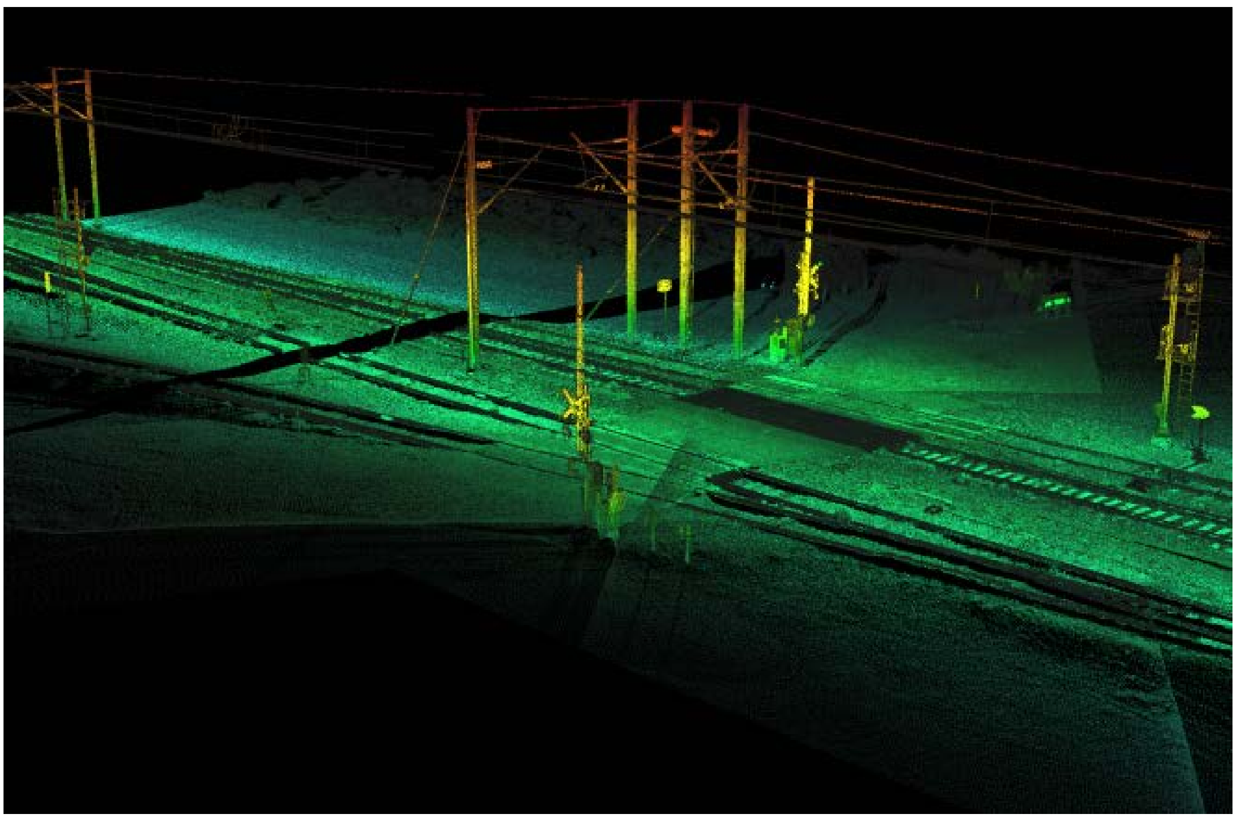
U.S. Department of Transportation

Federal Railroad Administration

Positive Train Control Track Data Auditing System

Office of Research, Development and Technology
Washington, DC 20590



DOT/FRA/ORD-18/16

Final Report
May 2018

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.			
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE May 2018		3. REPORT TYPE AND DATES COVERED Technical Report – August 2017
4. TITLE AND SUBTITLE Positive Train Control Track Data Auditing System			5. FUNDING NUMBERS DTFR53-11-D-00008L Task Order 0017
6. AUTHOR(S) Gacnik, J., Dasher, J., Oztekin, E., and Brosseau, J.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Transportation Technology Center, Inc. 55500 DOT Road Pueblo, CO 81001			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Railroad Administration Office of Railroad Policy and Development Office of Research, Development and Technology Washington, DC 20590			10. SPONSORING/MONITORING AGENCY REPORT NUMBER DOT/FRA/ORD-18/16
11. SUPPLEMENTARY NOTES COR: Jared Withers			
12a. DISTRIBUTION/AVAILABILITY STATEMENT This document is available to the public through the FRA Web site at http://www.fra.dot.gov.			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) The Federal Railroad Administration (FRA) contracted with Transportation Technology Center, Inc. (TTCI), to develop documentation for a system which automates the auditing of railroad track data for Positive Train Control (PTC). TTCI developed a Concept of Operations (ConOps) document and established a set of high-level requirements from which to design and implement a Track Data Auditing System (TDAS). The TDAS is designed to utilize machine vision sensors to capture georeferenced data for PTC critical assets and support the auditing of PTC track databases. This ensures track data used by the PTC system accurately represents the actual location and attributes of assets in the field that are critical to train operation. Using the ConOps and the system requirements, a Request for Information (RFI) was developed and delivered to vendors. RFI responses revealed significant gaps between the TDAS requirements and available technology.			
14. SUBJECT TERMS Geographic Information System, Global Positioning System, Interoperable Train Control, Light Detection and Ranging, Positive Train Control, Track Data Auditing System, track database, machine vision, PTC critical asset, track data auditing, GIS, GPS, ITC, LiDAR, PTC, TDAS			15. NUMBER OF PAGES 93 16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

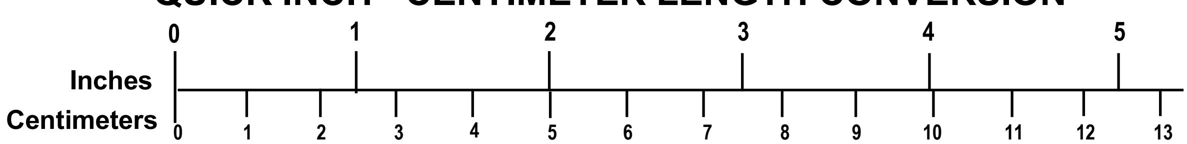
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

Acknowledgements

Transportation Technology Center, Inc. would like to recognize the collaborative efforts and assistance provided by the railroad stakeholder advisory group (AG).

