Development and Use of FRA Autonomous Track Geometry Measurement System Technology

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ABSTRACT
The Federal Railroad Administration’s (FRA’s) Office of Research, Development and Technology has long advocated for the development and advancement of Autonomous Track Geometry Measurement Systems (ATGMS) and related technologies to improve rail safety by increasing the availability of track geometry data. Routine use of ATGMS technology by the rail industry will eventually lead to minimized interference of inspections to revenue operations, increased inspection frequencies and reduced life-cycle cost of inspection operations, all of which will lead to improved safety and maintenance planning.

FRA’s ATGMS research program has demonstrated the potential benefits and uses of the unmanned inspection approach as well as its impact on information management. A natural consequence of increased inspection frequencies associated with ATGMS is the large amount of actionable information produced. Therefore, managing ATGMS data and assessing the quality of this information in a timely manner will be challenging as will be the changes to current maintenance practices to address a greater number of identified track issues across large geographic areas in an efficient and practical manner.
This paper presents an update on the accomplishments of the FRA’s ATGMS research and development program with emphasis on its evolution from a proof-of-concept prototype to a fully operational measurement system. The paper also provides a summary of how the FRA Office of Safety is employing unmanned inspection in track assessments, lessons learned from the implementation of this approach and FRA’s vision for the role of this technology in track inspection and safety assurance.

INTRODUCTION

Autonomous track inspection is a process in which the track is inspected using unattended instrumentation with minimal direct involvement from human operators. Building on the experience of implementation and application of autonomous ride quality and vehicle/track interaction monitoring systems by Amtrak, Maryland Transit Administration’s (MTA) and Union Pacific Railroad, FRA took steps to develop and evaluate an autonomous track geometry measurement system to report track issues in near real-time to remote stakeholders (1).

To that end, the FRA Office of Research, Development and Technology undertook a research program focused on the advancement of autonomous track geometry measurement systems (ATGMS) that improves rail safety by increasing the availability of track geometry data for safety and maintenance planning purposes. FRA’s vision is the development and use of relatively low cost, self-powering geometry measurement systems on a wide range of rail vehicles, including freight cars, that:

- Reduce the life-cycle costs of geometry measurement operations;
- Eliminate interference with revenue operations;
- Increase inspection frequencies and productivity;
- Provide data of the highest quality possible.

The FRA’s goal is not necessarily to replace manned automated inspection systems as a quality assurance tool, but to create and facilitate the use of more flexible, efficient tools for use in quality control and maintenance planning activities.

ATGMS TECHNOLOGY ARCHITECTURE

A modular architecture was employed in the FRA’s ATGMS to allow for maximum flexibility in incremental development, evaluation, and implementation of system capabilities. The architecture consists of four main modules: onboard Data Collection Module, remote Data Processing Servers, a Cellular Communication Link to allow for the exchange of information between the Data Collection Module and Data Processing Servers, and web-based applications that provide authorized users access to the ATGMS database for near real-time analysis of track data.

As shown in Figure 1 the Data Collection Module includes sensors, electronics, communication devices, and associated mechanical assemblies that constitute the measurement system on the track-bound vehicle. Mounted on a rugged mechanical
platform, inertial sensors capture the platform’s position in space as the vehicle travels on track while the optical sensors capture the contour of the rails as well as their location with respect to the platform. An encoder measures distance travelled and a Differential Global Positioning System captures highly accurate location information. The Data Collection Module collects, synchronizes, and packages foot-by-foot raw sensor data and system diagnostic information for transmission from the measurement system to the Data Processing Server via a commercial Cellular Communication Link.

The manner in which power is provided to the Data Collection Module depends on the type of vehicle. On rail cars with available head-end power (HEP), such as passenger coaches and locomotives, a rugged Uninterruptable Power Supply (UPS) is used to minimize power disruptions to allow for operations at the end of survey to complete transfer of queued data and orderly shutdown of ATGMS when the railcar loses power for an extended period of time. On freight railcars without HEP, the power module consists of a battery bank that is charged by a solar power system. Supplemental charging power can be provided by a variety of other sources including specially designed diesel generators or fuel cells.

