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RAIL SAFETY

Federal Railroad Administration Should Report on Risks to the Successful Implementation of Mandated Safety Technology

GAO-11-133

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Highlights

Highlights of GAO-11-133, a report to congressional committees

Why GAO Did This Study

Positive train control (PTC) is a communications-based train control system designed to prevent some serious train accidents. Federal law requires passenger and major freight railroads to install PTC on most major routes by the end of 2015. Railroads must address other risks by implementing other technologies. The Department of Transportation's (DOT) Federal Railroad Administration (FRA) oversees implementation of these technologies and must report to Congress in 2012 on progress in implementing PTC. As requested, this report discusses railroads' progress in developing PTC and the remaining steps to implement it, the benefits of and challenges in implementing other safety technologies, and the extent of FRA's efforts to fulfill the PTC mandate and encourage the implementation of other technologies. To conduct this work, GAO analyzed documents and interviewed FRA and rail industry officials. GAO also interviewed and surveyed rail experts.

What GAO Recommends

GAO recommends that the Secretary of Transportation direct DOT's Administrator of FRA to (1) include in its 2012 report to Congress information about PTC implementation risks and strategies to mitigate them and (2) monitor and report on the adoption of other technologies supported by the agency's efforts. DOT reviewed a draft of this report, provided technical comments, and said it would consider the recommendations.

View GAO-11-133 or key components.
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What GAO Found

The four largest freight railroads and Amtrak have made progress in developing PTC and are preparing for implementation, but there is a potential for delays in completing the remaining sequence of steps to implement PTC in time for the 2015 deadline. For example, although railroads have worked with suppliers to develop some PTC components, the software needed to test and operate these components remains under development. As a result, it is uncertain whether components will be available when needed, which could create subsequent delays in testing and installing PTC equipment. Additionally, publicly funded commuter railroads may have difficulty in covering the $2 billion that PTC is estimated to cost them, which could create delays if funding for PTC is not available or require that railroads divert funding from other critical areas, such as maintenance. The uncertainties regarding when the remaining steps to implement PTC can be completed, as well as the related costs, raise the risk that railroads will not meet the implementation deadline, delaying the safety benefits of PTC. Additionally, other critical needs may go unmet if funding is diverted to pay for PTC.

Other technologies hold promise for preventing or mitigating accidents that PTC would not address, but face implementation challenges. Experts identified technologies to improve track inspection, locomotives and other rail vehicles, and switches as having promise to provide additional safety. But challenges to implementing these technologies include their costs, uncertainty about their effectiveness, regulations that could create disincentives to using certain technologies, and lack of interoperability with existing systems and equipment. For example, electronically controlled pneumatic brakes are a promising technology to improve safety by slowing or stopping trains faster, but are expensive and not compatible with some common train operations.

FRA has taken actions to fulfill the PTC mandate and has the opportunity to provide useful information on risks and mitigation strategies to Congress in its 2012 report. FRA has developed PTC regulations, hired new staff to monitor implementation of PTC, and created a grant program to provide funding to railroads. Going forward, as it monitors railroads' progress, FRA will have additional information for determining whether the risks previously discussed are significant enough to jeopardize successful implementation of PTC by the 2015 deadline. Prior GAO reports have noted that the identification of risks and strategies to mitigate them can help ensure the success of major projects. Including such information in FRA's 2012 report would help Congress determine whether additional actions are needed to ensure PTC is implemented successfully. Additionally, FRA's actions to encourage the implementation of other rail safety technologies align with some, but not all, best practices for such efforts. For example, FRA has followed the best practice of involving the industry early in developing new technologies, but it does not monitor the industry's use of technologies that it helped develop. Monitoring and reporting on the industry's adoption of new technologies could help the agency better demonstrate the results of its efforts.

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Abbreviations

AAR	Association of American Railroads
DOT	Department of Transportation
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
PTC	positive train control
R&D	research and development
TTCI	Transportation Technology Center, Inc.

United States Government Accountability Office
Washington, DC 20548

December 15, 2010

The Honorable John D. Rockefeller
Chairman
The Honorable Kay Bailey Hutchison
Ranking Member
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Frank R. Lautenberg
Chairman
The Honorable John Thune
Ranking Member
Subcommittee on Surface Transportation and
Merchant Marine Infrastructure, Safety, and Security
Committee on Commerce, Science, and Transportation
United States Senate

Railroad accidents, which are mainly caused by human factors, track defects, or equipment problems, pose safety risks to railroads and their employees, passengers, and the public.[1] Although railroad accidents have generally decreased since 2000, several accidents since 2005 have raised concerns about the potential for the most severe accidents to result in significant casualties. Specifically, in January 2005, a freight train carrying hazardous materials collided with a standing freight train in Graniteville, South Carolina, resulting in the release of a toxic airborne chemical that led to 9 deaths, 292 injuries, and the evacuation of 5,400 people. Then in September 2008, a commuter train collided with a freight train in Los Angeles, California, resulting in 25 deaths and 126 injuries. Both of these accidents were caused by human factors.[2]

[1]Human factor accidents result from unsafe acts of individuals, such as employee errors, and can occur for a number of reasons, such as employee fatigue or inadequate supervision, training, or staffing. Management decisions at the organizational level, such as decisions regarding the allocation of resources or crew scheduling, can have consequences in the workplace that can contribute to human factor accidents.

[2]Specifically, the accident in South Carolina was caused by a switch left in the wrong position, and the accident in California was caused by a train operator who should have stopped at a signal but instead went through it.

In the wake of these accidents, the Rail Safety Improvement Act of 2008 required passenger and major freight railroads to implement positive train control (PTC) on most major lines by the end of 2015.[3] PTC is a system designed to prevent accidents caused by human factors, including train-to-train collisions and derailments that result from trains exceeding safe speeds. It is also designed to prevent incursions into work zones and movement of trains through switches left in the wrong position. PTC accomplishes this by establishing a communications-based network linking trains to equipment along the track and centralized office locations to provide information to a locomotive about its authority to proceed along the track at a particular speed. If the train is going too fast or is approaching a section of track that it should not enter—such as a section of track occupied by another train or work crew—the locomotive computer applies the brakes to slow or stop the train to prevent a derailment due to speeding or a possible collision.[4] The Department of Transportation (DOT) has noted that the technology has the potential to prevent the most catastrophic types of railroad accidents that result in significant loss of life and property, including the accidents we have previously discussed. The statute also calls for railroads to develop risk-based safety strategies that include a plan for implementing other rail safety technologies and requires railroads to implement certain technologies in areas that both lack train signaling systems and are not required to have PTC installed.

DOT's Federal Railroad Administration (FRA) provides regulatory oversight of the safety of U.S. railroads and is responsible for implementing requirements of the Rail Safety Improvement Act of 2008.[5] FRA's research and development (R&D) program contributes to the agency's safety oversight by sponsoring and conducting research in collaboration with industry and universities, including the development of new rail safety technologies, and the agency's safety oversight includes

[3]Pub. L. No. 110-432, div. A, title I, §104(a), 122 stat. 4848, 4856-4858 (Oct. 16, 2008).

[4]Train control systems similar to PTC have been implemented in other countries. In Japan, for example, systems have been implemented to automatically stop or slow trains to prevent collisions, such as when a train operator fails to stop as instructed by a signal. European countries also have train control systems and are currently involved in a joint project to establish interoperability among these systems.

[5]The Rail Safety Improvement Act of 2008 vests certain responsibilities with the Secretary of Transportation, who has since delegated authority to FRA to carry out the functions and exercise the authority vested in the Secretary by the statute. See 49 C.F.R. § 1.49(oo), 74 Fed. Reg. 26981 (June 5, 2009), and 49 U.S.C. § 103(g).

efforts to promote the implementation of these technologies. In addition to its safety oversight role, legislation enacted in recent years has significantly expanded FRA's role in the investment and oversight of the development of intercity passenger rail, including high-speed passenger rail.

Emphasizing the need to further improve the safety of the nation's railroad system, as called for in the Rail Safety Improvement Act of 2008, you asked us to examine new rail safety technologies under development and what additional federal roles should be considered to encourage their implementation. This report discusses (1) the progress railroads have made in developing and implementing PTC and the remaining steps to implement PTC systems, (2) the potential benefits of other rail safety technologies under development as well as the challenges to implementing them, and (3) the extent of FRA's efforts to fulfill the PTC mandate and encourage the implementation of other rail safety technologies.

To describe railroads' progress in developing and implementing PTC, as well as the remaining steps to implement PTC systems, we reviewed documents and interviewed officials from the four largest freight railroads, Amtrak, a selection of commuter railroads of different ridership levels and geographic locations, a selection of railroad supply companies that are major PTC suppliers or were recommended by others we interviewed, and associations that represent railroads and suppliers about their progress in developing and implementing PTC. To describe the potential benefits of other rail safety technologies under development, as well as the challenges to implementing them, we sought information from rail safety technology experts and other rail industry stakeholders about their views of various technologies currently under development. Specifically, based on our initial research and interviews, we compiled a list of other rail safety technologies currently under development in the United States. We refined this list on the basis of input from DOT; the Association of American Railroads (AAR); and the Transportation Technology Center, Inc. (TTCI), an industry-operated, DOT-owned railroad research facility.[6] With

[6]We limited the scope of these technologies to those that would prevent or mitigate train-to-train collisions and derailments. We also did not review other FRA R&D efforts related to accident prevention, such as other research efforts to examine and address causes of accidents related to human factors. For example, FRA has worked with railroads to pilot a system that would allow railroad employees to confidentially report incidents that could have resulted in an accident, which would provide information FRA, railroads, and other stakeholders could use in analyzing and addressing the root causes of such incidents to improve safety.

assistance from the National Academies' Transportation Research Board, we identified a group of 20 rail safety technology experts that we interviewed and then asked to complete a questionnaire about the potential benefits of and challenges to implementing a number of rail safety technologies under development.[7] We analyzed the results of the questionnaire to identify which technologies are the most promising on the basis of the experts' views of these technologies' potential safety benefits, their worth compared with the cost of additional R&D and implementation, and their stage in product development. We also interviewed officials from railroads, railroad associations, FRA, and the DOT Volpe National Transportation Systems Center (Volpe Center) about the potential benefits and challenges of implementing other rail safety technologies under development. To identify whether there were any major differences with rail safety technologies under development in other countries, we interviewed foreign representatives from railroad industry associations, universities, and governments about the implementation of rail safety technologies in European and Asian countries. To evaluate the extent of FRA's efforts to fulfill the PTC mandate and encourage the implementation of other rail safety technologies, we obtained and reviewed documents from and interviewed FRA officials responsible for the agency's rail safety technology R&D, safety regulatory efforts, and efforts to fulfill the PTC mandate. We also interviewed rail experts and the other stakeholders that we have previously mentioned about their views of FRA's efforts to fulfill the PTC mandate and encourage the implementation of other technologies. See appendix I for a more detailed description of our scope and methodology.

We conducted this performance audit from December 2009 to December 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The U.S. railroad industry consists mostly of freight railroads but also serves passengers. Freight railroads are divided into classes that are based on revenue. Class I freight railroads earn the most revenue and generally

[7] Of the 20 experts to whom we sent a questionnaire, 19 completed the document.

provide long-haul freight service, while the smaller freight railroads—those in Classes II and III—earn less revenue and generally haul freight shorter distances.[8] Amtrak provides intercity passenger rail service, while commuter railroads serve passengers traveling within large metropolitan areas. Freight railroads own most of the track in the United States, with a notable exception being the Northeast Corridor between Washington, D.C., and Boston, Massachusetts, which Amtrak predominantly owns.[9] Railroads grant usage rights to one another, and passenger trains share track with freight railroads. While freight and passenger railroads share many characteristics, there are also key differences in their composition and scope (see table 1).

Table 1: Characteristics of U.S. Freight and Passenger Railroads

Characteristic	Freight railroads	Passenger railroads
Composition	There are 7 Class I freight railroads, of which 4—BNSF Railway, CSX Corporation, Union Pacific, and Norfolk Southern—earn the majority of revenue. There are over 500 Class II and Class III freight railroads, which provide service to connect rural, agricultural, industrial, and port areas to the national freight network.	Amtrak is the only national provider of intercity passenger rail service; there are 25 commuter railroads in the United States.
Scope	The freight industry consists of about 140,000 track miles. U.S. freight traffic in 2007 totaled 2.3 billion tons.	Amtrak operates on 21,000 miles of track, the majority of which is owned by freight railroads. In 2009, Amtrak carried 27.1 million passengers. Commuter railroads, which generally operate on freight- or Amtrak-owned track, provided service to over 450 million passengers in 2009 (as measured in passenger trips).

Source: GAO analysis of industry data.

Note: Figures cited in this table represent the latest available data.

The railroad industry also includes companies that produce railroad supplies, including locomotives, train cars, track, signal equipment, and related components, and national associations that work with and represent railroads. AAR, which primarily represents freight railroads (including all seven Class I freight railroads), as well as Amtrak and some other railroads, develops standards for the implementation of technology, manages the implementation of industrywide technological programs, and

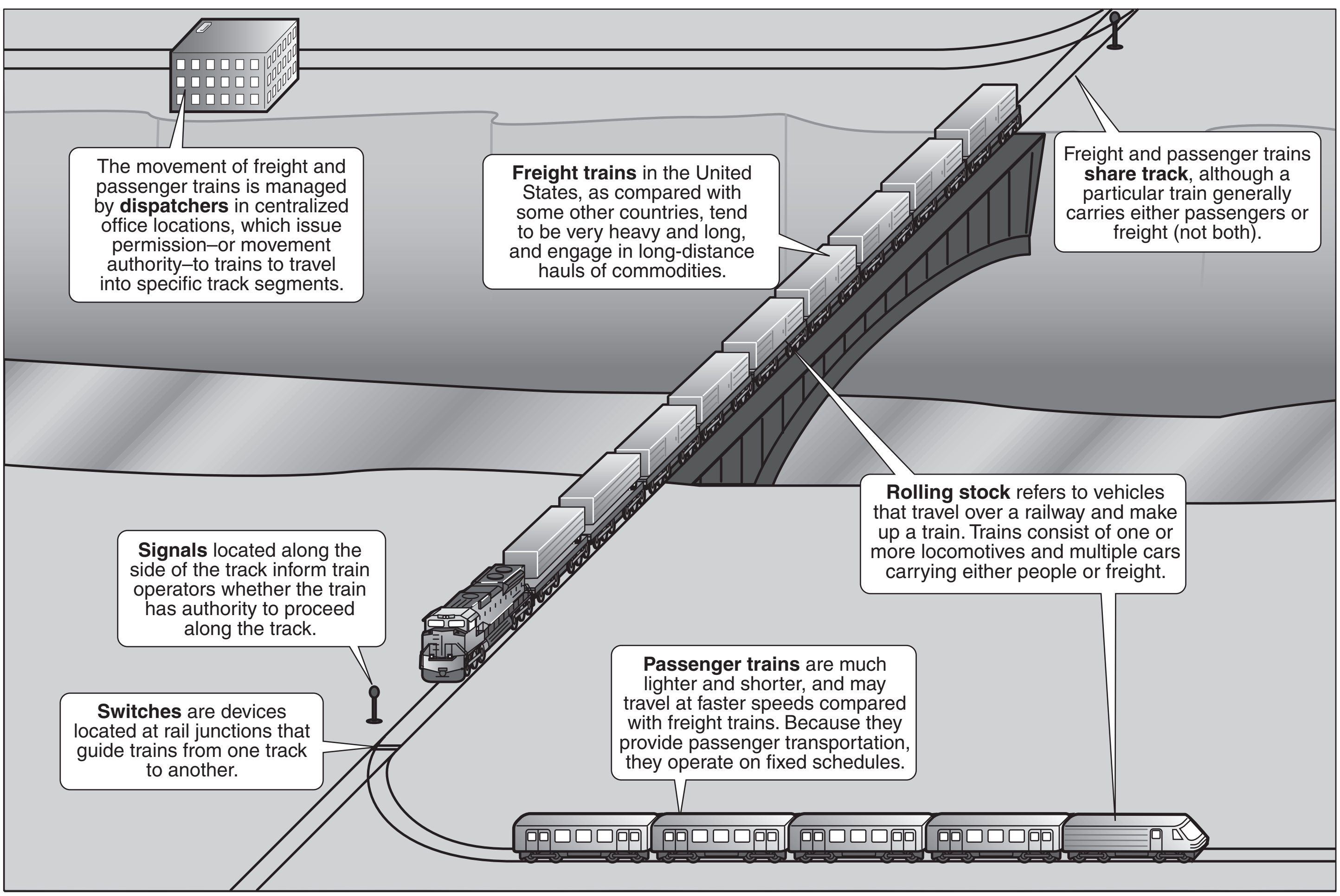
[8]As of 2008, Class I freight railroads are those railroads that earn more than about $401 million annually; Class II railroads earn from about $32 million to about $401 million; and Class III railroads earn less than about $32 million. Revenue amounts that define railroad classes change each year on the basis of inflation.

[9]Amtrak also owns a section of track in Michigan and some commuter railroads own track.

assesses the railroads' needs for safety and technological development. It also works to develop new technologies at TTCI near Pueblo, Colorado, an FRA-owned railroad research facility operated by AAR through a contract. The American Short Line and Regional Railroad Association represents Class II and Class III freight railroads in legislative and regulatory matters. The American Public Transportation Association represents commuter railroads and develops standards for their use of technology.

