NTSB Investigative Process for Crashes Involving Highly Automated Systems

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ABSTRACT

The National Transportation Safety Board (NTSB) is an independent federal agency charged by Congress to investigate every civil aviation accident and significant accidents in all other modes of transportation, including highway, railroad, marine, pipeline and hazardous materials. The NTSB is not part of the Department of Transportation. The NTSB uses a similar investigative process for all the transportation modes, regardless of the complexity of the accident or the vehicle systems involved. The objective of this paper is to document the NTSB's process for investigating all crashes with a focus on vehicle and system automation, particularly in the highway mode where the transition to automated control systems is occurring in the current vehicle fleet.

The NTSB follows a systematic investigative process for all modes of transportation, with modal specialists leveraging support from in-house research and engineering laboratories. The paper explains each step of the investigative process from start to finish, including the initial crash notification, launch selection, the on-scene phase, the party process, recorded data, laboratory capabilities, investigative hearings, factual reports, technical reviews, analysis reports, safety recommendations, and the final NTSB products. The paper will highlight the breadth and diversity of the NTSB disciplines covered throughout the investigation: biomechanical engineers, survival factors specialists, human factors experts, meteorologists, structural engineers, materials scientists, recorder engineers, medical and toxicological specialists, and vehicle dynamics engineers. Examples from NTSB investigations are highlighted to elucidate the investigative process and its application to vehicle and system technologies. Measures of NTSB effectiveness are discussed, including recommendation acceptance rates and outreach efforts.

The goal of the NTSB investigation is to determine the probable cause of the crash and to issue safety recommendations to prevent future crashes or reduce the severity of future crashes; the goal is not to assign blame or determine fault. Through a formal system involving designated parties to the investigation, the NTSB leverages the technical knowledge of organizations associated with a crash, such as the operators, manufacturers, unions, maintenance operators, and regulatory agencies. The party system ensures that all factual information is collected, agreed to, and reported correctly. This process enables the party members to obtain knowledge of critical aspects of a crash investigation in a timely manner. The NTSB takes full responsibility for determining the probable cause and making recommendations; this unbiased reporting fosters public trust that safety is being properly addressed. The NTSB's investigative process has successfully documented the probable cause and issued safety recommendations for complex investigations in all transportation modes. Case examples from recent investigations will serve as examples of the investigative process: the crash during landing of Asiana Flight 314, the Washington Metro Area Transit Authority red line crash, and the high-speed derailment of the Amtrak train in Philadelphia, PA.

INTRODUCTION

In 1967, Congress consolidated all transportation agencies into a new U.S. Department of Transportation (DOT) and established the NTSB as an independent agency placed within the DOT for administrative purposes. In creating the NTSB, Congress envisioned that a single organization with a clearly defined mission could more effectively promote a higher level of safety in the transportation system than the individual modal agencies working separately. An aviation predecessor of the NTSB originated in the Air Commerce Act in 1926, which in turn evolved into the Civil Aeronautics Board in 1940. Since 1967, the NTSB has investigated accidents in the aviation, highway, marine, pipeline, and railroad modes, as well as accidents related to the transportation of hazardous materials.

In 1974, Congress reestablished the NTSB as a completely separate entity, outside the DOT, reasoning that " ...No federal agency can properly perform such (investigatory) functions unless it is totally separate and independent from any other ... agency of the United States. " Because the DOT has broad operational and regulatory responsibilities that affect the safety, adequacy, and efficiency of the transportation system, and transportation accidents may suggest deficiencies in that system, the NTSB's independence was deemed necessary for proper oversight. The NTSB, which has no authority to regulate, fund, or be directly involved in the operation of any mode of transportation, conducts investigations and makes recommendations from an objective viewpoint.

The NTSB is comprised of five Board members who are nominated by the president and confirmed by the Senate to serve five-year terms. One member is designated as the Chairman and another as the Vice Chairman, with each serving a two-year term. The NTSB staff of about 400 individuals includes technical experts in all transportation modes including aviation, railroad, highway, marine, pipeline, and hazardous materials. Supporting the modal offices are the Office of Research and Engineering, which includes laboratories dedicated to recorded information, materials investigations, simulation, data analysis, and animation, along with other administrative offices.