Contents

Executive Summary

Transportation Technology Center, Inc. (TTCI) was contracted by the Federal Railroad Administration (FRA) to research technologies for supporting the enhancement of Positive Train Control (PTC) track database auditing processes. Specifically, FRA tasked TTCI with:

- Facilitating and documenting a railroad consensus for the functionality and requirements for a machine vision-based system to support PTC track map auditing.
- Developing high-level system specification documentation on the basis of stakeholder engagement and railroad need.
- Surveying/evaluating technologies and concepts which could meet the documented requirements.

This project was conducted to support the industry in enhancing the processes associated with track database auditing. To achieve interoperability, the large Class I freight railroads established the Interoperable Train Control (ITC) standards, which specify requirements for an interoperable PTC system, including standards for track data and track database format. The PTC system uses the track database, along with Global Positioning System (GPS) input, to resolve the location of the train along the rail network. The track database requires regular management and timely updates to ensure safe rail operations; otherwise, safety and efficiency could be compromised. Processes exist to document and update PTC track databases following changes made to the track or PTC critical assets. However, the potential exists for changes to occur without the track database being updated.

TTCI, together with an industry advisory group (AG), developed a Concept of Operations (ConOps) document and established a set of high-level requirements for a Track Data Auditing System (TDAS). Additionally, market research for available technologies was conducted and a Request for Information (RFI) was distributed to 21 vendors. Eight RFI responses were received with 13 vendors declining to submit a response. The RFI responses were evaluated to identify any significant gaps between the TDAS requirements and available technologies. The period of performance of this work was September 2015 through September 2016.

The key industry expectations identified in this phase of work are:

- Different suppliers should independently develop primary system segments.
- Open standard interfaces and segment-level requirements should be developed to support multiple products.
- The system should have flexibility in implementation of the audit management process.
- The system should have the capability to communicate data through various methodologies (e.g., wireless or cellular connections).
- The system should support configurable audit frequency dependent on PTC critical asset type and territory.

