop correlations that lack sufficient detail to make

direct links to the causes of deterioration. As emerging measures of track structural condition become more common, it is expected that more meaningful statistical studies will emerge.

Have we invested in this topic in the past and what have we learned to date?

FRA has invested in different components of this comprehensive project. Those past investments include research in GPR, track deflection, ballast lab testing, transition zone accelerometer testing, and ATGMS. The use of these prior research topics and technologies together in consist, represents a first for FRA and industry.

Objectives, activities, and what is the problem being addressed?

Reduced track support related to ballast can limit the capacity of track to withstand load, which can result in advanced track geometry deterioration rates or failure of track components. This project seeks to link reduced track support as measured by increasing ballast fouling and moisture saturation conditions to track performance. In this study, track performance has been mainly focused on track geometry degradation rates based on data collected using autonomous inspection systems.

The objective of the study is to assist RRS enforcement in developing quantitative means to assess fouled ballast locations requested by the industry in the waiver request. Both the industry and the FRA Office of Railroad Safety Enforcement envision having quantitative methods to identify noncompliant ballast in accordance with TSS section 213.103. To meet the objective, the project requires development of a better definition of reduced performance or fouled ballast, based on: field data linking track condition to track deterioration rate; monitoring of a full ballast deterioration cycle and associated track geometry trending analysis of those cycles from identifiable conditions to safety critical conditions; and development of a non-class-specific approach to the safety standards relative to the presence of fouled ballast, associated track geometry parameters, and safety risk.

The main activities during this project include routine autonomous (biweekly) track geometry measurements, field instrumentation of multiple sites to document any deterioration occurring at a rate faster than can be captured in biweekly track geometry trends, and periodic inspection using the single pass track structural assessment system to document the ballast condition along with other indicators of track structural condition.

Alignment with DOT Strategic Goals and/or DOT research priorities,

This effort aligns with DOT Strategic Goals of Safety, Infrastructure, and Innovation. With regard to Innovation, the single-pass track structural evaluation system (DOTX 218/220 consist) being used for the first time on this project, provides a comprehensive set of measurements linking track geometry to the structural performance of the track.

Expected total project cost and expected funding for FY 2020,

RD&T plans to request $190K for the final year (FY 2020) of this research project.

Is there a non-Federal financial contribution? If so, how much?

There is no non-Federal financial contribution to this project. There is, however, a substantial in-kind contribution from Burlington Northern Santa Fe (BNSF) Railway in the form of significant track time for instrumentation placement and maintenance, consist placement and movement of FRA's ATGMS vehicles (DOTX 225/226), periodic testing with the FRA single-pass inspection system (DOTX 218/220), fouled ballast site identification and selection, the hosting of ballast waiver field training sessions, and the hosting

of Ballast Waiver Pilot team meetings. In addition, BNSF has shared inspection and maintenance records critical to the success of interpreting the data collected on this project.

Train Control and Communication (TC&C) - High Priority Project 4: Railroad Crossing Violation Warning System (RCVW)

The TC&C division will continue the RCVW application project. RCVW is a vehicle-to-interface (V2I) application that leverages the latest developments in connected vehicle components and technologies developed under previous U.S. DOT-connected vehicle deployment projects, as well as expected deployment of connected vehicle technology in new cars. It consists of two physically separate subsystems: a vehicle-based subsystem (VBS) installed in connected vehicles and a roadside-based subsystem (RBS) integrated with roadside infrastructure at highway-railroad intersections (HRIs). Both subsystems are comprised of the same hardware and software components, such as a computing platform (CP) on which the RCVW software application executes, radios, and a Global Positioning System (GPS) module. A unique component to the VBS is the driver visual interface (DVI), which provides RCVW alerts and warnings to the vehicle operator.

Why should we pursue (or invest in) this research?

The project applies a systems engineering methodology to design, develop, test, and evaluate a prototype RCVW application, and demonstrate the potential for leveraging real-time connected vehicle concepts and services to enhance and transform rail crossing safety. Currently the auto industry is focusing on roadways and vehicles, not the safe traversing of the grade crossings. FRA RD&T is taking the lead with this research to focus the attention on grade crossing safety for connected and automated/autonomous vehicles.

The RCVW system provides real-time, conditions-based audible and visual alerting to vehicle operators to predict and warn drivers of predicted and imminent rail crossing violations for vehicles approaching or stopped within active rail crossings, respectively. The primary intended benefit for the RCVW application is the reduction in the frequency and severity of HRI safety-related incidents. However, the scalable and flexible design of the RCVW system affords potential future safety and mobility-related operational improvements, including:

- Reductions in emergency vehicle response times.
- Improved traffic flow and routing efficiency with nearby traffic control devices.
- Reduction in energy consumption.
- Improved air quality.

Who else is researching this issue?

RD&T is not aware of any public research that examines the safe interaction between a connected vehicle and a grade crossing. RD&T's research started in 2015, and the resultant technologies of that research was encouraging to further pursue refinement and suitability for commercialization. RD&T expects easy adoption by the auto industry due to RD&T's partnership with Honda Motors, which is providing vehicles and engineering support to the effort.

Have we invested in this topic in the past and what have we learned to date?

Yes, FRA has proven the viability of the technology and successfully demonstrated a prototype system.

Objectives, activities, and what is the problem being addressed?

The RCVW system uses the connected vehicle infrastructure and grade crossing status to determine if a vehicle is about to violate the active grade crossing warning (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.

RD&T 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, facilitating safe and consistent navigation of highway-rail grade crossings.
- Strengthening coordination between government safety agencies and private developers.

FY 2020 activities:
- Facilitate development of closed-loop communication protocols that can be supported by both railroads and automakers.
- Evaluate driver acceptance and effectiveness of connected vehicle technologies for grade crossing safety.

Alignment with DOT Strategic Goals and/or DOT research priorities,

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 2020,

Total cost through FY 2019 has been $1.66M. FY 2020 new funding is $1M.

Is there a non-Federal financial contribution? If so, how much?

Honda is providing vehicles and engineer support as an in-kind contribution to this research.

Human Factors - High Priority Project 5: FRA Office of Railroad Safety Support - Railroad Information Sharing Environment (RISE)

Why should we pursue (or invest in) this research?

FRA's Human Factors division is developing a pilot study to test the feasibility of a voluntary information sharing program for the rail industry. FRA has been supporting the development of non-regulatory strategies to address safety (e.g., Confidential Close Call Reporting System, Switching Operations Fatality Analysis).

Railroad operations are increasing in complexity. PTC is an example of how systems are increasing in complexity, and particularly, in terms of automation (e.g., track inspection vehicles), allowing greater interdependence between different parts of the railroad system. The result is that FRA may have less insight into how safe the system is and how unsafe events can occur. Technology is changing rapidly, making it difficult for individual organizations to keep up. Railroads, like other organizations, are also collecting more data than ever before (e.g., event recorder data, video data, communications and signal data, text narratives). This creates a multitude of data sources and data that can be difficult to organize without the necessary resources (people with analytical capabilities and software to make sense of it). FRA should take the lead in

determining how to better collect and manage safety data given this growing complexity and increasing quantity of data that is available to inform decision-making. One solution is to use these additional sources of data in a collaborative way through the pooling of resources (people and data) to better manage safety. RISE represents a research effort to learn if the railroad industry can make sense of this data in ways that can enhance safety.

Who else is researching this issue?

RISE is modeled after Federal Aviation Administration's (FAA's) Aviation Safety Information Analysis and Sharing (ASIAS). No other organization is creating an information-sharing partnership between the regulator, railroads, trade associations, labor organizations, and suppliers to share safety-sensitive data for mitigating safety problems. FRA would like to adopt a similar program that accomplishes the same purpose: Mitigate safety problems that railroad industry stakeholders want to solve.

Have we invested in this topic in the past and what have we learned to date?

No, FRA has not conducted a feasibility study to determine whether an information-sharing collective like RISE could be implemented in the railroad industry.

Objectives, activities, and what is the problem being addressed?

RISE is an industry partnership between stakeholders to learn from pooled sources of data. The idea behind RISE is to identify problems that stakeholders are aware of and analyze these pooled data sources to understand how they occur. RISE also uses these sources of data to identify emerging issues that may not be apparent yet. It can also be used to address known issues for which a feasible solution has not been found.

RISE can help a railroad identify interdependencies between different parts of the railroad system that create unsafe conditions but may not be evident from other methods used for identifying safety concerns. It can help the railroad learn how the individual, technology, and organizational practices interact to produce unintended outcomes. RISE can show how interactions between different parts of an organization and other entities can contribute to unsafe outcomes. Other methods that focus on a single source of data may miss these interactions that contribute to a railroad's safety concerns.

Alignment with DOT Strategic Goals and/or DOT research priorities,

RISE is aligned with the DOT Strategic Goal of Safety.

Expected total project cost and expected funding for FY 2020,

The total project cost for FY 2020 is $500,000. The expected total project cost is $5M.

Is there a non-Federal financial contribution? If so, how much?

No, there is no non-Federal financial contribution. However, railroads are providing in-kind support. RISE builds on existing partnerships between FRA and the railroads, similar to the collaboration on Railroad System Oversight Manager (RSOM), Confidential Close Call Reporting System (C3RS), Switching Operation Fatalities Analysis (SOFA), and Fatality Analysis of Maintenance-of-Way Employees and Signalmen (FAMES). It is a natural evolution in the development of safety management practices toward more collaboration to solve safety concerns.

Completed Project 1 - Stop Signal Overrun Good Practices Guide

Objectives and activities:

This report documents the findings and recommendations from an investigation into stop signal violations at several passenger railroads. The study collected data on accidents related to stop signal overruns (SSOs) from National Transportation Safety Board (NTSB) reports and from the FRA accident database to identify the common factors and provide a descriptive summary of the frequency and severity with which these events occur. SSO data for six passenger railroads was collected and analyzed to identify their frequency over time. Qualitative data in the form of documents describing SSOs and interviews with employees were conducted to identify how the railroad system produces SSOs. The study identified a wide variety of factors that contributed to SSOs and offered recommendations for mitigating these events.

Alignment with DOT Strategic Goals and/or DOT research priorities:

This research is aligned with DOT's Strategic Goal of Safety.

What was learned?

FRA learned that most often, SSOs are not the result of a single cause, but result from the confluence of multiple interacting factors. Regulatory, organizational, individual, and physical factors can exert a negative or positive effect on SSOs. These factors include:

- The physical environment and available technology;
- Individual and team behavior;
- Railroad organizational processes;
- Regulatory activities; and
- External factors.

Consequently, approaches to mitigating SSOs need to address these multiple factors. Addressing these multiple factors will not only result in reduced SSOs but will also contribute to overall system safety. FRA detailed findings and recommendations as they relate to these factors throughout the report.

What were the research outputs/outcomes?

RD&T produced a "Good Practices Guide" as a deliverable. This guide is non-regulatory and intended to be used by passenger railroads concerned with SSOs. Further, the practices recommended can improve safety in both new and existing systems. The practices are broadly applicable and informed by railroad data and employee first-hand accounts, as well as by research about the limits of human cognition. Individual railroads should evaluate this material and determine what is most suitable for them to put into practice given existing conditions and operational context.

Does further research need to be done? If yes, for what purpose?

No additional research is currently planned. This research was a follow-on from a previous FRA Technical Report, which documented why passenger trains pass stop signals. RD&T converted the recommendations from that report into a practical guidance document that railroads can use on their properties.

Will non-Federal stakeholders contribute to further research? If yes, how much?

No additional research in this area is currently planned.

What was the total cost?

The total cost of this research was $358,090.

Were non-Federal dollars leveraged? If so, how much?

Non-Federal dollars were not leveraged; however, six passenger railroads provided in-kind support. RD&T estimates the railroads provided 558 hours of in-kind support to the researchers, who conducted interviews, made observations and analyzed the railroads' safety data related to SSOs.

Completed Project 2 - *Driver Behavior at Highway-Rail Grade Crossings Using Naturalistic Driving Study Data and Driving Simulators*

Objectives and activities:

The Human Factors division provided funding to Michigan Technological University (Michigan Tech) to perform a quantitative evaluation of driver behavior at highway-rail grade crossings (HRGCs). The overall objective of this two-phase project was to investigate driver behavior at HRGCs using two distinct, but complimentary, techniques. Phase 1 of this project takes advantage of the extensive Second Strategic Highway Research Program (SHRP2) Naturalistic Driving Study (NDS) database, collected over several years. The NDS study approach allows for systematic analysis of in-vehicle video and other sensors for direct observation of drivers during typical driving activities at HRGCs. Specifically, Michigan Tech examined:

- Driver response to different traffic control devices (TCDs) in place at HRGCs.
- Driver behavior at HRGCs that have had accidents between 2000 and 2010 to see if there was a difference in behavior at these locations versus non-accident locations.

In Phase 2, Michigan Tech created simulated scenarios that resembled environments found in the NDS data. Driver data from these simulated scenarios was collected and compared with the NDS data sets, in the context of driver behavior when approaching HRGCs. More specifically, the objectives were to:

- Develop two simulated scenarios based on real-world crossings that are included in the NDS dataset.
- Recruit student drivers to participate in a driving simulation study where drivers are exposed to different HRGCs.
- Compare and contrast driver behavior between the NDS and simulated data sets, using the previously developed driver behavior score.

Alignment with DOT Strategic Goals and/or DOT research priorities,

This research was aligned with the DOT Strategic Goal of Safety.

What was learned?

The main findings of the study included the following:

- The NDS data analysis showed very little statistical difference in driving behavior between any of the TCDs analyzed. The only exception was the significantly higher mean scores at passive HRGCs equipped with stop signs. The other consistent finding was the higher mean scores for traversals that took place during the day versus night time.
- There was no significant evidence of systematic driver behavior differences in most other categories tested, such as behavior between genders or between age groups.
- While no statistical significance was tested, analysis on annual average daily traffic (AADT), trains per day and train/highway speed impact on driver behavior score provided interesting trends.

- In general, similar trends could be observed between NDS and simulator datasets, but there was more significant difference between scenarios in NDS than in simulated setting, a finding that may be attributed to the relative perception of "safeness" of the simulated environment.

What were the research outputs/outcomes?

The research output was a Technical Report and a presentation to the FRA Grade Crossing Task Force. Additionally, Michigan Tech produced the following reports, presentations, and Masters' thesis:

- Salim, A., and Lautala, P., *A Human Behavior Analysis of Highway-Railroad Grade Crossings Based on Environmental Conditions and Driver Demographics,* Transportation Research Board 98th Annual Meeting of the National Academies, Washington, DC, January 13-17, 2019.
- Landry, S., Jeon, M., Lautala, P., Dean, A, and Nelson, D. *How Do Drivers Behave at Highway-Rail Grade Crossings – Comparison of Data from Actual and Virtual Environments.* American Railway Engineering and Maintenance of Way Association (AREMA) 2018 Annual Conference, Chicago, IL, September 16-19, 2018.
- Landry, S., Wang, Y., Lautala, P., Nelson, D., and Jeon, M., *Driver behavior at simulated railroad crossings*. Proceedings of the 20th International Conference on Human-Computer Interaction (HCII2018), Nevada, USA, July 15-20, 2018.
- Salim, A., Lautala, P., Jeon, M., and Nelson, D., *Using Naturalistic Driving Study Data to Investigate Driver Behavior at Highway-Rail Grade Crossings,* ASME/ASCE/IEEE 2018 Joint Rail Conference, Pittsburgh, PA, April 18-20, 2018.
- Lautala P., Muhire, M., Salim, A., Jeon, M., Nelson, D., and Dean, A., *The Assessment of Driver Compliance at Highway-Railroad Grade Crossings Based on Naturalistic Driving Study Data*, Transportation Research Board 97th Annual Meeting of the National Academies, Washington, DC, January 7-11, 2018.
- Lautala P., Nelson, D., Dean, A., and Muhire, M., *Evaluating Driver Compliance at Highway-Rail Grade Crossings*, the Railway Interchange, Indianapolis, IN, Sept. 17-20, 2017.
- Dean, A., Lautala, P, and Nelson, D., *Effectiveness of Using SHRP2 Naturalistic Driving Study Data to Analyze Driver Behavior at Highway-Rail Grade Crossings*, ASME/ASCE/IEEE 2017 Joint Rail Conference, Philadelphia, PA, April 4-7, 2017.
- Oduru, S., and Lautala P., *Incorporating Life Cycle Assessment (LCA) in Freight Transportation Infrastructure Project Evaluation*, ASME/ASCE/IEEE 2017 Joint Rail Conference, Philadelphia, PA, April 4-7, 2017.
- Muhire, M., Lautala, P., Nelson, D., and Dean, A., *Selection of Representative Crossings Database for the Evaluation of Driver Behavior Over Highway-Rail Grade Crossings,* ASME/ASCE/IEEE 2017 Joint Rail Conference, Philadelphia, PA, April 4-7, 2017.

Presentations:

- Lautala, P., *Driver Behavior at Level Crossings – In-Vehicle Auditory Alerts and Naturalistic Driving Data Research in the USA,* International Union of Railways (UIC) Level Crossing Workshop, Paris, France, March 26, 2019.
- Lautala, P., Nelson, D., Jeon, M., and Muhire, M., *Using NDS data to evaluate driver behavior at highway – rail grade crossings,* Tenth SHRP 2 Safety Data Symposium, Washington, DC, October 6, 2017.
- Dean, A., Lautala, P., Nelson, D., and Jeon, M., *Development and Validation of Post-Processing Methods for the SHRP 2 Mask Head Pose Data,* Tenth SHRP 2 Safety Data Symposium, Washington, DC, October 6, 2017.

Master's Thesis:

- Salim, A., *Evaluation of Driver Behavior at Highway-Railroad Grade Crossings Based on Environmental Conditions and Driver Demographics,* MS Report, Michigan Technological University, Summer, 2018.

Does further research need to be done? If yes, for what purpose?

Yes, additional examinations of motorist behavior at grade crossing should be conducted.

Will non-Federal stakeholders contribute to further research? If yes, how much?

To be determined.

What was the total cost?

The total cost of the Michigan Tech study was $271,223.

Were non-Federal dollars leveraged? If so, how much?

Yes, Michigan Tech leveraged $112,000 in funding from the National University Rail Center (http://www.nurailcenter.org/), a former Tier-1 University Transportation Center.

Chapter 3 – FY 2020 Program Descriptions

FY 2020 RD&T Program Funding Details

RD&T Program Name	FY 2020 Enacted ($000)	FY 2020 Basic ($000)	FY 2020 Applied ($000)	FY 2020 Development ($000)	FY 2020 Technology ($000)
Railroad Systems Issues	$3,871*		$2,007	$1,084	$780
Track Research	$11,279		$4,540	$1,917	$4,822
Rolling Stock	$8,322*		$4,464	$1,508	$2,350
Train Control & Communication	$8,086		$1,132	$1,705	$5,249
Human Factors	$3,542*		$1,884	$734	$924
Totals	**$35,100****		**$14,027**	**$6,948**	**$14,125**

**Amounts exclude 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 excludes earmarks. All carryover amounts are included in the Project Spend Plan.*

FY 2020 RD&T Program Budget Request by DOT Strategic Goal

RD&T Program Name	FY 2020 Enacted ($000)	SAFETY ($000)	INFRA-STRUCTURE ($000)	INNOVATION ($000)	ACCOUNT-ABILITY ($000)
Railroad Systems	$3,871*	$3,871*			
Track Research	$11,279	$11,279			
Rolling Stock	$8,322*	$8,322*			
Train Control & Communication	$8,086	$8,086			
Human Factors	$3,542*	$3,542*			
Totals	**$35,100****	**$35,100****			

**Amounts exclude 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 excludes earmarks. All carryover amounts are included in the Project Spend Plan.*

Research, Development, and Technology
Research Portfolio Overview

Program Description/Activities/Objectives:

The mission of Federal Railroad Administration's (FRA) Office of Research, Development and Technology (RD&T) is to ensure the safe movement of people and goods by rail through research and the development of innovative technologies and solutions.