The U.S. railroad environment consists of train vehicles (rolling stock) and infrastructure, such as track, bridges and tunnels, switches and signals, and centralized offices with dispatchers (see fig. 1).

Figure 1: Key Components of the U.S. Railroad Environment



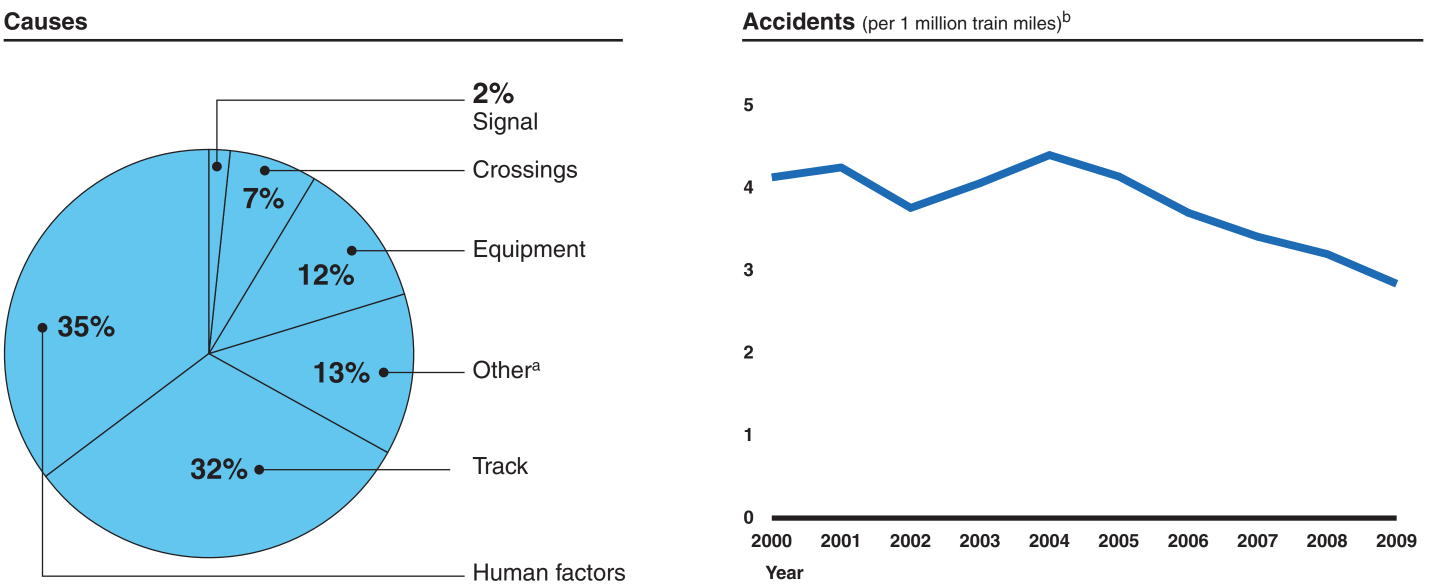
Source: GAO.

Railroad accident rates have generally declined from 2000 to 2009. During that time, human factors and problems with track were the leading causes of rail accidents, according to our analysis of FRA data (see fig. 2).[10] These problems can lead to train derailments or collisions, which can result in significant damage and loss of life. For example, the 2005 accident in Graniteville, South Carolina, was attributed to a switch being left in the wrong position, an example of human error, while the 2008 collision between freight and passenger trains in the Chatsworth neighborhood of Los Angeles, California, was the result of a commuter train going through a red signal it should have stopped at, which was likely caused by human error.[11] Track-related causes of accidents include irregular track geometry, which occurs when rail is misaligned or too far apart; breaks in the rail or joints that connect rail segments; and damage to railroad bridges, among other causes. Such defects can lead to train derailments.

[10]Human factors that cause accidents include failure to properly use equipment, including brakes and signals, and failure to follow the appropriate train speed, among other causes.

[11]In its accident report, the National Transportation Safety Board said that the probable cause of the accident was that the commuter train operator failed to obey a red signal because he was distracted by wireless text messaging. The report also noted that the lack of a PTC system to stop the train short of the red signal contributed to the accident. See National Transportation Safety Board, *Collision of Metrolink Train 111 with Union Pacific Train LOF65-12, Chatsworth, California, September 12, 2008*, NTSB/RAR-10/01 (Washington, D.C.: Jan. 21, 2010).

Figure 2: Causes and Rate of Rail Accidents, 2000-2009



Source: DOT.

[a]The "other" accident category encompasses a number of other causes, including environmental conditions, such as snow or ice; objects on track; an improperly loaded car; and vandalism.

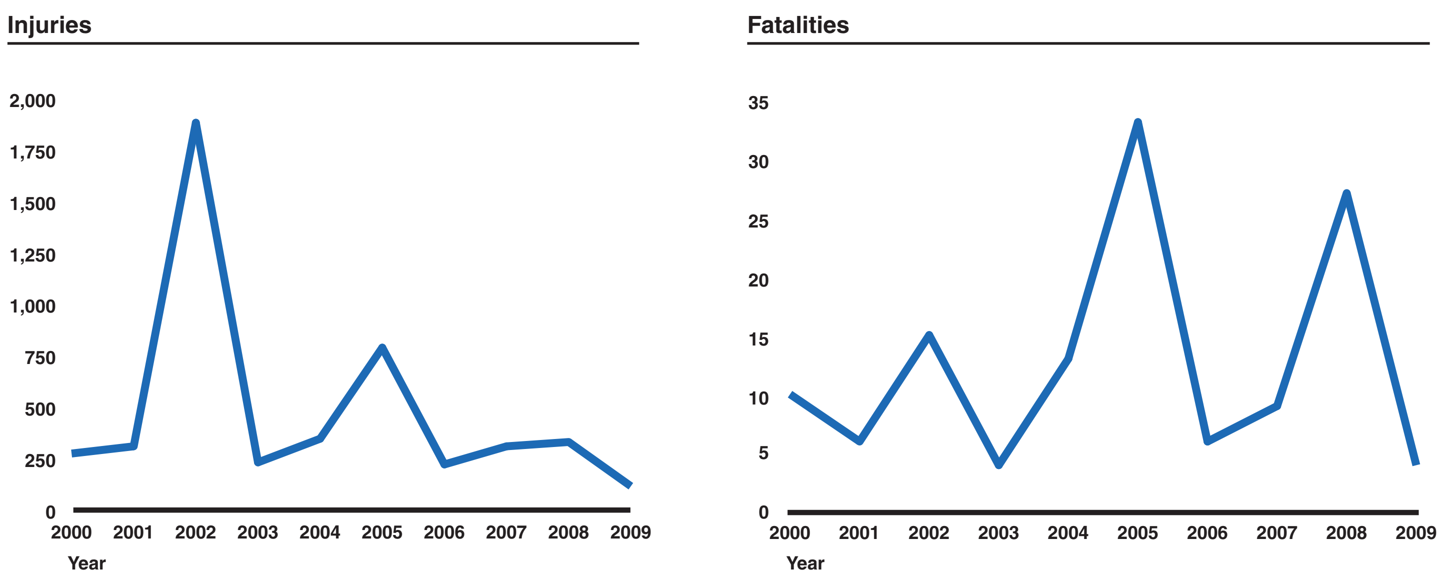
[b]This figure excludes accidents that occurred at intersections between tracks and roads, known as grade crossings.

Although the rate of accidents has decreased from 2000 through 2009, injuries and fatalities have fluctuated, with the largest spikes being tied to specific incidents.[12] For example, injuries increased dramatically in 2002 due to one accident in North Dakota in which 1,441 people were injured from a derailment caused by track problems that resulted in the release of hazardous materials (see fig. 3). The number of fatalities per year from 2000 through 2009 ranged from a low of 4 in 2003 and 2009 to a high of 33 in 2005, the year of the accident in Graniteville, South Carolina, that

[12]The analyses of accidents, injuries, and fatalities exclude accidents that occurred at grade crossings because the causes of such accidents involve issues not related to railroad safety performance, such as driver awareness of grade-crossing safety. Additionally, the rail safety technologies examined in this review primarily address train-to-train collisions and derailments and do not include technologies designed primarily to prevent grade-crossing accidents.

killed 9 people. The second-highest year for fatalities was 2008; that year, there were 27 fatalities, including 25 fatalities from the accident in Los Angeles, California.

Figure 3: Number of Rail-Related Injuries and Fatalities, 2000-2009



Source: DOT.

Note: Figure excludes injuries and fatalities due to trespassing, suicides, and accidents that occurred at grade crossings.

In its role as federal regulator and overseer of railroad safety, FRA prescribes and enforces railroad safety regulations and conducts R&D in support of improved railroad safety and rail transportation policy.[13] Within the agency, FRA's Office of Railroad Safety promulgates and enforces railroad safety regulations, including requirements for track design and inspection; signal and train control systems; grade-crossing warning device systems; mechanical equipment, such as locomotives and freight

[13]From 2005 to 2008, FRA's oversight was guided by the National Rail Safety Action Plan, which FRA issued in May 2005 to improve its oversight by targeting efforts to high-risk areas. FRA issued a final report on its efforts under this plan in May 2008. As part of our 2007 review of FRA oversight, we said that the National Rail Safety Action Plan provided a reasonable framework for guiding FRA's safety oversight efforts. See GAO, *Rail Safety: The Federal Railroad Administration Is Taking Steps to Better Target Its Oversight, but Assessment of Results Is Needed to Determine Impact*, GAO-07-149 (Washington, D.C.: Jan. 26, 2007).

cars; and railroad operating practices. For example, FRA's regulations for track and equipment include detailed, prescriptive minimum requirements, such as wheel safety requirements and formulas that determine the maximum allowable speeds on curved track. In developing most of its regulations, FRA seeks input from the railroad industry and other organizations through its Railroad Safety Advisory Committee.[14] FRA's Office of Research and Development sponsors and conducts R&D of new rail safety technologies in support of FRA's safety mission. This work contributes information used to support FRA's development of regulations, standards, and best practices as well as encourages the development and use of new safety technologies. FRA's R&D work is done collaboratively with industry and universities and is also supported by the Volpe Center, which is DOT's transportation research center in Cambridge, Massachusetts.

Although its role has traditionally been that of a regulatory agency, recently enacted laws have expanded FRA's role in other areas. The Passenger Rail Investment and Improvement Act of 2008 authorized over $3.7 billion for three federal programs for high-speed rail, intercity passenger rail congestion, and capital grants,[15] while the American Recovery and Reinvestment Act of 2009 appropriated $8 billion for these three programs.[16] By creating a significant grant-making role for funding the development of high-speed passenger rail, these laws effectively transformed what was essentially a rail safety organization to one that is making multibillion-dollar investment choices while also carrying out its safety mission. Regarding rail safety technologies, the Rail Safety Improvement Act of 2008 directs FRA to oversee railroads' implementation of PTC and other technologies.[17] Specifically, the act requires passenger and major freight railroads to implement PTC by the

[14]To adopt a participatory approach to its rulemaking, in 1996, FRA created the Railroad Safety Advisory Committee, which is designed to bring together all segments of the rail community in developing solutions to safety regulatory issues. The committee includes representatives from railroads, railroad associations, labor, state government groups, and agencies with railroad regulatory safety responsibility in Canada and Mexico.

[15]These three programs are Section 301–Capital Assistance for Intercity Passenger Rail Service Grants, Section 302–Congestion Grants, and Section 501–High Speed Rail Corridor Program. See Pub. L. No. 110-432, div. B.

[16]Pub. L. No. 111-5, title XII (Feb. 17, 2009).

[17]The act also directs FRA to reform its regulations regarding limits on railroad employees' hours of service.

end of 2015, with FRA playing a role as overseer of the industry's implementation through rulemaking and review of railroads' implementation plans.[18] The act also directs FRA to require railroads to improve safety through the development of risk-reduction programs that include plans for implementing new rail safety technologies and to create a grant program to fund the deployment of rail safety technologies, authorized at $50 million per fiscal year from 2009 through 2013 (see table 2).

Table 2: Rail Safety Technology-Related Requirements of the Rail Safety Improvement Act of 2008

PTC	Other rail safety technologies
• Class I railroads, commuter railroads, and Amtrak must install PTC on lines that carry passengers or a certain level of traffic and type of hazardous materials by December 2015.[a] • Railroads' PTC systems must be interoperable. Specifically, they must be able to communicate with one another and provide for seamless movement between sections of track owned by different railroads. • Railroads are required to submit plans to FRA by April 2010 outlining how they will implement PTC and address interoperability. FRA must review and approve/disapprove plans by July 2010. • Once installed, railroads may not operate PTC systems until they are certified by FRA. • FRA must report to Congress on the status of PTC implementation by December 2012.	• FRA required to develop a 5-year strategy for improving rail safety that includes improving research efforts to enhance and promote rail safety and performance and report to Congress annually on the strategy beginning in 2009. • By October 2009, FRA required to prescribe standards, guidance, regulations, or orders governing the development, implementation, and use of rail safety technologies in areas of track that lack signals or train control systems. • By October 2012, Class I freight railroads, intercity and commuter passenger railroads, and other railroads that FRA identifies on the basis of risk must develop a safety risk-reduction program that includes a technology implementation plan, which should describe the railroad's plan to develop and implement new safety technologies to reduce risks identified in the program.[b]
Both PTC and other rail safety technologies	
• FRA required to create a 5-year grant program to support the deployment of PTC and other rail safety technologies, which is authorized at $50 million per fiscal year from 2009 through 2013.[c]	

Source: Rail Safety Improvement Act of 2008.

[a]FRA's PTC rule provides for a "limited operations" exception, allowing a railroad not to implement and operate a PTC system on a particular track segment. See 49 C.F.R. § 236.1019(c). The requirement to install PTC on lines that carry hazardous materials applies only to those lines that carry at least 5 million gross tons of annual traffic and poisonous-by-inhalation hazardous materials. Additionally, some Class II and Class III freight railroads are required to install PTC on certain track segments. FRA has given these railroads additional time—until 2020—to equip some locomotives. FRA also has the authority to grant these smaller railroads certain exemptions from PTC implementation requirements.

[18]See 49 U.S.C. § 20157. Prior to the enactment of the Rail Safety Improvement Act of 2008, FRA already had rules under which railroads could develop and implement PTC systems, although these rules did not require that railroads do so. See 70 Fed. Reg. 11,052 (Mar. 7, 2005).

[b]The law requires that such railroads implement PTC by 2018 if they have not already done so.

[c]Although the grant program is for rail safety technologies broadly, the law and FRA have given PTC priority for funding.

PTC is a communication-based system designed to prevent some accidents caused by human factors, including train-to-train collisions and derailments caused by exceeding safe speeds. Such a system is also designed to prevent incursions into work zones and movement of trains through switches left in the wrong position.[19] PTC achieves these capabilities via communication with various components, namely locomotive computers, devices along the track (known as wayside units), and dispatch systems in centralized office locations (see fig. 4).[20] New data radios are being developed to enable wireless communication between locomotives and wayside units. Centralized offices and locomotives have access to a track database with information about track routes and other data, including speed restrictions, track configuration and topography, and the location of infrastructure such as switches and signals that indicate places where a train's speed may need to be enforced by PTC. Using this information, locomotive computers can continuously calculate a train's safe speed. If the train exceeds that speed, the PTC system should enforce braking as necessary. By preventing trains from entering a segment of track occupied by another train or from moving through an improperly aligned switch, PTC would prevent accidents such as those mentioned above that occurred in Los Angeles, California, and Graniteville, South Carolina.[21] While the law does not require railroads to implement the same PTC system, it does require that railroads' PTC systems be interoperable, which means that the components of different PTC systems must be able to communicate with one another in a manner to provide for the seamless

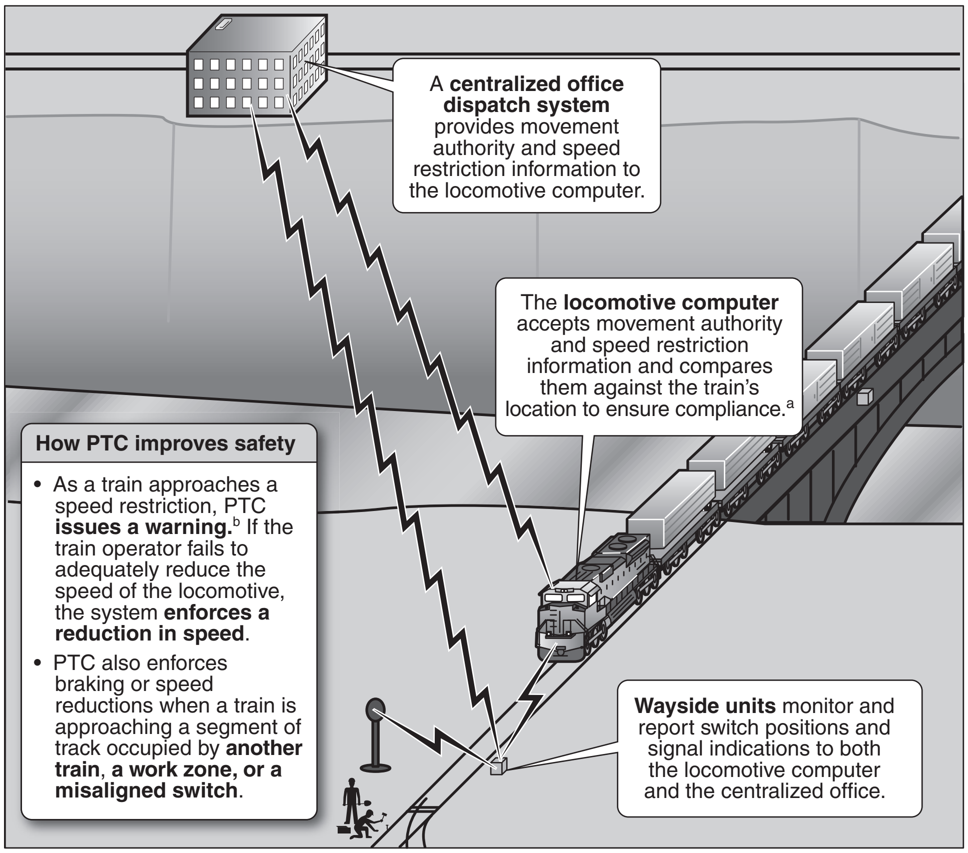
[19]Although railroads are developing and implementing slightly different PTC systems, all systems must be designed to prevent train-to-train collisions, derailments caused by exceeding safe speeds, incursions into work zones, and movement of trains through switches left in the wrong position, as required by the Rail Safety Improvement Act of 2008. See 49 U.S.C. § 20157(i)(3).