In 1996, Congress assigned the NTSB the additional responsibility of coordinating Federal assistance to families of aviation accident victims. While originally legislated to provide assistance following major aviation accidents, the program has expanded to provide assistance in all modes of transportation on a case-by-case basis.

To date, the NTSB has issued over 14,400 safety recommendations to more than 2,300 recipients. [1] Because the NTSB has no formal authority to regulate the transportation industry, our effectiveness depends on our reputation for conducting thorough, accurate, and independent investigations and for producing timely, well-considered recommendations to enhance transportation safety. The objective of this paper is to document the NTSB's process for investigating all crashes with a particular focus on vehicle and system automation, particularly in the highway mode where the transition to automated control systems is occurring in the current vehicle fleet.

METHODS

The NTSB process for investigating a crash begins with the initial notification. Early notification is critical to an organized investigation and the notification process is defined by procedures in each mode. For highway crashes, this notification typically comes from the NTSB 24-hour Response Operations Center, which monitors the news reporting systems watching for events that match an active list of crash types of interest. The NTSB may also be notified by our industry and government partners. Initial information concerning the circumstances of the crash are communicated to a modal duty officer who makes initial contact with the local law enforcement personnel on-scene to confirm the nature of the crash. Based on the circumstances of the crash, a management decision to launch to a crash site is determined and a go-team is formed.

Launch Selection

The launch selection process is established by each transportation mode at the NTSB. In highway crash investigations, the NTSB has the ability to select crashes that have national importance, represent a significant loss of life, address emerging technologies or threats, or contribute knowledge to areas of special investigation. Recent crash investigations have focused on infrastructure failures, large school buses, railroad grade crossing collisions, multi-vehicle crashes involving commercial vehicles, catastrophic motorcoach crashes, pedestrian collisions, and collisions involving vehicles with advanced technologies.

Go-Team

A highway investigation go-team consists of NTSB specialists in human factors, survival factors, vehicle performance, crashworthiness, highway factors, motor carrier factors, data- and video-recorders, biomechanics, medical factors, and crash reconstruction. The composition of the team is based on the nature of the crash. The go-team is led by an investigator-in-charge (IIC), who is a senior investigator with years of NTSB investigative experience. On major investigations, those involving a full go-team and with national interest, an NTSB Board member accompanies the go-team to serve as the primary spokesperson for the investigation. The go-team typically departs for the crash scene within several hours of the initial notification in order to initiate the investigative process to capture perishable forensic evidence.

Investigative Process

The investigative process begins with the on-scene phase of the investigation. This phase usually continues for approximately one week, depending on the location of the crash and the complexity of the investigation.

On-scene investigation

During the on-scene phase, NTSB specialists are responsible for a clearly defined portion of the investigation. Working groups are formed with each NTSB specialist serving as the group chair. These specialized working groups are staffed by technical experts from the parties (see the party system in the next section) to the investigation. While most working groups operate on-scene, some groups such as the recorders group may operate at the NTSB headquarters to ensure the security of the recorded data.

The party system

The NTSB designates participating organizations to be parties associated with the crash investigation. Party members bring a technical or specialized expertise to contribute to a specific working group. For example, in a highway investigation, party status may be offered to an equipment manufacturer, a union representative, the vehicle manufacturer, the local law enforcement agency and the branch or branches of the DOT responsible for oversight of the situation. This designation as a party enables the NTSB to work with those involved in a crash to ensure that a complete and technically correct factual documentation of the circumstances and evidence are gathered and documented for each crash. The party members participate in the working groups where they have technical expertise and are responsible for reviewing and validating the documentation of factual evidence. This process further enables the party members to obtain knowledge of critical aspects of a crash investigation in a timely manner. Persons in legal or litigation positions are not allowed to be assigned as party members to the investigation. All party members report to the NTSB, and agree that the NTSB will be the sole source of information about the investigation for the media.

Factual Phase

Once the on-scene phase of the investigation is complete, the NTSB technical specialists, working with their party group members, finalize the factual reports. During this period, the IIC, working with management and the engineering labs, plans the additional work required for the investigation, which may include additional tests and documentation of equipment or examination of exemplar vehicles and systems. Medical records may be subpoenaed and autopsy reports are requested to fully document the injuries sustained by those involved in the crash. Toxicology tests may be processed on vehicle operators to better understand their fitness to operate the vehicle at the time of the crash. Design drawings, equipment specifications, maintenance records, and business records may be needed to understand vehicle operations. Simulations representing the crash dynamics may also be performed during this phase of the investigation. Party members assigned to each working group are responsible for reviewing the factual reports to ensure their accuracy and completeness.