The Railroad Systems Issues (RSI) Research program directs the entire 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), FRA, and the Office of Railroad Policy and Development (RPD). The RSI Research program defines the strategy to meet these goals. Safety is the principal focus and goal of the RD&T program. While maintaining a safety focus, FRA's RD&T program yields solutions that contribute to all DOT goals to advance infrastructure, innovation, and accountability.

Rail safety has improved over the last 10 years, with accidents trending downward. However, FRA is still focused on improving the safety of railways for the American public and rail workers. RD&T's main objectives are:

- To reduce incidents and accidents involving America's railroads, saving lives, and reducing environmental hazards.
- To promote innovation and facilitate leadership across the industry.
- To understand the impact of technology on safety and the industry workforce.

RD&T achieves its objectives with continuous stakeholder engagement throughout a project's research, technology transfer, and acquisition life cycles. An additional RD&T objective is to promote innovation and facilitate leadership across the railroad industry in the exploration and use of technology and automation, advancing the railroad safety culture. For over a decade, RD&T's objective has been to better understand the benefits and impacts of technology on safety and workforce development. Due to the increased impact of technology and automation on the railroad industry, 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. Working with internal stakeholders like FRA's RRS, RD&T meets industry needs and address safety issues as they evolve.

The problems FRA is solving include:
- Reducing accidents caused by human error.
- Reducing track-related derailments.
- Reducing incidents and accidents related to grade crossing and trespassing.
- Investigating automation and technology.

Impact of Additional Funding:

RD&T's $40.6M planned spending (detailed on the FY 2020 Project Spend Plan) focuses research and activities to improve railroad safety in FY 2020. This AMRP considers the FY 2020 president's budget ($19M) and RD&T's full funding amount ($40.6M without carryover). RD&T's FY 2020 AMRP and president's budget reflects a reduction in funding which translates to a reduction of research investment. As a result, RD&T reprioritized projects through stakeholder engagement and alignment to DOT research priorities to meet the president's budget. Full funding with the additional $21.6M planned impacts RD&T's research program and railroad safety improvement as follows:

- 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.
- The additional funding will also help RD&T better respond to RRS needs.

Statutory Requirements:

Railroad research and development is statutorily mandated in the budgets prepared by the U.S. President, House of Representatives, and Senate. RD&T research and outcomes are aligned directly to the statuary requirements. The Short Line Safety Institute (SLSI) grant is managed by FRA's Human Factors division to improve the safety culture of Class II and Class III railroads. FRA has been working with the ASLRRA and the SLSI since funding was provided for this investment. The Rolling Stock division manages Safe Transportation of Energy Products (STEP) research to improve the safe transport of energy/hazardous materials on America's railroads. The RSI division created a contracting vehicle for administering and managing funding to universities on intelligent railroad systems. The RSI division created a contracting vehicle for administering and managing funding for public, private, and university partnerships to research rail system safety, capacity, and efficiency. The Human Factors and Train Control and Communication divisions conduct research on grade crossings (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,
- Automated train control,
- Train communications,
- Trespassing,
- Train environmental control, and
- Railcar signs.

Investments throughout the five divisions explore solutions to each of these priority areas, with the exception of electronically controlled pneumatic (ECP) brakes, which, per Congress, is no longer a priority. All RD&T divisions address automation issues that align with this recommendation. GX and trespassing are also a priority for RD&T, as it is a priority for FRA RRS. Each division's section reviews activities and outcomes relative to these statutory requirements.

RD&T collaborates with FRA RRS, which has a statutory requirement for a trespasser prevention strategy and a risk model to address the causal factors that lead to trespassing incidents on railroad property. The national strategy aims to prevent trespasser accidents and includes milestones and 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 RD&T 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. All five RD&T divisions conduct research in automation technology to help understand how to best use new technologies and minimize human errors associated with automation.

Projects conducted by the Track Research, Train Control and Communication (TC&C), 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 supporting the infrastructure of America's railroads. Projects conducted by Human Factors improves railroad safety culture. Project evaluations support RD&T's goals of 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	OST-R Research Topic Area
Safety	Automation, Systemic Safety Approach, and Human Factors

RD&T projects focus on problems that impact urban, suburban, and rural communities. FRA structures research to address high-priority problems wherever they may occur, maintaining a long-term vision on improving safety and responding to incidents during a fiscal year. 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. The Research with Universities on Intelligent Railroad Systems project will provide preference for projects that implement technology in rural areas (see the Program/Activities section).

USDOT Research Priorities:

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, 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 enable 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 the Office of Railroad Safety 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 49 *Code of Federal Regulations (CFR)* as outlined in this table:

Part #	Section Description
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
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 #	Section Description
Part 924	Highway Safety Improvement Program
Appendix E to Part 236	Human Machine Interface (HMI) Design

In addition to addressing 49 CFR, 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 Train Control and Communication Research program develops performance-based specifications and standards for Positive Train Control (PTC) safety systems and establishes the methodologies and procedures for data collection, monitoring, and analyses to improve safety and performance. The Track Research program focuses its efforts on developing the scientific basis for removing prescriptive-based regulations and moving toward performance-based regulations. 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. Each research program is working with the Office of Railroad Safety 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 involved in 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 the early detection of rail wheel defects reduces the risk of an accident caused by that type of defect. Positive Train Control research conducted by the Train Control and Communication division 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 line railroads, 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 research will inform FRA of rural and underserved areas' unique concerns and challenges 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 for 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. TT&C's cybersecurity focus is securing the communication and ensuring authentication of sender and receiver of PTC communications. Multiple PTC research efforts address cybersecurity in coordination with the individual railroads, the railroad industry as a whole, and with the U.S. Department of Homeland Security.

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, manufacturers/suppliers, universities, non-profits, private industry, city/State/Federal Government DOTs, and DOT 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 U.S.	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 the Environmental Protection Agency's (EPA's) revisions to noise emissions limits for trains

Beneficiary	Benefit(s) Received
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

Railroad Systems Issues
Funding Request $4,871,000

Program Description/Activities/Objectives:

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; research prioritization; strategic collaborations and partnerships; performance-based regulations; non-regulatory recommendations; railroad environmental issues; locomotive safety; project evaluation; 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, Colorado; and contractor support.

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.

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) $400,000
The TRB initiated this effort in conjunction with FRA to address safety needs and advanced improvements within the railroad industry. The focus of this project is to solicit innovation, ideas, and advanced technology applications in railroad safety. The Rail Safety IDEA committee members meet once a year (usually in December) and discuss all submitted proposals (about 15-20 are received annually) to select the most promising 2 or 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 fully independent, with no bias on behalf of any organization.

Anticipated Activities:
- Announcement – An IDEA Program Announcement will be issued annually to solicit proposals for Rail Safety IDEA program exploratory research projects. The announcement describes the program and criteria and provides guidelines for eligibility and preparing and submitting proposals.
- Evaluation of Proposals – Proposals will be evaluated on a competitive basis. The Rail Safety IDEA program committee will evaluate those proposals that meet technical eligibility criteria.
- Widespread announcement of contract opportunities for rail inventors.
- Management of projects to completion.
- Tracking of successful implementation of completed projects.

Expected Outcomes:

- Detailed Project Work Plan, Budget, and Schedule.
- Project Agreement between TRB and Sub-awardees (consultants/contractors).
- Quarterly Progress Reports (QPRs), using the FRA QPR template.
- Final Performance Report that should describe the cumulative activities of the project, including a complete description of the grantees' achievements with respect to the project objectives and milestones.
- Final Report for each selected project by the end of its POP. All Rail Safety IDEA reports will be published on TRB's website.

Project Selection $174,411

RD&T assesses its research priorities on an annual basis. RD&T implements this assessment using the Decision Lens software package. This project includes the activities and costs associated with maintaining the license for the prioritization software and implementing the prioritization process. RD&T conducts prioritization activities to effectively manage its budget and ensure that stakeholder and industry needs are included in the RD&T 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 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 R&D life cycle, RD&T staff evaluate the progress and usefulness of the research data and products in collaboration with research partners and other stakeholders. RD&T considers research progress as an input into its 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 determine how harm (expressed as equivalent fatalities, injuries, property damage, and evacuations) is distributed in the railroad industry and inform RD&T of areas where additional research may provide benefit. The SRM provides RD&T insight into where research investment may have influence on improving safety and is an input to the prioritization process.

Prioritization of research is accomplished using Decision Lens 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 alignment with DOT and FRA strategic priorities and risk.
- Weights – In collaboration with stakeholders, RD&T staff develop weighting for project prioritization each year, especially input from the Office of Railroad Safety.

During FY 2018, the Decision Lens model was significantly modified and is currently under review, testing, and assessment to determine if the prioritization tool will more accurately represent FRA RD&T requirements and better align with DOT Strategic Goals.

Anticipated Activities:

- Renew Decision Lens software license for an additional option year.
- Apply improved rating process to candidate research project for FY 2021 (Oct-Dec timeframe).
- Use results to inform FY 2021 AMRP.
- Exercise option for continued development and refinement of SRM.

Expected Outcomes:
- Robust FY 2021 research portfolio.
- Update SRM, which will be used to inform project selection process and serve as input to Decision Lens model.

Program Support $991,988
This project provides technical editing, analyst, and management support to RSI. FRA research produces various deliverables as part of the 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 $0**
The focus of this project is to educate and train RD&T PMs about project evaluation techniques, develop performance measures, and improve project progress and efficiency. PMs and external parties will evaluate projects conducted by the five RD&T divisions to measure success and 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.

* Funding for this research will be $0.00 with any current activities continuing.

Facilities and Equipment - Transportation Technology Center (TTC) $600,000
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 mission. 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. This effort aligns with DOT Strategic Goals of Safety, Infrastructure, Innovation, and Accountability. Other government agencies also 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 the 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 FTA and the U.S. Department of Defense are also involved in utilizing the facility.
- The U.S. Department of Energy (DOE) has used the facility to test new railroad cars to transport spent nuclear fuel.

RSI provides project evaluation funding to RD&T projects, including the TTC. Every year, TTC conducts an evaluation and assessment of facilities and equipment. TTC has a variety of track conditions, types of construction, and test bed configurations to test a large variety of laboratory equipment, track vehicles, operating conditions, and material types.

The Rail Dynamics Laboratory (RDL) was designed to house two major rail vehicle simulators and facilities to support laboratory services. The Vibration Test Unit (VTU) was placed in service in 1977 and is still in operation. The VTU is a computer-controlled, full-scale laboratory test device used in evaluating suspension characteristics of rail vehicles, component and vehicle natural frequencies, ride comfort, and lading responses. The VTU is used in modal characterizations to determine rigid body roll, pitch, bounce, yaw, and flexible modes of railcars, locomotives, and lading as well as in-ride quality evaluations.

The second unit, called the Simuloader, donated by the Union Tank Car Company in the mid-1980s, was installed in the low-bay portion of the RDL, and is currently in operation. The Simuloader is a computer-controlled, electro-hydraulic structural test device for applying dynamic forces directly to a full-scale railcar body, highway vehicle, and other heavy structure. It is used for full-scale multi-axial fatigue and durability testing of railcars, locomotives, on some off-highway vehicles, and in truss sections.

The third unit is the Mini-Shaker Unit (MSU). The unit is used to measure vehicle truck suspension system characteristics. The MSU is a system of reaction masses and a computer-controlled hydraulic actuator capable of applying vertical, lateral, or roll input dynamic forces. All machines use hydraulic pumps that are 34 years old and inefficient.

Anticipated Activities:
- Continue to refurbish and 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 mission.
- FRA and TTCI are responsible for the facility maintenance and make significant capital improvements to help ensure that it can adequately support research and test requirements. Therefore, as funding becomes available, FRA will fund, or share in funding, selected site improvements at the TTC.

Expected Outcomes:
- These activities will enhance the capabilities of supporting and conducting rail transportation technology, development, testing, standards-development, and training at the TTC.

*Railroad Systems Issues $0**
This project conducts research focused on safety, with secondary strategic alignment to innovation, infrastructure, and accountability in the railroad industry.

Anticipated Activities:
- No activities

Expected Outcomes:
- No activities

***** Funding for this research will be $0.00 with any current activities continuing.

Workforce Development (WFD) $150,000
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 workforce development in the railroad industry and impacts of automation and technology.

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 survey and analysis published.
- Continued stakeholder engagement.

Energy and Emissions Safety Research $300,000
In support of DOT Strategic Goals of Safety and Innovation and its research target of environmental stewardship, FRA undertakes research that will investigate the efficacy of alternative fuels to improve energy efficiency and reduce emissions in rail transportation. This research area focuses on supporting activities related to the real-world demonstration of alternative fuels, technologies, and improvements in standards for noise emissions to ensure its implementation on rail across the nation.

Research provides data in support of the safe operation and use of alternative fuels and engine improvement technologies. Newer innovative solutions for switching and passenger operations, such as hydrogen and fuel cell technologies, hold great potential for the U.S. rail market. Research on the structural requirements for liquid and gaseous hydrogen containers and their structural design is needed. The efficacy of current CFR standards to address and ensure the safe use of such fuels will be analyzed and decisions made to adjust accordingly. The research provides FRA RRS with the scientific basis for decision-making and the development of standards and requirements. FRA will collaborate with other federal agencies to ensure safe use of energy products.

Anticipated Activities:
- Impact and applicability study of hydrogen for rail applications.
- Identification of standards and best practices for hydrogen fuel usage for rail applications.
- Initial safety assessment of hydrogen and fuel cell technology for rail applications.

Expected Outcomes:
- Impact merit of study of hydrogen for rail transportation.
- Identification of safety research needed to further hydrogen and fuel cell technologies in the U.S.

Accessibility $75,000
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. Passengers using wheeled mobility devices on board passenger trains are at a disadvantage compared to other passengers. To reduce injuries and fatalities of rail passengers during derailments and collisions, intercity and commuter passenger railcar interiors are designed with row-to-row seating. Research has shown that row-to-row seating protects passengers by containing them between their seat and the seat in front of them by reducing the travel distance during a sudden deceleration of the train. Such protection is not afforded to passengers in wheeled mobility devices, who ride in open bay accessible locations. Research in the relative movement of wheeled mobility devices and its occupants in various seating configurations under low-speed collision will be assessed.

Anticipated Activities:
- Test of rear- and forward-facing wheeled mobility devices and its occupant in low-speed train-to-train collisions.
- Assessment of current state-of-the-art securement systems for wheeled mobility devices on board trains.

Expected Outcomes
- Data on the relative motion of wheeled mobility devices and their occupants in non-contained spaces.
- Assessment of rear-facing versus forward-facing seating to protect occupants of wheeled mobility devices.

Locomotive Safety (formerly Locomotive Engine Efficiency Research) $55,400
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 Goals of Safety and Innovation and the DOT Topical Research Areas of Promoting Safety and Preserving the Environment.

If FRA does not participate in these initial technology assessments, 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 on rail, the unique characteristics of such fuel will require a comprehensive gathering of base knowledge to ensure Federal standards are adequate for transportation in fuel tenders. There is no precedent for the safe transportation of this type of energy as a fuel or commodity.

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

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

Expected Outcomes:
- Improve efficiency and maintain safety through knowledge of the performance of locomotive engine systems.
- Foster relationships with the rail private sector.
- Ensure that emerging, innovative locomotive engine efficiency improvement technologies are safe.

*Research with Universities on Intelligent Railroad Systems $1,000,000**
This project will utilize funding from FY 2017 – FY 2019 provided to RD&T to support university research on intelligent railroad systems. FRA will use a broad agency announcement (BAA) to solicit 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 FY 2017, FY 2018 and FY 2019, 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 FY 2020.

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 that advance these technologies for rural application.
- Intelligent transportation systems.
- Workforce development.

*Office of Railroad Safety Support $412,485**
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:

- Establish and implement at FRA a program similar to FAA's Aviation Safety Information Analysis and Sharing (ASIAS).
- 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 to initiatives supporting RRS.

*****This research was originally funded at $0.00 with the $19M budget for FY 2020 with current activities continuing. RD&T planned for $412,485 for research activities if $40.6M was received in FY 2020.

Public, Private, and University Cooperative Research Agreement $450,000 (Totaling $2M from all divisions)

The Public, Private, and University Cooperative Research Agreement is a collaboration with the AAR to provide research opportunities to American academic institutions. 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 and 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 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 significant in-kind support from the railroad industry.

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.

Program Funding Note: Railroad Systems Issues amount includes $142,400 for travel as part of the Administrative expenses and $119,316 for Small Business Innovative Research RSI.

Statutory Requirements:

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

RD&T is collaborating with FRA RRS, which has a statutory requirement to implement the National Trespassing Strategy. RSI is the program that manages the Research with Universities on Intelligent Railroad Systems (IRS) funding and up to $4M for partnerships with universities to improve rail infrastructure.

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 DOT's Safety goal. Many RD&T research projects yield additional benefits in the goal 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. 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. 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 divisions and TRB support RD&T's goals of accountability and help gain insight on how RD&T will mature its performance measurement and evaluation efforts. Project prioritization conducted by the divisions to select research topics and focus supports RD&T's goal of accountability. RSI's research partnerships with TRB and AAR increase innovation and improve infrastructure in the railroad industry. 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. RSI supports the technology transfer efforts of all five divisions supporting DOT's Strategic Goal of Innovation.

DOT Strategic Goal	OST-R Research Topic Area
Safety	Systemic Safety Approach

USDOT Research Priorities:

Performance Based Regulations and Safety

All RD&T divisions support RRS by providing SME consultation, research, data, and tools to improve railroad safety and reduce accidents and incidents. This support provides RRS resources needed to establish safety requirements without creating additional regulation.

Improving the Mobility of Freight

Research conducted through the Research with Universities on Intelligent Railroad Systems and Public, Private, and University Cooperative Research Agreement projects will improve the mobility of freight. These projects have the ultimate goals of improving railroad safety and performance; enhancing 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.

Improving Mobility for Underserved Communities

Research conducted through the Research with Universities on Intelligent Railroad Systems and Public, Private, and University Cooperative Research Agreement projects will improve the mobility for underserved communities. These projects will seek to provide funding to research geared to increasing technology innovation in rural communities.

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 a biennial 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 a free FRA booth at the TRB annual exhibit.
Universities across the U.S.	In-kind contributions; subject matter expertise and research	Provide locomotive engine, duty cycle data; support testing activities; 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.
U.S. 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.
Railroads	Access to rail facilities	Subject matter expertise
Private industry	Product commercialization	Subject matter expertise
AAR	Funding, in-kind contribution; subject matter expertise	Subject matter expertise; insight into safety trends and problems and research needs
California Department of Transportation	In-kind contribution; subject matter expertise	Funding; subject matter expertise
U.S. Department of Energy	In-kind contribution; subject matter expertise	Funding; 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
Public	Reduced railroad accidents and fatalities High speed rail transportation, safer rail travel, reduced noise emission

Beneficiary	Benefit(s) Received
	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 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.