[20]Wayside units are PTC computers placed along a track at existing switches and signals as well as other locations. Computers in centralized office locations provide route information and issue permission to trains to proceed along track routes.

[21]When FRA issued its PTC implementation rule in January 2010, the agency provided a regulatory impact analysis of the safety benefits of PTC and estimated that, over a 20-year period, implementing PTC would result in $440 million to $674 million in safety benefits from reduced accidents, about one-third of which would result from avoided fatalities. See 75 Fed. Reg. 2598, 2684 (Jan. 15, 2010).

movement of trains as they cross track owned by different railroads that may have implemented different PTC systems.

Figure 4: Basic Operation of PTC



Source: GAO.

[a]Train location information is determined through various methods depending on the specific PTC system, including through satellite-based positioning systems and sensors installed along the track.

[b]Although the law does not require PTC systems to issue such warnings, the PTC systems that most railroads are implementing will do so.

Train control systems similar to PTC already exist in other countries. For example, a system to automatically stop trains if a train operator fails to stop a train at a stop signal has been widely used in Japan since the 1960s, although this system has been upgraded over time to provide advanced warning of the need to slow a train and automatically apply train brakes in such situations. A more advanced system to continuously calculate a train's safe speed—similar to the capability that PTC is designed to achieve—is being implemented on the country's high-speed passenger rail lines. In Europe, countries use various signal and train control systems, presenting technical and logistical challenges for trains that travel between countries. To establish interoperability among these systems, the European Union has embarked on an effort to implement the European Rail Traffic Management System, a common signaling and train control system, as well as a radio communications network, that would overlay countries' existing signal and train control systems to establish interoperability among them.[22] Like PTC, this system relies on a locomotive computer to calculate a train's safe speed and enforce that speed on the basis of certain information, such as a train's movement authority, the track speed limit, and the position of signals ahead of the train.

In addition to the implementation plans outlined in the Rail Safety Improvement Act of 2008, FRA's subsequent PTC regulations also require railroads to submit PTC development plans and PTC safety plans. These three plans are related, and FRA requires different information for each of them:

- *PTC development plan:*[23] To get approval for the type of PTC system a railroad intends to install, the railroad must submit to FRA a plan describing the PTC system the railroad intends to implement and the railroad operations the PTC system will be used with.[24] Following FRA's review of this plan, if approved, the agency would issue the system described in the plan a "type approval," which is a number assigned to a particular PTC system indicating FRA agreement that the system could fulfill the requirements of the PTC regulations.[25]

[22]The European Rail Traffic Management System is expected to be implemented on over 15,000 miles of track in Europe by 2020.

[23]49 C.F.R. §§ 236.1009 and 236.1013.

[24]If the railroad intends to implement a PTC system that FRA has already approved, a railroad may instead submit documentation of that prior approval. FRA's PTC regulations also allowed railroads to submit a "notice of product intent" instead of the PTC development plan, which would describe the functions of the proposed PTC system but include fewer details about its operation. However, a railroad that elects to do this could receive only "provisional" approval of its PTC implementation plan, requiring it to submit a PTC development plan or plans to implement a system that has already received a type approval from FRA within 270 days to qualify for full approval.

[25]49 C.F.R. §§ 236.1013(b) and 236.1003.

- *PTC implementation plan:* This plan describes the functional requirements of the proposed PTC system, how the PTC system will achieve interoperability between the host railroad (the railroad that owns the track) and the tenant railroads (those railroads that operate on the host's track), how the PTC system will be installed first on track routes with greater risk, the sequence and schedule for installing PTC on specific track segments, and other information about PTC equipment to be installed on rolling stock and along the track. The law required railroads to submit these plans by April 16, 2010, and FRA to review and approve or disapprove them within 90 days.

- *PTC safety plan:*[26] This plan must include information about planned procedures for testing the system during and after installation, as well as information about safety hazards and risks the system will address, among other requirements. By approving a safety plan, FRA certifies a railroad's PTC system, which must happen before a railroad can operate a PTC system in revenue service. FRA set no specific deadline for railroads to submit this plan.

In its PTC rulemaking, FRA also included requirements for implementing PTC on high-speed passenger rail lines, with trains operating at or above 90 miles per hour, that specify additional safety functions for PTC systems installed for trains operating at these higher speeds.[27] FRA's High-Speed Rail Safety Strategy, released in November 2009, acknowledges the importance of implementing PTC for high-speed passenger rail operation and also calls for the evaluation of other specific technologies to determine their suitability for reducing risk for high-speed rail.

[26] 49 C.F.R. § 236.1009.

[27] For example, a railroad that operates passenger trains above 125 miles per hour must explain in its PTC safety plan how its PTC system is designed to detect incursions onto the track, such as from motor vehicles diverging onto the track from adjacent roads and bridges. See 49 C.F.R. § 236.1007(c).

Railroad Industry Has Made Progress in Developing PTC, but Key Tasks Remain to Completing Implementation

Railroad Industry Has Made Progress in Developing PTC Components, and Railroads Are Preparing for Widespread Implementation

Amtrak and the four largest Class I freight railroads have led PTC development efforts and most other railroads plan to implement PTC systems developed by these railroads.[28] Amtrak worked with suppliers to develop PTC for the Northeast Corridor and began installation in 2000.[29] Since that time, Amtrak has made improvements to this system, and FRA certified Amtrak's PTC system on the Northeast Corridor in May 2010—the first PTC system FRA certified under the PTC rules it issued in January 2010. Amtrak has also installed a different PTC system on a portion of track in southern Michigan. The four largest Class I freight railroads have identified suppliers of PTC technology and are working with these suppliers to develop PTC components; however, they have not yet installed PTC, except for some limited pilot installations.[30] Although there are differences between the PTC systems being installed by Amtrak and those being installed by the freight railroads, they are designed to achieve the same basic functions.

The PTC systems being developed by the four largest Class I freight railroads differ from PTC systems that exist in other countries and on

[28]One exception is the Alaska Railroad, which began implementing a train control system in 1997 that it is upgrading to achieve PTC certification under the current FRA rules. Additionally, four other commuter railroads and a Class III freight railroad indicated in their PTC implementation plans that they intend to install PTC systems other than those being developed by Amtrak and the four largest Class I freight railroads.

[29]In 1998, during the time Amtrak was upgrading the Northeast Corridor to permit operation of high-speed passenger trains—a service known today as Acela—FRA required Amtrak to install a new train control system on some portions of the corridor as a safety measure. That system, with some additional communications upgrades, will serve as Amtrak's PTC system on the Northeast Corridor.

[30]BNSF Railway began development of a PTC system in 2002. Although FRA has not yet certified that this system meets the requirements outlined in the agency's January 2010 PTC rules, FRA had approved this system under prior regulations that had governed development of PTC systems in 2006.

some Amtrak routes. According to AAR officials, existing PTC systems were designed specifically for passenger rail operations and would not address the needs of the U.S. freight railroads. For example, the system that Amtrak uses on the Northeast Corridor combines PTC speed enforcement capabilities with an existing onboard system that provides track status information, such as signal status, to the locomotive engineer. Not all of the freight railroads currently use such an onboard track information system, and such a system would not be feasible to use on segments of track that lack signals, which accounts for about 13,000 miles of track owned by Class I freight railroads that requires PTC. Additionally, in developing new PTC systems, railroads must ensure that their systems are interoperable among the many different railroads that plan to use them.[31] To achieve interoperability, the four largest Class I freight railroads created the Interoperable Train Control Committee to develop system specifications and standards for interoperability, including protocols for how PTC components should function and communicate with each other as part of an overall system.[32] To achieve interoperability with the Class I freight railroads' systems, Amtrak will equip its locomotives that operate on freight-owned track with PTC radios capable of operating on the same frequencies as those used by the freight railroads.

Components of PTC systems being developed by Class I freight railroads are in varying stages of development, with some components currently being produced; however, these components cannot be used or fully tested without software, which remains under development:

- *Wayside units:* These units consist of devices installed at signals, switches, and other locations along the track. The units will monitor the status of signals and switches and communicate that information to

[31]The Rail Safety Improvement Act of 2008 requires that PTC systems provide interoperability, which means that a PTC system can communicate with and control locomotives from different railroads operating trains on the same host railroad's track and that the systems allow trains to move uninterrupted over the boundaries between host railroads. See 49 U.S.C. § 20157(a)(2),(i)(1). Railroads plan to achieve interoperability through the use of common technology and the development and use of standard communication protocols that will allow communication between the locomotives and PTC infrastructure of different railroads.

[32]In addition to the four Class I freight railroads that formed this committee, AAR, Amtrak, Kansas City Southern (a Class I freight railroad), the two Canadian-owned Class I freight railroads, some commuter railroads, and FRA also participate.

locomotives directly or through railroads' centralized office systems. Hardware for these units is currently available and being tested by railroads.

- *Locomotive computers:* These computers will provide centralized offices information on the train's location. Based on the status of upcoming signals or switches—which will be communicated to the locomotive by the wayside units—the locomotive computer will calculate the train's braking distance and enforce braking, if needed, to slow or stop a train to comply with speed restrictions and ensure it does not enter a segment of track occupied by another train or a work crew. Locomotive computers are available for railroads to install on newer locomotives. However, railroad associations told us that older locomotives that lack electronic systems will have to be upgraded before such computers and other PTC components can be installed on them.

- *Data radios:* The freight railroads' PTC systems require the use of new data radios installed on locomotives and wayside units to enable PTC communication. Prototype specifications for these radios are still under development, and the railroad industry estimates that these radios will be in production starting in early 2012. The four largest Class I freight railroads share ownership in the company that is developing PTC data radios and jointly purchased radio spectrum to enable PTC communications.

For these components to operate as a system, PTC software is necessary to perform all train control functions, including determining a train's location and calculating a train's braking distance. Complete PTC systems cannot be tested and implemented until software is finalized. PTC software is still under development, and railroad industry officials told us they expect it to be available sometime in 2011.

Forty-one railroads submitted their required PTC implementation plans to FRA in 2010, comprising the 7 Class I freight railroads, 2 Class II freight railroads, 9 Class III freight railroads, Amtrak, and 22 commuter railroads.[33] In these plans, railroads were required to provide information about the extent to which they will implement PTC, provide a schedule for progressive implementation, and prioritize implementation on the basis of risk.[34] Railroads have begun implementing PTC in some locations. Amtrak has installed PTC on just over 200 miles of the 363 miles it owns along the Northeast Corridor and plans to expand its system along the corridor and its connections. It has also installed PTC on about 60 miles of track in southern Michigan and will extend this system along the full 97 miles of track it owns in that area. Class I freight railroads have selected the PTC systems they intend to implement and have informed FRA of their selections by submitting PTC development plans. Some freight railroads and commuter railroads that operate on the Northeast Corridor are already equipped with Amtrak's PTC system. Commuter railroads that connect with the corridor will equip their additional rail lines with this system.

Other freight and commuter railroads that are required to implement PTC have not yet begun implementation. Many of these commuter railroads and Class II and Class III freight railroads plan to implement the same systems being developed by the Class I freight railroads.[35] As we have previously stated, components for PTC systems being developed by the Class I freight railroads are not yet available. Officials from the American Public Transportation Association and the American Short Line and Regional Railroad Association—which represent commuter railroads and Class II and Class III freight railroads, respectively—told us that those railroads are awaiting these components to begin installation of PTC. While only a small number of Class II and Class III freight railroads are required by the Rail Safety Improvement Act of 2008 to implement PTC on

[33]The Rail Safety Improvement Act of 2008 specifically required all Class I freight railroads, Amtrak, and commuter railroads to submit PTC implementation plans. See 49 U.S.C. § 20157(a). In its PTC rulemaking, FRA clarified that Class II and Class III freight railroads that host passenger rail service must also file PTC implementation plans. See 49 C.F.R. § 236.1005. Other railroads that must install PTC equipment only on their locomotives were not required to submit PTC implementation plans; however, FRA directed railroads submitting PTC implementation plans to identify these other tenant railroads in their plans. This included some commuter railroads that do not own track.

[34]In reviewing these plans, FRA approved implementation plans from five smaller freight railroads and one commuter railroad that requested exemption from implementing PTC on their track.

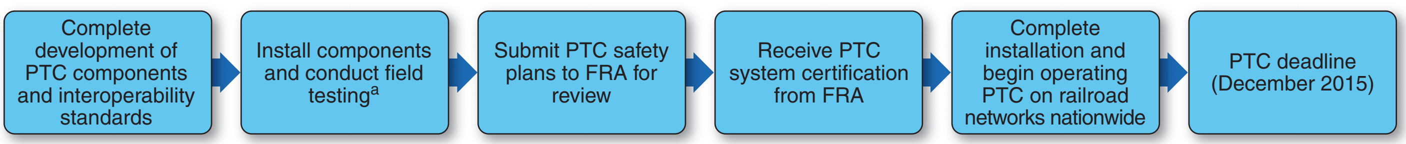
[35]Amtrak also plans to install the freight railroads' systems on its locomotives that operate on tracks owned by freight or commuter railroads that are implementing those systems. Amtrak will also install the same systems on a few discrete track segments that it owns.

their property, FRA regulations require some additional Class II and Class III freight railroads to install PTC on their locomotives if they operate on track equipped with PTC and share that track with passenger trains.[36]

Key Steps Remain to Implement PTC by 2015, with a Potential for Delay

By law, the rail industry must complete development, testing, and full implementation of PTC on most major routes within 5 years. Progress has been made by railroads and suppliers in preparing to implement PTC, but many actions must still be taken to achieve full implementation of PTC, and they must be completed in a specific sequence (see fig. 5). Since PTC implementation requires the completion of a specific sequence of steps, any delay in one step could affect the entire implementation schedule, potentially resulting in railroads missing the implementation deadline, which would delay achieving the intended safety benefits of PTC.

Figure 5: Sequence of the Railroad Industry's Upcoming PTC Implementation Steps



Source: GAO.

[a]Some installation of components has begun. Also, railroads plan to conduct tests throughout these implementation steps, including tests required by FRA to receive system certification.

As we have previously discussed, all PTC components for the Class I freight railroads' systems are not yet developed. In addition, the development of PTC software and new data radios requires the development of interoperability standards, which the four largest Class I freight railroads and AAR have not yet finalized.[37] Specifically, AAR officials told us that the Interoperable Train Control Committee had expected to complete all of these standards by July 2010, but as of August, only 3 of the approximately 40 standards needed were ready. Furthermore, AAR officials told us in September that although the committee continues

[36]Class II and Class III freight trains that meet these criteria, but make no more than four trips per day in excess of 20 miles, are not required to equip locomotives with PTC until 2020. See 49 C.F.R. § 236.1006.

[37]Interoperability standards would address a number of technical issues associated with implementing interoperable PTC systems, such as standards for communications and data management.

to make progress in developing these standards and has consolidated some standards to cut down the total needed, it has not set a new date for when it expects to complete this effort. AAR officials explained that delays are due to the complexity and amount of work that must be completed. FRA officials monitoring this effort told us in September that they do not know when the standards will be completed, and that they have some concerns about the potential for the delay in developing these standards to impact railroads' ability to procure PTC components in a timely manner. FRA officials also said that although it is their understanding that the remaining standards have been drafted and are undergoing industry review, they expect this process to last at least through the first quarter of calendar year 2011.

System complexity was a factor that led to delays in an earlier PTC development effort. In 2001, FRA, Amtrak, the Union Pacific Railroad, AAR, and the State of Illinois created the North American Joint Positive Train Control Project, an objective of which was the development of interoperable PTC standards. However, this objective was not achieved by the time the project came to a close in 2006.[38] Specifically, system testing revealed that a significant amount of software development would be required for the PTC system to be compatible with normal railroad operations, which FRA concluded would require several additional years to complete.