From the development of the documentation and the findings from this phase of work, TTCI and the AG developed recommendations for future work in this area. It was recognized that the focus should be on development of the open standard segment-level requirements, interface definitions, and use cases for the audit management and data collection segments. Accelerating the development of these segments will allow the systems to begin collecting data which can be used to support the development of requirements and software to automate the data processing with better success.

1. Introduction

The Federal Railroad Administration (FRA) contracted with Transportation Technology Center, Inc. (TTCI), to develop documentation for a system which automates the auditing of railroad track data for Positive Train Control (PTC). TTCI developed a Concept of Operations (ConOps) document and established a set of high-level requirements from which to design and implement a Track Data Auditing System (TDAS). The TDAS is designed to utilize machine vision sensors to capture georeferenced data for PTC critical assets and support auditing of PTC track databases. This ensures track data used by the PTC system accurately represents the actual location and attributes of assets in the field that are critical to train operation.

1.1 Background

The Rail Safety Improvement Act of 2008 (RSIA) [1] requires the implementation of interoperable PTC on rail lines over which intercity passenger or commuter transportation is regularly provided or over which poisonous or toxic-by-inhalation hazardous materials are transported, and any additional lines identified by the sitting U.S. Secretary of Transportation. PTC is defined within RSIA as a system designed to prevent:

- Train-to-train collisions
- Overspeed derailments
- Unauthorized incursions into established work zones
- Movement of a train through a mainline switch in the improper position

The scope of PTC implementation covers approximately 60,000 miles of the national railroad network.

To achieve interoperability, the largest Class I freight railroads established the ITC standards, which specify requirements for an interoperable PTC system, including system segment requirements, interface requirements, human-machine interface (HMI) standards, messaging standards, as well as standards for track data and track database format.

The system defined by the ITC standards is currently designed as an overlay system, providing enforcement of movement authorities and speed limits defined by an underlying method of operation, such as centralized traffic control (CTC) or track warrant control (TWC). In the ITC system, movement authorities and speed limits are transmitted digitally to a computer onboard the locomotive. The onboard computer checks the train speed and location relative to the defined authority and speed limits. It then calculates the estimated stopping distance of the train on a regular basis and assess if the train is predicted to exceed the limits of authority or allowable speed. In case of any impending authority or speeding violation, the system alerts the train crew and automatically initiates a penalty brake application.

The onboard computer tracks its position and speed using information from the Global Positioning System (GPS) and locomotive tachometer. It also uses a track database, which is a collection of geographical information defining the unique characteristics of each rail line and the locations of all PTC critical assets. In an effort to support the ITC system, each railroad must create their track database according to the interoperable database format. The track database file is created in accordance with the ITC Geographic Information System (GIS) logical model, used by the ITC PTC onboard application system [1]. Accurate track database information, such as location and attributes of assets in the field, is essential for a PTC system to calculate precise warning and enforcement distances [2].

The lifecycle of a track database consists of four stages: survey, generation, validation, and maintenance.

- Survey – Prior to generating a track database, a survey of the track and PTC critical assets must be conducted, using several methods. For example, a number of railroads have used airborne and mobile mapping, using Light Detection and Ranging (LiDAR) as the baseline for the railroad's PTC track database. This technology provides high resolution results that can be used for surveying and geospatial applications. While some railroads use airborne and mobile mapping, others rely on their field personnel to collect data to develop the track database baseline.
- Generation – The track database is generated, per the PTC track data model, using the collected GIS survey data.
- Validation – The track database is field-validated to ensure the location and attributes of each PTC critical asset, as defined in the track database, accurately match the assets in the field, within the required accuracy.
- Maintenance – Once the track database is established, ongoing maintenance of the track database is performed, including updating the track database per known changes and auditing the track database to ensure all changes are captured.

Validating and maintaining the track database is currently a manual, time-consuming process. Track databases are not updated until PTC critical assets are visually inspected, surveyed, and documentation is submitted and verified. Track databases require regular management and timely updates to ensure safe rail operations; otherwise safety and efficiency could be compromised.