Track Research
Funding Request $11,279,000

Program Description/Activities/Objectives:
The Track Research program prepares for the future of rail transportation through applied research, development, and demonstration. As new technologies 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 Government. There are three primary research areas included in the program:

- Track structures and components,
- Vehicle and track performance, and
- Operation of research assets, including the DOT TTC Facility.

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

- Identifying, understanding, and mitigating track-related failure modes that pose significant risk to safe heavy axle load (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 the Office of Railroad Safety, the railroad industry, and consultants on how to build, model, and simulate different vehicle or track components to better understand the fundamentals of vehicle/track interaction and reduce derailment risk.
- Predicting, detecting, and preventing internal rail defects that lead to train derailments.
- Ensuring the safe and effective implementation of engineered-polymer composite (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.
- Supporting research partners and the railroad manufacturing community in vehicle qualification and evaluation testing.
- Understanding the root cause of rolling contact fatigue 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 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 focuses on overall railroad system efficiency.

Preventing derailments is a component to this efficiency. However, significant cost goes into track inspection, planned maintenance, and spot repair to prevent derailments.

The Track Research program 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 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 researchers to develop technology that will function well in practice. The Track Research program also benefits from partners providing non-Federal funding. Track Research receives $830,000 in supporting funds from AAR for HAL research and in-track testing, improved composite tie performance, and rolling contact fatigue testing.

In FY 2020, the Track Research program will conduct the following activities:

- Rail Performance Research Area
  - 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.
  - Prototype 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, vision) to identify broken rail discontinuities and alert railroad operating authorities before the next train arrives.
  - Automated, Solid-State Rail Joining Technology – Research and development of friction welding technologies to join rail sections. Cooperative research with industry, TTCI, and FRA to reduce or eliminate performance issues associated with flash butt and thermite welding techniques.
  - Innovative Treatments for Rail Steel – Research on heat treatment, coatings, and other technologies to improve the service life of running rails and special track work. (New Project)
  - Automated Frog Repair – Continue research and development of automated methods to repair worn frogs, wings, and other track appliances.

- Predictive Analytics Research Area
  - Predictive Analytics Using ATGMS – Leverage large volumes of ATGMS data to develop automated processes using innovative machine-learning techniques to analyze, predict, and report on safety-critical areas regarding track degradation.
  - Methodologies for the Evaluation of Track Inspection Technology Effectiveness – Develop sound methods and practices aimed at standardizing the procedure for evaluating the effectiveness of existing and emerging track inspection technologies prior to use in industry. (New Project)
  - Artificial Intelligence (AI) Technology for Track-related Defect Detection and Prediction – This includes innovative approaches for implementing AI technologies for the detection and/or prediction of track-related defects. The primary objective of this research is to develop AI-enabled, data-driven technologies. (New Project(s))
  - Automated Processing and Evaluation Tools – Continue development of innovative tools for predicting track structure degradation behavior as part of a multi-year cooperative research initiative with Metro-North Railroad (MNRR). With the practical procedure established in FY 2019, machine-learning algorithms can be effectively employed to automatically monitor track geometry measurements and identify locations with large deviations suggestive of excessive degradation rates, which will alert maintenance personnel of safety-related issues long before they become problematic.

- Track Stability Research Area
  - Improved Composite Tie Performance, Phase II – Augment testing and modeling currently being conducted to develop enhanced design, testing, and performance guidelines and criteria for EPC ties

to improve safety and reliability regarding their use in industry. Specifically, the areas of fatigue and thermal expansion will be addressed.
    - Prototype Reference Free Measurement of Rail Force Device – Effective management of thermal stresses in rail is critical to preventing rail buckles and pull-apart. 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.
    - Ballast Research Testing Program – Conclude 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.
    - Integrated Sensor Networks – Quantify track instabilities due to ballast movement using integrated sensor networks. Identify 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 a revenue service train.

- FRA Research Assets Area
    - HAL Research and In-Track Testing – Investigate the root cause of potential issues that may arise affecting safe HAL operations in our Nation's rail network. Install and evaluate new and innovative ideas and technologies at TTC and in revenue service, intended to mitigate the adverse effects HAL operating conditions pose to track system integrity. (New Project)
    - Innovative Track Inspection Technologies – Implement a ground-penetrating radar (GPR), light detection and ranging (LIDAR), vertical track deflection, nuclear magnetic resonance, and other technologies 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 Inspection Research Area
    - Change Detection Technology for FRA RRS DOTX 220 – Design, develop, install and test innovative change detection technology that leverages the existing Track Component Inspection System image data stream. The objective is defect detection and detection of safety-related track changes between inspection runs. (New Project)
    - Automated and Autonomous Change Detection Technology – Research and development of change detection technology suitable for deployment on Hi-Rail vehicles and on autonomous inspection platforms such as DOTX 225 and 226. The objective is to automate data analysis of track inspections to determine safety related changes to the track structure and report this information to stakeholders with limited human intervention.
    - Drone-Based Detect of Track Safety Risks – Develop image-based safety inspection technology that is deployed via Part 107 compliant unmanned aerial vehicle (UAV) platforms. (SBIR project Phase 2)
    - Intelligent Track Systems Technology – Innovative approaches to imbed sensors and detection and communications technologies within the track structure to allow for a type of self-enunciation when conditions warrant remedial maintenance or pose a threat to safe rail operations. The long-range objective is to develop technology that permits railroad track to communicate its state-of-repair directly, in a manner that is somewhat analogous to the way modern devices communicate via the internet of things (IoT). (New Project)
    - Automated Detection of Broken Spike Fasteners in Wood-Tie Railroad Track – Develop an automated inspection method for the detection of broken spike fasteners in the field. Specifically, develop a market-ready prototype ready for field testing (to establish operational capabilities and limitations) and possible commercialization.

- Special Activities Research Area
  - Collision Detection for Bridges – Research and development of technology to help categorize the type (train traffic, vehicle, maritime, etc.) and magnitude of bridge impacts to quantify the nature of bridge strikes. Procurement of one or two projects to develop bridge impact detection and characterization technology. These projects will be sourced through BAA 2019. (New Project)
  - University Research in Collaboration with AAR – Joint-funded research with universities resulting from AAR and FRA collaboration on the research topics.
  - Wireless Bridge Condition Monitoring – Continue research and development of wireless smart sensor technology to automatically assess the response of bridges to rail traffic to highlight safety issues. Advance the prototype wireless bridge condition monitoring system to near commercial status and execute technology transfer through industrialization partners. Research will continue to refine the data produced by the system and to gauge the effectiveness of the prototype rating scales developed in prior work. Expect to continue partnership with railroads and the FRA RRS office during this phase of development.
  - Robotics for Bridge Inspection – Phase 1 of the project will develop intelligent robotics to inspect rail bridges, thus eliminating the safety risk to track personnel. Robotic devices can perform cleaning and other "hands-on" activities not possible with drone aircraft. FY 2020 SBIR topic – Robotics for Bridge Inspection. One or two SBIR Phase 1 projects will begin development of robotics technology for detailed bridge inspection. (New Project, SBIR)
  - UAV Technology for Rail Applications – Coordinate the evaluation of UAV technology through cooperative programs with industry to demonstrate safety improvements by leveraging UAV technologies for more efficient and effective track inspections. (SBIR)
- Vehicle Track Performance
  - Precision Anomaly Curved Test Track – Construct at TTC a curved track section, in addition to the existing tangent section, that 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 used for simulation of vehicle/track performance.
  - Vehicle/Track Modeling, Simulation, and Validation – Continue 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 Surface Defects – This is an 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.

<u>Track and Structures – Rail Performance</u> $1,353,663

Rail integrity derailments and accidents cost the United States and its railroads about $50 million per year,[3] more than any other track defect. The 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.

Anticipated Activities:

- Automation of Detection for Ultrasonic Rail Inspection
  - Develop an automated rail head internal flaw characterization and sizing technology based on phased array ultrasonic inspections removing the burden of flaw size estimation from the field inspector.

[3] FRA Database

- Develop a remaining rail life estimator for an identified rail flaw. The rail inspection methodology is based on the damage tolerance approach, which implies existence of a "safe crack growth time," during which necessary repairs could be performed.

- Development of Rail Flaw Imaging Technology based on Ultrasonic Tomography
  - Develop a device that 3D image internal rail flaws for better sizing and identification and develop remaining rail life calculation through experimental testing and theory.
- Laser Vibrometer Measurements for Rail Integrity Inspection
  - Develop a non-contact rail integrity inspection system utilizing Doppler laser vibrometers.
- Non-contact Rail Inspection Prototype Improvements
  - Develop a non-contact rail integrity inspection system utilizing acoustic sensors and signal processing.
- TTCI Rail Integrity Research
  - Quantification and Evaluation of Rail Flaw Inspection Practices and Modern Rail Steel Defect Growth Analysis:
    (1) Expand the rail flaw master gage library at TTC to include naturally occurring rail flaws from the FAST, TTC and from the revenue service.
    (2) Optimize ultrasonic rail flaw detection parameters for commonly missed defect types.
    (3) Conduct modeling and simulation study to determine the feasibility of the flash IRT (infrared thermography) approach to detect anomalies in the rail base area.
    (4) Conduct modern rail steel studies to determine defect growth rate and rail life.
- Advancing Rail Flaw Detection Capability (New Project)
  Internal rail flaws can lead to train derailments that result in human fatalities and injuries, environmental damage, and high costs. This topic seeks projects that address one or more of the following rail flaw inspection research objectives:
  - Non-contact rail inspection at track speed (i.e., up to 45 mph or greater).
  - Full rail (i.e., not just rail head) inspection for internal and external defects.
  - Automation of rail flaw detection through machine learning, AI, or other means.
- Volpe Center Support IAA for Rail Performance
  - Support research and data analysis, Office of Railroad Safety requests, validation of deliverables, and evaluation of research proposals. Conduct and publish independent research which progresses the state of the art and understanding of rail science and defect growth in modern rail steels.
- Technical Support for FRA Office of Railroad Safety (Applied)
  - Support data and analysis requests from the FRA Office of Railroad Safety for rail performance issues.

Expected Outcomes:

- Improve automation of detection for internal rail flaws. These are difficult to detect and there is an undesirable variability between human operators in their detection performance.
- Refine and upgrade prototype able to display 3D images of internal rail flaws, resulting in more accurate sizing and rail life estimation.
- Improve capabilities of non-contact rail integrity inspection systems, both acoustic and laser Doppler-vibrometer-based. These systems could one day result in autonomous revenue service internal rail flaw inspection. This would be a game changer in terms of safety for the industry.
- Expand rail flaw library at TTCI and complete the feasibility study of the flash IRT (Infrared Thermography) approach to detect anomalies in the rail base area.
- Provide technical support to RRS for their work in the field, accident and defect investigations, RSAC, etc.
- Publish paper on rail science and support for evaluating proposals and technical deliverables.

<u>Track and Structures – Track Inspection Research Area</u> $1,920,000

This research addresses inspection technology and processes to improve track safety and decrease derailments through:

- Technology research that yields effective methods to detect and mitigate track safety risks.
- 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:

- Change Detection Technology for FRA RRS DOTX 220 (Applied) (New Project)
  - Design, develop, install and test innovative change detection technology that leverages the existing Track Component Inspection System image data stream and defect detection and detection of safety-related track changes between inspection runs.
  - Procurement of change/defect detection system for DOTX 220 along with research support to develop data products from the TCIS data stream. Work with FRA Automated Track Inspection Program (ATIP) program to establish requirements.
- Automated and Autonomous Change Detection Technology
  - Research and development of change detection technology suitable for deployment on Hi-Rail vehicles and on autonomous inspection platforms such as DOTX 225 and 226. The objective is to automate data analysis of track inspections to determine safety-related changes to the track structure and report this information to stakeholders with limited human intervention.
  - Continued development of change detection technology suitable for deployment on Hi-Rail vehicles in partnership with Amtrak and Class I railroads. This work will begin development of autonomous-capable system for use on DOTX 225/226, or another autonomous inspection platform.
- Drone-Based Detect of Track Safety Risks (SBIR project)
  - SBIR Phase 2/3 development of image-based safety inspection technology that is deployed via Part 107-compliant UAV platforms.
  - Continue development of UAV-based image technology to highlight safety concerns in railroad right-of-way (defects, safety changes, etc.) Project is Phase 2 of a SBIR program started in FY 2019 as Phase 1.
- Intelligent Track Systems Technology (New Project)
  - Innovative approaches to imbed sensors, detection, and communications technologies within the track structure to allow for a type of self-enunciation when conditions warrant remedial maintenance or pose a threat to safe rail operations. The long-range objective is to develop technology that permits railroad track to communicate its state-of-repair directly, in a manner somewhat analogous to the way modern devices communicate via the internet of things (IoT).
  - Launch one or two projects from BAA 2019 around intelligent track technologies. The objective is to embed sensors in critical areas of the track structure to constantly monitor performance, and report status on demand. In addition, the research will help to translate IoT technology to track safety management.
- Automated Detection of Broken Spike Fasteners in Wood-Tie Railroad Track (SBIR Phase 2 project)
  - Develop an automated inspection method for the detection of broken spike fasteners in the field. Specifically, develop a market-ready prototype ready for field testing (to establish operational capabilities and limitations) and possible commercialization.
- Volpe Center Support IAA
  - Support research and data analysis, validation of deliverables, and evaluation of research proposals. Conduct and publish independent research which progresses the state-of-the-art and understanding of advanced track inspection technologies.

Expected Outcomes:

- Useful data products from DOTX 220 image stream—defect detection and change control.
- Pre-production prototype and field testing of Hi-Rail change detection technology.
- Preliminary design and engineering of change detection system suitable for autonomous operation.
- Early applied research (feasibility assessment through lab and controlled field testing) of systems that will self-enunciate track safety issues.
- Field testing of drone-based inspection system.

- Develop and initiate field testing of an automated system for the detection of failed spikes in wood-tie track.
- Technical support from Volpe.

Track and Structures – Special Activities Research Area $200,000
This research area is focused on improving safety and state-of-good-repair of bridges, structures, track design, and special track work. The scope of this research includes collaborative projects with industry, including AAR.

Anticipated Activities:
- Collision Detection for Bridges (New Project)
  - Research and development of technology to help categorize the type (train traffic, vehicle, maritime, etc.) and magnitude of bridge impacts to quantify the nature of bridge strikes; and procurement of one or two projects to develop bridge impact detection and characterization technology. These projects sourced through BAA 2019.
- University Research in Collaboration with AAR
  - Joint-funded research with universities, because of AAR and FRA collaboration on the research topics.
- Wireless Bridge Condition Monitoring
  - Continue research and development of wireless smart sensor technology to automatically assess the response of bridges to rail traffic to highlight safety issues; advance the prototype wireless bridge condition monitoring system to near commercial status; and, execute technology transfer through industrialization partners. Research will continue to refine the data produced by the system and to gauge the effectiveness of the prototype rating scales developed in prior work. Expect to continue partnership with railroads and FRA RRS office during this phase of development.
- Robotics for Bridge Inspection (SBIR project)
  - Phase 1 project—develop intelligent robotics to inspect rail bridges, thus eliminating the safety risk to track personnel. Robotic devices can perform cleaning and other "hands-on" activities that are not possible with drone aircraft.
- UAV Technology for Rail Applications (SBIR)
  - Coordinate the evaluation of UAV technology through cooperative programs with industry to demonstrate safety improvements by leveraging UAV technologies for more efficient and effective track inspections. Possible Phase 2 SBIR from FY 2019 Phase 1 topic: Automated Drone-Based Grade Crossing Inspection System. Continue monitoring the use of drones for railway inspection and other activities. Continue close coordination of activities with FAA UAS office.

Expected Outcomes:
- Technical reports, journal articles, and other technology transfer items from the university research program with AAR.
- Early prototype development of bridge impact and characterization technology.
- Close wireless bridge condition monitoring system research with successful transfer to industry for commercialization.
- Early development of robotic bridge inspection technology.

Track and Structures – Track Stability – $2,328,000
This research addresses track support and subgrade issues to improve track safety and decrease derailments through:
- Track support and substructure research to support higher loads.
- Track buckling and panel shift research to study rapid track failure.

Track Support and Substructure
The goal of this research is to prevent derailments caused by track support and subgrade issues through improved understanding of track support and substructures. 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 those that have arisen with crude oil by rail traffic volume increases, exposes 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 and track conditions, including advanced GPR, gage restraint measurement systems, vertical track deflection systems, track geometry measurement systems, machine-based vision systems, and bridge scour/impact sensors—to name a few. 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.