The Data Processing Server module includes features for communication with the onboard Data Collection Module, processing of incoming data, transmission of important status messages, as well as data archiving. Following receipt of data from the onboard module, the server-based software performs a series of quality checks to ensure continuity of data and subsequently converts sensor data into foot-by-foot geometry measurements while diagnostic information transferred to the servers is

Figure 1. FRA’s ATGMS Technology Architecture

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electronically sent to the technical support team as Status and Alert Messages. Processed foot-by-foot geometry measurements are further analyzed to detect geometry measurements outside established thresholds. The validity of the detected exception is checked to remove false positives and a record of all exceptions is sent out to survey reviewers.

The web-based Remote Editor Desk application provides authorized reviewers access to ATGMS database for near real-time analysis of geometry data. An operator can select one or more surveys and perform all aspects of quality assurance on the data. The user is provided the ability to make necessary adjustments to survey parameters such as track class and track number or update the status of geometry exceptions. Inputs to these decisions are facilitated by use of electronic timetables, track charts, detailed maps using a Google™ Map display of geographical location of selected data, displays of foot-by-foot track geometry measured in areas of interest and railroad-provided timetables. The results of the exception review process can then be sent to a list of authorized recipients including railroad personnel. Reviewers can also remotely identify and address data quality issues caused by specific Data Collection Module malfunctions and develop recommended actions to be performed during scheduled maintenance stops.

ATGMS TECHNOLOGY DEVELOPMENT PLAN
To achieve its vision of autonomous geometry measurement systems, FRA created a multi-phase development plan to guide the research and evaluation efforts as well as the transition of ATGMS technology to the railroad industry. Highlights of this development, which has been previously detailed (2), include the following:

Stage 1: Long Term Pilot with Standard Inspection Technology
The first stage centered on the creation of the basic elements of a ruggedized pilot ATGMS. Commercial, off-the-shelf equipment was employed to facilitate early development and evaluation. The original Data Collection Module was designed to alert stakeholders to areas of concern. The system was configured to measure track geometry, analyze the measurements for any locations exceeding established limits, and transmit “exception reports” to the server for storage and transmission to survey stakeholders. Early efforts focused on the creation of automated filters employing a variety of statistics-based algorithms and logic rules to identify and eliminate “false” exceptions. The pilot ATGMS was operated over CSX track between Lorton, VA, and Sanford, FL, on Amtrak 39000, a Superliner II railcar, in revenue service operations within Amtrak’s Auto Train service; an illustration of the measurement equipment located under the vehicle is included as Figure 2. Between January 2008 and March 2011, ATGMS surveyed almost 460,000 miles of track, an average of approximately 153,000 miles per year. This extensive testing allowed identification of system problems and limitations, facilitating design modifications that moved the technology towards increased robustness and reliability.
Stage 2: Simulation of Standard Revenue Operations
This stage centered on the demonstration of ATGMS accuracy in wider scale revenue operations and increased functionality. During this stage, the system was re-engineered to transmit all raw sensor data collected by the Data Collection Module to the Data Processing Servers in order to allow for automatic transfer of all track geometry measurements. Other key features of the technology that were either developed or refined during this stage included:

- Automated health and status reporting;
- Self-diagnostics and auto-recovery features;
- Improved hourly “status” email messages that provided detailed system and survey information;
- On-demand “Alert” messages that automatically report sensor malfunction;
- Self-diagnostic and auto-recovery features on the Data Collection Module to detect communication issues, corruption of data or configuration files, etc. and initiate a pre-defined sequence of actions to orderly shutdown and restart the system.

These features were successfully demonstrated during operation of the unmanned system on FRA's DOTX221, a sleeper-lounge car operated in consist with FRA's DOTX220 manned inspection vehicle. DOTX221 and the installation of the autonomous system are shown in Figure 3. The performance of the unmanned system was compared to that of a traditional geometry inspection vehicle as part of FRA's Automated Track Inspection Program (ATIP) surveys conducted over Amtrak passenger routes between September 2011 and June 2013. This testing demonstrated that the two systems produced geometry data of equal quality with differences between measured geometry data within acceptable limits established for geometry
measurements from multiple vehicles for this effort. Exceptions generated by the ATGMS and the manned system were compared and differences in reporting were attributed to:

- ATGMS speed-based class of track determination logic;
- Difference in geometry measurements from the two systems;
- Automated exception validation logic used with ATGMS as compared to crew observation of track features such as switches;
- Erroneous deletion and/or validation of exceptions.