Railroads currently expect that key PTC components will be available by 2012, but there is uncertainty regarding whether this can be achieved, given the delays in developing the interoperability standards and current lack of software for PTC components. Any delays in component development would consequently delay pilot installations for field testing. The lack of developed components raises questions about the technological maturity of the Class I freights' PTC systems. If the railroad industry is unable to develop fully functional components within the expected time frame, it is possible that testing and installation of these components could not be completed by the 2015 deadline. Our prior work

[38] While this specific project came to a close in 2006, further development and testing of PTC was moved to TTCI in Pueblo, Colorado. In its project report, FRA stated that lessons learned from the project included the necessity for incremental development of such a complex system, the need for thorough and unambiguous specifications, early test planning, and a rigorous sequence of development steps. See Federal Railroad Administration, *Research Results: The North American Joint Positive Train Control (NAJPTC) Project* (April 2009).

examining the development of military weapon systems has shown that demonstrating a high level of maturity before allowing new technologies into product development programs increases the chance for successful implementation, and that, conversely, technologies that were included in a product development program before they were mature later contributed to cost increases and schedule delays.[39]

Once PTC components are developed, railroads must test them in the field to ensure that PTC systems function properly and that components of PTC systems are able to communicate with each other regardless of railroad ownership. Any problems that are identified during the field-testing process will need to be addressed to ensure the PTC systems function as required. AAR officials told us that PTC tests have only been conducted in very controlled environments, as opposed to a truly operational environment where the systems could experience stress.[40] For example, railroads must ensure that PTC systems provide reliable communication among centralized offices, wayside units, and locomotives. However, it is uncertain how well system communication will fare in densely populated areas, such as Chicago, Illinois, where many railroads—both passenger and freight—operate simultaneously.[41] Furthermore, railroad industry officials have expressed concern that all electrical components associated with PTC contain inherent failure rates. Since PTC implementation requires the installation of a large number of devices, the possibility of failure must be addressed and railroads must ensure that any possible failures do not negatively affect railroad safety or operational capacity. Any problems identified during field testing, if they cannot be quickly addressed, could contribute to missing the PTC implementation deadline. Conversely, implementing an immature system to meet the deadline could pose serious safety risks. After railroads complete PTC field tests, they must submit safety plans to FRA for review, and FRA must certify PTC systems before railroads can begin operating them in revenue service.

[39]GAO, *Joint Strike Fighter: Additional Costs and Delays Risk Not Meeting Warfighter Requirements on Time*, GAO-10-382 (Washington, D.C.: Mar. 19, 2010); and *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999).

[40]While BNSF Railway has installed and tested PTC on some subdivisions, the system has not yet been tested with the simultaneous operation of freight trains and Amtrak passenger trains.

[41]Officials from the company developing PTC radios told us they are considering St. Louis, Missouri, as a possible testing ground, given the city's similarities in geography and railroad density to Chicago, Illinois.

Given the extent to which railroads must implement PTC, installation will require a considerable amount of work, since it will include the installation of thousands of physical devices on both track and locomotives. Class I freight railroads, for example, must implement PTC on over 70,000 of the approximately 94,000 miles over which they operate, which is about 75 percent of their network.[42] The railroad industry estimates that about 50,000 wayside units must be installed along track, and data radios must be installed on each wayside unit. Class I freight railroads also expect to install PTC computers and data radios on over 17,000 locomotives, which represent about 70 percent of their fleet that is used for mainline operations. Additionally, commuter railroads must install PTC on their vehicles, even if the railroads do not own track, which FRA estimates will mean equipping about 4,100 vehicles. As we have previously stated, PTC computers are available for installation on new locomotives, but some older locomotives need to be upgraded first before PTC can be installed. Officials at some Class I freight railroads and commuter railroads have expressed concern that a limited number of companies are currently responsible for supplying PTC components to railroads, and that the availability of equipment could impact railroads' ability to complete implementation on time. While rail supply companies told us they expect to meet the demand for PTC components, some also acknowledged that they may need to expand to do so.

Completing implementation will be costly for the railroad industry and could make it difficult for commuter and smaller freight railroads to meet the 2015 deadline. In 2009, FRA estimated that developing, purchasing, installing, and maintaining PTC would likely cost railroads between $9.5 billion and $13.1 billion. However, because these costs are still uncertain, the agency acknowledged that costs could be as low as $6.7 billion or as high as $22.5 billion. The large amount of equipment needed to complete implementation before the deadline will create a temporary increase in demand for suppliers. FRA has acknowledged that having multiple railroads purchasing the same equipment at the same time could cause the prices of PTC equipment to rise and, therefore, could raise the overall cost of implementation.

[42]We did not review all railroads' PTC implementation plans to determine the extent to which they must implement PTC. FRA regulations permit exceptions for the implementation of PTC on the basis of certain conditions. For example, FRA may approve exceptions on segments that trains use for limited operations, either at restricted speed or while separated from other trains.

Among passenger railroads, the cost of PTC could be especially problematic. For example, Amtrak officials expressed concern about the cost of PTC implementation on Amtrak routes supported with state funding, since some states may not be able to fund the additional costs associated with PTC implementation.[43] Commuter railroads are publicly funded, and some are facing funding shortfalls that are leading them to increase fares or reduce service levels. In their implementation plans, some commuter railroads stated that funding for current operations is already at risk due to stress on their state funding partners, and officials from other commuter railroads told us that they are unsure how they will be able to pay for PTC implementation. The American Public Transportation Association has estimated that PTC implementation will cost the commuter railroad industry at least $2 billion. Although the cost of implementation will be spread over a number of years, it could still strain the budgets of some commuter railroads.[44] For example, a transit agency in San Diego, California, told us that implementing PTC for its commuter railroad could cost as much as $60 million to $90 million, while the annual capital budget for the agency, which also provides bus service, is about $10 million. In its PTC implementation plan, this agency stated that it did not have any significant approved funding available for implementation, and that its funding plan assumed receipt of both federal and state funding. Furthermore, the Federal Transit Administration (FTA) has estimated that commuter railroads face a $12.6 billion backlog to attaining a state of good repair, indicating that these railroads must make significant capital investments to improve the condition of their current assets.[45] The cost of PTC could further delay commuter railroads making such investments.

[43]These costs may not be limited to equipping Amtrak locomotives with PTC where they operate on Class I territory. Agreements with freight railroads state that Amtrak pays the incremental costs of using the freight networks. If implementation of PTC along the track is required solely due to the presence of passenger trains, Amtrak may have to cover the cost of implementation.

[44]FRA's cost estimates were for a 20-year period; however, railroads would likely incur all development and installation costs, as well as some maintenance costs, early on. FRA's analysis indicates that about 50 percent of the total cost of PTC implementation would be incurred through 2015.

[45]Federal Transit Administration, *National State of Good Repair Assessment* (June 2010).

Class II and Class III freight railroads may also have difficulty in paying for PTC implementation.[46] These freight railroads earn much less revenue than Class I freight railroads, and officials from the American Short Line and Regional Railroad Association expressed concern about the ability of these railroads to cover the costs of PTC. Class II and Class III freight railroads tend to have older equipment, for which the costs of PTC installation will be higher since, as we have previously discussed, some older locomotives will require electronic upgrades to enable the installation of PTC components. According to officials at the American Short Line and Regional Railroad Association, the cost of installing PTC on some locomotives could exceed the total value of those locomotives. The four Class II and Class III freight railroads that included a description of implementation risks in their PTC implementation plans included cost as a risk factor, with one railroad noting that paying for PTC will require it to divert funding from its routine maintenance requirements. Even the larger freight railroads acknowledged that paying for PTC could have implications on their budgets. Specifically, officials from Class I freight railroads and AAR have indicated that paying for PTC could result in the diversion of funds from capital investments, such as capacity-improving projects, and could impact their ability to invest in other safety technologies.

The uncertainties that we discuss regarding when the remaining tasks to implement PTC can be completed, as well as the cost of doing so, raise certain risks to the successful completion of PTC by the deadline. Potential delays in developing PTC components, software, and interoperability standards, as well as delays that could occur during the subsequent testing and implementation of PTC systems, raise the risk that railroads will not meet the implementation deadline and that the safety benefits of PTC will be delayed. Furthermore, the extent to which commuter railroads and small freight railroads have difficulty in covering the costs of PTC implementation raises the risk that these railroads could miss the deadline if funding is not available or that other critical needs may go unmet if money is diverted to pay for PTC. As we noted, commuter railroads are already facing challenges in funding current operations, and

[46]The total cost of PTC implementation to Class II and Class III railroads is less clear. Although FRA has indicated that only a limited number of these railroads will be required to implement PTC on the basis of the requirements in the Rail Safety Improvement Act of 2008, Class I freight railroads could require railroads that operate in Class I territory equipped with PTC to install PTC on their locomotives.

paying for PTC could impact the ability of these railroads, as well as smaller freight railroads, to make the necessary investments in maintenance.

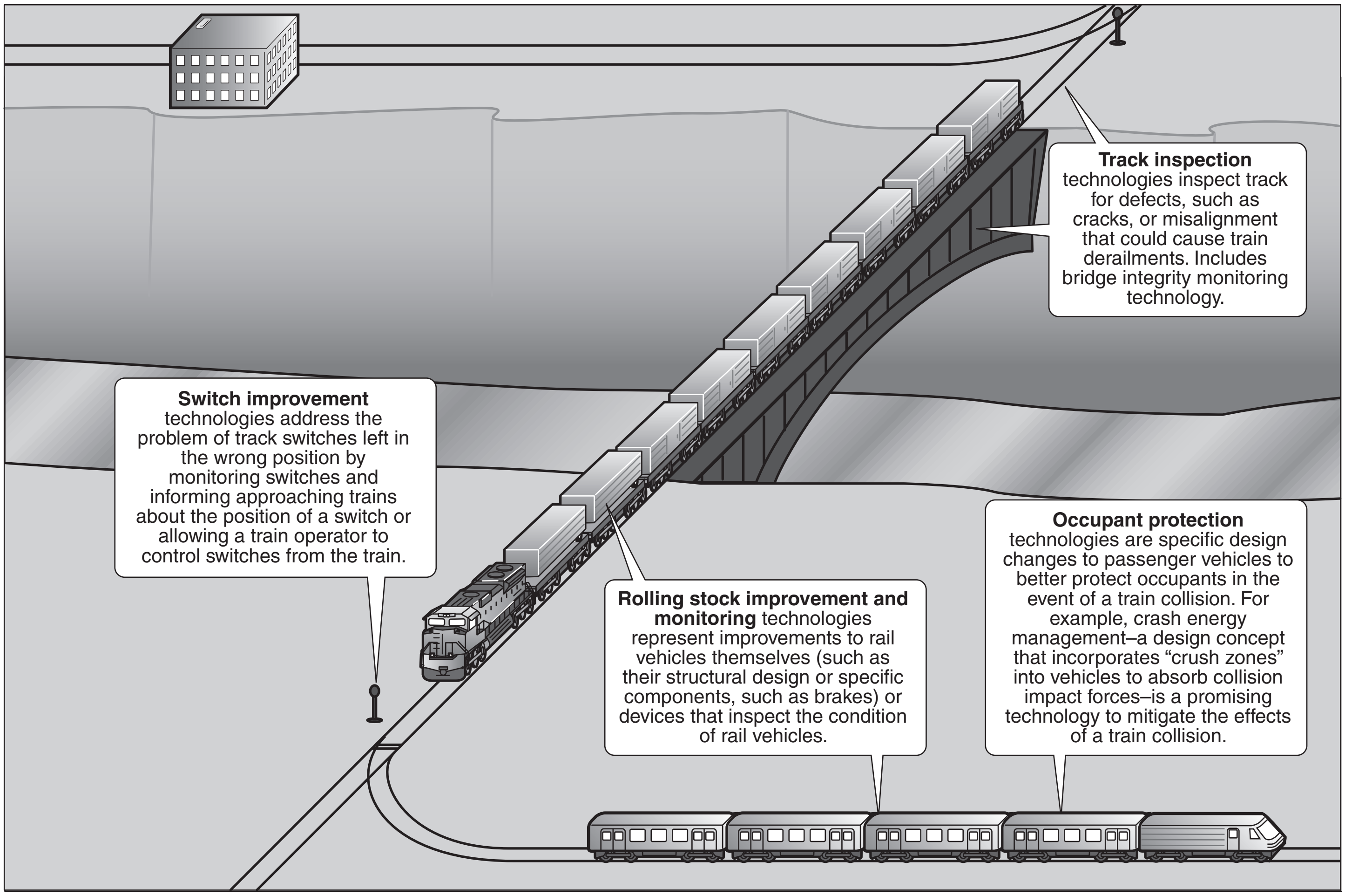
Other Rail Safety Technologies Hold Promise for Preventing or Mitigating Collisions and Derailments, but Face Implementation Challenges

Rail Safety Technologies to Inspect Track, Improve or Monitor Rolling Stock, Protect Occupants, and Improve Switches Hold Promise for Addressing Key Causes of Accidents

While PTC addresses some accidents caused by human factors, other technologies being developed can address other causes of accidents, such as problems with track or equipment that account for a significant portion of accidents and would not be addressed by PTC. According to experts and other stakeholders from the railroad industry and government, a number of rail safety technologies under development hold promise for improving safety.[47] In particular, some of these technologies may be essential for addressing the safety of high-speed passenger rail or areas of track that lack signals or PTC. We identified four broad categories of technologies that current development efforts are focused in. Figure 6 shows where such technologies can be integrated into the existing rail environment to improve safety.

[47] Information in this section of our report is based, in part, on information we obtained from rail safety technology experts through interviews and a subsequent questionnaire. Of the 20 experts we identified and interviewed, 19 responded to the questionnaire; however, the number of experts that answered each question varied because experts were asked to answer only those questions about technologies that they were familiar with, and not every expert was familiar with all of the technologies in the questionnaire. For detailed results of the questionnaire, see appendix III.

Figure 6: Integration of Other Rail Safety Technologies in the Rail Environment



Source: GAO.

- *Track inspection:* New technologies have the potential to better inspect track for cracks in the rail that could lead to breakage as well as measure the track's alignment to ensure that rails are laid at the proper angle and distance apart. About one-third of rail accidents are caused by track defects, such as broken or misaligned rail that could cause a train to derail. Experts and other stakeholders noted that some of these technologies have the potential to allow railroads to better manage track risks by providing more accurate data about the size and nature of track defects. Railroads could then monitor such defects over time and make risk-based track maintenance decisions. Such technologies could be particularly useful for high-speed passenger rail operations, since track that carries high-speed trains must be maintained to a higher standard.

- *Switch improvement:* These technologies address the problem of track switches left in the wrong position, which could lead a train onto the wrong track and cause an accident. Several experts observed that technology to monitor and indicate the position of a switch would provide particular benefit for sections of track that lack signals, and two experts told us the technology would have prevented the 2005 accident in Graniteville, South Carolina. This technology is among those that the Rail Safety Improvement Act of 2008 suggests DOT include when prescribing the development and implementation of rail safety technologies in areas of track that lack signals or train control systems.

- *Rolling stock improvement and monitoring:* New technologies to improve the function or design of rail vehicles, as well as devices to inspect them, can provide safety benefits by improving the safe operation of trains and better identify when train components develop problems that could cause an accident. For example, experts and other stakeholders noted that technology to provide real-time monitoring of certain wheel assembly components is an important technology for high-speed trains, since overheating of these components can quickly lead to failure. European officials from an association of rail supply companies told us this technology is used for European high-speed passenger trains.[48]

- *Occupant protection:* Incorporating new designs into passenger rail vehicles, such as crash energy management—a design concept that incorporates parts designed to crumple under stress to absorb collision energy to mitigate impact forces—represents a new way of thinking about crashworthiness, which has traditionally involved designing vehicles with hard exteriors to resist deformation. European rail officials told us this technology is used in European passenger trains. FRA's crashworthiness regulations have included standards for incorporating crash energy management into rail vehicles since 1999 and require crash energy management for high-speed passenger trains operating up to 150 miles per hour.[49]

Among the technologies we examined, we identified some as being more promising, based on experts' views about the technologies' potential to improve safety, their worth in doing so compared with their additional

[48]European safety standards for high-speed passenger trains that travel above 155 miles per hour require the installation of onboard equipment to monitor the temperature of bearings in the cars' wheel assemblies and inform the driver of any potentially dangerous deterioration.

[49]49 C.F.R. § 238.403.

cost for development and implementation, and their being in a later stage of product development (see table 3).[50]

Table 3: Most Promising Rail Safety Technologies under Development, Based on Expert Views, by Category

Technology	Description
Track inspection	
Bridge integrity monitoring systems	Sensor-based systems used to detect bridge damage or structural defects that could lead to collapse.
Rolling stock improvement and monitoring	
Wayside detectors	Devices installed along tracks that inspect vehicles as they pass to monitor vehicle health or examine them to identify potential problems that could cause an accident in certain locations, such as examining wheel structures before trains go down hills.
Electronically controlled pneumatic brakes	Advanced braking system that increases the speed at which brake signals are sent through a train, which can reduce stopping distances and prevent braking-related derailments.
Occupant protection	
Crash energy management	Incorporates crush zones into vehicle design to absorb energy and better control the deformation of a vehicle in the event of a collision to preserve occupant space.
Improved design of interior passenger car fixtures	Modification to interior fixtures of passenger cars, such as seats and tables, to reduce the severity of injury during an accident.
Switch improvement	
Switch position monitors/indicators	Monitors the position of track switches and provides this information to train operators.