Track Buckling and Panel Shift
This is caused when continuously welded rails heat up well above their stress-free temperature. This results in large compressive loads in the rails and can cause the track to explode out of alignment and cause a train derailment. These derailments and accidents cost the United States and its railroads about $14 million per year[4]. Some of the activities below work to improve the safety and reduce derailments in this area. –

Anticipated Activities:
- Ballast Waiver Study – Use of automated inspection systems to determine track geometry degradation rates as they relate to ballast fouling levels and moisture content and further develop guidance for the Office of Railroad Safety enforcement of fouled ballast locations having degraded track geometry conditions as applied in TSS section 213.103. The study will be conducted in partnership with AAR/BNSF.
- Track Strength and Innovative Track Inspection Technologies – The Gage Restraint Measurement System (GRMS) research program has achieved substantial success in demonstrating the technology of gage restraint measurement and its potential for improving railroad safety and maintenance planning efficiency by measuring and analyzing the lateral restraint capacity of track. Innovative technologies such as GPR, LIDAR, vertical track deflection, nuclear magnetic resonance, and others have huge potential to improve track safety, especially if the data products were tightly integrated with traditional track inspection systems such as GRMS and TGMS.
- Support for FRA R&D Fleet – Provide support across RPD-30 for automated testing of track, track support, and track substructure—as well as provide a research platform for demonstration of new technologies that have regulatory impact.
- GPR Research (testing and analysis) – GPR is part of automated suite of systems on FRA's DOTX 220/218 consist. Research in this area provides quantitative and qualitative data and analysis for fouled ballast, moisture levels, ballast pockets, and general ballast instability, in support of multiple FRA RRS projects.
- Volpe Center IAA- Ballast and Subgrade – Integration of project specific research to improve detection of track structural failure including assessment of fouled ballast impact on lateral resistance and track stability, track geometry degradation, and structural deterioration. Results are applied to the deployment of structural inspection technologies to develop improved structural deterioration forecasting using predictive analytics.
- Investigation of Ballast Characteristics Before and After Maintenance to Identify Locations of Continued Degradation – The support provided to the track structure from the ballast and subgrade is a critical

[4] FRA Database

contributor to smooth and stable track geometry. In locations where track geometry degrades, ballast maintenance/placement is routinely performed to smooth the track and in accordance with Track Safety Standards. Sometimes the track may continue to degrade after maintenance due to ballast instability. This research will investigate the ballast characteristics before and after maintenance to identify characteristics of locations where track could continue to degrade. In cooperation with engineers from Amtrak, researchers from the French National Railroad (SNCF), and a U.S. university, an advanced model of ballast dynamics during maintenance will be applied to North American ballast maintenance procedures, specifically as it applies to rail safety. The resulting projections of track structural characteristics will be validated using recently completed research, such as the SmartRock project at Penn State. This research is expected to result in recommendations for improved safety through optimization of ballast maintenance procedures and improve track inspectors' ability to identify recurring problem areas that present safety critical issues. (New Project)

- Automated Machine Vision Based Ballast Scanning System – This research will develop and demonstrate implementation of a machine vision-based ballast inspection system mounted on a moving platform. It will be a portable and efficient tool that acquires consistent images and laser scans from longitudinal shoulder cross-sections, and provide a non-destructive automated evaluation approach, capable of performing inspection continuously along the track. Percent degraded segments extracted from images will be linked to Selig's Fouling Index (FI). (New Project)
- Enhance Acoustic Birefringence Method for Measuring Rail Stress (Development)
    - Develop a reference-free longitudinal rail stress measurement device utilizing acoustic birefringence to prevent track buckle derailments.
- Image Processing and Machine Learning Algorithms to Measure Axial Stress in Rails (Development)
    - Develop a reference-free longitudinal rail stress measurement device utilizing image processing and machine learning to prevent track buckle derailments.
- Longitudinal Stress Measurements in Rail Using a Non-Contacting Reference-Free Vision-Based Approach (Development)
    - Develop a reference-free longitudinal rail stress measurement device utilizing a unique vision approach utilizing digital image correlation to prevent track buckle derailments.
- Longitudinal Rail Stress Measurement Using Ultrasound (Development)
    - Develop a reference-free longitudinal rail stress measurement device utilizing the interference of ultrasound to prevent track buckle derailments.
- Reference-free Longitudinal Rail Stress & Neutral Temperature Measurement Utilizing Multidirectional Elastic Waves (Development)
    - Develop a reference-free longitudinal rail stress measurement device utilizing multidirectional elastic waves to prevent track buckle derailments.
- Rail Temperature and Buckling Risk Prediction Website (Applied)
    - Upgrade Rail Temperature and Buckling Risk Prediction website to be more functional for FRA Office of Railroad Safety and industry.
- Upgrade of Continuous Welded Rail (CWR)-SAFE software (Applied)
    - Upgrade CWR-SAFE buckling prediction software to run on modern computers and provide a better user experience with input and output.
- TTCI Management of Rail Neutral Temperature (RNT) and Longitudinal Rail Force (Applied)
    - 1) Scoping/constructing of an RNT test bed at TTC; 2) determine the effects of track maintenance on RNT loss; 3) better curve movement monitoring technologies—all to prevent track buckle derailments.
- Volpe Center Support IAA – Track buckling and panel shift
    - Support research and data analysis, Office of Railroad Safety requests, validation of deliverables, and evaluation of research proposals.

Expected Outcomes:

- Expected outcomes for Track Support and Substructure research include providing data on the condition of existing rail infrastructure (track support and substructure), the analysis of that data thereof exposing,

quantifying, and assessing associated failure risks of the rail infrastructure. By providing a history of the condition change over time, these technologies and associated research can be applied to ensure accountability of the industry to maintain proper track support and stability to ensure safety.
- Expected outcomes for Track Buckling and Panel Shift research include: 1) Completing two or three promising Reference-free Longitudinal Rail Stress prototypes. (The funding on the others will be cut.) These prototypes have the potential to reduce buckled track derailments significantly. 2) Upgrading software, the industry can use to significantly reduce buckled track derailments. 3) Collaborative work with industry that will start designing a rail stress test bed in live track at TTCI to evaluate new technologies and build upon research and practices to reduce stress in rails that leads to buckled track derailments.

Tie and Fastener Performance and Integrity
This research will improve track safety and decrease derailments caused by tie and fastener performance through:
- Improved design and testing standards for EPC ties with respect to stress/load environment and thermal expansion characteristics.
- Development and timely incorporation of data-driven recommended practices for EPC tie use.

Anticipated Activities:
- Improved Composite Tie Performance, Phase II
    - Augment testing and modeling currently being conducted to develop enhanced design, testing, and performance guidelines and criteria for EPC ties to improve safety and reliability regarding their use in industry. Specifically, the areas of fatigue and thermal expansion will be addressed.

Expected Outcomes:
- Validated thermal expansion model for EPC ties.
- Applied research in the form of laboratory and controlled in-track testing of instrumented EPC ties.
- Improved performance guidelines and criteria for EPC ties, to be submitted for balloting and inclusion within the AREMA Manual for Railway Engineering.

R&D Facilities and Equipment – FRA Research Assets – On-Track Research and Testing $450,000
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 optimal operations and risk management practices for HAL through provision of critical research and technical assistance.

Anticipated Activities:
HAL Research and In-Track Testing:
- Investigate the root cause of potential issues that may arise affecting safe HAL operations.
- Install and evaluate new and innovative ideas and technologies, both at TTC and in revenue service, intended to mitigate the adverse effects HAL operating conditions pose to track system integrity.

Expected Outcomes:

- Expanded testing using the "Rainy Section" at TTC to investigate weld strains and failures associated with progressively deteriorated track support.
- Initiation of long-term study investigating the effects of varying track parameters on RNT loss and remediation.
- Evaluation of improved running-surface design for turnout frogs, to improve overall dynamic performance and reduce impact loads.

<u>System Performance and Analysis – Predictive Analytics</u> $1,000,000

This research focuses on the utilization of "Big Data" sources as well as the automation of track-related data processing and analyses to improve track safety and decrease derailments through:

- Leveraging large volumes of recursive track-related measurements to develop and implement automated processes for analyzing, predicting, and reporting locations affecting track safety.
- 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 track structure degradation and rail-related issues in the Nation's rail network.
- Development of data-driven technologies and innovations aimed at real-time decision making.

Anticipated Activities:

- Development of Predictive Analytics Using ATGMS
  - Leveraging large volumes of ATGMS data to develop automated processes using innovative machine-learning techniques to analyze, predict, and report on safety-critical areas regarding track degradation.
- Development of Methodologies for the Evaluation of Track Inspection Technology Effectiveness (New Project)
  - Develop sound methods and practices aimed at standardizing the procedure for evaluating the effectiveness of existing and emerging track inspection technologies prior to use in industry.
- AI Technology for Track-related Defect Detection & Prediction (New Project(s))
  - Innovative approaches for implementing AI technologies for detection and/or prediction of track-related defects. The primary objective of this research is to develop AI-enabled, data-driven technologies.

Expected Outcomes:

- Completion of an AI-driven decision-support tool for evaluating track segments for the risk of rail-related defects and derailments.
- Automate the alignment, processing, and reporting of ATGMS data for predicting areas approaching maintenance and safety limits.
- Improved capabilities for near-real-time analysis of track-related data
- Build upon groundwork for standardizing the evaluation of effectiveness of existing and emerging track inspection technologies.
- Initiate research efforts focused on the application of AI into track-related safety inspection techniques.

<u>R&D Facilities and Equipment – Transportation Technology Center (TTC)</u> $1,100,000

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:
The anticipated activities of this program area are to continue to refurbish and maintain the one-of-a-kind infrastructure at 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 mission. These activities include:

- Continue providing a facility that can perform railroad research and development, testing, and training, to enhance the safety of rail systems in both safety and security operations.
- Continue the enhancement of TTC's capabilities through strategic investment to existing facilities and equipment to support upcoming research and test needs.
- Continue the refurbishment of the rail system at TTC by replacing track materials such as rail, concrete and wood ties, switch components, anchors, spikes, etc., to refurbish track areas such as CSB yard tracks, Railroad Test Track (RTT), Precision Test Track (PTT) and Transit Test Track (TTT).
- Support environmental and green technology goals encouraging energy efficiency, use of renewable energy, reduction of toxins, recycling, reuse of materials, and water conservation.
- Raise awareness and encourage broader use of TTC facilities through creative and effective outreach efforts to other Government agencies and the private sector, while ensuring priority for FRA-sponsored activities and providing fair access to TTC facilities.

Expected Outcomes:
These activities will enhance the capabilities of facilities and equipment:

- Supporting and conducting Amtrak's high-speed new trainset testing.
- Commissioning of new locomotives.
- Upgrading the RTT catenary and substation system.
- Refurbishing track components around TTC.
- Upgrading the HVAC (heating, ventilation, and air conditioning) and lighting system in buildings by applying High Performance Sustainable Building guidelines.

System Performance and Analysis – Vehicle & Track Performance $2,200,000
This research area focuses on all aspects of vehicle/track interaction safety. Many train derailments or accidents cannot be attributed to defects in either track or train alone. Rather, they result from the adverse dynamic interaction between the two or the existence of unsafe conditions at the wheel-to-rail interface, (e.g., improper lubrication or contact geometry). Such interaction includes the instantaneous transfer of dynamic forces from vehicle to track and extends to cover cumulative effects on track degradation, such as wheel and rail wear, surface fatigue of the railhead, and deterioration of track geometry. Safety-related issues, which will benefit from this research, include the development of optimum wheel/rail profile maintenance and monitoring methods, the improved understanding of the impact of high-speed passenger service on existing tracks, and the influence of combined track geometry anomalies on vehicle safety, the establishment of limits of vehicle motion for minimum ride safety and quality, the refinement of performance-based vehicle-track interaction standards, and the development of guidelines for optimum inspection and maintenance practices to enhance system safety and durability. Research in this area presents an integral approach to understanding the behavior of the vehicle/track system to identify the safety implications arising from the dynamic interaction between track and train.

Anticipated Activities:

- Wheel/Rail Interface Research – Work with researchers from TTCI, National Railroad Construction and Maintenance Association, and Virginia Tech to study wheel/rail contact forces and influence of the friction modifier, wheel/rail profile on contact pressure and the creation of RCF.
- Influence of Track Irregularity and Surface Conditions on Vehicle Dynamics – Characterize track geometry for various operating conditions. Evaluate the performance of the vehicle over different track irregularities and establish safe threshold levels to prevent derailment.
- Development of Models and Procedures for Analysis of Railroad Vehicle/Track Dynamic – Work with Volpe Center, TTCI, and others to develop vehicle/track interaction models that are used to study and

investigate derailment safety, vehicle stability, ride quality, and loading on track structure. This work addresses best practices for model building and validation, modeling and testing of derailments, and examining the effects of falling friction, speed, and third body layer on wheel/rail contact forces.
- TGMS evaluation – Continue development of test procedure for testing TGMS and building the test track for testing the systems.

Expected Outcomes:
- Establish root cause for development of RCF and wheel/rail surface damage. Surface damage can cause catastrophic wheel/rail break. Another goal is to establish a method to evaluate the depth of RCF effectively to help in grinding and removal of RCF.
- Publish track geometry characterization for different operations in the U.S rail network. This information will be useful for establishing criteria for establishing track input for vehicle testing and evaluation and vehicle performance. Another potential outcome could be the establishment of thresholds for individual and combined geometry irregularities based on vehicle performance.
- Procedure and guidelines for creating and devaluating different components, friction modifiers, and suspension components for modelling vehicles for evaluating vehicle performance. Perform testing and simulations to assist the Office of Railroad Safety in vehicle qualification.
- Recommend procedure for testing track geometry measurement systems on tangent track. Finish the design of the curved test track at TTC and evaluate track construction options.

Public, Private, and University Cooperative Research Agreement $400,000 (Totaling $2M from all divisions). See Railroad Systems Issues for description, activities, and expected outcomes.

Program Funding Note: Track Research amount includes $327,337 for Small Business Innovative Research.

Statutory Requirements:

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

Program Alignment with Strategic Goals:

The 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 railroads such as longitudinal rail stress, the underlying cause of sun kinks, and rail pull-aparts. 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	OST-R Research Topic Area
Safety	Automation and Systemic Safety Approach

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 the mobility of passengers and freight. Throughout its research phases, 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.[5] Short line railroads provide critical transportation services for rural markets, such as farms and ranches. 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.

USDOT Research Priorities:

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 Performance program, computer modeling has been developed to evaluate 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 49 CFR Part 213 Track Safety Standards. By using computer-based modeling to determine current track safety thresholds, regulators can 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 more 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 Research 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, combined with the predictive analytics program, is an effort to improve the quality and coverage of inspections using automated means. The results of these programs 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 49 CFR 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

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

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 processing has 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 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. Short lines are typically located in underserved communities.

Research Collaboration Partners:

FRA works closely with universities, suppliers, and the railroad industry, including 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 include:

- 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 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 Railway	Track materials for test bed	More realistic testing than an average laboratory set-up
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
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)/Association of American Railroads (AAR)	Transportation research, development, security, training, and test activities, reliability, and productivity	Testing and training expertise and support and operation and maintenance of TTC

Benefits Detail

Beneficiary	Benefit(s) Received
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.

Rolling Stock
Funding Request $10,322,000

Program Description/Activities/Objectives:

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 crewmembers involved in 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. The program conducts tank car and hazardous materials research to improve the tank cars and packages that transport hazardous materials. Program staff also investigate accidents/incidents that release hazardous materials to find a way to reduce or mitigate the consequences of a release.

FRA's Rolling Stock research program improves railroad safety by evaluating risks and prioritizing RD&T projects to reduce these 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 derailments or collision accidents. This program's research helps determine criticality and methods for identifying, analyzing, and evaluating potential failure modes. FRA invests in research to develop 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 that are subsequently adopted by the industry.

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.

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

PHMSA is responsible for all HazMat regulations, including those pertaining 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 significant economic benefits. The cost of a HazMat release due to a train derailment has the potential to be in the billions of dollars, depending on where it happens and the hazard of the material that is released. Reducing this risk ensures that the occurrences and consequences 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 addition 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 PM of the Rolling Stock HazMat research program collaborates across DOT transportation modes to coordinate and 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, railcars, and intermodal tanks. PHMSA concentrates research on non-bulk packaging, including cylinders, drums, cardboard boxes, and bottles that can travel on any mode of transportation. Both PHSMA and RD&T collaborate to prevent the duplication of research, especially on topics that overlap their agreed-upon research responsibilities. For example, RD&T collaborates with PHMSA and the Maritime Administration (MARAD) to ensure the safety of containers and tank cars intended to transport LNG. The HazMat program manager meets bi-monthly with PHMSA to discuss research (current and future), attends meetings and conferences with PHMSA, and informs PHMSA of the results of inspections.

Some research areas require RD&T and PHMSA 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 the duplication of research. Frequent communication between the Operating Administrations (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 $0**
This research develops and improves the packages that carry hazardous materials, helping to reduce the release of material and minimize the consequences during rail accidents and incidents.

Anticipated Activities:
- Conduct tank car fire test.
- Perform over-the-road test with instrumented tank car.

Expected Outcomes:
- Provide FRA with information on the survivability of tank cars under fire conditions in case of train derailment accident.
- Determine cars' behavior and failure modes under normal transportation of tank cars.
- Provide a foundation for modifying, eliminating, or creating standards by leading research and capturing the results.
- Disseminate information to the rail and tank car industry so it can be used for tank car designs.
- Provide a realistic fire exposure to the test assembly (tank on flatcar) and make several key measurements, including interior and external temperatures, tank pressure, blast pressure a (if applicable), and heat flux.

* Funding for this research will be $0.00 with any current activities continuing. Tank Car Research is also funded in STEP.

HazMat – Structural Integrity $475,810
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 the study of the current fleet, identifying problems with current equipment and packages during routine inspections and accident investigations.

Anticipated Activities:
- Conduct tank car shop inspections.
- Review data for the One-Time Movement approvals submitted by the industry.

Expected Outcomes:
- Identify possible studies to address defects that affect the structural integrity of safety equipment and packages.
- Identify projects that can be proactive for existing and future safety equipment and packages.
- Provide RD&T and 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 $634,022
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.
- Evaluate the current computer models and improve the fire computer models, such as Analysis of Fire Effects on Tank Cars (AFFTAC).

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.
- Evaluate and document damage to railroad tank cars, and study and capture the results of the liquid/vapor release flow on pressure relief.

HazMat – Risk Analysis $200,000
This research will focus on the design and fabrication of an LNG tender in accordance with the AAR Standard in preparation for testing a highway-rail crossing accident. This research will evaluate the survivability of the cabinet that protects the valves.

Anticipated Activities:
- Design and fabricate a LNG tender with the cabinet that protects the enclosed valves and fittings in the event of a collision with a tractor-trailer.
- Evaluate the current computer models and improve the fire computer models, such as AFFTAC.

Expected Outcomes:
- To understand the structural performance of LNG tenders and tank cars.

*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 whether unit train operation of hazardous materials presents any unique or additional risks. Comparisons will be drawn between 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 assess the means for mitigating these risks.

As part of this project, FRA will continue providing engineering support in the research, design, fabrication, and test planning of ISO tanks, tank car fire testing, and the structural performance of this equipment when used as fuel tenders and energy products as a 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 FY 2020.

Anticipated Activities:
- Risk Analysis Methodology for Hazardous Material Unit and Manifest Trains Risk Analysis and Mitigation for Hazardous Material Unit Trains.
- Rapid Brake Signal Propagation on Freight Trains.

Expected Outcomes:
- Develop an online hazardous material (HazMat) release probabilistic risk assessment platform for real-time, local track risk analysis.
- Develop an alternate mechanism for rapid brake signal propagation—to be used on unit trains transporting energy products (High-Hazard Flammable Trains).

Rolling Stock Equipment and Components (RSEC)
Research efforts in the Rolling Stock Equipment and Components (RSEC) program area focus on the development and advancement of equipment and components. Improvements in defect detection, monitoring, and control are also critical to help reduce risks and improve safety. Both wayside and onboard detection and control systems offer diverse platforms for such research, demonstrations, and advances in safe train operations.

RSEC research addresses the improvements of 49 CFR Part 231 Railroad Safety Appliance Standards and 49 CFR 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, leading to more cost-efficient general repairs to their equipment.

<u>RSEC – Rolling Stock Component Safety</u> $2,462,190
The research comprised in this project proactively reduces risks through the prevention of above-track equipment and component failures (e.g., situational hazard prevention), and provides 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:
  - Conduct evaluations and demonstrations of advanced devices.
  - Research damage resistance models of freight components. (Tonnage carried per wheel has progressively increased, thus increasing stress to railway equipment, leading to increased risks).
  - Collaborate with the industry to evaluate failure modes and characteristics.

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.
- Increase understanding of equipment failure mechanisms and facilitate mitigation to reduce public safety risks.

RSEC - Rolling Stock Maintenance & Inspection $400,000

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.
- Collaborate and support the development, demonstration and implementation of advanced wayside and onboard monitoring and inspection of equipment and components to help reduce risks and ensure safe train operations.
- Develop methods to identify and track defective equipment and component systems.
- Assess and increase knowledge of advanced technology and its effectiveness in improving the safety of train operations and detection of defects.
- Conduct data analysis to support the evaluation of the performance of equipment and component systems.
- Improve the process for demonstrating and implementing new technology. Establish a standard process for wayside technology pilot demonstrations and implementation.

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 research.

- Advanced detection of failing equipment and component systems, including improved performance leading to more efficient and safe train operations; advanced equipment and component inspection and detection can lead to improved safety and will reduce in-service defects and proactively improve safety.
- Reduced incidents and accidents through proactive maintenance.