Recorded data

In commercial aviation, flight data recorders (FDR) and cockpit voice recorders (CVR) are common and NTSB's experience with them has developed an expetise that is applied to locomotive recorders, marine voyage recorders, and event data recorders from all modes. Highway vehicles may also be equipped with electronic data recorders, airbag modules, engine control modules, and other devices that can document event and crash related information. Commercial highway vehicles may also equipped with recording devices such as event-based and continuous video recording systems. Further, additional recorded data in all modes of transportation may be available from non-traditional devices such as surveillance cameras, smart phones, tablet computers, and medical devices.

Laboratory capabilities

The NTSB laboratories are located in the headquarters facility in Washington, DC and include laboratories focusing on recorders, vehicle and infrastructure materials, simulation, animation, and data analysis. The recorders laboratory is a state-of-the-art facility originally designed to enable downloads of aviation flight data recorders and cockpit voice recorders, both intact and after damage and fire sustained during a crash. The laboratory supports all modes with a capability to recover, download, and document recorded data from trains, ships, pipelines, highway vehicles, and all other forms of video, audio, and personal electronic devices. This laboratory also supports foreign investigations.

The materials laboratory staff of multi-disciplinary engineers examine vehicle components and infrastructure wreckage from crashes in all transportation modes. Staff performs expert scientific analyses to determine if the performance of materials and structures in the crash conditions were related to the cause or severity of the event.

The simulation lab consists of a cab-based commercial vehicle driving simulator used to recreate crash related circumstances in a laboratory environment. The simulation lab also uses three-dimensional (3D) laser scanning technologies to document crash related evidence including the crash scene, damaged vehicles, and exemplar vehicles. The 3D laser scanning data enables review of the crash environment and vehicles virtually.

An animation laboratory combines all of the factual data from the other laboratories, along with additional pertinent investigative information, into animations depicting the crash scenarios to highlight key information that aids in understanding a complex sequence of events.

The laboratories, resident within the Office of Research and Engineering, also include a statistical and data analysis division. Research staff prepare safety reports based on analyses of transportation accident data which are used to determine factors common to a series of events and to identify safety improvements or evaluate the value of transportation-related devices or policy. The laboratory also provides statistical expertise to support the analytical projects of the NTSB. Also within the Office of Research and Engineering are medical officers, biomechanical engineers, and fire/explosion specialists.

Investigative hearing

The Board may choose to hold an investigative hearing to gather additional factual information in support of a major investigation. During an investigative hearing, sworn testimony is gathered from subpoenaed witnesses addressing specific aspects of the investigation. The investigative hearing also serves to allow the public to observe the factual portion of the investigative process. Typically, an investigative hearing is held within the first six months after a crash has occurred but may be held after that time for more complex investigations.

Technical review

During the technical review, the party members are provided draft factual reports from all the investigative working groups, including groups on which they may not have technical representation. During the technical review, the party members review the factual reports and provide technical information to support any substantive changes that are proposed. Once the factual information has been reviewed and finalized, the groups' factual reports and any associated factual information are archived in the NTSB's public docket management system, which is available on the NTSB's web page.

Analysis Phase

Following completion of the factual reports, the NTSB technical specialists then analyze the factual information to identify safety deficiencies that need to be addressed in order to mitigate the severity or to prevent the occurrence of a similar crash in the future. The party members do not participate in the analysis of the factual information or in writing the analytical reports but may still contribute key information to group leaders during this phase. Analytical reports are not available in the docket management system because those reports are viewed as staff opinions concerning the investigation, whereas the analysis and conclusions from the investigation are considered to be the opinion of the NTSB.

Final Board Report

The final Board report is a compilation of the relevant factual and analytical information gathered and developed during the investigative process. The Board report includes the Board's statement of probable cause, investigative conclusions and recommendations issued to prevent or mitigate the severity of a future crash. Parties to the investigation are permitted to submit their proposed findings of cause and proposed safety recommendations, which are made part of the public docket.