Subsequent research efforts focused on developing and implementing the secure web-based Remote Editor Desk Console for near real-time review and validation of geometry exceptions as part of FRA's data management and quality assurance processes. Examples of some of the displays available to the operator of the Remote Editor Desk Console are provided in Figure 4. This stage represented the foundation for the use of ATGMS by FRA's Office of Safety that will be discussed in subsequent sections of this paper.
Stage 3: Advancing Measurement Technology
The objective of this stage was to improve the technology to allow for a wider range of applications. As part of this effort, a carbody-mounted ATGMS was developed to minimize interference with truck and wheelset maintenance activities, better protect the measurement platform from flying debris and mud, and allow for installation of ATGMS on a wide range of vehicle designs with a lower installation and maintenance cost. During this stage, efforts focused on new sensor and processing algorithms to account for new measurement techniques that measured track from a location further away from the track. For demonstration and evaluation purposes, a carbody-mounted ATGMS was
installed and operated on Amfleet I passenger car 82602 in Amtrak revenue service on the east coast between September 2012 and August 2013; the installation of the system is shown in Figure 5. Its performance was evaluated and compared to Amtrak’s 10002 manned geometry inspection vehicle equipped with a truck-mounted geometry measurement system.

![Figure 5. FRA's Carbody-Mounted ATGMS on Amtrak 82602 – (a) Tachometer, Measurement Beam and Electronics Enclosure, (b) GPS and Communication Antennae Installations](image)

This testing demonstrated that the carbody-mounted ATGMS produced data of equal quality when compared with a truck-mounted track geometry measurement system. Differences between measured geometry data were within acceptable tolerances established for geometry measurements from multiple vehicles for this effort.

**Stage 4: Development of Energy Harvesting Technology**

The fourth stage conducted in 2011 and 2012 targeted development and evaluation of the technologies that allow for ATGMS to be deployed on freight vehicles and other rail cars without electrical power. Solar, wind, fuel cell, and fossil fuel power sources under different operational and environmental conditions such as vehicle speed and solar radiation values were assessed. This analysis identified the appropriate operating temperature range, mechanical, electrical, and safety requirements for the equipment to maximize use of the off-the-shelf components and facilitate future use of other secondary power sources such as fuel cells. Results of this analysis and historical data from solar power systems operated on railcars indicated that solar power can be effectively used as the primary source of power.

**Stage 5: Future Demonstration of System in Freight Service**

In the current development stage, FRA’s approach to autonomous inspection technology will be demonstrated on freight vehicles operating under typical revenue service operations to establish the vision of the use of this technology for track assessment throughout the industry. Plans are underway to deploy the FRA carbody-mounted ATGMS on a typical box car for demonstration on short lines and regional railroads in early 2015. FRA's Office of Research, Development and Technology will
arrange for an instrumented freight car to be deployed to volunteer railroads; following the traversing of the tracks designated by the participating railroad, results of the inspection will be provided to survey stakeholders through the same reporting mechanism employed by the FRA Office of Safety during Amtrak assessment surveys.

Technology and procedures developed by FRA throughout the first four stages of this program will be relied upon for the intended round of demonstrations. The survey vehicle will be equipped with an Electrical Power System that will employ both solar energy and direct methanol fuel cell technology as its primary and secondary sources of power for charging the ATGMS battery system. Charge controllers, the charger/inverter and the methanol fuel cells will communicate their status with the ATGMS system in a manner similar to other operational parameters communicated to operators through Alert and Alarm messages. A conceptual illustration of the instrumented vehicle is provided in Figure 6.

![Figure 6. FRA's Carbody-Mounted ATGMS Concept on Freight Vehicle – (a) Freight Car, (b) Measurement Beam, (c) Internal Arrangement of Electronics and Electrical Power System Components](image)

It is anticipated that demonstration of FRA's ATGMS in freight service will be completed in early 2015. FRA is preparing a research report on its ATGMS technology research program that is anticipated for publication in the fall of 2014.
FRA OFFICE OF SAFETY USE OF ATGMS TECHNOLOGY

Approach
Following FRA’s long-term pilot study, the truck-mounted ATGMS was removed from its initial host vehicle and installed on FRA’s DOTX221, a sleeper-lounge car, for use in Stage 2 development and evaluation under simulated revenue operations.