Railroad field assets that are considered to be critical to the operation of the ITC system are referred to as PTC critical assets. Asset types and attributes critical to the ITC system may include:

- Track centerline points
- Integer mileposts, milepost signs
    - Sign text
- Signals
    - Direction of signal
    - Type of signal
    - Signal graphic
- Crossings, grade crossings
- Switches
    - Turnout leg

    - Switch orientation
- Permanent speed restrictions, speed signs
    - Sign text
- The beginning and ending limits of track detection circuits in non-signaled territory
- Clearance point locations for every switch location installed on the main and siding tracks
- Clearance/fouling points
- Inside switches equipped with switch circuit controllers
- Method of operation signs
    - Sign text
- Derails

Note that not every individual asset of the above asset types is necessarily a PTC critical asset. For example, derails are only considered critical assets if they act as a clearance point. The specific assets that need to be audited are specified in each PTC track database.

FRA has mandated that assets critical to PTC systems must be geolocated to a horizontal precision of less than 2.2 meters to provide the accuracy necessary to safely warn or stop a locomotive [3]. The horizontal requirement is interpreted as an "along track" geolocation of a point on a line perpendicular to the track "alignment," a line which runs from the center of the PTC critical asset to the center of the track. The location in the track file is the location (as measured/geolocated) of the point along the track centerline adjacent to the PTC critical asset. The point georeferenced and placed in the track database for the PTC critical asset is the point along the centerline of the track at top of rail height adjacent to the PTC critical asset. The geolocated PTC critical feature is ascribed an XY (lat/lon or northing/easting) GIS location along the centerline of the track and not that of the actual location of the PTC critical asset.

1.2 Objectives

The objectives of this project were to:

(a) Provide railroads and vendors with documentation of concepts and high-level requirements for a PTC track database auditing system. Envisioned to use any variety of machine vision sensors to capture georeferenced data of PTC critical assets for enhancing auditing processes.

(b) Identify existing technologies and vendors that could support the development and implementation of system concepts.

1.3 Overall Approach

TTCI conducted this project in close cooperation with an industry advisory group (AG). The AG consisted of representatives from FRA, Alaska Railroad (AKRR), BNSF Railway, Canadian National Railway (CN), CSX Transportation, Norfolk Southern Railway (NS), and Union Pacific Railroad (UPRR).

To meet the objectives of the project, TTCI along with the AG, executed the following major tasks:

- Established a railroad consensus for the functionality and requirements for a Track Data Auditing System (TDAS) utilizing machine vision technology to support PTC track data auditing.
- Developed a Concept of Operations (ConOps) document and a high-level system requirements document for the TDAS to support auditing of PTC track databases. These documents are intended to help ensure that the track data used by the PTC system accurately represents the actual track and PTC critical assets in the field.
- Evaluated existing technologies and concepts that could meet the documented concepts and high-level requirements.
- Identified available technologies and vendors ready to meet the documented requirements.
- Developed and issued a formal Request for Information (RFI) to potential vendors.
- Reviewed the vendor RFI responses to identify any significant gaps between the TDAS requirements and available technologies.

1.4 Scope

The scope of this project focused on defining the concepts and requirements for a system that supports the track database auditing process. In the future, the concepts and systems may be expanded to support PTC track database surveying, generation, and validation, but that is outside the scope of this effort.

During this project, the system specification document developed are intended to define the concept of operations and high-level functional and performance requirements. These documents will also provide sufficient detail for facilitating a consensus on the general approach and evaluating existing technologies. However, these documents are not intended to provide a level of detail enough for suppliers to develop a product that will meet the needs of the railroads.

1.5 Organization of the Report

This report is organized into three major sections as follows:

- Section 1 provides background information on the project to provide context for the work performed.
- Section 2 provides an overview of the project tasks.
- Section 3 provides a summary of project findings and recommendations for next steps.

This report also includes the following appendices, which represent the primary outputs/deliverables from the work performed:

- Appendix A, "PTC Critical Asset Track Data Auditing System Concept of Operations"
- Appendix B, "PTC Critical Asset Track Data Auditing System - System Specification"

- Appendix C, “Request for Information - PTC Track Data Auditing System”
- Appendix D, “PTC Track Data Auditing System Trade Table”

2. Project Overview

The PTC track data auditing project consisted of the following three major technical tasks:

- Facilitation and documentation of a railroad consensus for the functionality and requirements for a machine vision-based system to support PTC track map auditing.
- Development of system specification documentation on the basis of stakeholder engagement and railroad requirement.
- Survey and evaluation of technologies and concepts that meet the documented requirements.