Source: GAO analysis of expert questionnaire responses.

[50]Specifically, experts viewed certain technologies as having more potential to improve safety, being worth the additional cost of R&D and implementation, and being in later stages of product development. In our questionnaire, we asked experts their views on technology maturity using five categories of technology development ordered from earlier to later stages: concept exploration, proof of concept and initial design, refinement and pilot testing, production and some deployment, and widespread industry deployment. Because we focused on technologies currently under development, we removed from our scope any technologies for which there was a consensus among the experts that they were fully deployed.

Regarding their stage in product development and implementation, experts mostly viewed these technologies as having some deployment, except for wayside detectors, which experts viewed as more widely deployed; however, this may vary depending on the type of detector.[51]

Some of these most promising technologies are also deployed in other countries; however, differences in the nature of rail systems in those countries as compared with the United States could mean that the benefits of a particular technology may not be the same. As we have previously discussed, the U.S. rail system consists mostly of freight railroads; however, in Europe and Japan, passenger rail, including high-speed rail, is more predominant. Such differences in the rail systems may lead to differences in how new rail safety technologies are implemented. For example, although foreign stakeholders told us that electronically controlled pneumatic brakes are common on passenger trains in Europe, they are not used on freight trains. Because European freight trains are generally lighter and shorter than American freight trains, they can stop in a shorter time and distance than longer, heavier American freight trains can stop. Consequently, a European freight railroad would realize less benefit from the improved stopping efficiency that this technology offers. Additionally, unlike in the United States, there is not a significant amount of European track miles that lack signals, so the challenge of addressing safety for unsignaled areas with technologies such as switch position monitors/indicators is generally not an issue. Additionally, philosophical differences in approaches to railroad safety may affect how rail safety technologies are implemented. Specifically, foreign rail officials and academics with knowledge of rail practices in Europe and Japan, as well as FRA officials, told us that safety efforts in Europe and Japan are driven more by a desire to avoid accidents, rather than to mitigate their effects.

[51]For example, one academic expert noted that infrared-based devices that examine wheel bearings are mature and deployed, but that newer acoustic-based devices that inspect bearings are being developed and tested.

Cost, Uncertainty about Effectiveness, Regulations, and Lack of Interoperability Create Challenges to Implementing New Rail Safety Technologies

Experts and other stakeholders identified costs, uncertainty about effectiveness, regulations, and lack of interoperability with existing systems and equipment as key challenges to implementing new rail safety technologies:

- *Cost:* Most experts indicated that cost was a major challenge for implementing rail safety technologies in all four technology categories, including for some of the most promising technologies—specifically electronically controlled pneumatic brakes, crash energy management, and switch position monitors/indicators.[52] Additionally, according to some experts, other stakeholders, and FRA officials, because of the costs they are incurring to implement PTC, railroads are not looking to spend capital to implement other rail safety technologies. Commuter railroads and short line railroads also lack the capital budgets to invest in new technologies. Some experts and other stakeholders, as well as FRA officials, also told us there is sometimes a disconnect between who would pay for a particular technology and who would benefit from it. For example, one of the experts and representatives from a railroad association we interviewed told us that electronically controlled pneumatic brakes would most benefit the railroads, while the cost of installing them would fall on the car owner, which could be a shipping company and not a railroad.

- *Uncertainty about a technology's effectiveness:* Several of the experts and other stakeholders we interviewed identified uncertainty about a technology's effectiveness as a key implementation challenge and noted that proving the effectiveness of a new technology is critical to gaining its acceptance for use by the industry. In particular, most experts noted that uncertainty about effectiveness was a challenge to implementing several of the track inspection and measurement technologies, presumably because of their lack of maturity, since the experts also tended to indicate that these technologies were in the early stages of development.[53] The reluctance by railroads to implement a technology due to cost is also

[52]Specifically, the numbers of experts that identified cost as a major challenge for implementing these technologies were 10 of 12 experts for electronically controlled pneumatic brakes, 7 of 9 experts for crash energy management, and 7 of 11 experts for switch position monitors/indicators. Although a total of 19 experts responded to our questionnaire, the number of experts that answered these questions varied because the experts were only asked to answer questions about technologies they were familiar with.

[53]For example, 9 of 13 experts said that uncertainty about technology effectiveness was a major challenge for implementing a new track inspection technology that uses lasers to enhance ultrasonic rail inspection (laser-based, noncontact ultrasonic rail inspection), and 8 of 11 experts viewed this technology as being in a pilot testing or proof of concept phase of product development.

affected by uncertainty about a technology's effectiveness. According to FRA officials, railroads will not adopt a new technology unless they know it will deliver a positive return on their investment.

- *Regulations:* Experts and other stakeholders reported a disincentive under current regulations to use new track inspection technologies. Specifically, they were concerned that such technologies identify track defects perceived as too insignificant to pose a safety risk, but which nonetheless require remedial action under current regulations once such defects are identified. Regulations were generally not cited by experts and other stakeholders as a major challenge to implementing the other new technologies.[54]

- *Lack of interoperability with existing systems and equipment:* Most experts indicated in our questionnaire that lack of interoperability was a major implementation challenge for electronically controlled pneumatic brakes.[55] Specifically, they told us that for such brakes to function properly, all cars on a train would have to be equipped with them, which, although practical for a passenger train or a train that does not exchange cars with another train—such as a train that carries one type of cargo, like coal—would not be practical for a mixed-freight train whose cars are exchanged with other trains, which is common in rail operations. Additionally, some stakeholders said that crash energy management is difficult to retrofit into existing rolling stock. Experts did not agree that lack of interoperability was a major challenge for the other technologies.

[54]FRA regulations provide that if a track owner learns of a rail defect through inspection or other means, operation over the track is not permitted until the rail is replaced or a prescribed remedial action is taken. Such actions include applying joint bars to the track and limiting train speed over the defective track. See 49 C.F.R. § 213.113.

[55]Specifically, 11 of the 12 experts that answered this question indicated that lack of interoperability was a major implementation challenge, while 1 expert said it was a minor challenge.

FRA Has Taken Actions to Fulfill the PTC Mandate and Promote Other Technologies, but Opportunities Exist to Inform Congress of Risks and Improve Monitoring

To Date, FRA Is Taking the Necessary Steps to Fulfill the PTC Mandate

To fulfill the PTC mandate, FRA (1) has developed regulations regarding the implementation of PTC systems, (2) is monitoring PTC implementation efforts, and (3) is managing funding programs to support PTC implementation.

Development of Regulations

In January 2010, FRA issued final regulations on PTC implementation on the basis of requirements in the Rail Safety Improvement Act of 2008.[56] These regulations were developed in collaboration with the railroad industry and other stakeholders through FRA's Railroad Safety Advisory Committee. Among other things, the regulations describe the requirements of a PTC system; require railroads to submit PTC development, implementation, and safety plans and FRA to review and approve them; require railroads to implement PTC by December 31, 2015; and establish a schedule of civil penalties for violations.

Oversight of Railroads' PTC Implementation Efforts

To oversee railroads' progress in implementing PTC, FRA has provided guidance and is monitoring implementation, including by reviewing railroads' PTC-related plans and directly observing railroads' PTC-related activities. Specifically, FRA has provided guidance to the railroad industry on PTC implementation by speaking at industry conferences, meeting with railroads to discuss PTC implementation plans, and providing railroads

[56] 75 Fed. Reg. 2598 (Jan. 15, 2010).

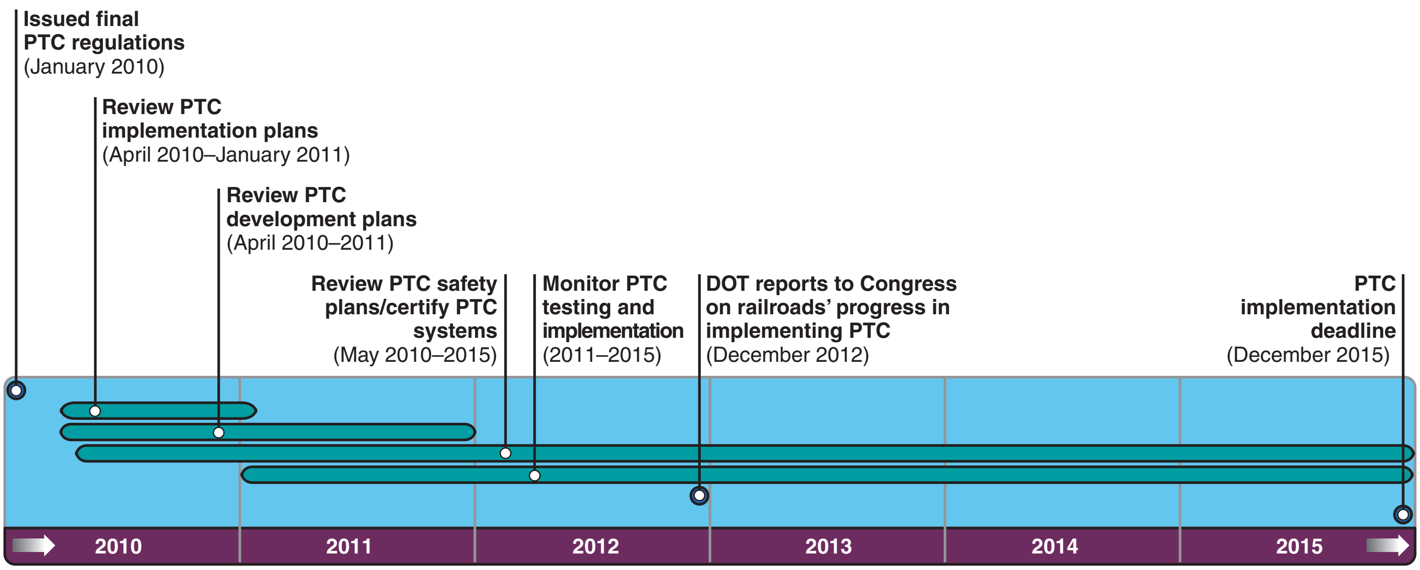
with a template for drafting their PTC implementation plans.[57] The Rail Safety Improvement Act of 2008 and FRA's regulations require the agency to provide timely review and approval of PTC development, implementation, and safety plans.[58] FRA must review and approve PTC development plans before railroads can submit their PTC safety plans, receive PTC system certification from FRA, and begin operating PTC systems (see fig. 7). FRA reviewed PTC implementation plans before completing its review of all PTC development plans, since the implementation plans had a review deadline set by statute, whereas development plans did not. As of July 2010, FRA completed its first review of all 41 of the PTC implementation plans railroads submitted. As of December 3, 2010, according to FRA officials, 21 plans were fully approved and 13 were provisionally approved. The remaining 7 plans were disapproved; the agency returned these plans to railroads with requests to make technical corrections or provide more detailed information and resubmit them to FRA for subsequent approval.[59]

[57]FRA is also developing a tool for evaluating risks associated with removing PTC from routes when making decisions regarding rerouting of airborne toxic chemicals. In October 2010, FRA officials told us that the agency would begin a rulemaking to solicit stakeholder comments in developing this tool.

[58]Specifically, the Rail Safety Improvement Act of 2008 requires FRA to review PTC implementation plans within 90 days of receipt. See 49 U.S.C. § 20157(c). Additionally, FRA's final PTC rule calls on the agency to review PTC development plans within 60 days of receipt and PTC safety plans within 180 days of receipt. If FRA is unable to meet the deadlines for PTC development and safety plan reviews, it must notify the relevant railroads. See 49 C.F.R. § 236.1009(j).

[59]The provisional approval FRA issued to some railroads required those railroads to submit a revised PTC implementation plan within 270 days accompanied by a PTC development plan, evidence that the railroad intended to implement a PTC system that FRA had already approved, or a PTC safety plan. FRA requested the railroads with a disapproved plan to meet with the agency to discuss resolution of the remaining issues in their plans. FRA officials expect to issue final approval for five of the seven disapproved plans in December 2010 and are working with the other two railroads in hopes of resolving their remaining issues in early 2011.

Figure 7: Approximate Timeline of Key FRA Actions to Meet the PTC Implementation Mandate



Source: GAO.

Note: Dates are approximations based on information provided by FRA.

FRA has since been reviewing PTC development plans. According to the PTC final rule, FRA, to the extent practicable, will approve, approve with conditions, or disapprove these plans within 60 days of receipt.[60] In March 2010, three of the four largest Class I freight railroads jointly submitted a PTC development plan. In a May 2010 letter to those railroads, FRA stated it would not complete review of the plan within the 60-day time frame specified in the final rule because agency personnel were needed to review the large number of implementation plans FRA received, which had a review deadline set by statute. FRA completed an initial review of the development plan in July 2010 and sent a letter to the railroads asking them to (1) revise the development plan and resubmit it after making some corrections and (2) provide FRA with specific details on the magnitude of the risk the delay in FRA's review and approval of the development plan would have on the timely implementation of PTC. FRA officials told us

[60] If FRA has not approved, approved with conditions, or disapproved the PTC development plan within the 60-day window, the agency must provide a statement of the reasons why the submission has not been acted on and a projected deadline for doing so. See 49 C.F.R. § 236.1009(j)(2)(iii).

they met with representatives from these railroads in August and October 2010 to discuss resolution of FRA's remaining issues and concerns and are working with the railroads on an ongoing basis to do so. Several experts and other stakeholders told us that if development or implementation plan approvals were delayed, railroads' PTC implementation schedules could, in turn, be delayed, possibly resulting in railroads not meeting the PTC implementation deadline. In this specific case, the three Class I freight railroads noted in a July 2010 letter to FRA that a delay in approving their PTC development plan could delay PTC development and implementation time frames. Other railroads could also be affected, since three other Class I freight railroads, three smaller freight railroads, Amtrak, and nine commuter railroads are relying on the approval of this plan, because they are also implementing the same PTC system.

FRA plans to monitor railroads' progress in implementing PTC by requiring railroads to provide periodic information on implementation progress and by directly observing railroads' testing and implementation of PTC. In its final PTC rule, FRA requires that railroads report annually on the percentage of their trains that are PTC-equipped and operating on PTC-equipped track.[61] FRA officials told us that the intent of this reporting is to monitor railroads' implementation of PTC so that railroads gradually implement this technology in the years leading to the 2015 deadline. Members of the newly established PTC branch within FRA's Office of Safety will conduct further monitoring of PTC implementation. According to FRA officials, these 11 new staff members in headquarters and regional offices will monitor railroads' work to verify the accuracy of information in PTC track databases; observe testing conducted by railroads prior to PTC system certification; and, if needed, advise railroads to conduct more tests or different tests to establish that the PTC system complies with FRA regulations.[62] Additionally, FRA is required to report to Congress in 2012 on the progress railroads have made in implementing PTC.[63]

Financial Assistance

FRA manages two funding programs to assist with PTC implementation. First, as required by the Rail Safety Improvement Act of 2008, FRA

[61] 49 C.F.R. § 236.1006(b)(2).

[62] In advertising for PTC branch staff, FRA sought individuals experienced in the design, construction, maintenance, testing, and use of railroad signal and train control systems, in general, and in PTC systems, in particular. According to FRA officials, these positions have been filled with experienced individuals.

[63] 49 U.S.C. § 20157(d).

manages a grant program to fund the deployment of rail safety technologies. This program is authorized to offer up to $50 million in grants to railroads each year for fiscal years 2009 through 2013. Congress did not appropriate funding for this program in fiscal year 2009 and provided $50 million in fiscal year 2010.[64] The law stipulates that funding under this program be prioritized for implementation of PTC over other rail safety technologies. In November 2010, FRA awarded grants totaling $50 million to seven projects for fiscal year 2010, six of which were related to PTC, while the seventh was awarded for implementation of a risk management system. FRA received 41 applications seeking over $228 million in funding for the fiscal year 2010 grants. This grant program is particularly popular, but its funding as authorized will cover only a small portion of the estimated costs of PTC implementation, which FRA has acknowledged could range from $6.7 billion to $22.5 billion. Second, FRA also manages the Railroad Rehabilitation and Improvement Financing Program, which authorizes FRA to provide loans and loan guarantees up to $35 billion ($7 billion of which is reserved for non-Class I freight railroads). Funding awarded under this program may be used for several purposes, including implementation of PTC and other rail safety technologies, but can also be used for more general improvements to infrastructure, including track, bridges, and rail yards. FRA staff told us that as of September 2010, no railroads have applied to this loan program for PTC implementation and speculated that the program's requirement to demonstrate creditworthiness may have deterred some railroads from applying. It may also be too soon in the PTC implementation time frame for most railroads to need loans, if they are not yet purchasing PTC equipment. Officials from the American Short Line and Regional Railroad Association told us that using these loans to pay for PTC would help smaller freight railroads meet the implementation mandate.[65]

In addition, FRA officials said that the agency is working with FTA to see whether FTA could provide financial assistance to commuter railroads for PTC implementation. FRA officials said that to provide this financial assistance, FTA would need to seek additional funds in its annual budget

[64]The funds appropriated in fiscal year 2010 are available until expended. See Consolidated Appropriations Act, 2010, Pub. L. No. 111-117, Div. A, Title I, 123 stat. 3034, 3056 (Dec. 16, 2009).