The investigative staff presents their work to the Board Members that deliberate over the final report in a public Board meeting in Washington, D.C. The Board Members debate all aspects of the draft report and conduct separate votes on the probable cause, the conclusions, and the recommendations, and may file an assenting and/or dissenting opinion. The final report and presentations shown during the public meeting are available on the NTSB web page shortly after the conclusion of the Board meeting.

RESULTS

The results section of this paper presents a summary of several on-going and completed NTSB investigations.

Williston, Florida

The Williston, Florida crash involves the first known fatality in a vehicle operating using automated control systems. As of April 2017, the crash remains under investigation by the NTSB. A final report is expected during the 2017 calendar year. The NTSB's preliminary report detailed the collision involving a 53-foot semitrailer in combination with a 2014 Freightliner Cascadia truck tractor and a 2015 Tesla Model S, which occurred on May 7, 2016. [2] The vehicle's system performance data revealed the driver was using the advanced driver assistance features Traffic-Aware Cruise Control and Autosteer lane keeping assistance to tactically control the vehicle. Used in combination, these systems are referred to by Tesla Motors as an Autopilot system. The semitrailer and passenger vehicle were scanned using a 3-dimensional (3D) laser scanner. Figure 1 and Figure 2 shows images from the laser scanner of semitrailer and vehicle, respectively.

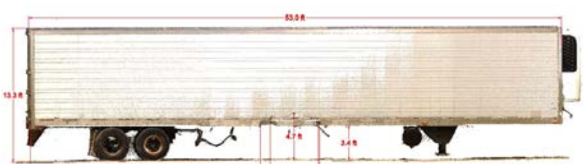

Figure 1. The image depicts certain dimensional data as measured from the 3D scan point cloud of the semitrailer.

Figure 2. Image depicting linked 3D scans of the passenger vehicle used for measurements.

A team of NTSB investigators traveled to Williston to conduct the on-scene phase of the investigation. The team used 3D laser scanning technology to document the crash location, the damaged trailer, and the damaged passenger car. NTSB investigators continue to collect and analyze performance data from the car's multiple electronic systems. This data along with other information collected during the on-scene phase of the investigation will be used to evaluate the crash events. Parties to the investigation are Tesla Motors and the Florida Highway Patrol. All aspects of the crash remain under investigation.

Collision of Two Washington Metropolitan Area Transit Authority Metrorail Trains near Fort Totten Station, Washington, D.C.

On June 22, 2009, inbound Washington Metropolitan Area Transit Authority (WMATA) Metrorail train 112 struck the rear of stopped inbound Metrorail train 214. The accident occurred on the aboveground track on the Metrorail Red Line near the Fort Totten station in Washington, DC. As shown in Figure 3, the lead car of train 112 struck the rear car of train 214, which resulted in a loss of occupant survival space in the lead car of about 63 feet (about 84 percent of its total length). Nine people aboard train 112, including the train operator, were killed. Emergency response agencies reported transporting 52 people to local hospitals. Damage to train equipment was estimated to be $12 million. [3]

Figure 3: The postcrash positions of Metrorail train 112 and 214.

The NTSB determined that the probable cause of the accident was (1) a failure of the track circuit modules, built by GRS/Alstom Signaling, Inc., which caused the automatic train control system to lose detection of train 214 (the struck train) and thus transmit speed commands to train 112 (the striking train) up to the point of impact and (2) WMATA's failure to ensure that the enhanced track circuit verification test (developed following the 2005 Rosslyn near-collisions) was institutionalized and used systemwide, which would have identified the faulty track circuit before the accident.

Contributing to the accident were (1) WMATA's lack of a safety culture, (2) WMATA's failure to effectively maintain and monitor the performance of its automatic train control system, (3) General Railway Signal/Alstom Signaling, Inc.'s failure to provide a maintenance plan to detect spurious signals that could cause its track circuit modules to malfunction, (4) ineffective safety oversight by WMATA's Board of Directors, (5) the Tri-State Oversight Committee's ineffective oversight and lack of safety oversight authority, and (6) the Federal Transit Administration's lack of statutory authority to provide Federal safety oversight.

Contributing to the severity of passenger injuries and the number of fatalities was WMATA's failure to replace or retrofit the 1000-series railcars after these cars were shown in a previous accident to exhibit poor crashworthiness. The NTSB issued multiple recommendations as a result of this investigation. The WMATA Metrorail system has still not fully returned to the automatic train control system.