The following sections provide a summary of each of these project tasks.

2.1 System Definition

To develop and establish the system specification documentation, TTCI worked with the AG and facilitated a consensus regarding the following:

- High-level operational and functional requirements
- PTC-critical assets to be audited
- Overall system architecture, including primary system segments
- Operational scenarios supported by the system
- Track data audit process management functions
- Necessary field-of-view requirements
- Environmental operating conditions
- Required detection accuracy

2.2 Development of ConOps Document

A ConOps document was developed, using the information above, to define the architecture and functions of the proposed TDAS. The ConOps, included in Appendix A, establishes the concepts and processes by which the TDAS will perform.

During the course of this project, TTCI documented and analyzed:

- The current process for auditing and validating the track database.
- The deficiencies and limitations with the current process.
- The user needs and expectations for the TDAS.
- The desired system functions.
- The system architecture, which used a flexible, phased implementation approach.

The purpose of the track database audit process is to ensure that changes are updated, and the information accurately represents the features in the field. In general, most railroads adhere to a similar process of revalidating and maintaining track databases. However, an industry standard is not in place to accomplish these tasks. Absent a standard process, each railroad would need to engineer its solution to ensure that PTC critical assets are audited on a regular basis. Audits may be performed at irregular intervals due to manual audit tracking, scheduling, and prioritization.

The users need an efficient auditing system that integrates with current railroad processes and systems. Furthermore, a system that is flexible regarding level of automation and other functions in each implementation is essential and will allow for future expansion.

With the implementation of the TDAS, the goal is to establish a more structured and standardized approach for auditing PTC track data and maintaining track databases on a regular, periodic basis.

2.3 TDAS Requirements Development

A high-level system requirements document was developed for the TDAS. This document focused on defining the high-level system requirements including:

- Functional requirements,
- Interface requirements,
- Data storage requirements,
- Performance requirements,
- Security requirements,
- System effectiveness requirements,
- Extensibility requirements,
- Environmental and physical requirements

The ConOps contains details of the information from which the requirements were derived on the basis of user needs and desired system functions.

Appendix B, "PTC Critical Asset Track Data Auditing System - System Specification" provides the key TDAS requirements.

2.4 Technology Survey and Request for Information

TTCI conducted market research and documented recommendations for available technologies, sensor types, and concepts. Then the TDAS ConOps and System Requirements were released under an RFI to gather input from technology vendors.

2.4.1 Vendor Research and Identification

The AG provided contact information for potential vendors, and TTCI conducted further research to identify additional vendors that may have a product or have the potential to develop a product that could meet the documented concepts and system requirements. Potential vendors that TTCI and the AG identified were contacted to gain additional information about their systems or products prior to developing and distributing the formal RFI. At the time the research was conducted, none of the vendors had a product that met all of the desired system functions; however, many had products or components that were developed to support PTC track data auditing functions. TTCI and the AG considered vendors with the potential to develop a TDAS, as well as vendors that have experience with machine vision technology and analyzing PTC critical assets. The purpose of this effort was to; (a) identify vendors that could potentially provide all or a subset of the system functionality needed to support the PTC track data audit process and (b) document the current state of the market for these types of systems and technologies (c) better understand where the risks and areas of opportunity for deploying a PTC TDAS that meets the defined concepts and requirements.

2.4.2 TDAS Request for Information (RFI)

In May 2017, TTCI, with support from the AG, developed and issued an RFI to potential vendors. The purpose of the RFI was to find any significant gaps between the TDAS requirements and available technologies in the market and to ascertain the ability of vendors to meet or develop a system using the established ConOps and system requirements of the TDAS. The RFI, included in Appendix C, was sent to 21 vendors that had been identified by TTCI and the AG as having experience with machine vision technology or analyzing PTC critical assets.

Eight vendors submitted responses by the May 17th, 2017 deadline. However, 13 vendors declined submissions. To encourage detailed feedback, received RFI responses are considered proprietary; as a result, specific vendors and detailed responses are not identified within this report.