[65]Additionally, FRA officials told us that PTC implementation projects are eligible for possible competitive funding provided by the American Recovery and Reinvestment Act of 2009. Examination of such funding is beyond the scope of this review.

request to Congress. FTA did not request such funds for fiscal year 2011 and is currently developing its budget request for fiscal year 2012.

FRA Has an Opportunity to Identify and Report to Congress on PTC Implementation Risks and Potential Mitigation Actions

As we have previously discussed, there are uncertainties regarding when the remaining tasks to implement PTC can be completed, which raise certain risks to the successful completion of PTC by the 2015 deadline. FRA officials told us they are aware of some of these risks, but they said that it is too early to know whether they are significant enough to jeopardize successful implementation by the 2015 deadline. However, as FRA moves forward with monitoring railroads' implementation of PTC, the agency will have more information regarding the risks previously discussed. In particular, the agency should have a clearer picture of whether it is likely railroads will meet the 2015 implementation deadline and what the associated implications would be. For example, by the time FRA reports to Congress in 2012 on PTC implementation progress, it will be clearer whether the state of PTC component maturity poses a risk to timely implementation, since the railroad industry currently expects components will be available by 2012. Additionally, the cost to implement PTC should be more certain, and therefore it will be clearer whether problems in financing PTC—particularly for commuter and smaller freight railroads—could lead to delays or whether the costs of PTC could result in other operational needs, such as maintenance, going unmet due to the diversion of funds to pay for PTC.

Our past work has shown that the early identification of risks and strategies to mitigate them can help avoid negative outcomes for the implementation of large-scale projects. For example, our 2004 report examining an Amtrak project to improve the Northeast Corridor noted that early identification and assessment of problems would allow for prompt intervention, increasing the likelihood that corrective action could be taken to get the project back on track.[66] Furthermore, for our work examining the transition from analog to digital television broadcasting, we pointed out how such efforts are particularly crucial when the implementation of a large-scale project relies on private organizations to

[66]GAO, *Intercity Passenger Rail: Amtrak's Management of Northeast Corridor Improvements Demonstrates Need for Applying Best Practices*, GAO-04-94 (Washington, D.C.: Feb. 27, 2004). The need to address risks early, particularly risks associated with a project's cost and schedule, has long been part of our work to assess efforts related to major capital investments. See GAO, *Executive Guide: Leading Practices in Capital Decision-Making*, GAO/AIMD-99-32 (Washington, D.C.: December 1998).

achieve public benefits.[67] Such is the case with the implementation of PTC, which was mandated for reasons of public safety but is largely the responsibility of railroads to accomplish. FRA's 2012 report to Congress presents the agency with an opportunity to inform Congress of the likelihood that railroads will meet the 2015 implementation deadline, as well as potential implementation risks and strategies to address them. Such information would help Congress determine whether the railroad industry is on track to successfully implement PTC by 2015 or whether there are major risks associated with this effort that require intervention by Congress, FRA, railroads, or other stakeholders. FRA officials told us they have not yet determined what information will go in their report.

FRA Has Taken Some Actions to Encourage the Implementation of Other Technologies, but Does Not Fully Use Best Practices

In keeping with its mission of promoting safety throughout the national railroad system, FRA has taken a number of actions to encourage the use of rail safety technologies other than PTC—such as electronically controlled pneumatic brakes or switch position monitors/indicators—by (1) collaborating with industry on R&D efforts, (2) supporting demonstration and pilot projects, (3) analyzing technology costs related to benefits, and (4) issuing or revising regulations.[68]

Collaboration with Industry on R&D

FRA has worked with members of the railroad industry—through the Railroad Safety Advisory Committee, AAR, and TTCI—to prioritize and select technologies to be included in FRA's R&D program. FRA and AAR collaborate extensively on R&D projects at TTCI, a DOT-owned, AAR-operated research facility. Additionally, FRA's Office of Research and Development may select a railroad partner when beginning a new R&D project. For example, FRA partnered with one of the largest Class I freight railroads to demonstrate a new technology that measures the interaction between rail cars and the track—known as vehicle/track interaction technology. According to a senior FRA official, these devices are now widely deployed, and FRA continues to study ways to model vehicle/track interaction. Each year, FRA also presents information about its completed and ongoing R&D projects to the Transportation Research Board—a body

[67]GAO, *Digital Television Transition: Increased Federal Planning and Risk Management Could Further Facilitate the DTV Transition*, GAO-08-43 (Washington, D.C.: Nov. 19, 2007).

[68]According to FRA officials, a demonstration project involves testing a technology to show how it works and whether it achieves its intended result. A pilot project generally follows a demonstration project and is used to compile data about the technology to demonstrate its benefits.

that includes railroad industry representatives—which then conducts an evaluation of FRA's R&D program.[69] Additionally, the Rail Safety Improvement Act of 2008 called for FRA to develop a railroad safety strategy, which the agency issued in 2010 with its fiscal year 2011 budget request. Although this plan does not include any efforts to encourage implementation of specific rail safety technologies, it does state that FRA's Office of Research and Development has expanded its use of grants and partnerships with railroads and suppliers to improve stakeholder participation in its R&D and support the demonstration of results as soon as possible.

Support of Demonstration and Pilot Projects

FRA has conducted and provides support for a number of demonstration and pilot projects that examine technologies aimed at improving rail safety and help to demonstrate to railroads the effectiveness of these technologies. According to FRA staff, the agency has put a focus on funding technology demonstration projects and has a cooperative agreement with AAR to do this work. Based on our review of FRA's list of 143 current R&D projects for fiscal year 2010, 49 of these projects appear to involve demonstrations of new technologies or existing technologies used in new ways to improve safety. For example, there is a current demonstration project examining the use of electronically controlled pneumatic brakes. Past demonstration projects have examined a variety of rail safety technologies, including devices that measure track—known as gage restraint measurement systems[70]—vehicle/track interaction technology and automated inspection devices. Additionally, an FRA risk-reduction grant program supports several ongoing pilot projects with railroads, two of which are examining technologies aimed at continuously testing track to collect data on the track's performance as well as to

[69]The Transportation Research Board's Committee for Review of the FRA Research and Development Program includes members from government, the railroad industry, academia, and labor. See Transportation Research Board, *Review of the Federal Railroad Administration Research and Development Program: Letter Report February 2010* (Washington, D.C.: Feb. 24, 2010).

[70]Gage refers to the distance between the two rails of a track, which, if changed, could cause a derailment. Gage restraint is the ability of rail infrastructure to maintain this requisite distance, which can be affected by problems such as defective rail ties or changes in the underlying material the track sits on.

identify defects.[71] FRA produces summary reports of some of its R&D efforts and publishes these reports on its Web site.

Analysis of Technology Costs and Benefits

FRA has taken recent actions to analyze the potential costs and benefits to railroads of implementing new rail safety technologies. When issuing the final rule on electronically controlled pneumatic brakes, FRA conducted a cost-benefit analysis and included this information in the rule. Additionally, FRA analyzed potential return on investments for vehicle/track interaction technology to demonstrate to freight railroads potential cost-savings that could be achieved from implementing this technology by preventing derailments and reducing the need for emergency repairs or slow speed orders on sections of track with defective rail. FRA staff noted that railroads generally will not adopt a new technology unless it can be demonstrated to have a positive return on investment within 1 to 2 years. FRA staff also noted that because the agency demonstrated a positive return on investment for a new vehicle/track interaction system, a major Class I freight railroad adopted the technology.

Issuance and Revision of Regulations

FRA has also issued or revised regulations and is planning further regulatory changes in an attempt to encourage the use of new rail safety technologies. For example:

- FRA issued final regulations promoting the use of electronically controlled pneumatic brakes in October 2008.[72] The regulations create an incentive for installing this technology by allowing railroads that install these brakes and comply with the regulations to conduct less frequent brake inspections, thereby decreasing the railroads' inspection costs and potentially allowing for more frequent train operations. Prior to the establishment of these regulations, railroads were not permitted to use these specialized braking systems without first applying for an exemption from existing FRA regulations. FRA will provide an exemption from existing regulations on a case-by-case basis to railroads that seek such approval. For example, before PTC was required by law, FRA issued regulatory exemptions and eventually established regulations promoting

[71] According to FRA officials, the agency awarded $433,000 in grants to seven pilot projects in fiscal year 2009 and an additional $350,000 to five of those projects in fiscal year 2010. In addition to this funding, FRA officials told us that the railroads cover the majority of the costs associated with these pilots.

[72] 49 C.F.R. § 232.

the use of PTC.[73] FRA has also issued regulatory exemptions allowing for the use of unmanned track inspection machines to monitor track conditions and crash energy management designs in passenger rail vehicles.

- FRA is currently working with the Railroad Safety Advisory Committee to revise its track inspection regulations, which, according to some experts and stakeholders we spoke with, create a disincentive for railroads to implement new track inspection technologies. As previously discussed, current FRA regulations generally require railroads to take remedial action, such as limiting train speeds or replacing track, when a track defect is found.[74] Stakeholders we spoke with noted that using newer track inspection technologies would detect a greater number of small, relatively minor defects that pose little to no safety risk, along with more significant defects. However, stakeholders stated that FRA's current track inspection regulations could create a situation in which railroads using newer inspection technologies might find more small defects than they could practically examine and fix in a timely manner, and could be held liable for identifying defects they did not quickly repair. To account for these newer technologies, FRA staff said they are considering changes to the remedial actions railroads must take in response to identified rail defects. FRA expects to issue a notice of proposed rulemaking on this and other changes to its track inspection regulations in the spring of 2011. Additionally, pursuant to its safety strategy for high-speed rail, FRA officials said they are considering revisions to FRA's passenger vehicle regulations to encourage the implementation of technologies that monitor the condition of rail vehicles, although the agency has not yet identified these specific requirements.

- The Rail Safety Improvement Act of 2008 also requires FRA to take action in two specific ways to encourage the use of rail safety technologies in addition to PTC. First, the act requires FRA to prescribe standards, regulations, guidance, or orders by October 2009 for railroads to implement rail safety technologies in areas of track without signals or PTC. FRA officials began this effort in September 2010 by proposing that the Railroad Safety Advisory Committee establish a task force to develop a proposed rule. This proposal was accepted; however, the task force will delay meeting until representatives serving on another task force involved

[73]49 C.F.R. §§ 209, 234, and 236.

[74]49 C.F.R. § 213.113.

in PTC issues are available.[75] FRA staff stated that the agency has delayed meeting the October 2009 requirement because FRA gave priority to the PTC rulemaking. Second, by October 2012, FRA must develop regulations requiring Class I freight railroads, Amtrak, commuter railroads, and other railroads that FRA determines have an inadequate safety record to develop a risk-reduction program that includes a technology implementation plan describing railroads' efforts to implement new rail safety technologies.[76] FRA issued an advanced notice of proposed rulemaking on December 8, 2010, seeking comment on the possible requirements of this program.

The National Academies' Transportation Research Board has identified a number of best practices for encouraging the implementation of new technologies. Of these best practices, those most applicable to FRA's efforts fall into four key areas:[77]

- *Early involvement of users:* Involving potential users of a technology early on in its development, such as seeking information from users about their needs and enlisting their assistance, can help ensure that products developed respond to users' requirements.
- *Demonstrating technology effectiveness:* Agency efforts aimed at demonstrating the effectiveness of a technology can help other potential users decide whether to implement the technology. Activities that can help to demonstrate a technology's effectiveness include supporting demonstrations or pilot projects and conducting cost/benefit or similar analyses.

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[75]FRA officials told us that the timing of the task force's first meeting and its membership will be discussed at the December 2010 Railroad Safety Advisory Committee meeting.

[76]49 U.S.C. § 20156(d).

[77]The Transportation Research Board has identified a number of other best practices. See Transportation Research Board, *Transportation Technology Transfer: Successes, Challenges, and Needs: A Synthesis of Highway Practice*, National Cooperative Highway Research Program Synthesis 355 (Washington, D.C.: 2005); and *Managing Technology Transfer: A Strategy for the Federal Highway Administration*, Special Report 256 (Washington, D.C.: 1999). These reports focused on technologies related to highways, but the practices are applicable to other transportation modes, such as railroads. We are citing in this report those best practices we identified as most applicable to FRA's efforts to promote the implementation of new rail safety technologies on the basis of our review of these Transportation Research Board studies.

- *Offering incentives:* Activities to provide financial assistance and efforts to revise regulations to create other incentives can help encourage the implementation of new technologies.

- *Monitoring and reporting on technology adoption:* Careful monitoring of the acceptance, adoption, refinement, and satisfaction among users of the technologies being promoted can provide lessons learned about agency efforts to encourage technology implementation. Reporting this information can help demonstrate program results and build support for the agency's efforts.

The actions we previously discussed that FRA has taken to encourage the implementation of rail safety technologies align with most of these practices and help to address some of the implementation challenges experts identified, including uncertainty about technology effectiveness and regulatory disincentives. Specifically, FRA's collaboration with the railroad industry in its R&D efforts involves potential technology users early and helps to ensure its efforts address industry needs while also expediting the potential adoption of new technologies. FRA's sponsorship of demonstration and pilot projects and its analyses of technology costs and benefits help to demonstrate the effectiveness of new technologies. FRA's current efforts to revise some track inspection regulations may address the disincentives in these regulations that discourage railroads from implementing new inspection technologies. Additionally, FRA has a grant program to provide funding for implementing new rail safety technologies, although, at present, the program has been prioritized for PTC and is not being used to fund implementation of other types of rail safety technologies.

Although FRA has taken actions that align to most of the best practices previously identified, the agency lacks a method to effectively monitor implementation of new rail safety technologies that would allow it to better demonstrate the results of its efforts. Specifically, FRA officials stated that the agency does not have a method to track the extent to which the railroad industry implements technologies that FRA's R&D efforts contributed to developing. FRA staff said they have some information about the use of such new technologies, but this information is not comprehensive. For example, FRA officials said they would be aware of a railroad adopting a new safety technology if the railroad is required to seek regulatory exemption from FRA for its use. Our past work looking at the R&D program of DOT's Office of Pipeline Safety—now within the Department's Pipeline and Hazardous Materials Safety Administration—has shown that agencies that monitor and report on industry adoption of technologies supported by the agency's R&D efforts can better assess the effectiveness of those R&D efforts.[78] Specifically, the Pipeline and Hazardous Materials Safety Administration monitors and reports on its Web site the number of technologies supported by the agency's R&D efforts that have been commercialized. Without a similar method to monitor and report on the adoption of technologies supported by FRA's R&D efforts, the agency lacks information it could use to refine future R&D efforts or help demonstrate the results of its R&D program, an important consideration because FRA is currently in the process of updating its R&D strategic plan. FRA's last R&D strategic plan included the goal to expedite widespread deployment of new technologies that have the potential for significant improvement in track safety—a goal for which information about the industry's adoption of new technologies could be useful for demonstrating results.[79]

Additionally, 15 of the 20 experts we spoke with indicated that FRA could do more to encourage technology implementation and suggested actions that align with the Transportation Research Board's best practices. Specifically, 3 experts said that FRA should conduct more demonstration or pilot projects, and 4 experts said that FRA should do more to identify the costs and benefits of implementing new technologies—actions that align with the best practice of demonstrating technology effectiveness. Also, 8 experts said that FRA should offer more financial assistance, and 6 experts said that the agency should revise its regulations to provide incentives for the introduction of new technologies—actions that align with the best practice of offering incentives. While additional use of the best practices identified by the Transportation Research Board could better encourage the implementation of rail safety technologies, we are not making a recommendation at this time because FRA has other efforts that it needs to give priority to, such as overseeing investment in high-speed passenger rail and reforming its hours of service regulations.

Conclusions

Although the safety of U.S. rail continues to improve, recent railroad accidents prompted the enactment of the Rail Safety Improvement Act of 2008, including the requirement to implement PTC. Other recently enacted

[78]GAO, *Pipeline Safety: Systematic Process Needed to Evaluate Outcomes of Research and Development Program*, GAO-03-746 (Washington, D.C.: June 30, 2003).

[79]Federal Railroad Administration, *Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations* (Washington, D.C.: March 2002).

laws indicate significant interest in expanding passenger rail services, particularly high-speed passenger services, which will change the nature of the mode and introduce new safety risks. The strategic development and implementation of PTC and other new rail safety technologies can help FRA and the industry address these risks while ensuring that rail remains a safe form of transportation.

The railroad industry is making progress in developing and implementing PTC, but much remains to be accomplished to develop, test, and install fully functional PTC systems in time to meet the 2015 implementation deadline. At present, it is unclear whether various issues—such as the lack of mature PTC components and the cost of implementation, particularly to commuter and smaller freight railroads—could result in railroads missing this deadline or lead to other operational impacts for railroads. However, the PTC implementation deadline is still 5 years away, so it is too soon to determine for certain whether the industry will be able to meet it. This timing presents an opportunity to look ahead at what risks lie in wait that could jeopardize successful implementation and identify potential strategies to address them, rather than wait and see what problems develop and were not addressed. FRA will have the chance to publicly identify such risks, as well as potential ways Congress, the agency, or other stakeholders could address them, when it reports to Congress on PTC implementation progress in 2012. Identifying and mitigating risks sooner, rather than later, would better ensure a reliable PTC system can be fully implemented to provide the intended safety benefits of this technology without resulting in unintended consequences.