*RSEC - Train Handling & Operating Practices $0**
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 will also address Topology-based Resilience of Freight Transportation Networks, mainly to enhance the national freight system to address key challenges corresponding to several major trends affecting freight transportation including: (1) expected growth in freight tonnage; (2) underinvestment in the freight system; (3) difficulty in planning and implementing freight projects; (4) continued need to address safety, security, and resilience; and (5) increased global economic competition.

This research will also improve passenger truck designs that can provide superior equalization and curving performance to better handle rough track geometry. This work 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 strategies to identify and quantify safety risks in train operations.
- Evaluate and encourage safe practices for train makeup and handling to reduce accidents and derailments. Develop train handling and operational strategies to help reduce adverse effects on train operations.
- Defining the network topology of the freight transportation system. Also, defining the nodal and linkage bottlenecks, and the investment strategies to be examined.
- Investigate the current passenger truck designs and diagnose the main issues that need improvement.

Expected Outcomes:
- Improved safety of train operations and reliability.
- Conduct simulations to improve safety of train operations.
- Improved train makeup, reduced incidents/derailments, improved operational safety, reduced risk exposure to public.
- Improving the network topology to have the topological structure to offer robustness, resiliency, efficiency and effectiveness.
- Improved passenger truck designs that can provide superior equalization and curving performance to better handle rough track geometry.

* Funding for this research will be $0.00 with any current activities continuing.

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 *49 CFR Part 238 Passenger Equipment Safety Standards* and *49 CFR 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 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 – Passenger Locomotive Crashworthiness and Occupant Protection $1,475,000
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:
- Literature review is needed to analyze/investigate the current and previous state-of-the-art methods in Crash Energy Management (CEM) Technology and Implementations (world-wide).
- Conducting accurate and reliable feasibility analysis to improve the CEM capabilities of existing (in-service) passenger and critical HazMat equipment.
- Continued participation in the restarted APTA Passenger Rail Equipment Safety Standards committees to revise existing and/or develop new safety standards which are complementary to existing Federal regulations.
- Conduct of train-to-train test to affirm the behavior of the prototype deformable anti-climber and pushback coupler system as an effective means for inhibiting vehicle-to-vehicle override in collisions.
- Complete the engineering analyses related to passenger car side structure requirements which are being performed to address the outstanding NTSB recommendation to FRA.
- Completion of testing to assess the efficacy of retrofit collision posts on older "legacy" locomotives which are not compliant with modern industry crashworthiness standards.

Expected Outcomes:
- Improving the Crash Energy Management (CEM) capabilities of existing (in-service) passenger and critical hazmat equipment, through cost-effective adaptations and retrofit technology.
- Improved industry standards related to passenger car safety which are based on sound engineering derived from research outcomes.
- Evaluate results from train-to-train test with respect to override inhibition. Assess performance of alternate crashworthiness features and concepts which will be incorporated in the test program.
- Assess results from train-to-train to re-affirm the crash pulse (deceleration profile) in current regulations is soundly based on engineering data.
- Technical report on side strength alternatives and implications/impacts of potential changes to the existing FRA requirements.
- Technical report on effectiveness of retrofit collision posts on crashworthiness of legacy locomotives.

*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 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:
- Evaluating the results of the glazing retention test program to derive appropriate metrics for consideration in possible rulemaking and/or development of industry standards for enhanced glazing retention capacity.
- Leverage results from test program to make recommendations to the industry on most effective mechanisms from improving glazing retention capacity.

Expected Outcomes:
- Realistic test protocols and evaluation metrics for glazing retention capacity. This information will inform potential Federal regulations or industry (APTA) standard(s) related to glazing integrity.
- Industry recommendations for passenger car design alternatives to improved protection of glazing in derailments which are achievable and practical.

* Funding for this research will be $0.00 with any current activities continuing.

TOP - Fire Safety Research $980,000
The Fire Safety Research program will focus on improving current Federal regulations and industry standards for crashworthiness of passenger locomotive fuel tanks, fire performance of materials and components used in passenger rail equipment through research activities. Modern, innovative, alternative methods for evaluating fire performance of materials and components will improve safety, yield cost-savings opportunities, and advancement of modern tools for the passenger rail sector. The FRA requirements for materials fire safety performance and fuel tank crashworthiness were developed over 20 years ago. Passenger locomotive fuel tank structural requirements are based on static loading. Research into the performance of passenger locomotive fuel tanks under dynamic loads such as those seen in derailments and collisions is needed. Smaller profile diesel multiple unit (DMU), which is not a traditional passenger locomotive, fuel tanks are being assessed for their ability to perform under these loads as well. The research allows FRA to not only evaluate conventional and DMU fuel tanks under dynamic loads, it also validates test methods for evaluation of these types of equipment. This research allows FRA to review the current requirements for equivalency with newer standards, possibly allowing for the application of newer industry standards, promoting innovation and safety.

Anticipated Activities:
- Conduct room corner tests to validate scaling laws developed through simulations.
- Evaluate modern methods for measuring toxicity of burning materials.
- Simulation of other scenarios of fuel tank puncture using validated models.

Expected Outcomes:
- Validated scaling laws for modeling and simulation of rail car fire growth predictions.
- List of toxicity measurement methods.
- Final recommendations and reporting on performance of diesel multiple unit under dynamic loads.

*TOP - Emergency Preparedness Research $0**
Emergency Preparedness standards set forth the basic minimum requirements for communication and safe evacuation of passengers and crew in emergency situations. Understanding the dynamics of passenger interaction as evacuation ensues on a passenger train will provide FRA with quantitative data to make

decisions for improving the current standards. 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. It also supports providing vital safety information in a central location for all interested parties; this includes producing training videos and distributing it among related stakeholders and on FRA's website.

* Funding for this research will be $0.00 with any current activities continuing.

Anticipated Activities:
- Evaluate railEXODUS and other modern available emergency evacuation simulation tools for effectively predicting evacuation of passengers under various scenarios.
- Investigate integration of emergency evacuation tools such as railEXODUS with fire dynamics models for safety and emergency preparedness research.
- Educating the public and emergency responders on how to locate and use the Emergency Notification System (ENS) sign information.

Expected Outcomes:
- Identification of modern effective evacuation modeling tools for rail applications.
- Develop plan for integration of evacuation simulation tool and fire dynamics models.
- A training video to be distributed to the public and emergency responders on how to locate and use the ENS sign information. The format of the video should follow the same method as used for the rail safety videos. The video shall contain an overall safety message and details of the ENS signs.

*TOP - Cab Displays, Controls, & Environment $0**
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:
- Test and validate the candidate LED headlights for railroad application.

Expected Outcomes:
- Validate the new LED headlights and assist in adopting new standards and regulations for LED lights on locomotives.

* Funding for this research will be $0.00 with any current activities continuing.

*Natural Gas Safety Research $0**
Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG) are viable alternatives to diesel fuel. There are prototype service utilizations of natural gas (LNG and CNG) in the railroad industry. FRA provides support to the safe operation and use of such fuels through research focusing on the safety of fuel tenders and transportation containers. Efficacy of current CFR standards to address and ensure the safe use of such fuels will be analyzed and decisions made to adjust accordingly. The research provides FRA RRS with the scientific basis for decision-making and development of standards and requirements. FRA will collaborate with other federal agencies to ensure use of the energy product are safe.

Anticipated Activities:
- Development of standards for natural gas fuel tender.
- Review railroads natural gas fuel usage programs.

Expected Outcomes:
- Guidance documents to Office of Railroad Safety on natural gas fuel usage by nation's railroads.
- Grade-crossing impact test of LNG fuel tender.

*This funding comes from Congress and it is not included in the FY 2020 appropriations. Funding will be spent on LNG if RD&T has carryover from the last appropriations.

*TOP - Train Handling & Operating Practices $500,000**
This research will develop simulation scenarios to evaluate different network and capacity related parameters PTC technologies, and compare these to the conventional signaling and braking applications. Simulation scenarios include network topology, traffic type, and PTC 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 PTC, higher speed operations, and shared corridors. This research will also address Topology-based Resilience of Freight Transportation Networks, mainly to enhance the national freight system to address key challenges corresponding to several major trends affecting freight transportation including: (1) expected growth in freight tonnage; (2) underinvestment in the freight system; (3) difficulty in planning and implementing freight projects; (4) continued need to address safety, security, and resilience; and (5) increased global economic competition.

This research will also improve passenger truck designs that can provide superior equalization and curving performance to better handle rough track geometry. This work 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 strategies to identify and quantify safety risks in train operations.
- Evaluate and encourage safe practices for train makeup and handling to reduce accidents and derailments. Develop train handling and operational strategies to help reduce adverse effects on train operations.
- Defining the network topology of the freight transportation system. Also, defining the nodal and linkage bottlenecks, and the investment strategies to be examined.
- Investing in a new BAA topic.

Expected Outcomes:
- Improved safety of train operations and reliability.
- Conduct simulations to improve safety of train operations.
- Improved train makeup, reduced incidents/derailments, improved operational safety, reduced risk exposure to public.
- Improving the network topology to have the topological structure to offer robustness, resiliency, efficiency and effectiveness.
- Development of modeling and completed simulations for high-speed wireless networks.

Public, Private, and University Cooperative Research Agreement $400,000 (Totaling $2M from all divisions). See Railroad Systems Issues for description, activities, and expected outcomes.

Program Funding Note: Rolling Stock amount includes $530,000 for Program Management and $264,978 for Small Business Innovative Research.

Statutory Requirements:

Rolling Stock Research program is part of FRA's statutory requirement, it is the program that manages the Safe Transportation of Energy Products (STEP)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 standards and Federal regulations and more effective safety enforcement and compliance with those standards and regulations. 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 and collisions due to equipment failures, minimizing the consequences of those accidents, and minimizing hazardous material accidental releases.

DOT Strategic Goal	OST-R Research Topic Area
Safety	Systemic Safety Approach

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

USDOT Research Priorities:

Performance Based Regulations and Safety

The Rolling Stock Research program is involved in multiple performance-based regulations efforts. The program has established partnerships with other DOT modes, the railroad industry, law enforcement and state and local governments.

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 into 49 CFR Part 174). The program is working with 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, and maintenance of tank cars, addressing NTSB Safety Recommendations to FRA.

Rolling Stock PMs collaborated with the American Public Transportation Association (APTA) to revise standards and develop new safety standards as part of the Passenger Rail Equipment Safety Standards (PRESS) reactivation effort. 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 can perform longitudinal train dynamics simulations to conduct safety and risk evaluations, energy consumption studies, accident/incident investigations, train operations studies, ride quality evaluations, safety assessments 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 railroads about the condition of the rolling stock equipment and components and allow them to make more cost-efficient general repairs to their equipment to reduce risks and improve safety. The program is working with RRS to review the Class I railroads' waiver from the 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.

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 on-going research efforts. Program staff also publish research results for peer review in technical journals domestically.

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

Partner Detail

Partner Name	Contributions	Benefits of Partnership
Tank cars owners	In-kind contribution which include tank cars, valves, engineering consultation	Equipment, subject matter expertise

Partner Name	Contributions	Benefits of Partnership
Tank car shops	In-kind contribution which 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 and 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 Railway	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
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 FRA 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

Partner Name	Contributions	Benefits of Partnership
TTC, APTA, AAR, and TTCI	Passenger rail equipment manufacturers (e.g., Siemens, Alstom, Stadler) have donat window glazing for the 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
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	Transportation Review Board
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

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

Program Description/Activities/Objectives:
The Train Control and Communication (TC&C) 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.

FRA's TC&C 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.

TC&C Collaboration with Intelligent Transportation Systems Joint Programs Office (ITS-JPO)

The TC&C Research program collaborates with Intelligent Transportation Systems Joint Program Office (ITS-JPO) on multiple efforts. TC&C 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 efforts on research. Currently, RD&T is collaborating with ITS-JPO on automated behavior related to grade crossing (GX) to determine how to protect people in connected vehicle scenarios. TC&C received $1.5M funding over a 3-year period from ITS-JPO in a research collaboration on 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. RA will engage approximately 30 stakeholders across all modes of transportation to discuss a comprehensive review of automation systems, safety system designs and direction quarterly. 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.

Positive Train Control (PTC) Research $5,800,000

The PTC Research program conducts research to improve system safety, increase capacity and reduce railroad accidents. This is accomplished through research, development and test 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 Rail Safety Improvement Act (RSIA) of 2008 with complete implementation scheduled for December 31, 2020.

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, the trains can be continuously monitored to ensure that 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 the 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 will provide large safety benefits to the railroad industry as well as 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 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.

PTC Technology $1,000,000
This research addresses problems associated with finalizing PTC development, deployment, and continued long-term evolution and maintenance. It supports the design and development of innovative systems to ensure PTC interoperability and reliability continue to evolve with the pace of technology development.

The goal of this research 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 the RSIA '08 are satisfied while maintaining the value of this critical national transportation system.

Anticipated Activities:
- Investigation and enhancement of Track Circuit technologies to increase the safety and throughput.
- Development of technologies to safely increase the capacity of freight and passenger trains through densely populated areas.
- Development of improved PTC Adaptive Braking Algorithms.

Expected Outcomes:
- Increased efficiency of Positive Train Control without reducing safety.
- Increased rail capacity and throughput.
- Increased braking accuracy for freight and passenger trains.

PTC Interoperability $2,250,000
Interoperability is a requirement of Rail Safety Improvement Act of 2008 (RSIA '08). 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, costly and create extreme burden on FRA, railroads, passengers and freight railroad customers.

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 development of an automated system that will ensure interoperability.

The goal of this research 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.

Anticipated Activities:
- Positive Train Control Interoperability Testing Support.
- Monitoring and Analysis of Integrated Network (MAIN).
- Development of Interoperable Lifecycle Management (ILM) network.

Expected Outcomes:
- Efficient and reliable interoperability controls between railroads.
- Automated interoperability verification between differing railroads.
- Automated file transfers between railroads to determine problem areas and corrections.
- Centralized test facilities that serve small freight and commuter railroads to streamline testing and validation of their PTC systems.

PTC Next Generation $2,250,000
This research will identify and develop the methods, facilities, equipment and capabilities required for providing future industry PTC development. 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.

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.

Anticipated Activities:
- Early stage Automated Train Operation research and development.
- Development of advanced train location and positioning system.
- Investigation of novel Rail Communication Security approaches.

Expected Outcomes:
- Improved rail network capacity and decrease delays caused by PTC.
- Ability to accurately determine head of train and end of train locations to maintain safe train spacing at reduced headways.
- Rail network safety and efficiency improvements through interoperable automation.
- Increased cyber security of PTC systems.

*Intelligent Transportation Systems (ITS) $300,000**
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 connected 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 of the 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 crossing, in general, pertain to the requirements that the railroads must maintain regarding the safety devices and general upkeep of the highway-rail grade crossing. 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:
- Research cooperative automation technologies to improve grade crossing safety.
- Evaluate effectiveness of connected vehicle technologies in a field environment.
- Develop rail industry driven standards for communicating grade crossing status to connected or automated vehicles.

Expected Outcomes:
- Advancement of connected and automated vehicle technologies with a focus on grade crossing safety.
- Communication standards tightly coordinated between rail and automotive industry groups.

*****This research was originally funded at $0.00 with the $19M budget for FY 2020 with current activities continuing. RD&T planned for $300,000 for research activities if $40.6M was received in FY 2020.

Grade Crossing Safety and Trespass Prevention $1,627,248

The Grade Crossing Safety and Trespass Prevention research program conducts research to improve safety at highway-rail grade crossings and along railroad right-of ways (ROW), reduce collisions and incidents at highway-rail grade crossings, and decrease trespassing incursions at either highway-rail grade crossing or along the ROW. This is accomplished through research, development, and testing of new safety technologies for highway-rail grade crossings and trespassing countermeasures, as well as developing best practices for communities and stakeholders. Results of this research and development directly support the development of technology and safety standards to improve railroad operations as well as providing scientific research and data to support FRA regulations and rulemaking.

RD&T's Highway-Rail Grade Crossing and Trespass Countermeasures research improves *49 CFR Part 234 Grade Crossing Safety*. FRA has no regulations that deal with trespassers on railroad property, however FRA has developed strategies to target railroad trespassing. A complete list of this strategies is available at https://www.fra.dot.gov/Page/P1159. FRA has developed a Highway-Rail Grade Crossing and Trespassing Task Force (TF) which is responsible for implementing the strategies outlined above. The TF will develop new tools to identify areas that have high concentrations of trespassing and grade crossing violations and identifying what factors might be contributing to the high occurrences. RD&T's Highway-Rail Grade Crossing and Trespass Program Manager will work closely with the TF to research, development, and test new safety technologies for highway-rail grade crossings, as well as trespassing countermeasures that may be identified.

RD&T's research of ITS improves *49 CFR Part 234 Grade Crossing Safety* and *Part 924 Highway Safety Improvement Program*. Most of the 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 crossing, in general, pertain to the requirements that the railroads must maintain regarding the safety devices and general upkeep of the highway-rail grade crossing. 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 $127,248

Trespassing is the leading cause of incidents that occur on a railroad property. 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.

More than 70 percent of casualties happening on a railroad are due to trespass activities on railroad property. The goal of this research 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.

Anticipated Activities:

- Continue the research on how AI algorithms and related technologies can be used in reducing trespass occurrences along the railroad's ROW.
- Initiate the research on the effectiveness of mobile systems in monitoring unauthorized access to the railroad right of way. Mobile systems include but are not limited to unmanned aircraft vehicles or portable cameras (new).

Expected Outcomes:

- New technologies and solutions researched in this area are expected to be then evaluated, tested and implemented in a railroad or community environment leading to technology transfer and an increase to public safety.

Grade Crossing Technology $1,250,000

This research area 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.

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 area provide ways and tools to decrease this weakness.

Anticipated Activities:

- Explore the design and implementation of novel or improved warning devices (new).
- Investigate and test the integration of grade crossing locations into mapping providers (new).
- Investigate the use of PTC at grade crossings (new).
- Continue the investigation of use of cloud services for crossing inventory enhancements.

Expected Outcomes:

- New technologies and solutions are expected to be developed or tested for feasibility under this set or activities in this research area. Increased safety and reliability, along with a significant reduction in accountability and liability are expected.

*Grade Crossing Pedestrian Safety $0**

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.

When a grade crossing warning device activates, vehicles and pedestrians sometimes try to "go around the gates" or "beat the train." This objective of this research is to develop and test solutions that help prevent pedestrians from crossing the tracks in the presence of a moving train, leading to less incidents and accidents.

Anticipated Activities:

- Investigate the use of enforcement tools to mitigate the risk of accidents by pedestrians at grade crossings.
- Continue research on new and innovative treatments at pedestrian crossings.

Expected Outcomes:

- This research on how effective enforcement tools and innovative treatments is expected to result in increased safety as well and an increase in applied innovative techniques.

*This research will not include any additional funding for FY 2020, it will continue with any existing activities.

Grade Crossing Modeling and Simulation $150,000

This project will evaluate scenarios of possible safety improvements at grade crossing 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 are also evaluated to understand several implications that could result from a safety improvement. Also, part of this research area, is the analysis of new accident prediction models to better help stakeholders in decision making for grade crossing improvements including planning for grade separation, crossing closures or crossing upgrades.