A trade table identifying the most critical TDAS requirements was developed, and TTCI, in collaboration with the AG, applied the information received from each vendor's RFI response to the trade table appropriately. The trade table identified how close a vendor's existing system or existing technology came to meeting the system requirements, or if a vendor had the ability to develop a system to meet the requirements of the TDAS in the future.

2.4.3 RFI Review Meeting

On May 24, 2017, TTCI and members of the AG met at the TTC in Pueblo, Colorado, to discuss the RFI responses received. During this meeting, each requirement was appropriately weighted, and the table was populated according to each potential vendor's response.

Completion of the trade table led to the following conclusions and developments:

- Multiple sensor technologies are available with the ability to automatically capture raw audit data
    - Camera
    - Georeferenced video recorder
    - LiDAR
- Some of the identified systems/technologies are not currently designed to be flexible in how they are implemented; for example, some technologies are limited to specific vehicles or rail cars.
- Each vendor can communicate data through wireless or cellular connections.

- Capability exists to collect raw audit data in a range of directions at vehicle velocities up to 79 miles per hour (mph) and at lateral distances of 50 feet on either side of the track centerline.
- Some vendors claim their systems can confirm the location of a PTC critical asset to be less than 2.2 meters of its identified location along the track centerline.
- It was apparent that some vendors did not fully comprehend the complexity associated with the PTC track data auditing process, including items such as:
    - Range of asset shapes, sizes, complexity
    - In-track assets as well as wayside assets
    - Accuracy (drift) of GPS equipment
- At this time a product does not exist that can:
    - Determine if critical attributes associated with PTC critical assets match the critical attribute defined in the track database
    - Automatically compare raw audit data against reference data in the field or back office
    - Manage/track the status of audits for each PTC critical asset

The generated trade table, in Appendix D, provides a summary of the vendors' ability to meet or potentially meet the key system requirements.

Some RFI respondents exhibited promising concepts for subsystems, but not a holistic integrated system. Based on this it was decided that the system segments should be defined as black box applications/components independent of each other, and could be developed by different vendors, which will support a range of potential solutions and flexibility for railroads.

3. Conclusion

Under FRA oversight and support from the AG, TTCI successfully developed a ConOps document, which defined the overall concepts, architecture and functions of the TDAS, and established a set of high-level system requirements for the TDAS. Using the ConOps and the system requirements documents, an RFI was developed and sent to 21 potential vendors. Responses to the RFI were received from eight vendors, and 13 vendors declined to submit a response. TTCI, in collaboration with the AG, developed a trade table that recognized the most critical TDAS requirements and applied the information received from each vendor's RFI response to the trade table. The trade table classified how each vendor's existing or proposed system or technology addresses the system concepts and requirements.

The project identified the following three primary system segments. To facilitate incremental deployment and diverse supply chain, each segment could be developed as an individual component from unique suppliers:

- Audit management software component
- Sensor platform and data collection component
- Automated data processing software component

The AG came to consensus on the system priorities, operational scenarios, and development sequence. It is recommended that open standard segment-level requirements and development initially focus on two technologies: LiDAR and photo imagery. This focus will allow standardization of aspects of the system and interfaces between segments necessary to allow multiple suppliers to develop initial products against these standards. The AG, with the responses from the RFI, agreed that these two technologies would be the best to begin with, but that the system should be expandable to include other sensor technologies in the future.

Some of the key industry expectations identified in this phase of the work include:

- Open standard interfaces
- Segment-level requirements to support multiple products
- Flexibility in implementation for management of the audit process
- Capability of communicating data through various methodologies (e.g., wireless or cellular connections)
- Configurable audit frequency dependent on PTC critical asset type and territory.

Based on the development of the documentation and the findings from this phase of work, TTCI and the AG developed recommendations for the next phase of work to focus on the development of the open standard segment-level requirements, interface definitions, and use cases for the audit management and data collection segments. Accelerating the development of these segments will allow the systems to begin collecting data that can be used to support the development of requirements and software to automate the data processing with better success. Future research would build on these findings to develop detailed specifications and open standards to support the development of these individual system segments.

4. References

[1] Public Law 110–432, "Rail Safety Improvement Act of 2008," 16 October 2008. [Online]. Available: https://www.fra.dot.gov/eLib/Details/L03588. [Accessed 01 August 2017].