While recent laws have expanded FRA's role, its mission to promote safety remains a core responsibility. Much focus has been placed on implementing PTC to address accidents caused by human factors, but technologies besides PTC hold promise for improving safety by addressing other accident causes, such as problems with track or equipment. While FRA has employed several key best practices for encouraging the use of new technologies, employing a method to monitor and report on the industry's adoption of new technologies that FRA was involved in developing could provide useful information for demonstrating the results of its R&D program and refining future efforts. Importantly, such efforts could help the agency better fulfill its mission to promote safety throughout the national rail network.

Recommendations for Executive Action

We recommend that the Secretary of Transportation take the following two actions:

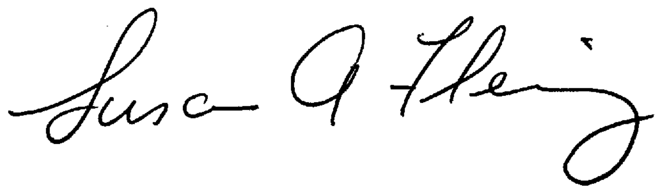
- To support the effective identification and mitigation of risks to the successful fulfillment of PTC requirements by 2015, direct the Administrator of FRA to include in FRA's 2012 report to Congress an analysis of
  - the likelihood that railroads will meet the PTC implementation deadline;
  - the risks to successful implementation of PTC; and
  - actions Congress, railroads, or other stakeholders can take to mitigate risks to successful PTC implementation.
- To better encourage the implementation of rail safety technologies other than PTC, direct the Administrator of FRA to develop and implement a method for monitoring and reporting information on the adoption of technologies supported by FRA's R&D efforts.

Agency Comments

We provided a draft of this report to the Department of Transportation for review and comment. DOT provided technical clarifications, which we incorporated into the report as appropriate. DOT also said that it would consider our recommendations. We also provided a draft of this report to Amtrak for its review and comment. Amtrak provided a technical comment, which we incorporated.

As we agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution of it until 30 days from the date of this letter. At that time, we will send copies of this report to the appropriate congressional committees, the Secretary of Transportation, and other interested parties. In addition, the report will be available at no charge on GAO's Web site at http://www.gao.gov.

If you or your staffs have any questions on this report, please contact me at (202) 512-2834 or flemings@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Contact information and key contributors to this report are listed in appendix IV.



Susan Fleming
Director, Physical Infrastructure Issues

Appendix I: Objectives, Scope, and Methodology

This report discusses (1) the progress railroads have made in developing and implementing positive train control (PTC) and the remaining steps to implement PTC systems; (2) the potential benefits of other rail safety technologies under development as well as the challenges to implementing them; and (3) the extent of the Federal Railroad Administration's (FRA) efforts to fulfill the PTC mandate and encourage the implementation of other rail safety technologies.

To obtain information about railroads' progress in developing and implementing PTC and the steps remaining to implement PTC, we interviewed representatives of the four largest Class I freight railroads (BNSF Railway, CSX Corporation, Norfolk Southern, and Union Pacific); Amtrak; five selected commuter railroads (Massachusetts Bay Transportation Authority (Boston, Massachusetts), Metra (Chicago, Illinois), North County Transit District (San Diego, California), Tri-Rail (Miami and Fort Lauderdale, Florida), and Virginia Railway Express (Washington, D.C.)); selected rail supply companies (ENSCO, MeteorComm, and Ansaldo); railroad industry associations (the Association of American Railroads (AAR), the American Short Line and Regional Railroad Association, and the Railway Supply Institute); and FRA.[1] We selected the commuter railroads to represent a range of geographic locations and levels of ridership, while selecting railroads that had relationships with all four of the largest Class I railroads and included a mix of railroads that both owned and leased track. We selected the railroad supply companies on the basis of recommendations from railroad industry associations and railroads and included all of the major suppliers for key components of the freight railroads' PTC systems. We reviewed PTC development and implementation requirements in the Rail Safety Improvement Act of 2008 and FRA regulations. We also reviewed PTC implementation plans that Class I freight railroads and Amtrak submitted to FRA. In addition, we visited and met with officials at the Transportation Technology Center, Inc. (TTCI), near Pueblo, Colorado, where some PTC components are being tested.

To obtain information about the benefits of other rail safety technologies under development, as well as the challenges to implementing them, we compiled a list of rail safety technologies currently under development in

[1]Additionally, we received written answers to our questions from another rail supply company, WabTec, and sought information from another supplier, ARINC, which declined to participate in our review.

the United States on the basis of interviews with railroads, railroad associations, FRA, and the Department of Transportation's Volpe National Transportation Systems Center (Volpe Center). We organized these technologies into four categories and refined this list during the course of our work as we obtained additional information from other stakeholders. We sought periodic feedback on the list from FRA, the Volpe Center, AAR, and TTCI. We limited the scope of these technologies to those that would prevent or mitigate train-to-train collisions and derailments and excluded technologies that addressed other risks or that experts indicated were widely deployed and therefore no longer under development.[2]

We identified, with assistance from the National Academies' Transportation Research Board, a group of 20 rail safety technology experts from railroads, rail suppliers, federal agencies, labor organizations, and universities (see app. II for a list of these experts). We interviewed these experts about their knowledge of the benefits of the rail safety technologies within the scope of this engagement, as well as their views on the challenges to implementing them, and surveyed them with a standardized assessment tool seeking information about the benefits, maturity, and implementation challenges of all the technologies in our scope. We received completed assessments from 19 of the 20 experts (see app. III for complete assessment results). Based on the rail safety technology experts' responses to our questionnaire, we identified some technologies as being more promising than others. In our questionnaire, we asked experts about their views of these technologies' potential to improve safety, the value of funding additional research and development (R&D) and implementation, and the technologies' current stages of product development. For the purposes of this analysis, we defined a technology as being more promising if it has a higher potential to improve safety, is most worth additional R&D and implementation costs, and is in a later stage of development, which presumably would mean it could be implemented sooner than a technology that is in an earlier development stage. By assigning values to the experts' responses, we determined which of the technologies in our scope most satisfied these three criteria—in other words, which technologies the experts viewed as having the most potential to improve safety, being most worth additional costs, and being

[2]We did not examine technologies specifically designed to address trespassing and highway-rail grade-crossing accidents, since the causes of these accidents are largely outside the control of railroads. Although we contacted leading government and railroad industry experts to identify rail safety technologies under development, the technologies we identified may not be comprehensive of all such technologies under development.

in the later stages of product development.[3] We also interviewed government officials, railroad industry representatives, and academics from the European Union, Japan, and Taiwan about rail safety technologies implemented in other countries, seeking insights about potential differences in implementation. We identified these stakeholders on the basis of input from FRA, the Volpe Center, the Transportation Research Board, and suggestions from foreign officials.

To obtain information about the extent of FRA's efforts to fulfill the PTC mandate and encourage the implementation of other rail safety technologies, we reviewed documentation obtained from FRA officials—including information on R&D projects, technology pilots, guidance, strategic planning, and technology implementation grants—and interviewed FRA officials responsible for the agency's rail safety technology R&D, safety regulatory efforts, and efforts to meet the PTC mandate. We also reviewed FRA's requirements in the Rail Safety Improvement Act of 2008 and related FRA regulations to fulfill the PTC mandate and encourage the implementation of other rail safety technologies. Additionally, we interviewed the experts and other railroad industry stakeholders that we have previously named about their views on FRA's efforts to fulfill the PTC mandate and encourage the implementation of other rail safety technologies. We focused our review on FRA efforts related to the implementation of these technologies and did not attempt to comprehensively review FRA's R&D program. We identified best practices for encouraging the implementation of new technologies by reviewing reports from the National Academies' Transportation Research Board and prior GAO reports.

[3]In our questionnaire, we asked experts their views on technology maturity using five categories of technology development ordered from earlier to later stages: concept exploration, proof of concept and initial design, refinement and pilot testing, production and some deployment, and widespread industry deployment. Because we focused our review on technologies under development, we excluded from our scope any technologies that a consensus of these experts indicated was widely deployed.

Appendix II: List of Rail Safety Technology Experts

Christopher Barkan, University of Illinois at Urbana-Champaign
Anna Barry, Massachusetts Bay Transportation Authority
John Bell, Federal Transit Administration
Joshua Coran, Talgo
Robert Dorer, Volpe National Transportation Systems Center
Carlton Ho, University of Massachusetts Amherst
Rick Inclima, Brotherhood of Maintenance of Way Employes Division
Semih Kalay, Transportation Technology Center, Inc.
Kevin Kesler, FRA
Francesco Lanza di Scalea, University of California, San Diego
George Long, Siemens Industry
Dan Magnus, KLD Labs
Tim Male, CSX Corporation
Alan Polivka, Transportation Technology Center, Inc.
Thomas Pontolillo, Brotherhood of Locomotive Engineers and Trainmen
Eileen Reilly, Alaska Railroad
Mark Stehly, BNSF Railway
James Stem, United Transportation Union
Michael Trosino, Amtrak
Steve Zwart, Alstom

Appendix III: Detailed Results of Experts' Assessment of Rail Safety Technologies

Following is the tool used to assess experts' views about rail safety technologies under development, complete with detailed results. We do not include the responses for open-ended questions.

Introduction

The U.S. Government Accountability Office (GAO) is an independent, non-partisan agency that assists Congress in evaluating federal programs.

We are interested in your expert professional opinions on a number of technologies for potentially improving railroad safety. We have identified the technologies included in this assessment tool through our first round of interviews with you, other experts and stakeholders, and a review of available literature. These technologies are separated into four categories – Remote Control and Switches, Rolling Stock and Condition Monitoring, Occupant Protection, and Track Inspection and Measurement.

- For the purposes of this review, we have limited our scope to reviewing only those technologies that would potentially increase safety by preventing or mitigating train-to-train collisions and derailments.

We ask that you please assess the technologies across several factors, providing comments where appropriate. In addition, we are also interested in your thoughts about possible actions that the U.S. Department of Transportation could take to encourage the implementation of new technologies. Lastly, we are interested in your opinion on the extent to which specific issues may pose a challenge to implementing positive train control by the December 31, 2015 deadline.

Instructions for Completing This Tool

You can answer most of the questions easily by checking boxes or filling in blanks. A few questions request short narrative answers. Please note that these blanks will expand to fit your answer.

Please use your mouse to navigate throughout the document by clicking on the field or check box you wish to fill in. Do not use the "Tab" or "Enter" keys as doing so may cause formatting problems.

- To select or deselect a check box, simply click or double click on the box.

Deadline

To assist us, we ask that you complete and return this document by June 15, 2010. Please return the completed survey by e-mail. Simply save this file to your computer desktop or hard drive and attach it to your e-mail.

Contact Information

Thanks in advance for taking the time to share your expertise with GAO. If you have any questions about this tool, please contact us. You may direct questions to Andrew Huddleston, Senior Analyst.

Thank you for your help.

Part 1: Remote Control and Switch Technologies

In this section we refer to Remote Control and Switch Technologies.[1] Please use the following descriptions as a guide when thinking about these specific technologies.

Descriptions of technologies referred to in this section	
a. Remote-control locomotives[2]	Use of remote control to move trains in yard switching operations or through work zones
b. Remote-control switches	Modifications for enhanced control of track switches from the locomotive or other remote location
c. Switch position monitors/indicators	Devices to monitor and report position of track switches

1. How would you rate your overall level of knowledge of increasing railroad safety through the development and use of the following remote control and switch technologies?

1 None → SKIP TO PART 2 (QUESTION #10)
6 Minimal → SKIP TO PART 2 (QUESTION #10)
5 Basic → CONTINUE TO QUESTION #2
4 Proficient → CONTINUE TO QUESTION #2
3 Advanced → CONTINUE TO QUESTION #2

[1]The names of the technology categories for parts 1 through 4 of the assessment tool appear differently in this appendix than in the body of this report, since we clarified the names of the technology categories while developing the report to characterize them more accurately.

[2]Although we included remote-control locomotives in our questionnaire, we excluded this technology from our analysis of the most promising technologies because we focused our analysis on technologies that are currently under development, and, when asked about this technology's stage in product development, all experts that answered this question indicated they viewed the technology as widely deployed.

2. How much potential, if any, does further development and implementation of the following <u>remote control and switch technologies</u> have for improving rail safety?

Remote control and switch technology	No potential	Low potential	Medium potential	High potential	No basis to judge
a. Remote-control locomotives	4	2	2	3	1
b. Remote-control switches	0	4	4	2	2
c. Switch position monitors/indicators	0	2	3	7	0

3. Considering the potential for additional safety benefits and likely research and development (R&D) costs—regardless of funding source—do you believe *further R&D* of the following <u>remote control and switch technologies</u> would be worth the investment?

Remote control and switch technology	No	Maybe	Yes	No basis to judge
a. Remote-control locomotives	6	3	3	0
b. Remote-control switches	2	3	6	1
c. Switch position monitors/indicators	1	2	9	0

4. Considering the potential for additional safety benefits and likely implementation costs—regardless of funding source—do you believe the *procurement, operation, and maintenance* of the following <u>remote control and switch technologies</u> would be worth the investment?

Remote control and switch technology	No	Maybe	Yes	No basis to judge
a. Remote-control locomotives	5	4	3	0
b. Remote-control switches	1	4	6	1
c. Switch position monitors/indicators	1	4	7	0

5. At what product development stage are the following remote control and switch technologies in the United States?

Remote control and switch technology	Concept exploration	Proof of concept and initial design	Refinement and pilot testing	Production and some deployment	Widespread industry deployment	No basis to judge
a. Remote-control locomotives	0	0	0	0	10	2
b. Remote-control switches	0	0	0	4	5	3
c. Switch position monitors/indicators	0	0	2	6	2	2

6. How much of a challenge, if any, do the following issues present for the implementation of remote-control locomotives?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	1	7	1	0	3
b. Lack of incentive under current regulations	6	2	0	1	3
c. Technology cannot be used without a regulatory waiver	5	0	1	3	3
d. Lack of interoperability with existing systems and equipment	5	2	1	0	4
e. Uncertainty about the effectiveness of the technology	3	2	3	0	4

7. How much of a challenge, if any, do the following issues present for the implementation of remote-control switches?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	4	6	0	2
b. Lack of incentive under current regulations	7	2	1	1	1
c. Technology cannot be used without a regulatory waiver	8	1	1	0	2
d. Lack of interoperability with existing systems and equipment	4	5	0	1	2
e. Uncertainty about the effectiveness of the technology	6	2	1	1	2

8. How much of a challenge, if any, do the following issues present for the implementation of switch position monitors/indicators?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	1	3	7	0	1
b. Lack of incentive under current regulations	6	3	2	0	1
c. Technology cannot be used without a regulatory waiver	8	0	1	1	2
d. Lack of interoperability with existing systems and equipment	6	3	1	0	2
e. Uncertainty about the effectiveness of the technology	6	5	1	0	0

9. What other challenges, if any, that are not listed above impede the implementation of remote control and switch technologies in the United States?

Part 2: Rolling Stock and Condition Monitoring Technologies

In this section we refer to Rolling Stock and Condition Monitoring Technologies. Please use the following descriptions as a guide when thinking about these specific technologies.

Descriptions of technologies referred to in this section		
a.	Electronically controlled pneumatic brakes	Advanced braking system that increases the speed at which brake signals are sent through a train, which can reduce stopping distances and prevent braking-related derailments
b.	Improved design of tank cars and other hazardous material cars	Improvements to hazardous material-carrying cars (e.g. structural integrity, damage tolerance) that reduce potential release of hazardous material in the event of an accident
c.	High performance wheel steels	Development of alternative wheel steels to extend wheel life and improve safety
d.	On-board condition monitoring systems	Systems installed on rail cars that continuously monitor mechanical components including bearing temperature, bearing and wheel defects, and longitudinal impacts
e.	Wayside detectors	Condition monitoring systems installed along tracks that can identify defects in various rolling stock components as trains drive by. For example, acoustic bearing detectors, wheel impact load detectors, truck performance detectors, cracked wheel detectors, wheel profile measurement.

10. How would you rate your overall level of knowledge of increasing railroad safety through the development and use of the following <u>rolling stock and condition monitoring technologies</u>?

1 None → SKIP TO PART 3 (QUESTION #21)
4 Minimal → SKIP TO PART 3 (QUESTION #21)
5 Basic → CONTINUE TO QUESTION #11
5 Proficient → CONTINUE TO QUESTION #11
4 Advanced → CONTINUE TO QUESTION #11

11. How much potential, if any, does further development and implementation of the following rolling stock and condition monitoring technologies have for improving rail safety?

Rolling stock and condition monitoring technology	No potential	Low potential	Medium potential	High potential	No basis to judge
a. Electronically controlled pneumatic brakes	0	0	5	7	2
b. Improved design of tank cars and other hazardous material cars	0	1	5	7	1
c. High performance wheel steels	0	1	8	4	1
d. On-board condition monitoring systems	0	3	4	7	0
e. Wayside detectors	0	2	2	10	0

12. Considering the potential for additional safety benefits and likely research and development (R&D) costs—regardless of funding source—do you believe *further R&D* of the following rolling stock and condition monitoring technologies would be worth the investment?