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 project helps mitigate those costs.

Anticipated Activities:

- Continue the research on the effect of orientation of the Emergency Notification System (ENS) sign at grade crossings.
- Develop a new grade crossing accident prediction and severity model for use by the states and local communities.

Expected Outcomes:

- The new accident prediction and severity model will greatly assist state and local communities in better planning investments for either grade crossing improvements, closure or grade separation.
- The use of the simulation tools will allow to propose improvements in a non-destructive manner allowing for an increase in safety in an innovative way.

Grade Crossing and Trespass Outreach and Education $100,000
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.

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.

Anticipated Activities:
- Collaborating with organizations such as Operation Lifesaver.
- Assisting the FRA Office of Railroad Safety in events such as the listening sessions ongoing this year for grade crossings, and listening sessions at the top 10 counties with the highest trespass problems, as outlined in the Trespass Strategic Report recently submitted to Congress.
- Conclude the pilot law enforcement grant and develop a final report for internal use as well as the public.

Expected Outcomes:
- Improved public safety through further dissemination and reception of educational and training aids.
- Document the effectiveness of the presence of law enforcement along the railroad right-of-way.
- Formation of an international working group on trespass prevention.

Public, Private, and University Cooperative Research Agreement $400,000 (Totaling $2M from all divisions). See Railroad Systems Issues for description, activities, and expected outcomes.

Program Funding Note: Train Control and Communication amount includes $258,752 Small Business Innovative 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 TC&C program is funded with discretionary funds. The program meets the annual funding appropriation act's requirement to conduct train control and communications research. The TC&C 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 the 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 and rural communities' accessibility to participate in economic activities. This program also supports the Accountability goal in its role in reduction of regulatory burden.

DOT Strategic Goal	OST-R Research Topic Area
Safety	Automation and Systemic Safety Approach

Historically, "rural community impact" has not been a criterion for measuring the TC&C Division's research and development portfolio. The TC&C Division will develop metrics for assessing the impact of its research

on rural communities. The following shows how each TC&C research area aligns to DOT goals and impacts rural communities.

PTC research aligns with U.S. 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 U.S. 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, TC&C is working with FRA RRS to reduce the regulatory burden as part of the U.S. DOT Strategic Goal of Accountability. Rural communities will be safer PTC as the U.S. transportation system implements technology and interoperability.

GX and trespasser research aligns with U.S. 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 U.S. DOT Strategic Goals of Innovation and Infrastructure. TC&C 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.

USDOT Research Priorities:

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.

Cybersecurity

Train Control and Communication's research concerns include securing the communication and ensuring authentication of sender and receiver of the PTC communication.

Research Collaboration Partners:

All the research and development activities done by the TC&C Research program are done 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 percent or more of a project's value when you consider hourly wages, travel, and overhead.

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

- Annual evaluation by a special committee of the TRB.
- Monthly meeting and 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.
- Every research contract has a requirement to establish and maintain a project advisory group with project-specific monthly engagement meetings.

Finally, TC&C's Grade Crossing and Trespass Research program is conducting the trespass research described in the previous paragraphs with the objective to address the milestones outlined in Table 8, Strategic Area 1, of the "*National Strategy to Prevent Trespassing on Railroad Property*" Report to Congress.

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 Railway	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	Enhanced technology transfer success. Solutions that integrate seamlessly with railroad operations.
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.

Partner Name	Contribution	Benefit of Partnership
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 and system enhancements	Better product deploy ability
Meteorcomm	PTC 220 MHz 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
PanAm Railways	Right-of-way 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
SunRail	Right-of-way 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

Beneficiary	Benefit(s) Received
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

Human Factors
Funding Request $6,042,000

Program Description/Activities/Objectives:

Human errors account for more than one-third of all train accidents in the U.S. railroad industry. FRA's Human Factors (HF) Division conducts human factors research, engineering, development, and evaluation capabilities within a human systems integration framework related to safe rail operations and the safe integration of people with technology.

Railroads depend on the adaptability of people, as well as the performance of infrastructure, equipment, and control systems to keep the system safe. Railroad workers need knowledge, training, tools and alertness to do their jobs properly and to ensure the safety of the public, their coworkers, and themselves.

Across the rail industry there is a distinct lack of attention to human and human factors requirements in the design and development for safety and efficiency. Failure to include human factors requirements in the systems development of new technology, for example, will result in more risk-prone systems acquired by railroads. The HF Research program attempts to fill the gap in attention to human factors by providing the rail industry with education, guidance, and technology across four project areas: automation, operator performance (human fatigue), sponsorship and development of the Short Line Safety Institute (SLSI), and project evaluation.

Areas of research within the HF division include rail trespass and suicide prevention; motorist behavior at highway-rail grade crossings; program evaluation; automation, operating personnel information management and control; human fatigue; vigilance, attention and distraction; and support of the Short Line Safety Institute. Additionally, FRA's HF Research program provides support for FRA Office of Railroad Safety's training, education and outreach activities.

The Federal Government should fund human factors rail research 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 per the scientific method, which ensures high quality and a lack of bias.

HF 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 HF's projects, and how that benefits FRA, can be found in the next section. These contributions help FRA develop practical technology that will function well in practice. HF also benefits from partners providing non-federal funding on the following projects:

- A commuter railroad is contributing at least 50 percent of the cost of an SLSI safety culture assessment to support an RD&T pilot project (expected FY 2019).
- GE Global Research is contributing $247,553 towards *Design and Evaluation of a Robust Manual Locomotive Operating Mode as* part of a BAA.

Rail Trespass and Suicide Prevention $605,000
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. 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, and intentionally causing harm to oneself), FRA will need to continue to study mitigation strategies.

HF should examine the human behaviors associated with rail trespass and suicide, to increase rail safety and decrease the number of fatalities along the right-of-way. Fatalities along rights-of-way due to trespass and suicide can happen anywhere there is an active railroad.

FRA, which has tracked U.S. rail suicides since 2011, has learned that suicide prevention is something that rail carriers can do effectively, with the right training. FRA has also learned that media reporting of rail suicides can trigger copycat events.

The common causal factors for trespassing along railroad ROWs 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. 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.

Anticipated Activities:
FRA RD&T will assist FRA RRS in executing the Implementation Milestones listed in its 2018 report to Congress, *National Strategy to Prevent Trespassing on Railroad Property* (https://www.fra.dot.gov/eLib/Details/L19817).

These activities may include:
- Assisting rail transit agencies and non-profit organizations in developing targeted outreach and outreach campaigns for rail trespassing prevention, suicide prevention, and grade crossing safety.
- Identifying and developing, through independent analysis and collaboration with railroads and other stakeholders, known and new data sources and technology that could better identify trespasser hot spots or risk factors that lead to trespassing.
- Identifying, through collaboration with railroads as appropriate, existing and potential new analytical tools (including risk models) to effectively analyze trespasser data.
- Working through the executive and congressional budget cycles to identify funds for advocacy organizations to develop focused surveys of communities where trespasser incidents have been a persistent problem.
- Additional funding will be used to develop forms to collect information from the surveys, establish a database, and prepare reports for communities and FRA.
- Fund research that addresses trespasser mitigation through human factors engineering solutions and technology.
- Fund the research and development of technology to identify suicide risks and behaviors, including detection and intervention.
- Training railway staff on trespasser strikes using a high-fidelity simulator.

Expected Outcomes:
- Educational campaigns and outreach to communities related to the dangers of railroad trespassing and suicide prevention.
- Evaluation of the effectiveness of educational campaigns and outreach to communities, with assistance from non-profit organizations (e.g., SafeKids, Operation Lifesaver) and subject matter experts in FRA's Office of Railroad Safety.
- New analytic tools (e.g., risk models, additional datasets) to analyze trespasser data.
- Results of community surveys where trespasser incidents have been a persistent problem.
- Host trespasser prevention summits with representatives of the top 10 U.S. counties where trespass fatalities occur along railroad ROWs. Summits will include local community leaders, law enforcement,

railroads, and the public. Output will be community-specific action plans for addressing railroad trespassing.
- RD&T will begin coordination to work with rail carriers to better understand how training railway staff on trespasser strikes using a high-fidelity simulator may mitigate the effects of the incidents on railway workers and the number of incidents that occur.

Motorist Behavior at Highway-Rail Grade Crossings *$234,711*
This research studies GX to understand the underlying causes and human behaviors that result in pedestrians and vehicles 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.

This research seeks to develop interventions or solutions that increase motorist, pedestrian, and/or bicyclist compliance at active and passive highway-rail grade crossings through human factors engineering. The overall purpose is to reduce significant safety risks and improve safety by incorporating human factors engineering into grade crossing design and operation. FRA is interested in research ideas and pilot projects that address variables such as human perception, decision making, distraction and human fatigue.

RD&T's grade crossing safety research addresses *49 CFR Part 234 Grade Crossing Safety*.

Anticipated Activities:
- HF will work with TRAINFO (grade crossing status information indicating whether a train is at or near crossing the intersection) sent to passenger cars, if equipped, and to emergency vehicles. to develop a model that cross-references actual emergency service vehicle GPS data with detailed blockage data to precisely quantify the risk of crossing blockage delays for these vehicles, implement a system to predict when crossings will be blocked, and develop an in-vehicle notification system to help emergency service vehicle drivers avoid blocked crossings. This technology can be used to re-route while traveling to/from an emergency and help save response time and reduce fire damage. This research project was selected in the 2018 open competition BAA solicitation.
- Michigan Technological University, in collaboration with the Virginia Tech University, propose to develop in-vehicle auditory alerts (IVAAs) and investigate their effects on driver behaviors at highway-rail grade crossings (crossings). By using phased approaches, Michigan Tech team will explore the effects of various types of auditory alerts, driving/road conditions, distractors, and drivers' demographics. The project team will also develop an application and conduct a pilot test of IVAA designs in the real-world environment to investigate its feasibility and driver acceptance.

Expected Outcomes:
- The results of this research will help FRA quantify the risk of blocked crossings on emergency vehicles at a national level, evaluate the potential for information technology to mitigate this risk, and understand the most effective approaches for providing this information to emergency responders.
- The Michigan Tech study will provide a deeper understanding of how drivers behave depending on specific combinations of multiple factors at rail crossings. This research can yield both theoretical and practical outcomes. HF will obtain results about the complementary relationship between exterior visual signage and interior auditory alerts. In terms of practical applications, this research can provide critical information to developers interested in incorporating rail crossings (and IVAAs) in their applications. It can provide a data-based approach to design optimized in-vehicle auditory alerts for rail crossings and help with standardizing the warnings across platforms. More specifically, the project outcomes can provide design guidelines that consider different road conditions, auditory parameters, driver characteristics, distractions, and actual implementation directions.

Automation, Operating Personnel Information Management and Control $1,243,945
HF addresses the prudent integration of people with automation technology by conducting research on automation and manpower, personnel, human factors engineering, safety, and training. The objective of the Human Factors Division in this area is to conduct user and human reliability research with automation to help ensure safe and productive integration of automation technologies as industry develops them. 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 human-machine collaborative systems.

Information obtained from stakeholder meetings indicates the industry's interest in applying automated technology more widely to improve safety and efficiency. FRA Human Factors is responding to industry by exploring new display and HMI concepts and resulting technical requirements for technology implementation.

FRA seeks to explore the application and feasibility of electronic tools and automation to address rail operational safety, efficiency, and human performance issues. Research may address:

- The application of AI and machine learning in railroad operations.
- The integration of system functionality and system displays into a common operating interface (human interface) in railroad operations.
- The development of locomotive cab head-up display requirements, rail symbols, and messaging
- Risks of deskilling with the use of automation.
- Potential human performance issues related to training and operations with the introduction of automated systems.
- Development of electronic tools and automated systems to improve situational awareness (in dispatch, locomotive, other).

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

Anticipated Activities:

- Prototype development of a head-up display for locomotives to improve crew situational awareness for vehicle status and external environment status.
- Human-in-the-loop laboratory studies and tests of new head-up display interface.
- Select research related to the Automation and the Human-Machine Interface. FRA seeks to explore the application and feasibility of electronic tools and automation to address rail operational safety, efficiency, and human performance issues.
- The HF program will evaluate proposals meeting the technical eligibility criteria.

Expected Outcomes:

- Head-up display interface suitable for further testing in actual locomotive.
- Enhanced crew situational awareness.
- Path towards standards for HUD systems design.
- A vendor will be selected to research automation topics that may include the application of AI and machine learning in railroad operations.
- For each sponsored activity, the vendor will produce a Research Results report and a Technical report. Vendors will also submit Project Management Plans, Monthly Project Reports, and participate in monthly status calls.

Human Fatigue $200,000
HF will conduct research related to human fatigue, to better, understand workload factors and their contribution to human fatigue, and create human fatigue prediction models to help personnel work scheduling.

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, resulting in significant loss of life and property. fatigue brought on by sleep apnea and other medical and life style issues complicate this potential risk factor.

Commuting to work locations and yards to meet assigned trains figures into the total awake time for human fatigue calculations. To better understand the extent of commuting by locomotive crews, a survey of locomotive engineers and conductors will be conducted and analyzed. This is not unlike commute-time surveys taken in the aviation industry for flight crews, for example. One elemental outcome of this research will be to aid in the scheduling of locomotive crews so that the maximum opportunity to get proper rest is obtained.

Human Factors research also informs *49 CFR Parts 228 Hours of Service of Railroad Employees* and *270 System Safety Program*, which address railroad safety and human fatigue issues.

Anticipated Activities:

- Apply machine learning technology to develop an in-cab passive crew monitoring system.
- Conduct commute times survey for locomotive crews.
- FRA is interested in research and pilot projects that address the railroad industry's susceptibility to the risk of injury and property damage caused by human fatigue and loss of attentiveness. This susceptibility is the result of several inevitable factors surrounding the around-the-clock operations faced by railroaders, including irregular work hours, long shifts, and the unpredictability of on-duty times. FRA seeks to develop interventions and effective technological solutions to mitigate safety risks associated with these factors. Research proposals may address:
    - Scheduling/calling systems
    - Shiftwork
    - Calling assignments
    - Sleep disorder screening and treatment
    - Fail-safe technologies
    - Railroaders' Guide to Healthy Sleep (RGHS) website
- The HF Division will evaluate proposals meeting the technical eligibility requirements.

Expected Outcomes:

- Unlike the "alerter" systems, MEFA detects whether crew is mentally and physically disengaged in the driving task.
- Better crew scheduling.
- Provide non-regulatory guidance related to human fatigue issues railroaders commonly face, including an analogous sleep apnea screening tool.
- A vendor will be selected to research human fatigue topics that the identification of risk factors and mitigation strategies.
- For each sponsored activity, the vendor will produce a Research Results report and a Technical Report. Vendors will also submit Project Management Plans, Monthly Project Reports, and participate in monthly status calls.

<u>Project Evaluation</u> $180,000

Project evaluations of government-funded research projects use rigorous methods to assess the extent to which, and ways, programs goals are met. Project evaluations explain what is working/not working. 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:

- SLSI evaluation: The SLSI utilizes the most robust safety culture model in the U.S. railroad industry, and across the globe and across sectors, based on a systematic review of the academic literature conducted by RD&T through a program evaluation of the SLSI that has been ongoing since its inception. The SLSI is the only non-profit organization with a rigorously evaluated and demonstrated safety culture assessment process that can conduct a pilot safety culture assessment on a commuter operation. The HF Division will continue to support project evaluation activities; and, SLSI will also continue to provide funding for the evaluation activities.
- There is no existing resource on the Information and Communications Technology (ICT) knowledge, attitudes, and skills of the railroad industry. Many communication and outreach programs, such as the RGHS website, are developing products that use these ICT avenues or mediums, but little is known about how they might be received. This need has led to the development of a railroad industry focused ICT survey to gain a greater understanding of the industry's ICT.

  The HF Division will conduct a context evaluation, in the form of a needs assessment survey. This research will fill an important gap by identifying ICT knowledge, attitudes, and skills of TY&E railroaders, and their awareness and use of the RGHS website. Survey results could be used to 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:

- Results of the ICT Needs Assessment will allow for the improvement of the RGHS website content and modes of delivery. This research will provide a baseline for understanding the industry and answer important questions regarding how and where many railroaders can be reached by strategically and purposefully utilizing ICT.

*Vigilance, Attention, and Distraction $0**

Railroads require operators to manage and understand information provided by multiple systems while remaining cognizant of track and signal conditions. The goal of this research project is to understand ways to improve overall situational awareness through better vigilance and sustained attention. Research in this area includes conducting studies to learn more about cognition and behavior that indicates human sustained attention and vigilance and to develop displays or other interfaces that enable better situational awareness. The problems addressed by this research include:

- Poor operator/crew performance from lack of focus on the driving task.
- Poor operator performance due to failure to acquire and maintain proper situational awareness.
- Accidents caused by performance errors resulting from distraction or loss of situational awareness.

Anticipated Activities:

- Research on the human-machine interface, such as HUDs, to help crews acquire and maintain situational awareness and maintain focus on the driving task.
- Roadway Worker and Railroad Employee Protection: This research seeks solutions to mitigate risks to roadway workers, train crews, and railroad employees due to human factors errors by developing technologies to mitigate/eliminate risk. A thorough assessment of employee protection procedures and the associated human factors risks is necessary prior to developing countermeasures to these risks. Research proposals may address, but are not limited to:
  - Methods of protection outlined in CFR 214 Subpart C, such as Train Approach Warning
  - Adjacent track safety
  - Worker safety at highway-rail grade crossings
  - Railroad switching environment
- The HF Division will evaluation proposals meeting the technical eligibility.

Expected Outcomes:
- Fewer accidents due to distraction or loss of situational awareness.
- A vendor will be selected to research vigilance, attention and distraction topics that may include an assessment and development of countermeasures.
- For each sponsored activity, the vendor will produce a Research Results report and a Technical Report. Vendors will also submit Project Management Plans, Monthly Project Reports, and participate in monthly status calls.

*This research will not include any additional funding for FY 2020, it will continue with any existing activities.

*Short Line Safety Institute $2,500,000**
HF provides program monitoring and support of the SLSI. Since FY15, FRA RD&T has received at least $2 million annually from Congress specifically for the SLSI. Since FY 2014, FRA has partnered with the 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. The 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 SLSI. This is in addition to the total budget for FRA RD&T. If Congress chooses NOT to fund the $2.5M earmark, this activity will not be executed in 2019.

Anticipated Activities:
- Conduct safety culture assessments on Class II and Class III freight railroads.
- Pilot study of the Safety Culture Assessment process in that segment of the railroad industry.
- Develop training and education materials that address common safety gaps, as identified in the safety culture assessment process (e.g., leadership development training).
- Develop follow-up assessment process to measure change over time.

Expected Outcomes:
- Technical Reports, Research Results reports and presentations will be produced for FRA RD&T.
- The SLSI will present at key industry meetings (e.g., ASLRRA Annual Convention, ASLRRA Regional Meetings, Class I short line partners meetings).

FRA Office of Railroad Safety Support $315,000
The Human Factors Research program is collaborating with the Office of Railroad Safety to consider voluntary partnerships between industry and the regulator to improve railroad safety. RD&T supports a pilot project called the Railroad Information Sharing Environment (RISE), which is modeled after the successful Federal Aviation Administration (FAA) program, Aviation Safety Information Analysis and Sharing (ASIAS). ASIAS 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.