Crash of Asiana Flight 214, San Francisco, California

On July 6, 2013, a Boeing 777-200ER, Korean registration HL7742, operating as Asiana Airlines flight 214, was on approach to runway 28L when it struck a seawall at San Francisco International Airport (SFO), San Francisco, California. The airplane was destroyed by impact forces and a postcrash fire (Figure 4). [4]

Figure 4: Fire damage to the fuselage of flight 214.

There were many safety issues identified in the final report of the Asiana Flight 214 investigation, including pilot training and the use of standard operating procedures, aircraft fire and rescue operations and protocols, and survival factors issues related to the aircraft's evacuation and the airports emergency procedures. With regard to highly automated vehicles, the investigation called for reduced design complexity and enhanced training on the airplane's autoflight system.

The NTSB determined that the probable cause of this accident was the flight crew's mismanagement of the airplane's descent during the visual approach, the pilot flying's unintended deactivation of automatic airspeed control, the flight crew's inadequate monitoring of airspeed, and the flight crew's delayed execution of a go-around after they became aware that the airplane was below acceptable glidepath and airspeed tolerances. Contributing to the accident were (1) the complexities of the autothrottle and autopilot flight director systems that were inadequately described in Boeing's documentation and Asiana's pilot training, which increased the likelihood of mode error; (2) the flight crew's nonstandard communication and coordination regarding the use of the autothrottle and autopilot flight director systems; (3) the pilot flying's inadequate training on the planning and executing of visual approaches; (4) the pilot monitoring/instructor pilot's inadequate supervision of the pilot flying; and (5) flight crew fatigue, which likely degraded their performance.

As a result of this investigation, the NTSB made safety recommendations to the FAA, Asiana Airlines, Boeing, the Aircraft Rescue and Firefighting Working Group, and the City and County of San Francisco.

Derailment of Amtrak Passenger Train 188 Philadelphia, Pennsylvania

At 9:21 p.m. eastern daylight time on May 12, 2015, eastbound Amtrak passenger train 188 derailed in Philadelphia, Pennsylvania, with 245 passengers and 8 Amtrak employees on board. The train had just entered the Frankford Junction curve—where the speed is restricted to 50 mph—at 106 mph. As the train entered the curve, the locomotive engineer applied the emergency brakes. Seconds later, the train derailed, as shown in Figure 5. Eight passengers died, and 185 others were transported to area hospitals. [5]

Figure 5: The Philadelphia Amtrak derailment scene.

The NTSB determined that the probable cause of the accident was the engineer's acceleration to 106 mph as he entered a curve with a 50-mph speed restriction, due to his loss of situational awareness likely because his attention was diverted to an emergency situation with another train. Contributing to the accident was the lack of a positive train control system, which is a system that can monitor and control train movements specifically to avoid train to train collisions and derailments resulting from overspeed conditions. Contributing to the severity of the injuries were the inadequate requirements for occupant protection in the event of a train overturning.

As a result of the investigation of this accident, the NTSB made recommendations to Amtrak, the Federal Railroad Administration, the American Public Transportation Association, the Association of American Railroads, the Philadelphia Police Department, the Philadelphia Fire Department, the Philadelphia Office of Emergency Management, the mayor of the city of Philadelphia, the National Association of State EMS (Emergency Medical Services) Officials, the National Volunteer Fire Council, the National Emergency Management Association, the National Association of EMS Physicians, the International Association of Chiefs of Police, and the International Association of Fire Chiefs.

Orland, California

Although not a crash dealing with automated vehicles, this crash highlights the need for crash-survivable recorders. On April 10, 2014, a 2007 Volvo truck-tractor in combination with double trailers, operated by FedEx Freight, Inc., was traveling southbound in the right lane of Interstate 5 (I-5) in Orland, California. At the same time, a 2014 Setra motorcoach, operated by Silverado Stages, Inc., was traveling northbound on I-5 in the right lane. In the vicinity of milepost 26, the combination vehicle moved into the left lane, entered the 58-foot-wide center median, and traveled into the northbound traffic lanes of I-5. [6]

The truck-tractor collided with a 2013 Nissan Altima four-door passenger car, which then rotated counterclockwise and departed the highway to the east. The truck-tractor continued moving south in the northbound lanes and collided with the front of the motorcoach, before both vehicles partially departed the highway to the east.