[2] The Association of American Railroads, Manual of Standards and Recommended Practices (MSRP) K6, S-9501.V1.0, Table of Contents, Washington, DC: The Association of American Railroads, 2013.

[3] Federal Railroad Administration, "Positive Train Control Implementation Status, Issues, and Impacts," 1 August 2012. [Online]. Available: https://www.fra.dot.gov/eLib/Details/L03718. [Accessed August 2017].

[4] Office of Railroad Safety, *Field Audit Checklist: Positive Train Control Systems Track Database Implementation Process,* Washington, DC: Federal Railraod Administration, 2014.

Appendix A.
PTC Critical Asset Track Data Auditing System Concept of Operations

The PTC Critical Asset Track Data Auditing System (TDAS) Concept of Operations document established the concepts and processes by which the TDAS would perform.

U.S. Department of Transportation

Federal Railroad Administration

PTC Critical Asset Track Data Auditing System

Concept of Operations

Office of Research,
Development and Technology
Washington, DC 20590

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Contents

1. Scope

To function safely and effectively, Positive Train Control (PTC) systems rely on accurate track data. This Concept of Operations (ConOps) document aims to provide the purpose for and high-level system definition of a proposed system to manage auditing of railroad track data for PTC systems that use the Interoperable Train Control (ITC) PTC data model definition. The ConOps highlights major objectives and goals of the system; identifies the system users, primary functions, and high-level architecture; and describes the role the system plays in meeting the railroad industry's PTC track data auditing needs. Definition of and relationships among key system components are discussed along with capabilities and constraints. The document outlines and describes the environment in which the system will operate and the operational scenarios that detail how the system impacts different users under differing conditions.

1.1 System Identification

- Track Data Auditing System, TDAS, Version 1.0.

1.2 Definitions, Acronyms, and Referenced Documents

1.2.1 Definitions

The following terms are used within this document:

- Audit: process of comparing raw audit data against reference data, and verifying the data corresponds.
- Audit date: date raw audit data is compared against reference data and audit result is produced.
- Audit expiration date: date by which a PTC critical asset must be audited, as established by the railroad user.
- Audit data refresh date: date beyond the latest raw audit data collection date at which a notification will be sent indicating new raw audit data is needed.
- Audit management: process of tracking audits, performing audits, reporting, and alerting.
- Audit process: overall process of collection raw audit data, comparing raw audit data against reference data, and updating/reporting audit status.
- Audit result: result of the comparison between raw audit data and reference data for an individual PTC critical asset.
    - Pass: location and critical attributes of raw audit data and reference data correspond.
    - Fail: location and/or critical attributes of raw audit data and reference data do not correspond.
    - Insufficient data: location and/or critical attributes of raw audit data and reference data could not be reliably verified.
- Audit Status: information pertaining to the raw audit data collection date, audit date, audit data refresh date, audit expiration date, and result of last audit.
- Geospatial: relative position of objects on the earth's surface.

- LiDAR: an efficient, laser-based, remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light.
- Machine vision sensor: device that can capture georeferenced image data or similar.
- Positive Train Control (PTC): a form of train control where train movement authorities and speed limits are transmitted electronically and automatically enforced to prevent violations.
- PTC critical asset: PTC equipment which if destroyed, degraded, relocated, or otherwise rendered unavailable, would affect the safety, reliability or operability of the railroad.
- Raw audit data: data collected during audit process; to be compared against reference data.
- Reference data: data used for comparison when conducting an audit (e.g., data contained within the track database, georeferenced data that has been validated against the track database, or relative location information from a referenced object). Data obtained from various sources, validating the location of PTC critical assets, may be used as reference data.
- Raw audit data collection date: date raw audit data was collected.
- Track database: onboard track data file, or subdivision file, targeted for use with the onboard system, as defined in MSRP K-6, S-9503.V1.0.