Anticipated Activities:

- Evaluation planning, administrative, technical, and other evaluation support services to the DOT Safety Council Evaluation Planning and Action Team.
- Planning and stakeholder outreach support for the RISE Program.
- Planning and implementation support for the SOFA/FAMES evaluation.

Expected Outcomes:

- Contract with RISE program vendor who de-identifies and stores sensitive railroad data.

Public, Private, and University Cooperative Research Agreement $350,000 (Totaling $2M from all divisions). See Railroad Systems Issues for description, activities, and expected outcomes.

Program Funding Note: Human Factors amount includes Program Management $300,000 and $113,344 for Small Business Innovative Research.

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 of the President, Congress and Senate. The HF Research program manages the SLSI funding in collaboration

Program Alignment with Strategic Goals:

The HF Research program aligns with the DOT Strategic Goal Safety and the DOT Topical Research Areas *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 HF Division provides evidence to the railroad industry on safety issues 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.

HFs' 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—which in turn will promote safer operations, profitable railroads, and economic growth.

DOT Strategic Goal	OST-R Research Topic Area
Safety	Automation, Systemic Safety Approach, and Human Factors

The HF Division has an impact on rural communities, most notably through the following project areas: Grade Crossing Safety, Trespasser and Suicide Prevention, and the 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 2018, 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 43 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.[6]

The vast majority of trespassing accidents occurred in counties with low population densities—counties that are mostly rural.[7] 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 rural areas. Safe operations on Class II and Class III railroads have several public benefits. By reducing heavy-haul truck 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 the 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, the SLSI has conducted 69 safety culture assessments on Class II and Class III railroads, reaching 6,221 railroad employees. The SLSI plans to conduct safety culture assessments in 2019.

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.

USDOT Research Priorities:

Economic Impact of Regulatory Reform

Reduction of human fatigue related accidents and incidents is an important objective for the Human Factors Division and one of NTSB's Most Wanted List problems.[8] The objective of the human fatigue program is to provide industry and the FRA regulatory branch with useful, scientific information on human fatigue so that

[6] *Data Analysis of Grade Crossing Incidents.* Accessed at https://www.fra.dot.gov/eLib/details/L01325 on March 23, 2018.

[7] *Trespass Event Risk Factors*. Accessed at https://www.fra.dot.gov/eLib/details/L16047 on March 22, 2018.

[8] NTSB's 2017–2018 "Most Wanted" list: https://www.ntsb.gov/safety/mwl/Pages/default.aspx

a science-based policy for managing human fatigue can be developed. Research will be conducted to learn more about behaviors, work/rest habits of railroad workers, environmental working conditions contributing to excessive human fatigue, and current operating practices. Human Factors research informs *49 CFR Parts 228 Hours of Service of Railroad Employees* and *270 System Safety Program*, which address railroad safety and human fatigue issues.

Research Collaboration Partners:

The input of stakeholders and the American public is critical for the HF Division to execute its research programs. While no metrics were used in tracking input in previous fiscal years, HF PMs are defining how they can track input in FY 2020. HF PMs work with stakeholder groups to address the needs of 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 transfers (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 research, development, and project evaluation findings.

HF conducted a Cab Technology Integration Laboratory (CTIL)meeting with stakeholders in January 2019. The purpose of the meeting:

- Facilitate mutual learning across CTIL stakeholders.
- Gather research ideas and better understand human factors concerns regarding technology and its integration into operating practices.
- Provide insight into the simulation and automation capabilities of CTIL to meet a wide range of stakeholder needs.

Outcomes:

- The meeting garnered high interest among stakeholders which included 12 stakeholders ranging from railroads, railroad equipment manufacturers, labor unions, and AAR.
- Stakeholder feedback and insights informed research topics for RD&T's BAA. Stakeholders identified operational safety issues related to partial automation and in-cab technologies more broadly to be incorporated in RD&T's research proposals that detail five topics related to automation.
- Stakeholders indicated an interest in ongoing stakeholder engagement. Participants voiced the value of the discussion and continued engagement with a potential of late Summer meeting.

Stakeholder input has enhanced 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.

Partner Detail

Partner Name	Contribution	Benefit of Partnership
DOT Human Factors Coordinating Committee (HFCC)	Share Human Factors research/information with each DOT mode.	As mentioned 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 OAs with a human factors program.

Partner Name	Contribution	Benefit of Partnership
		FRA's Human Factors Division Chief 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 (OA), 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 Highway-Rail Crossing and Trespasser Programs Division	Subject matter expertise, collaboration and recommendations.	HF PMs supports staff in RRS's Highway-Rail Crossing and Trespasser Programs Division
TC&C (RPD-33)	Collaboration, subject matter expertise, stakeholder engagement	Working closely with TC&C PMs, conduct jointly sponsored research projects. HF and TC&C provide an engineering and human factors approach to GX and trespassing research.
Union Pacific	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
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
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 Railway	Subject matter expertise, collaboration, data and recommendations.	Stakeholder engagement/understanding of human error situations

Partner Name	Contribution	Benefit of Partnership
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
GE Global Research	Collaboration, research studies	Stakeholder engagement
Short Line Safety Institute	Subject matter expertise, collaboration, data and recommendations.	Improved safety and safety culture in Class II and Class III freight railroads
Massachusetts Institute of Technology	Subject matter expertise, collaboration, data and recommendations.	
Michigan Technological University	Subject matter expertise, collaboration, data and recommendations.	HF expertise.
University of Connecticut	Subject matter expertise, collaboration, data and recommendations.	HF 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
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

Chapter 4 – FY 2021 Program Descriptions
Railroad Systems Issues

Program Description/Activities/Objectives:

The principal focus and goal of the RSI program is safety; however, program 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 research strategy; safety risk analysis; research prioritization; strategic collaborations and partnerships; performance-based regulations; non-regulatory recommendations; railroad environmental issues; locomotive safety; project evaluation; TRB's independent evaluation recommendations; workforce development; RD&T related technology transfer and travel; operations, maintenance, and equipment at the TTC facilities in Pueblo, Colorado; and contractor support.

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.

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)
The TRB initiated this effort in conjunction with FRA to address safety needs and advanced improvements within the railroad industry. The focus of this project is to solicit innovation, ideas and advanced technology applications in railroad safety. The Rail Safety IDEA committee members meet once a year (usually in December) and discuss all submitted proposals (about 15–20 are received annually) to select the most promising two or 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:
- Announcement - An IDEA Program Announcement will be issued annually to solicit proposals for Rail Safety IDEA program exploratory research projects. The announcement describes the program and criteria and provides guidelines for eligibility and preparing and submitting proposals.
- Evaluation of Proposals - Proposals will be evaluated on a competitive basis. The Rail Safety IDEA program committee will evaluate those proposals meeting the technical eligibility criteria.
- Widespread announcement of contract opportunities for rail inventors.
- Management of projects to completion.
- Tracking of successful implementation of completed projects.

Expected Outcomes:

- Detailed Project Work Plan, Budget, and Schedule.
- Project Agreement between TRB and Sub-awardees (consultants/contractors).
- Quarterly Progress Reports (using the FRA QPR template).
- Final Performance Report that should describe the cumulative activities of the Project, including a complete description of the Grantee's achievements with respect to the Project objectives and milestones.
- Final Report for each selected project by the end of its POP. All Rail Safety IDEA reports will be posted on TRB's website/publication.

Note: Activities and outcomes are similar to previous fiscal years because new projects are selected, executed, monitored and completed each fiscal year.

Project Selection

RD&T implements this assessment using the Decision Lens software package. This project includes the activities and costs associated with maintaining the license for the prioritization software and implementing the prioritization process. RD&T conducts annual prioritization activities to effectively manage its budget and ensure that stakeholder and industry needs are included in the RD&T investment planning process. DOT priorities and safety priorities, especially those provided by FRA RRS, are a major input into the process.

Anticipated Activities:

- Renew Decision Lens software license for an additional option year.
- Apply improved rating process to candidate research project for FY 2022 (Oct–Dec timeframe).
- Use results to inform FY 2022 AMRP.

Expected Outcomes:

- Robust FY 2022 research portfolio.

Program Support

This project provides technical editing, analyst and management support to RSI. FRA research produces various deliverables as part of the 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

The focus of this project is to educate and train program managers (PMs) to improve 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, and 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.

Facilities and Equipment - Transportation Technology Center (TTC)
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 the application of new technology for railways, suppliers, governments, and others involved in rail transportation. Other government agencies utilize the TTC:

Anticipated Activities:
- Continue to refurbish and 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.
- FRA and TTCI are responsible for the facility maintenance and make significant capital improvements to help ensure that it can adequately support research and test requirements. Therefore, as funding becomes available, FRA will fund, or share in funding, selected site improvements at the TTC.

Expected Outcomes:
- These activities will enhance the capabilities of supporting and conducting rail transportation technology, development, testing, standards-development, and training at the TTC.
- Note: Activities and outcomes are similar to previous fiscal years because equipment and facilities assessment take place each fiscal year.

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

Anticipated Activities:
No activities are planned. This may change with BAA selection.

Expected Outcomes:
No outcomes are planned. This may change with BAA selection.

Workforce Development (WFD)
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

In support of DOT Strategic Goals of Safety and Innovation and its research target of environmental stewardship, FRA undertakes research that will investigate efficacy of alternative fuels to improve energy efficiency and reduce emissions of rail transportation. This research area focuses on supporting activities related to real-world demonstration of alternative fuels, technologies and improvements in standards for noise emissions to ensure their implementation on rail systems across the nation.

Research provides data in support of the safe operation and use of alternative fuels and engine improvement technologies. Newer innovative solution for switching and passenger operations such as hydrogen and fuel cell technologies hold great potential for the U.S. rail market. Research on the structural requirements for liquid and gaseous hydrogen containers and their structural design is needed. The efficacy of current CFR standards to address and ensure the safe use of such fuels will be analyzed and decisions made to adjust accordingly. The research provides FRA RRS with the scientific basis for decision-making and development of standards and requirements. FRA will collaborate with other Federal agencies to ensure safe use of the energy products.

Anticipated Activities:
- Continued impact and applicability study of hydrogen for rail applications.
- Identification of standards and best practices for hydrogen fuel usage for rail applications.
- Additional safety assessment of hydrogen and fuel cell technology for rail applications.

Expected Outcomes:
- Identification of safety research needed to progress hydrogen and fuel cell technologies in U.S.

Accessibility

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. Passengers using wheeled mobility devices (WMDs) on board passenger trains are at a disadvantage in comparison to other passengers. To reduce injuries and fatalities of rail passengers during derailments and collision, the interior of intercity and commuter passenger rail car is designed with row-to-row seating. Research have shown that row-to-row seating protects passengers by containing them between their seat and the seat in front of them by reducing their travel distance during sudden deceleration of the train. Such protection is not afforded to passengers in WMDs situated in an open bay accessible location. Research in the relative movement of wheeled mobility devices and its occupant in various seating configurations in low-speed collisions will be assessed.

Anticipated Activities:
- Continued testing of rear and forward-facing WMDs and its occupant in low-speed train-to-train collision.
- Assessment of current state of art securement systems for WMDs on board trains.

Expected Outcomes
- Data on relative motion of wheeled mobility device and its occupant in non-contained spaces.

Locomotive Safety
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.

Anticipated Activities:
- Complete assessment of technological innovation using high-pressure heat exchangers in a real-world environment.
- Complete development and prototype demonstration of hybrid systems.

Expected Outcomes:
- Knowledge of the performance of locomotive engine systems to improve efficiency while maintaining safety.
- Ensure that emerging, innovative locomotive engine efficiency improvement technologies are safe.

Research with Universities on Intelligent Railroad Systems
This project will utilize funding from FY17– FY19 provided to RD&T to support university research on intelligent railroad systems. FRA will use a broad agency announcement (BAA) to solicit 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 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 2021.

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

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:

- Analysis of safety risks and identifying mitigations to those risks.
- Growth and maturity of RISE including industry involvement.

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

Public, Private, and University Cooperative Research Agreement

The Public, Private and University Cooperative Research Agreement is a collaboration with the 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 significant in-kind support from the railroad industry.

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.

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 RD&T 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. 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. 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 divisions and TRB support RD&T goals of accountability and helped gain insight on how RD&T will mature its performance measurement and evaluation efforts. Project prioritization conducted by the divisions to select research topics and focus supports RD&T's goal of accountability. RSI's research partnerships with TRB and AAR increase innovation and improve infrastructure in the railroad industry. 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. RSI supports the technology transfer efforts of all five divisions supporting DOT's goal of innovation. Each research effort has a distinct timeline for milestones, outcomes, deliverables, and completion. An outcome may take 30 days to multiple months depending upon the complexity of the outcome.

DOT Strategic Goal	OST-R Research Topic Area
Safety	Systemic Safety Approach

Chapter 4 – FY 2021 Program Descriptions
Track Research

Program Description/Activities/Objectives:

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

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

Anticipated Activities:
- Broken Rail Detection System on End of Train (Development)
  - Develop a cost-effective end of train device that can detect rail breaks utilizing a unique line laser approach.
- Non-contact rail integrity inspection prototype (Development)
  - Either laser or acoustic based or both.
- 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 the TTC for the entire research community to utilize in developing better detection systems. (Applied)
- Refine towards commercialization a unique automation of detection protocol for ultrasonic rail inspection. (Development)
- Refine towards commercialization a unique 3D rail flaw imaging technology. (Development)
- Build a prototype to utilize flash IRT (infrared thermography) to detect anomalies in the rail base area. (Development)
- Automated, Solid-State Rail Joining Technology (Applied) (New Project)
  - Research and development of friction welding technologies to join rail sections. Cooperative research with industry, TTCI, and FRA to reduce or eliminate performance issues associated with flash butt and thermite welding techniques.
- Innovative treatments for Rail Steel (Applied) (New Project)
  - Research on heat treatment, coatings, and other technologies to improve the service life of running rails and special track work.
- Automated Frog Repair (Applied)
  - Continue research and development of automated methods to repair worn frogs, wings and other track appliances.

Expected Outcomes:
- Complete third-generation of broken rail detection system for the end of trains.
- Develop third-generation non-contact rail integrity inspection system prototype and complete a probability of detection study.
- Expanded FRA rail defect library at the TTC for the entire research community.

- Complete field tests and assessment of automation of detection protocol for ultrasonic rail inspection. Generate list of needed improvements and research.
- Complete compact 3D rail flaw imaging prototype and rail life estimator software. Both are ripe for the commercial sector to develop the rest of the way and get out into industry where they can make a difference.
- Complete first field tests of flash IRT (Infrared Thermography) to detect anomalies in the rail base area.
- Restart research to develop a solid-state process to join full section rails in cooperative partnership with industry and other research organizations.
- Procure support for rail treatment and coatings research. Complete early development testing in the laboratory.
- Successfully close out research into automated, solid-state frog repair technology with completion of field testing and technology transfer to industry for commercialization.
- Re-start research and development of friction welding technologies to join rail sections. Cooperative research with industry, TTCI, and FRA to reduce or eliminate performance issues associated with flash butt and thermite welding techniques.
- Research on heat treatment, coatings and other technologies to improve the service life of running rails and special track work.
- Complete research and development of automated methods to repair worn frogs, wings and other track appliances. Transition technology to industry for commercialization.

System Performance & Analysis – Predictive Analytics

This research focuses on the utilization of "Big Data" sources as well as the automation of track-related data processing and analyses to improve track safety and decrease derailments.

Anticipated Activities:

- Complete methodologies for the evaluation of track inspection technology effectiveness and initiate process to incorporate as recommend practice.
- Continue research efforts focused on the application of AI into track-related safety inspection techniques.
- Complete automated procedures for the alignment, processing, and reporting of ATGMS data for predicting areas approaching maintenance and safety limits.
- Conduct field investigation into the root causes of track geometry degradation associated with observed/predicted accelerated deterioration trends.

Expected Outcomes:

- Continue to improve automated processing capabilities to move from near real-time to real-time analysis of track-related data.
- Establish a standardized procedure for evaluating the effectiveness of existing and emerging track inspection technologies prior to use in industry.
- Recommend remedial methods associated with observed/predicted deterioration trends that most improve track geometry stability and safety.

Track and Structures - Track Inspection Technology and Processes

This research improves the track inspection process to automate the detection of conditions that causes track failure and report the conditions and location to the railroad for remediation.

Anticipated Activities:

- Continued research and development of change detection technology suitable for deployment on autonomous inspection platforms. In addition, developing automated data analysis of track inspections to determine safety related changes to the track structure, and reports this information to stakeholders with limited human intervention.

- Continue. developing innovative approaches to imbed sensors and detection and communications technologies within the track structure to allow for a type of self-enunciation when conditions warrant remedial maintenance or pose a threat to safe rail operations.

Expected Outcomes:
- The long-range objective is to develop technology that permits railroad track to communicate its "state-of-repair" directly to the railroads, in a manner that is somewhat analogous to the way modern devices communicate via the internet of things (IoT).

R&D Facilities and Equipment – On-Track Research and Testing (FRA Research Assets)
This research seeks to conduct track research and testing to prevent derailments caused by track and structures.

Activities:
- Continue revenue service testing focused on the effects of cold weather on the integrity of the track system.
- Continue to investigate root causes of potential issues that may arise during FY20 affecting safe HAL operations.
- Install and evaluate new and innovative ideas and technologies, both at the TTC and in revenue service, intended to mitigate the adverse effects HAL operating conditions pose to track system integrity.

Expected Outcomes:
- Report results of expanded testing using the "rainy section" at the TTC to investigate weld strains and failures associated with progressively deteriorated track support.
- Test results on the effects of cold weather on the integrity of the track system (e.g., effects of frozen ballast on RNT loss and remediation).

R&D Facilities and Equipment - Transportation Technology Center (TTC)
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:
- Continue to refurbish and 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.
- FRA and TTCI are responsible for the facility maintenance and make significant capital improvements to help ensure that it can adequately support research and test requirements. Therefore, as funding becomes available, FRA will fund, or share in funding, for selected site improvements at the TTC.

Expected Outcomes:
- These activities will enhance the capabilities of supporting and conducting rail transportation technology, development, testing, standards-development, and training at the TTC.

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

Anticipated Activities:
- Develop reliable and automated method to assess track fouling and the development of safety criteria through 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.

Expected 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 indicating 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 Stability
This research builds upon the FY 2020 first and second-generation prototypes for measuring rail stress without a zero reference.

Anticipated Activities:
- Develop third generation prototypes to measure rail stress without a zero reference.
- Upgrade of CWR-Safe Software
- Upgrade Rail Temperature and Buckling Prediction website.
- Initiate build of a rail stress and rail neutral temperature test bed at the TTC.
- Research lateral stability and track buckling practices research.

Expected Outcomes:
- Prototypes to measure rail stress without a zero reference that are robust and repeatable.
- Completion of CWR-Safe software upgrade. An asset to industry and track researchers trying to understand and prevent track buckles.
- Completion of upgrade of Rail Temperature and Buckling Prediction Website. An asset that will be valuable to field and management personnel, both in government and in industry, for preventing track buckle derailments.
- In-progress build of a rail stress and rail neutral temperature test bed at TTC.
- Quantified ways to build, monitor and maintain track to prevent track buckles.