Figure 6. Postcrash fire engulfing FedEx Freight truck double trailers and Setra motorcoach in Orland, California.

A postcrash fire ensued, as shown in Figure 6. Both the truck and the motorcoach drivers died, along with eight motorcoach passengers. The remaining 37 motorcoach passengers received injuries of varying degrees. The two occupants of the passenger car received minor injuries.

The safety issues identified in the investigation included fire performance standards for commercial passenger vehicle interiors and difficulties in motorcoach egress. The investigation also dealt with the need for event data recorder survivability for crash reconstruction and safety improvements.

The NTSB determined that the probable cause of the Orland, California crash was the inability of the FedEx Freight truck driver to maintain control of the vehicle due to his unresponsiveness for reasons that could not be established from available information. Contributing to the severity of some motorcoach occupant injuries were high impact forces; the release of combustible fluids, leading to a fast-spreading postcrash fire; difficulties in motorcoach egress; and lack of restraint use.

As a result of this investigation, the NTSB issued safety recommendations to the National Highway Traffic Safety Administration (NHTSA) and to the Federal Motor Carrier Safety Administration (FMCSA). The NTSB also reiterated safety recommendations to NHTSA and reclassified a recommendation to FMCSA.

Safety Report: Commercial Vehicle Onboard Video Systems

The NTSB has investigated many highway accidents where onboard video systems recorded critical crash-related information. This commercial vehicle onboard video systems report discussed two crashes where continuous video systems were installed on commercial vehicles. [7] In a 2012 school bus crash in Port St. Lucie, Florida, the video recording system captured all three phases of the crash, including precrash driver and passenger behaviors and vehicle motion; vehicle and occupant motion during the crash; and postcrash events, such as passenger evacuation, short-term injury outcomes, and emergency response. The school bus at final rest is shown in Figure 7.

Figure 7. Right side of the school bus involved in the Port St. Lucie, crash.

In a 2011 motorcoach crash in Kearney, Nebraska, the video recording system captured critical precrash information but had certain limitations that negated the potential benefits of crash and postcrash event data. The safety report summarized the analysis of the onboard video systems from these two crashes. Further, to advance biomechanical and pediatric trauma-based research, it presented the video analysis and subsequent extensive injury documentation from the Port St. Lucie investigation.

As a result of the safety report, the NTSB issued safety recommendations to NHTSA; to the American Bus Association, United Motorcoach Association, American Trucking Associations, American Public Transportation Association, National Association for Pupil Transportation, National Association of State Directors of Pupil Transportation Services, and National School Transportation Association; and to 15 manufacturers of onboard video systems.

Special Investigation Report: The Use of Forward Collision Avoidance Systems to Prevent and Mitigate Rear-End Crashes

Over a three-year period, the NTSB investigated nine rear-end crashes involving passenger or commercial vehicles striking the rear of another vehicle—the result of which was 28 fatalities and 90 injured people. This special investigation report reviewed the previous recommendations made by the NTSB pertaining to the reduction of rear-end crashes and examined collision avoidance technologies that would aid in their prevention. [8]

The report concluded that collision warning systems, particularly when paired with active braking, could significantly reduce the frequency and severity of rear-end crashes. As a result of this report, The NTSB issued safety recommendations to NHTSA and to vehicle manufacturers, both passenger and commercial.

DISCUSSION

The use of automated vehicles and systems is increasing in all modes of transportation. In some cases, automation is implemented to assist the operator in complex environments. In many other circumstances, automation is included in the vehicle design to increase safety, to reduce the consequences of human error, and to aid in the detection of risks that might not be recognized by a human.

In the Asiana crash, the pilots were confused by the aircraft's automation system and as a result of a misconfiguration and a lack of awareness of their airspeed, the aircraft slowed and descended below its desired flight path and crashed into the seawall at San Francisco's airport.

Common to many investigations involving automated vehicles and control systems is the operator's misunderstanding of the systems - examples include mode confusion, false assumptions, and system limitations. In many train crashes and high-speed derailments, positive train control has been documented as an automated system that can prevent or mitigate the consequences. In the Amtrak derailment in Philadelphia, the NTSB concluded that a fully implemented positive train control system would have enforced the 50-mph speed restriction and prevented the accident. The NTSB went further, including positive train control in the probable cause by stating that the lack of a positive train control system contributed to the accident.