FRA’s DOTX221 was operated in consist with ATIP’s DOTX220 manned track geometry inspection vehicle over Amtrak passenger routes between September 2011 and June 2012. Comparison of geometry data collected with the autonomous and the manned geometry systems demonstrated that the two produced track geometry data of equal quality. To ensure the highest quality survey reports possible, the FRA developed and implemented the Remote Editor Desk, a secure web-based application used for near real-time review and validation of geometry exceptions prior to distribution to rail. Following the launch of the Remote Editor Desk, FRA began use of DOTX221 and its unmanned geometry system for non-compliance assessments of cross-country passenger routes.

During a typical unmanned, or remote, survey, sensor data recorded by the Data Collection Module is transmitted back to the Data Processing Sever and exceptions to the Track Safety Standards are identified and presented to users of the Remote Editor Desk for review. ATGMS data is then processed and distributed in a manner similar to that used on manned inspection vehicles. Exceptions to the Federal Track Safety Standards are automatically identified and displayed for quality assurance checks. Users of the Remote Desk Console verify data quality and track class identification as well as proper identification of track in multi-track territory. Resources available to the reviewers through the Remote Editor Desk include satellite imagery available through Google™ Maps and railroad-provided information such as track charts and time tables. Once all quality checks are completed, survey results are provided to survey stakeholders. Non-Compliant Exception Reports (NCERs) identifying track conditions that cannot support the current speed of the host train are immediately sent via email to FRA and railroad personnel. Track Assessment Reports (TARs) that summarize all events identified within a particular territory are distributed to FRA and railroad personnel at the end of each survey.

Through this approach, FRA is able to dramatically reduce operational costs. By placing the survey vehicle in a revenue service train, movement costs associated with a dedicated survey car are practically eliminated. In addition, staffing of the Remote Editing Desk Console requires fewer personnel than a typical manned survey car, reducing both labor costs as well as travel costs associated with traditional survey operations.

ATIP Operations with Unmanned Inspection Technology
FRA Office of Safety’s initial use of the ATGMS-equipped DOTX221 on long distance passenger routes without an accompanying manned survey car started in Washington, DC, on July 29, 2013, and ended in Washington, DC, on September 29, 2013, covering
more than 20,000 miles of track. A similar inspection campaign started on April 14, 2014, and ended on June 14, 2014, covering more than 21,000 miles of track. The second dedicated unmanned inspection survey applied many lessons learned from previous campaigns, resulting in better overall performance of the system from transmission of quality data from the Data Collection Module to delivery of the Track Assessment Reports to ATIP and railroad personnel. Data transfer worked as expected with no data loss in transmission or processing. Performance of the web-based Remote Editor Desk Console for information management and quality assurance met general expectations. Geometry exceptions reported were regularly field verified by railroad maintenance personnel. Additional modifications to the remote console are planned to improve efficiency and user experiences.

Quality Assurance
To achieve consistent and reliable measures of track geometry for manned survey operations, ATIP employs Quality Assurance/Quality Control (QC) procedures that meet the requirements of International Standards Organization (ISO) 17025 certification. Wherever possible, ATIP has applied these procedures to the unmanned assessment operations.

Standard maintenance practices used for manned inspection systems are employed with the unmanned equipment. Instrumentation verifications are conducted with the ATGMS equipment during scheduled maintenance visits to the car, while quarterly and annual system verification/calibration activities used for manned survey cars have been applied to ensure accuracy of the ATGMS equipment. Standard Operating Procedures (SOPs) established for the remote use of ATGMS technology have been developed that address operations and maintenance of the Data Collection Module on the vehicle as well as web-based Remote Desk Console. The QA, QC, and SOPs provide clear guidance for system operations and maintenance by experienced individuals, directions for immediate review of completed activities for accuracy and completeness, and documentation for decisions and remedial actions.

As part of the data quality assurance process, foot-by-foot geometry data collected on three selected track segments at different times during the July 2013 ATIP assessment were compared to evaluate the general consistency of geometry measurements. This evaluation data included two sets of geometry data collected on the same track between Los Angeles, CA, and Oakland, CA, on consecutive days; two sets of geometry data collected forty days apart on the same track between Memphis, TN, and New Orleans, LA; and two sets of geometry data collected nineteen days apart on the same track between Tempe, TX, and San Antonio, TX. Statistics of differences between the respective sets of collected geometry data on these track segments confirmed acceptable repeatability of the system throughout Amtrak assessment campaign.