System Performance and Analysis – 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.

Anticipated Activities:
- Finish the design and start building a test bed that can be used to 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.

Expected Outcomes:
- Finished design and initiate building a test bed to validate the accuracy of track geometry measurement systems being 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 problematic conditions before they become a safety threat.

Anticipated 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.

Expected 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.

Anticipated Activities:
- Continue 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 3D 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 towards the end of 2020. Completion of the model perform simulation to see the response of the vehicle to multiple track input.

Expected 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 3D 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.

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.

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 the rail stresses will allow the railroads to monitor track condition and prioritize the maintenance needed to prevent derailments.

DOT Strategic Goal	OST-R Research Topic Area
Safety	Automation and Systemic Safety Approach

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 percent of freight rail in the U.S.[9] 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; these loads are common and particularly affect the rail support structure, including ties and ballast. The application of high loads to new territory to satisfy transportation demands (such as crude oil rail traffic) exposed 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.

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

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 towards the end of 2020.

Chapter 4 – FY 2021 Program Descriptions
Rolling Stock

Program Description/Activities/Objectives:

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

HazMat – Tank Car Research
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:
- Fire test on an LPG tank car
- Side and head impact test on a DOT 113 tank car

Expected Outcomes:
- Improve the computer model and update current regulation on thermos protection.
- Update computer model to include cryogenic tank cars.

HazMat – Structural Integrity
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 the current fleet, identifying problems with current equipment and packages.

Anticipated Activities:
- Testing of different pressure relief valves used on tank cars.
- Perform a rollover protection test on a current DOT 117.

Expected Outcomes:
- Improve the performance of pressure relief devices.
- Improve the rollover protection for new tank cars.

HazMat – Accident Consequence Reduction
This research will study the loading and unloading practices of hazardous material to improve the operating practices and securement of packages 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.

*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 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:

- Fire Performance of Alternative Fuel Tenders Continue with Phase II of the Risk Analysis Methodology.
- Continue with Phase II of Risk Analysis and Mitigation.
- Continue with Phase II of Rapid Brake Signal Propagation on Freight Trains.

Expected Outcomes:

- Develop an online hazardous material (HazMat) release probabilistic risk assessment platform for real-time, local track risk analysis.
- Develop an alternate mechanism for rapid brake signal propagation, to be used on unit trains transporting energy products (High Hazard Flammable Trains).
- Develop a detailed research and test plan to understand the risk exposure of LNG/CNG tender operations under fire conditions.

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 on-board detection and control systems offer diverse platforms for such research and demonstration.

RSEC - Rolling Stock Component Safety

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:

- 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.
- Continue to research methods to measure the predictability of equipment health and component wear life.
    - Conduct evaluations and demonstrations of advanced devices.
    - Research damage resistance models of freight components. (Tonnage carried per wheel has progressively increased thus increasing stress to railway equipment leading to increased risks).
    - Collaborate with the industry to evaluate failure modes and characteristics.

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.
- Increased understanding of equipment failure mechanisms and facilitate mitigation to reduce public safety risks.

RSEC - Rolling Stock Maintenance & Inspection

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:

- Analysis of broken axles trends and causes.

Expected Outcomes:

- Detailed analysis of broken axles trends and causes, and recommendation to eliminate or mitigate their hazards.

RSEC - Train Handling & Operating Practices

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 will also address Topology-based Resilience of Freight Transportation Networks, mainly to enhance the national freight system to address key challenges corresponding to several major trends affecting freight transportation including: (1) expected growth in freight tonnage, (2) underinvestment in the freight system, (3) difficulty in planning and implementing freight projects, (4) continued need to address safety, security, and resilience, and (5) increased global economic competition.

This research will also improve passenger truck designs that can provide superior equalization and curving performance to better handle rough track geometry.

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:

- Continue to define the network topology of the freight transportation system. Also, defining the nodal and linkage bottlenecks, and the investment strategies to be examined.
- Continue to investigate current passenger truck designs and diagnose the main issues that need improvement.

Expected Outcomes:

- Continue to improve the network topology to have the topological structure to offer robustness, resiliency, efficiency and effectiveness. Enhancing the network to meet the current increasing challenges.
- Continue to improve passenger truck designs that can provide superior equalization and curving performance to better handle rough track geometry.

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 is to promote and improve the safety of the national passenger rail transportation system.

TOP - Locomotive Crashworthiness and Occupant Protection

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:

- Continue the literature review and analyzation/investigation of the current and previous state-of-the-art methods in crash energy management (CEM) technology and implementations (world-wide).
- Continue conducting accurate and reliable feasibility analysis to improve the CEM capabilities of existing (in-service) passenger and critical hazmat equipment.
- Continue to evaluate geometric compatibility between coach cars and locomotives in collisions. Translate these into additional potential load cases with appropriate evaluation criteria to ensure stable performance under moderate collision conditions
- Re-evaluation of traditional anti-climbing requirements if push-back couplers and CEM are present (may not need same load requirements to be sustained while achieving the same or better performance when compared to conventionally designed equipment).
- Re-evaluation of end frame elastic requirements for passenger vehicles with CEM. Some designs may prematurely activate crush zones but still have significant residual strength to function as intended.

Expected Outcomes:

- Improving the crash energy management (CEM) capabilities of existing (in-service) passenger and critical hazmat equipment, through cost-effective adaptations and retrofit technology.
- The re-evaluation activities described above will take advantage of more sophisticated modelling capabilities which exist and apply them to the structural analyses of alternative passenger equipment

designs. Outcomes will be technical data which can be leveraged to inform potential improvements to existing safety standards.

TOP - Glazing Standards

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 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:

- Assuming that the activities occur in FY19 and FY20 as planned, this activity will essentially be completed. Activities to be performed would be limited to finishing what may not have been completed and/or revising the scope to respond to NTSB's assessment of FRA's response to this safety recommendation.

Expected Outcomes:

- Final draft of proposed APTA safety standard for improved glazing retention capacity.

TOP - Fire Safety Research

The Fire Safety Research program will focus on improving current Federal regulations and industry standards for crashworthiness of passenger locomotive fuel tanks, fire performance of materials and components used in passenger rail equipment through research activities. Modern, innovative, alternative methods for evaluating fire performance of materials and components will improve safety, yield cost-savings opportunities, and advancement of modern tools for the passenger rail sector. FRA requirements for materials fire safety performance and fuel tank crashworthiness were developed over 20 years ago. Passenger locomotive fuel tank structural requirements are based on static loading. Research into the performance of passenger locomotive fuel tanks under dynamic loads such as those seen in derailments and collisions is needed. Smaller profile diesel multiple unit (DMU), which is not a traditional passenger locomotive, fuel tanks are being assessed for their ability to perform under these loads as well. The research allows FRA to not only evaluate conventional and DMU fuel tanks under dynamics loads, it also validates test methods that can be for evaluation of these types of equipment. This research allows FRA to review the current requirements for equivalency with newer standards, possibly allowing for the application of newer industry standards, promoting innovation and safety. This research allows FRA to review the current requirements for equivalency with newer standards, possibly allowing for the application of newer industry standards, promoting innovation and safety.

Anticipated Activities:

- Conduct room corner tests to validate scaling laws developed through simulations.
- Evaluate modern methods for measuring toxicity of burning materials.
- Simulation of other scenarios of fuel tank puncture using validated models.

Expected Outcomes:

- Validated scaling laws for modeling and simulation of rail car fire growth predictions.
- List of toxicity measurement methods.

- Final recommendations and reporting on performance of DMU under dynamic loads.

TOP - Emergency Preparedness Research

Emergency Preparedness standards set forth the basic minimum requirement for communication and safe evacuation of passengers and crew in emergency situations. Understanding the dynamics of passenger interaction as evacuation ensues on a passenger train will provide FRA with quantitation data to make decisions for improving the current standards. 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. It also supports providing vital safety information in a central location for all interested parties; this includes producing training videos and distributing it among related stakeholders and on the FRA website.

Anticipated Activities:

- Continue to evaluate railEXODUS and other modern available emergency evacuation simulation tools for effectively predicting evacuation of passengers under various scenarios.
- Investigate integration of emergency evacuation tools such as railEXODUS with fire dynamics model for safety and emergency preparedness research.
- Educating the public and emergency responders on how to locate and use the Emergency Notification System (ENS) sign information.

Expected Outcomes:

- Identification of modern effective evacuation modeling tool for rail applications.
- Develop plan for integration of evacuation simulation tool and fire dynamics models.
- A training video to be distributed to the public and emergency responders on how to locate and use ENS sign information. The format of the video should follow the same method as used for the rail safety videos. The video shall contain an overall safety message and details of the ENS signs.

TOP - Cab Displays, Controls, & Environment

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:

- Continue to test and validate the candidate LED headlights for railroad application.

Expected Outcomes:

- Validate the new LED headlights and assist in adopting new standards and regulations for LED lights on locomotives.

Liquefied Natural Gas (LNG) - Natural Gas Safety Research

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

Anticipated Activities:

- Development of standards for natural gas fuel tender.
- Review of railroads' natural gas fuel usage programs.

Expected Outcomes:

- Guidance documents to RRS on natural gas fuel usage by nation's railroads.
- Grade-crossing impact test of LNG fuel tender.

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	OST-R Research Topic Area
Safety	Systemic Safety Approach

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

Chapter 4 – FY 2021 Program Descriptions
Train Control and Communication

Program Description/Activities/Objectives:

The Train Control and Communication (TC&C) 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
This research addresses problems associated with finalizing PTC development, deployment, and continued long-term evolution and maintenance. It supports the design and development of innovative systems to ensure PTC interoperability and reliability continue to evolve with the pace of technology development.

Anticipated Activities:
- Testing of enhanced track circuit technologies to increase the safety and throughput.
- Continue development of technologies to safely increase the capacity of freight and passenger trains through densely populated areas.
- Testing of improved PTC adaptive braking algorithms.

Expected Outcomes:
- Validate increased efficiency of PTC without reducing safety.
- Increased rail capacity and throughput.
- Increased braking accuracy for freight and passenger trains.

PTC Interoperability
Interoperability is the requirement that all railroads can 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, costly and create extreme burden on FRA, railroads, passengers and freight railroad customers.

Interoperability is a requirement of the 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 development of an automated system that will ensure interoperability.

Anticipated Activities:
- PTC interoperability testing support.
- Next phase development of Monitoring and Analysis of Integrated Network (MAIN).
- Development of ILM network.

Expected Outcomes:
- Efficient and reliable interoperability controls between railroads.
- Automated interoperability verification between differing railroads.
- Automated file transfers between railroads to determine problem areas and corrections.
- Centralized test facilities that serve small freight and commuter railroads to streamline testing and validation of their PTC systems.

PTC Next Generation
This research will identify and develop the methods, facilities, equipment and capabilities required for providing future industry PTC development. 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:
- Applied automated train operation research and development.
- Testing of advanced train location and positioning system.
- Standardization of new rail communication security techniques.

Expected Outcomes:
- Improved rail network capacity and decreased delays caused by PTC.
- Rail network safety and efficiency improvements through interoperable automation.
- Increased cyber security of PTC systems.

Intelligent Transportation Systems (ITS)
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 connected 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 of the highway-grade crossing regulations, especially those pertaining to the interactions of highway users, fall under FHWA or the Federal Motor Carriers Safety Administration (FMCSA). The regulations that FRA puts forth on highway-grade crossing, in general, pertain to the requirements that the railroads must maintain regarding the safety devices and general upkeep of the highway-rail grade crossing. 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 automation technologies to improve grade crossing safety.
- Evaluate effectiveness of connected vehicle technologies in a field environment.
- Develop rail industry-driven standards for communicating grade crossing status to connected or automated vehicles.

Expected Outcomes:
- Advancement of connected and automated vehicle technologies with a focus on grade crossing safety.
- Communication standards tightly coordinated between rail and automotive industry groups.

Trespass Countermeasures
Continue to work with stakeholders in developing new tools and technologies to address trespassing on railroad ROWs.

Anticipated Activities:

- Continue and/or develop new work on AI applied to railroad trespassing.
- Continue working on the effectiveness of mobile systems used for detection of trespassing activities within any given railroad.
- Develop new research ideas based on the input of the several stakeholders involved in trespassing issues.

Expected Outcomes:

- The outcome of the research described at a high level above is then expected to be transferred to other stakeholders, such as railroads or local communities for further development and implementation, thus increasing public safety.

Grade Crossing Technology

Continue to work with universities, industry, railroads and public sector in exploring new technologies geared toward innovative devices to increase safety at grade crossings.

Anticipated Activities:

- Explore new areas where PTC can play a role in increasing safety at grade crossings.

Expected Outcomes:

- With the wide introduction and implementation of PTC, its inclusion of a grade crossing warning system will increase overall public safety and, at the same time, reduce accountability and liability.

Grade Crossing Pedestrian Safety

Continue to explore measures to address accidents at grade crossings and along railroad ROWs that involve pedestrians.

Anticipated Activities:

- Explore new methods and techniques to improve pedestrian safety at rail grade crossings.
- Continue to explore enforcement and educational tools to reduce accidents at grade crossings involving pedestrians.

Expected Outcomes:

- Increase safety for pedestrians at crossings.

Grade Crossing Modeling and Simulation

Continue working on the new accident prediction and severity model for grade crossings, as well as developing models for studying behavior in general at grade crossings.

Anticipated Activities:

- Explore new modelling and simulation to reproduce real scenarios of human behavior at crossings. This can create new testing solutions without intervening on the actual railroad property or grade crossing itself.

Expected Outcomes:

- Simulation and modeling can provide insight on how safety can be improved once the solution simulated or modeled is implemented.

Grade Crossing and Trespass Outreach and Education

Continue developing and disseminating educational tools to the public, including local and state governments, law enforcement agencies, and schools, among others.

Anticipated Activities:

- Develop new research ideas based on the outcome of the listening sessions planned during FY 2020.
- Continue collaboration with organizations such as Operation Life Saver and others.
- Formation of an international working group on railroad trespass prevention.

Expected Outcomes:

- Increased safety overall in the railroad environment when interacting with grade crossing and trespass prevention.

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 and rural communities' accessibility to economic activities. This program also supports the Accountability goal by reducing regulatory burden.

DOT Strategic Goal	OST-R Research Topic Area
Safety	Automation, Systemic Safety Approach, and Human Factors

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

Chapter 4 – FY 2021 Program Descriptions
Human Factors

Program Description/Activities/Objectives:

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; motorist behavior at highway-rail grade crossings; project evaluation; automation; operating personnel information management and control; human fatigue; vigilance, attention and distraction; and support of the SLSI. Additionally, FRA's HF Research program provides support for FRA Office of Railroad Safety's training, education and outreach activities.

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 lose their lives every year on train tracks due to trespassing or suicide. HF will continue to examine the human behaviors associated with rail trespass and suicide.

Anticipated Activities:
- Partner with non-profit organizations to help improve education and outreach related to rail suicide and trespassing.
- Continue its suicide prevention research program, with activities in the following areas:
    - Pilot projects to examine suicide countermeasures.
    - Provide best practices to media outlets with regards to reporting on rail suicide incidents.
    - Lead the Global Railway Alliance for Suicide Prevention, an international working group.
    - Create geographic information system (GIS) map of suicide hotspots.
    - Examine and categorize the demographic and environmental characteristics of rail suicides.
- Lead any trespasser prevention research that is identified after completing the milestones listed in *National Strategy to Prevent Trespassing on Railroad Property*.

Expected Outcomes:
- Technical Reports, Research Results reports, and presentations related to the program activities.

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. Application of research results in this area by the industry will yield better performing man-machine collaborative systems.

Anticipated Activities:
- Research head-up display for passenger locomotives and operations.
- Research to develop new approach (human-automation teaming to exploit best characteristics of both) new operating display.

Expected Outcomes:
- Enhanced locomotive crew vehicle and operating environment situational awareness precursor for accident prevention.

- Developed human-machine interface (HMI) producing reduced workload, ease of use, and improved operational performance as impacts safety.

Human 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. HF 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 knowledge, training, tools and alertness to do their jobs properly and to ensure the safety of the public, their coworkers, and themselves.

Anticipated Activities:
- Gather and summarize research on physiological basis of human fatigue.
- Studies into the measurement and assessment of human fatigue.

Expected Outcomes:
- Inform industry on physiological basis of fatigue and how human fatigue is measured or assessed.
- Understanding of human fatigue and how to better manage it in the workplace.

Project Evaluation
HF will continue project evaluation of the SLSI, a non-profit organization funded with Federal grants. Project evaluation activities for the SLSI promote accountability, as evaluation provides unbiased evidence about the extent to which the SLSI's programs are (or are not) working as intended. 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. Project evaluation of the SLSI will continue as long as it receives funding from FRA.

Anticipated Activities:
- Provide feedback on the follow-up safety culture assessment process.
- Conduct follow-up interviews to understand the level of influence, impact, and outcomes of the assessment process on participating railroads.

Expected Outcomes:
- Technical Reports, Research Results reports, and presentations to SLSI stakeholders.

Highway-Rail Grade Crossing
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. HF will continue to pursue solutions to highway-rail grade crossing because investment in research on new technologies at grade crossings does not completely address grade crossing safety; one must understand how drivers will react to new technologies at crossings.

Anticipated Activities:
- Continuation of BAA selected research.

Expected Outcomes:
- Technical Reports, Research Results reports, and presentations to stakeholders.

Vigilance, Sustained 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 on cognitive and behavioral elements that affect human sustained attention and vigilance. Railroad operation requires operators to manage and understand

information provided by multiple systems, including track and signal status. The problems this research is solving include:

- Loss of operator focus and distraction.
- Accidents caused by human error.

Anticipated Activities:

- Summary research to examine the role of distraction in accident causation.
- Cross-modal comparative study of policy to manage distraction behaviors in transportation operations.

Expected Outcomes:

- Improved, more effective operating policy to mitigate distraction and its effects.
- Knowledge of cross modal prevalence of distraction behavior.
- Knowledge of the contribution of distraction to diminished operator performance to better inform policy to improve operator performance.

*Short Line Safety Institute **

- Human Factors provides program monitoring and support of the SLSI. SLSI addresses the safety of Class II and Class III railroads, 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 and training and education.
- The SLSI receives annual funding from FRA.
- 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.

** Funding for the Short Line Safety Institute is provided as an earmark to the Human Factors program.*

Anticipated Activities:

The SLSI will continue its core program areas:

- The SLSI will conduct safety culture assessments on Class II and Class III freight railroads.
- The SLSI will use findings from the safety culture assessments to identify training and education needs for the Class II and Class III freight industry.

Expected Outcomes:

- Improved safety and safety culture in Class II and Class III freight railroads.
- Possible expansion of safety culture assessment to passenger railroads.
- Technical Reports, Research Results reports, and presentations related to safety culture.

Program Alignment with Strategic Goals:

The HF Research program aligns with the DOT Strategic Goal Safety and the OST-R Research Topic Areas of related to Safety. Successful execution of the 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.

DOT Strategic Goal	OST-R Research Topic Area
Safety	Automation, Systemic Safety Approach, and Human Factors

The HF Division has an impact on rural communities, most notably through the following project areas: Grade Crossing Safety, Trespasser and Suicide Prevention, and the 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]