Rolling stock and condition monitoring technology	No	Maybe	Yes	No basis to judge
a. Electronically controlled pneumatic brakes	1	1	11	1
b. Improved design of tank cars and other hazardous material cars	0	2	11	1
c. High performance wheel steels	0	3	10	1
d. On-board condition monitoring systems	1	3	10	0
e. Wayside detectors	1	0	13	0

13. Considering the potential for additional safety benefits and likely implementation costs—regardless of funding source—do you believe the *procurement, operation, and maintenance* of the following rolling stock and condition monitoring technologies would be worth the investment?

Rolling stock and condition monitoring technology	No	Maybe	Yes	No basis to judge
a. Electronically controlled pneumatic brakes	0	3	10	1
b. Improved design of tank cars and other hazardous material cars	0	3	10	1
c. High performance wheel steels	0	4	9	1
d. On-board condition monitoring systems	2	5	7	0
e. Wayside detectors	0	2	12	0

14. At what product development stage are the following rolling stock and condition monitoring technologies in the United States?

Rolling stock and condition monitoring technology	Concept exploration	Proof of concept and initial design	Refinement and pilot testing	Production and some deployment	Widespread industry deployment	No basis to judge
a. Electronically controlled pneumatic brakes	0	0	4	7	1	2
b. Improved design of tank cars and other hazardous material cars	0	4	2	4	1	3
c. High performance wheel steels	0	1	2	2	0	9
d. On-board condition monitoring systems	1	4	2	5	1	1
e. Wayside detectors	0	0	0	4	10	0

15. How much of a challenge, if any, do the following issues present for the implementation of electronically controlled pneumatic brakes?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	2	10	0	2
b. Lack of incentive under current regulations	3	5	2	0	4
c. Technology cannot be used without a regulatory waiver	5	3	2	1	3
d. Lack of interoperability with existing systems and equipment	0	1	11	0	2
e. Uncertainty about the effectiveness of the technology	5	3	3	0	3

16. How much of a challenge, if any, do the following issues present for the implementation of improved design of tank cars and other hazardous material cars?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	1	10	0	3
b. Lack of incentive under current regulations	7	2	2	0	3
c. Technology cannot be used without a regulatory waiver	7	3	1	1	2
d. Lack of interoperability with existing systems and equipment	7	4	0	1	2
e. Uncertainty about the effectiveness of the technology	4	4	4	0	2

17. How much of a challenge, if any, do the following issues present for the implementation of high performance wheel steels?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	3	6	0	5
b. Lack of incentive under current regulations	7	2	0	1	4
c. Technology cannot be used without a regulatory waiver	6	2	0	2	4
d. Lack of interoperability with existing systems and equipment	5	3	0	2	4
e. Uncertainty about the effectiveness of the technology	3	7	0	0	4

18. How much of a challenge, if any, do the following issues present for the implementation of on-board condition monitoring systems?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	2	11	0	1
b. Lack of incentive under current regulations	6	3	5	0	0
c. Technology cannot be used without a regulatory waiver	9	1	0	4	0
d. Lack of interoperability with existing systems and equipment	4	6	2	0	2
e. Uncertainty about the effectiveness of the technology	3	6	5	0	0

19. How much of a challenge, if any, do the following issues present for the implementation of <u>wayside detectors</u>?

Challenge		Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a.	Costs	1	7	5	0	1
b.	Lack of incentive under current regulations	7	2	5	0	0
c.	Technology cannot be used without a regulatory waiver	8	2	1	3	0
d.	Lack of interoperability with existing systems and equipment	7	6	0	1	0
e.	Uncertainty about the effectiveness of the technology	9	4	0	1	0

20. What other challenges, if any, that are not listed above impede the implementation of <u>rolling stock and condition monitoring technologies</u> in the United States?

Part 3: Occupant Protection Technologies

In this section we refer to Occupant Protection Technologies. Please use the following descriptions as a guide when thinking about these specific technologies.

Descriptions of technologies referred to in this section		
a.	Crash energy management	Rail car designs with crumple zones that absorb energy from a collision in order to maintain occupant volume and reduce secondary impact velocities
b.	Improved design of interior passenger car fixtures	Design improvements to passenger car fixtures, such as tables and seats, to reduce the severity of injury during an accident

21. How would you rate your overall level of knowledge of increasing railroad safety through the development and use of the following <u>occupant protection technologies</u>?

3 None →SKIP TO PART 4 (QUESTION #29)
7 Minimal →SKIP TO PART 4 (QUESTION #29)
1 Basic →CONTINUE TO QUESTION #22
4 Proficient →CONTINUE TO QUESTION #22
4 Advanced →CONTINUE TO QUESTION #22

22. How much potential, if any, does further development and implementation of the following <u>occupant protection technologies</u> have for improving rail safety?

Occupant protection technology	No potential	Low potential	Medium potential	High potential	No basis to judge
a. Crash energy management	0	0	2	7	2
b. Improved design of interior passenger car fixtures	0	0	3	6	2

23. Considering the potential for additional safety benefits and likely research and development (R&D) costs—regardless of funding source—do you believe *further R&D* of the following <u>occupant protection technologies</u> would be worth the investment?

Occupant protection technology	No	Maybe	Yes	No basis to judge
a. Crash energy management	0	0	9	2
b. Improved design of interior passenger car fixtures	0	1	8	2

24. Considering the potential for additional safety benefits and likely implementation costs—regardless of funding source—do you believe the *procurement, operation, and maintenance* of the following occupant protection technologies would be worth the investment?

Occupant protection technology	No	Maybe	Yes	No basis to judge
a. Crash energy management	1	2	6	2
b. Improved design of interior passenger car fixtures	1	1	7	2

25. At what product development stage are the following occupant protection technologies in the United States?

Occupant protection technology	Concept exploration	Proof of concept and initial design	Refinement and pilot testing	Production and some deployment	Widespread industry deployment	No basis to judge
a. Crash energy management	0	1	2	6	0	2
b. Improved design of interior passenger car fixtures	1	0	3	4	1	2

26. How much of a challenge, if any, do the following issues present for the implementation of crash energy management?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	2	7	0	2
b. Lack of incentive under current regulations	4	3	2	0	2
c. Technology cannot be used without a regulatory waiver	5	1	3	0	2
d. Lack of interoperability with existing systems and equipment	3	3	3	0	2
e. Uncertainty about the effectiveness of the technology	3	5	1	0	2

27. How much of a challenge, if any, do the following issues present for the implementation of improved design of interior passenger car fixtures?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	7	2	0	2
b. Lack of incentive under current regulations	4	2	3	0	2
c. Technology cannot be used without a regulatory waiver	8	0	1	0	2
d. Lack of interoperability with existing systems and equipment	7	2	0	0	2
e. Uncertainty about the effectiveness of the technology	4	3	2	0	2

28. What other challenges, if any, that are not listed above impede the implementation of occupant protection technologies in the United States?

Part 4: Track Inspection and Measurement Technologies

In this section we refer to Track Inspection and Measurement Technologies. Please use the following descriptions as a guide when thinking about these specific technologies.

Descriptions of technologies referred to in this section		
a.	Machine vision-based automated track inspection	Automated visual inspection of track defects (e.g. fractures at joint bars and at switch points) through the use of digital imaging or video
b.	Laser-based non-contact ultrasonic rail inspection	Enhancement to existing ultrasonic rail inspection techniques using lasers to improve detection of rail defects, both internal and surface
c.	Ultrasonic phased array rail defect imaging	Use of phased arrays to more accurately determine the size and shape of a rail flaw
d.	Rail longitudinal stress detection systems	Systems for detecting internal rail stresses that could lead to track buckling or fractures
e.	Portable ride quality meters	Portable devices used on board of rail cars to measure ride quality and identify possible poor track conditions or poor wheel-rail interactions
f.	Autonomous track measurement systems	Devices installed on revenue service trains that measure track qualities (e.g. track geometry, gage restraint, and rail cant) in real time
g.	Track modulus measurement systems	Systems used to detect weak spots in track ballast that can weaken the vertical forces of rail and lead to instability or derailments
h.	Intrusion detection systems	Systems that provide engineers and dispatchers timely information on the status of track sections and crossings, including any unauthorized intrusions, to allow them sufficient time to decrease speed or stop
i.	Bridge integrity monitoring systems	Sensor-based systems used to detect bridge damage or structural defects that could lead to collapse

29. How would you rate your overall level of knowledge of increasing railroad safety through the development and use of the following <u>track inspection and measurement technologies</u>?

1 None → SKIP TO PART 5 (QUESTION #44)
4 Minimal → SKIP TO PART 5 (QUESTION #44)
2 Basic → CONTINUE TO QUESTION #30
5 Proficient → CONTINUE TO QUESTION #30
7 Advanced → CONTINUE TO QUESTION #30

30. How much potential, if any, does further development and implementation of the following track inspection and measurement technologies have for improving rail safety?

Track inspection and measurement technology	No potential	Low potential	Medium potential	High potential	No basis to judge
a. Machine vision-based automated track inspection	0	2	3	8	1
b. Laser-based non-contact ultrasonic rail inspection	0	0	7	6	1
c. Ultrasonic phased array rail defect imaging	0	0	8	2	4
d. Rail longitudinal stress detection systems	0	3	2	9	0
e. Portable ride quality meters	1	2	7	2	2
f. Autonomous track measurement systems	0	3	4	6	0
g. Track modulus measurement systems	1	3	6	2	2
h. Intrusion detection systems	0	2	7	4	1
i. Bridge integrity monitoring systems	0	0	6	7	1

31. Considering the potential for additional safety benefits and likely research and development (R&D) costs—regardless of funding source—do you believe *further R&D* of the following track inspection and measurement technologies would be worth the investment?

Track inspection and measurement technology	No	Maybe	Yes	No basis to judge
a. Machine vision-based automated track inspection	1	1	10	2
b. Laser-based non-contact ultrasonic rail inspection	0	2	10	2
c. Ultrasonic phased array rail defect imaging	0	1	10	3
d. Rail longitudinal stress detection systems	0	4	8	2
e. Portable ride quality meters	1	9	2	2
f. Autonomous track measurement systems	3	2	8	1
g. Track modulus measurement systems	3	3	6	2
h. Intrusion detection systems	1	4	8	1
i. Bridge integrity monitoring systems	0	3	11	0

32. Considering the potential for additional safety benefits and likely implementation costs—regardless of funding source—do you believe the *procurement, operation, and maintenance* of the following track inspection and measurement technologies would be worth the investment?

Track inspection and measurement technology	No	Maybe	Yes	No basis to judge
a. Machine vision-based automated track inspection	3	2	9	0
b. Laser-based non-contact ultrasonic rail inspection	0	6	7	1
c. Ultrasonic phased array rail defect imaging	0	5	7	2
d. Rail longitudinal stress detection systems	1	2	9	2
e. Portable ride quality meters	1	7	4	2
f. Autonomous track measurement systems	2	3	8	1
g. Track modulus measurement systems	3	4	5	2
h. Intrusion detection systems	0	6	7	1
i. Bridge integrity monitoring systems	0	3	11	0

33. At what product development stage are the following track inspection and measurement technologies in the United States?

Track inspection and measurement technology	Concept exploration	Proof of concept and initial design	Refinement and pilot testing	Production and some deployment	Widespread industry deployment	No basis to judge
a. Machine vision-based automated track inspection	0	2	5	5	0	2
b. Laser-based non-contact ultrasonic rail inspection	0	3	5	3	0	3
c. Ultrasonic phased array rail defect imaging	0	5	4	2	0	3
d. Rail longitudinal stress detection systems	2	3	1	6	0	2
e. Portable ride quality meters	0	0	1	6	4	3
f. Autonomous track measurement systems	1	1	3	6	1	2
g. Track modulus measurement systems	1	1	4	5	0	3
h. Intrusion detection systems	1	0	3	4	2	3
i. Bridge integrity monitoring systems	1	2	3	7	0	1

34. How much of a challenge, if any, do the following issues present for the implementation of machine vision-based automated track inspection?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	6	7	0	1
b. Lack of incentive under current regulations	2	4	7	0	1
c. Technology cannot be used without a regulatory waiver	3	1	3	3	0
d. Lack of interoperability with existing systems and equipment	7	2	1	2	2
e. Uncertainty about the effectiveness of the technology	1	7	5	0	1

35. How much of a challenge, if any, do the following issues present for the implementation of laser-based non-contact ultrasonic rail inspection?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	5	3	0	5
b. Lack of incentive under current regulations	4	6	3	0	1
c. Technology cannot be used without a regulatory waiver	6	2	2	2	2
d. Lack of interoperability with existing systems and equipment	8	2	0	1	3
e. Uncertainty about the effectiveness of the technology	2	2	9	0	1

36. How much of a challenge, if any, do the following issues present for the implementation of ultrasonic phased array rail defect imaging?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	8	2	0	4
b. Lack of incentive under current regulations	4	6	1	1	2
c. Technology cannot be used without a regulatory waiver	5	4	0	1	4
d. Lack of interoperability with existing systems and equipment	8	2	0	1	3
e. Uncertainty about the effectiveness of the technology	1	3	8	0	2

37. How much of a challenge, if any, do the following issues present for the implementation of rail longitudinal stress detection systems?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	3	6	0	5
b. Lack of incentive under current regulations	5	3	3	1	2
c. Technology cannot be used without a regulatory waiver	6	2	0	3	3
d. Lack of interoperability with existing systems and equipment	6	3	0	2	3
e. Uncertainty about the effectiveness of the technology	1	4	7	0	2

38. How much of a challenge, if any, do the following issues present for the implementation of portable ride quality meters?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	2	7	0	0	5
b. Lack of incentive under current regulations	4	5	2	0	3
c. Technology cannot be used without a regulatory waiver	7	3	0	1	3
d. Lack of interoperability with existing systems and equipment	8	2	0	1	3
e. Uncertainty about the effectiveness of the technology	5	6	0	0	3

39. How much of a challenge, if any, do the following issues present for the implementation of autonomous track measurement systems?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	6	6	0	2
b. Lack of incentive under current regulations	2	5	5	1	1
c. Technology cannot be used without a regulatory waiver	4	2	3	3	2
d. Lack of interoperability with existing systems and equipment	5	4	1	2	2
e. Uncertainty about the effectiveness of the technology	2	6	4	0	2

40. How much of a challenge, if any, do the following issues present for the implementation of track modulus measurement systems?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	5	5	0	4
b. Lack of incentive under current regulations	4	7	1	1	1
c. Technology cannot be used without a regulatory waiver	8	2	0	3	1
d. Lack of interoperability with existing systems and equipment	8	3	0	2	1
e. Uncertainty about the effectiveness of the technology	1	4	8	0	1

41. How much of a challenge, if any, do the following issues present for the implementation of intrusion detection systems?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	4	5	0	5
b. Lack of incentive under current regulations	6	3	3	0	2
c. Technology cannot be used without a regulatory waiver	10	0	0	1	3
d. Lack of interoperability with existing systems and equipment	5	6	0	0	3
e. Uncertainty about the effectiveness of the technology	1	9	2	0	2

42. How much of a challenge, if any, do the following issues present for the implementation of bridge integrity monitoring systems?

Challenge	Not a challenge	Minor challenge	Major challenge	Does not apply	No basis to judge
a. Costs	0	7	5	0	2
b. Lack of incentive under current regulations	7	5	1	0	1
c. Technology cannot be used without a regulatory waiver	9	1	0	2	2
d. Lack of interoperability with existing systems and equipment	5	6	0	2	1
e. Uncertainty about the effectiveness of the technology	2	7	4	0	1

43. What other challenges, if any, that are not listed above impede the implementation of track inspection and measurement technologies in the United States?

Part 5: Government Actions

44. What further actions, if any, could the U.S. Department of Transportation take to encourage the implementation of new rail safety technologies?

Part 6: Positive Train Control

45. How would you rate your overall level of knowledge about the development and implementation of positive train control in the United States?

1 None → SKIP TO QUESTION #49
2 Minimal → SKIP TO QUESTION #49
8 Basic → CONTINUE TO QUESTION #46
2 Proficient → CONTINUE TO QUESTION #46
6 Advanced → CONTINUE TO QUESTION #46

46. How much of a challenge, if any, do the following issues present to meeting the December 31, 2015 deadline for implementing positive train control (PTC)?

Issue		Not a challenge	Minor challenge	Major challenge	No basis to judge
a.	Achieving interoperability among all railroads	0	2	14	0
b.	Refining braking algorithms	0	9	7	0
c.	Acquisition of adequate spectrum in the 220 MHz frequency, specifically in dense, metropolitan areas	0	5	8	3
d.	Development of new high performance radio equipment	1	4	8	3
e.	Technological maturity of other PTC components	1	3	11	1
f.	Ability of suppliers to meet demand for PTC products	3	1	10	2
g.	Cost to larger railroads (Amtrak and Class I freights)	0	1	15	0
h.	Cost to smaller railroads (short lines, regionals, commuters)	0	2	13	1
i.	FRA's ability to certify PTC systems in a timely fashion	1	3	10	2

47. What other issues, if any, that are not listed above may present a challenge to meeting the December 31, 2015 deadline for implementing positive train control?

48. What further actions, if any, could the U.S. Department of Transportation take to facilitate the implementation of positive train control in order to meet the December 31, 2015 deadline?

Part 7: Additional Comments

49. What other comments, if any, do you have about the topics covered in this assessment tool?

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

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