Maintenance
Both vehicle and measurement system maintenance considerations were taken into account to determine appropriate scheduling of maintenance visits during the unmanned campaigns. Measurement system maintenance considerations include:
instrument verifications, inspection of measurement system component mounting hardware, archival of various data and diagnostic files stored on the remote computers, and the condition of the lenses on the optical gage system.

Engineering efforts to refine and improve on-board Data Collection Module components have increased reliability, accuracy, and mean time between maintenance actions of the system. During the April - June 2014 survey, the vehicle was only visited two times during the 34 days of the survey to perform minor system maintenance. Remedial actions were no more complicated than those required by a manned system for that same time period.

Lessons Learned
FRA Office of Safety has relied on its approach to remote unattended track geometry inspection for more than a year. Observations and takeaways from this experience, as well as those originating from the initial development and deployment of the technology can serve as important guides for the entire rail industry as various forms of autonomous track inspection is adopted:

- **Operational Costs and Efficiency** – It has long been anticipated that ATGMS technology would foster improved efficiencies and lower operational costs. These expectations appear to be well founded.

  Traditionally, inspection programs employing staffed inspection vehicles were able to survey close to 20,000 miles of Class I mainline track over the course of a calendar year. Employing unattended track inspection equipment on revenue service equipment in passenger service resulted in approximately twice as much track being surveyed in half the time.

  ATIP use of ATGMS technology has resulted in significant operational cost savings. Based on analysis of costs associated with passenger route assessments conducted in 2013, it is reasonable to expect on the order of 30 percent to 50 percent reduction in survey costs per mile when compared to more traditional inspection approaches. As the technology matures and operators develop optimized inspection strategies, these savings will likely increase.

- **Autonomous Instrumentation Check and Calibration** – Experience has shown that the equipment employed by ATIP has produced reliable data in a very stable fashion. The autonomous nature of this technology will only be enhanced with the development of reliable automatic, self-calibrating systems to minimize the need for manual instrumentation check and calibration activities.

- **Data Management** - The use of ATGMS or other autonomous inspection technology offers many benefits to the railroad industry, including high inspection frequencies, allowing for additional data availability for improved forecasting and trend analysis, and near instantaneous availability of data. This increase in data brings with it several challenges for the railroad, including issues with handling the increased...
volume of data resulting from higher inspection frequencies and the manner in which information collected with the system will be integrated into on-going inspection practices.

CONCLUSIONS
The FRA ATGMS development program has resulted in the demonstration of autonomous geometry measurement technology that can be deployed on range of standard rail vehicles, including freight cars, to collect and distribute continuous track geometry data accurately and reliably while running in standard revenue service. These demonstrations have not only illustrated advancements in geometry data collection but also the benefits of using autonomous track geometry measurement in regular operations. The transition of this technology to routine assessments conducted as part of FRA's ATIP in 2013 has shown that use of autonomous geometry inspection can result in significant reductions in operational costs, increased inspection coverage as well as frequency and virtually no impact on revenue service operations as compared to manned survey programs.

As with many technological advances, additional benefits can be realized through continued research and development. FRA has identified several technology areas for further improvement including methods for autonomous system calibration and advanced analysis methods to facilitate predictive maintenance as opposed to reactive maintenance. These advances, along with the completion of planned demonstrations to the freight rail community, are anticipated to accelerate the adoption of this technology throughout the rail industry.

As FRA's efforts to improve track safety and maintenance practices by enhancing conditional awareness through the use of autonomous inspection systems continues, it welcomes collaborative efforts with railroads that are willing to adopt autonomous technology and looks forward to supporting such initiatives.

ACKNOWLEDGMENTS
This paper presents the efforts of many people and organizations serving an ongoing effort to develop and promote autonomous track geometry measurement for widespread use in the railroad industry. The FRA's Office of Research, Development and Technology as well as its Office of Safety, particularly FRA's ATIP staff, spearheaded this effort in concert with ENSCO, Inc. of Springfield, Virginia. The authors would like to express their gratitude to Dr. Magdy El-Sibaie and Mr. Ali Tajaddini for their leadership and guidance during the early days of development.