In highway vehicles, despite the introduction of systems such as electronic stability control, advanced restraint systems, collision warning systems, and automatic emergency braking, the number of fatalities has been increasing significantly in recent years. [9] These increases may result from the improved economy, lower fuel costs, and additional miles traveled but the increases may also result from driver error including driver distraction. [10] Many vehicle manufacturers are looking toward automated systems to increase safety, reduce driver error, and to provide transportation for individuals that may not be able to drive themselves. NHTSA recently issued a Federal Automated Vehicles Policy addressing highly automated vehicles. [11]

Further, the NTSB has long advocated for more recorded data to monitor both systems and operators in order to better understand the causes of crashes. Both video and data based recording systems have provided critical information in understanding the crash causation and in developing persuasive recommendations to mitigate or prevent future crashes. Importantly, the recorded information must survive the crash and postcrash environment.

Through all of these past investigations and looking into the future, the NTSB has a unique multi-modal perspective on crash investigation, recorded data, vehicle automation, human performance, survival factors, and injury prevention. Further, the NTSB does not work in isolation but instead, leverages the technical knowledge and abilities of the party members in the investigation. Ultimately, this investigative process yields a comprehensive factual and analytical report of the circumstances surrounding an accident and the steps that need to be taken in order to prevent or mitigate the effects of a future accident.

CONCLUSIONS

The NTSB has issued more than 14,400 safety recommendations to more than 2,300 recipients in all transportation modes as a result of our investigations. Although the NTSB is a non-regulatory agency and does not have the power to enforce its recommendations, due to our reputation for objectivity, accuracy and effectiveness, the NTSB has an overall positive acceptance rate of more than 72 percent over the last 5 years. In addition, since 1990, the NTSB has also published a "Most Wanted List" of transportation safety improvements, highlighting safety-critical actions that the DOT modal administrations and others should take to help prevent accidents and save lives.

REFERENCES

[1] NTSB (National Transportation Safety Board). 2016. "Annual Performance Plan Fiscal Year 2017." In NTSB: https://www.ntsb.gov/about/reports/Documents/2017AnnualPerformancePlan_Final.pdf, DC: NTSB.

[2] NTSB (National Transportation Safety Board). 2016. "NTSB Issues Preliminary Report for Williston, Florida, Highway Crash." In NTSB: HWY16FH018, https://www.ntsb.gov/news/press-releases/Pages/pr20160726.aspx, DC: NTSB.

[3] NTSB (National Transportation Safety Board). 2010. "Collision of Two Washington Metropolitan Area Transit Authority Metrorail Trains near For Totten Station Washington, D.C.", NTSB/RAR-10/02. Washington, DC: NTSB.

[4] NTSB (National Transportation Safety Board). 2014. "Descent Below Visual Glidepath and Impact with Seawall Asiana Airlines Flight 214 Boeing 777-200ER, HL7742 San Francisco, California", NTSB/AAR-14/01. Washington, DC: NTSB.

[5] NTSB (National Transportation Safety Board). 2016. "Derailment of Amtrak Passenger Train 188 Philadelphia, Pennsylvania", NTSB/RAR-16/02. Washington, DC: NTSB.

[6] NTSB (National Transportation Safety Board). 2015. "Truck-Tractor Double Trailer Median Crossover Collision with Motorcoach and Postcrash Fire on Interstate 5 Orland, California", NTSB/HAR-15/01. Washington, DC: NTSB.

[7] NTSB (National Transportation Safety Board). 2015. "Commercial Vehicle Onboard Video Systems", Safety Report NTSB/SR-15/01. Washington, DC: NTSB.

[8] NTSB (National Transportation Safety Board). 2015. "The Use of Forward Collision Avoidance Systems to Prevent and Mitigate Rear-End Crashes", Special Investigation Report NTSB/SIR-15/01. Washington, DC: NTSB.

[9] U.S. Department of Transportation NHTSA (National Highway Traffic Safety Administration), Press Release 20-16, August 29, 2016, Washington, DC.

[10] U.S. Department of Transportation NHTSA (National Highway Traffic Safety Administration),2015 Motor Vehicle Crashes: Overview, DOT-HS 812-389, August 2016.

[11] U.S. Department of Transportation NHTSA (National Highway Traffic Safety Administration). Federal Automated Vehicles Policy. Federal Register 2016-28628, September 20, 2016.