The implementation of this technology could not have taken place in the manner in which it did without the essential logistical and in-kind support of both CSX Transportation and Amtrak who facilitated both short-term and long-term pilot studies at critical times within the research program. The authors would like to thank Ron Bright
and Larry Biess of CSX as well as Paul Steets and Mike Trosino of Amtrak for their efforts to facilitate this important research.

REFERENCES


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Outline

• Introduction – FRA’s Vision for Autonomous Inspection
• Architecture
• Technology Development
• FRA Office of Safety Use of ATGMS Technology
• Conclusions

What is Autonomous Inspection?

Automated Inspection – Collection and assessment of key track measurements using specialized equipment with trained operators.

Autonomous Inspection – Process of inspecting the track from revenue service trains using unattended instrumentation with minimal direct involvement.

Using autonomous track geometry measurement system (ATGMS) technology, every train movement presents an opportunity to assess the vehicle and track system . . .

Vision

• FRA envisions the future of track inspection embracing use of relatively low cost, self-powering autonomous measurement systems on a wide range of rail vehicles that:
  – Reduce the life-cycle costs of measurement operations;
  – Eliminate interference with revenue operations;
  – Increase inspection frequencies and productivity;
  – Provide data of the highest quality possible;
• FRA’s goal is not necessarily to replace manned automated inspection systems - or field inspectors - as a quality assurance tool, but to create and facilitate the use of more flexible, efficient tools for use in quality control and maintenance planning activities.

ATGMS Architecture

Technology Development

<table>
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<tr>
<th>Stage</th>
<th>Description</th>
<th>Platform/Operation</th>
<th>Estimated Surveyed Track Miles</th>
<th>Duration</th>
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<td>Long Term Pilot with Standard Inspection Technology</td>
<td>Amtrak Superliner II Car 39000 in Auto Train Service</td>
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<td>IV</td>
<td>Development of Energy Harvesting Technology</td>
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<td>V</td>
<td>Demonstration of System in Freight Service</td>
<td>Typical Boxcar in freight operations</td>
<td>10,000 (anticipated)</td>
<td>Jan 2015 – June 2015 (anticipated)</td>
<td>Short Lines &amp; Regional Railroads</td>
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Stage I – Long Term Pilot with Standard Inspection Technology

• Designed elements of a ruggedized truck-mounted pilot system using commercial, off-the-shelf equipment;
• Established onboard automated processing for exceptions to Track Safety Standards;
• Demonstrated cellular communication and transmission of exceptions.
Stage II – Simulation of Standard Service Operation

- Established cellular transmission of all sensor data to allow for collection of continuous foot-by-foot measurements;
- Demonstrated basic onboard self-diagnostics & auto-recovery features;
- Employed a web application for added data quality assurance and geometry exception validation through real-time review;
- Documented system accuracy through comparison of FRA’s DOTX221 and DOTX220 data.

Performance of Manned and Autonomous Systems at Various Survey Speeds Assessed in Detail Over Locations Representing Different Track Features between Los Angeles and Oakland, CA.

Switch Traversed During Stage II at 31 mph

In general, very strong agreement between foot-by-foot measurements collected by systems mounted on two different vehicles.

Stage III – Advanced Measurement Technology

- Demonstrated a carbody-mounted ATGMS designed to minimize interference with truck/wheel set maintenance, to better protect against flying debris/mud, and to allow for installation on a wide range of vehicles;
- Quantified system performance through comparison of FRA’s ATGMS on Amtrak 82602 and Amtrak 10002 geometry data;
- Carbody-mounted ATGMS measurements and performance comparable to traditional manned measurement systems.
Stage III – Advanced Measurement Technology

Data Collected by the Two Systems Over Twenty Six Locations between Washington, DC, and New York Representing Various Track Features Compared

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Comparison of Geometry Data Collected by FRA ATGMS and Amtrak Manned Inspection System on April 3, 2013

Stage IV – Development of Energy Harvesting Technology

- Evaluated solar, wind, and fossil fuel power sources under different operational and environmental conditions;
- Identified appropriate operating temperature, mechanical, electrical, and safety requirements to maximize use of off-the-shelf components;
- Identified solar energy and diesel fuel as the primary and secondary sources for charging ATGMS batteries;
- Ruled out wind energy out as an efficient source of power generation.

Stage V – Demonstration of System in Freight Service

- Design of a modular ATGMS electrical power system using solar energy and Direct Methanol Fuel Cell technology as primary and secondary sources of power:
  - To include remote monitoring/control of ATGMS electrical power system;
- Evaluation/demonstration of system survivability in interchange service (waybill service handling, hump yards, flat switching, etc.).
- Evaluation of operational feasibility/efficiency of waybilling vehicle to assess track across multiple railroads.

FRA Office of Safety Use of ATGMS Technology - Approach

- Operated in consist with manned inspection system on FRA’s DOTX220 during Fall 2011 and Spring 2012 operations on Amtrak passenger routes;
  - Evaluated ATGMS accuracy by comparing geometry data generated by both systems;
- Operated without accompanying manned inspection car during Fall 2013 and Spring 2014 under ATIP’s Amtrak Route Assessment:
  - Performance and operation of Remote Desk Console for quality assurance and information management met general expectations;
  - Reported geometry exceptions were regularly field verified by railroad maintenance personnel.

FRA Office of Safety Use of ATGMS Technology - ATIP Operations

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FRA Office of Safety Use of ATGMS Technology - Remote Desk Console

• Once user selects survey of interest, individual events are selected for confirmation;
• User reviews supplemental information to confirm proper track designation.

FRA Office of Safety Use of ATGMS Technology - Remote Desk Console

• Reviewer is able to apply updates to the track table to confirm/establish proper track class;
• Following class determination, Non-Compliant Exception Reports (NCERs) and Track Assessment Reports (TARs) are sent to survey stakeholders.

FRA Office of Safety Use of ATGMS Technology - Quality Assurance

• ATGMS applies the same Quality Assurance/Quality Control procedures as FRA's ATIP manned inspection system, whenever possible;
• Standard Operating Procedures are developed for:
  – Remote operation of on-board Data Collection Module;
  – Scheduled maintenance visits to the car;
  – Remote Desk Console operation;
  – Evaluation of reported exceptions and supporting information in near real-time;
• Foot-by-foot geometry data collected on selected track segments at different times during ATIP Amtrak Assessments were used for data quality assurance;
  – Statistics of differences between respective data sets confirmed acceptable system repeatability throughout the assessment campaign.

FRA Office of Safety Use of ATGMS Technology - Scheduled Maintenance

• On-board Data Collection Module reliability and mean time between maintenance have increased resulting in only two maintenance actions for DOTX221 during the 34 days of 2014 ATIP Amtrak Assessment;
• Actions during scheduled maintenance visits to the car are no more complicated than those required by a manned inspection system and take into account:
  – Car maintenance needs;
  – ATGMS maintenance requests by Remote Desk Console operators such as:
    • Instrument verification;
    • Mounting hardware inspection;
    • Cleaning of optical lenses;
    • Software update/maintenance.

FRA Office of Safety Use of ATGMS Technology - Lessons Learned

• Operational Cost and Efficiency:
  – ATGMS operations can result in 30 to 50 percent reduction in survey cost per mile when compared to manned survey operations;
  – ATGMS can survey twice as much track in half the time of a manned inspection system (~40,000 track miles) in passenger service;
• Autonomous Instrument Verification and Calibration:
  – On-board Data Collection Module consistently produced reliable data;
  – Development of automated systems for calibration and instrument verification will only enhance the autonomous nature of ATGMS.

Conclusions

• Goals of FRA's development effort have been achieved:
  √ Established and implemented on both truck- and carbody-mounted ATGMS installations;
  √ Data handling and processing methods and procedures have been established and continue to be refined;
  √ Demonstrated repeatable, accurate measurements on both truck- and carbody-mounted installations;
Conclusions

- Over 100,000 track miles of ATGMS surveys under standard revenue service operations demonstrated:
  - Increased inspection frequency and surveyed track miles;
  - Significant reductions in operational costs;
  - No impact on revenue service operations;

- Through use of ATGMS, FRA has been able to dramatically reduce operational burden relating to:
  - Car movement costs, compared with a manned dedicated survey operation;
  - Travel costs for a full complement of survey crew personnel;
  - Overall duration of the operations required for covering the planned mileage.