1.2.2 Acronyms

The following acronyms are used within this document:

- AAR: Association of American Railroads
- CEP: Circular Error Probability
- CTC: Centralized Traffic Control
- ConOps: Concept of Operations
- GIS: Geographic Information System
- GNSS: Global Navigational Satellite System
- GPS: Global Positioning System
- HMI: Human-machine Interface
- I-ETMS: Interoperable Electronic Train Management System
- ITC: Interoperable Train Control
- LiDAR: Light Detection and Ranging
- PTC: Positive Train Control
- RMS: Root Mean Square
- RSIA '08: Rail Safety Improvement Act of 2008
- RSS: Root Sum Square

- SBAS: Satellite-based Augmentation System
- TDAS: Track Data Auditing System
- TWC: Track Warrant Control
- WAAS: Wide Area Augmentation System

1.2.3 Referenced Documents

1. OpenEI. (n.d.). Retrieved 10 13, 2016, from en.openei.org: en.openei.org/wiki/Definition:Critical_Assets
2. Rail Safety Improvement Act of 2008, Public Law 110-432, Section 102, 122 Stat. 4852 (2008).
3. The Association of American Railroads, Manual of Standards and Recommended Practices (MSRP) K6, S-9501.V1.0, Table of Contents, 2013.
4. Administration, F. R. (2012). *Positive Train Control Implementation Status, Issues, and Impacts.* Washington D.C.
5. The Association of American Railroads, Manual of Standards and Recommended Practices (MSRP) K-6, RP-9511.V1.0, Interoperable Train Control (ITC) Onboard Track Database Field Survey and Validation, 2014.
6. Draft Subdivision File Specification File Format Version, Revision A, August 01, 2016, (assumed to be the next version to be listed in the Association of American Railroads, Manual of Standards and Recommended Practices (MSRP) K-6, S-9503.V1.0, Interoperable Electronic Train Management System ® (I-ETMS) Subdivision File).
7. Dictionary.com. (2012). Retrieved from http://www.dictionary.com/browse/geospatial.

1.3 Document Overview

This document contains information about the current PTC track data auditing process and the motivation to enhance this process. This document discusses the user's needs and expectations, and the proposed functionality of the new system.

- Section 1 contains the scope, document overview and purpose, intended audience and a brief overview of the proposed system.
- Section 2 describes the current process, analyzes the user classes, involved personnel, and user interaction.
- Section 3 provides information pertaining to the nature of the current process and the justification for changes.
- Section 4 outlines the proposed system concepts.
- Section 5 illustrates and describes the operational scenarios.
- Section 6 describes the process for adding and updating PTC critical asset data into the TDAS.

1.4 Intended Audience

The target audience for this document includes railroads implementing a PTC system that utilizes the onboard track data subdivision file, potential suppliers of the proposed Track Data Auditing System (TDAS) or system components and regulatory entities concerned with the accuracy of PTC track data.

Personnel in the railroad group include:

- Railroad PTC department - Personnel that generate, update, and maintain onboard track data files, or subdivision files (further referred to as the track database).
- PTC system integrators – Personnel responsible for implementing systems utilizing PTC track databases
- Audit system managers – Personnel who are responsible for managing the current auditing/validation process and who will be responsible for managing the TDAS

1.5 Track Data Auditing System Overview - Concept of Operations Outline

It is essential that track data used by PTC systems be accurate and up-to-date for the PTC system to function safely and effectively. Although processes exist to document and update PTC track databases following changes made to the track or other PTC critical assets, the potential exists for changes to occur without the track database being updated, for a variety of reasons that are outlined in further detail in Section 3. Auditing of the PTC track databases is necessary to ensure that the track data used by the PTC system accurately represents the actual track and PTC critical assets in place. Depending on the approach used, auditing can be a manual, time consuming process that can reduce track availability and consume resources. Additionally, the processes are manually managed, which can introduce the potential for irregular audit periods. A system that supports a more automated process for scanning PTC critical assets, and their locations and critical attributes, and auditing PTC track databases, could reduce the resource requirements and improve management of the PTC track data auditing processes.

The proposed TDAS is intended to support the ongoing management of PTC track data to meet the requirements of the ITC system. Key objectives of the proposed TDAS include flexibility of implementation, increased automation of auditing functions, and standardization of audit management, audit prioritization, and record keeping processes.

The proposed TDAS is conceived to manage the track data auditing functions for the entire railway network, including data collection, data storage, data comparison, reporting, and audit prioritization. Figure 1 shows a block diagram illustrating the primary components of the TDAS and how they interact. The track data auditing process management component will interface to the PTC back office, data collection, data storage, data comparison, and audit reporting components. The system is envisioned to utilize any of a variety of machine vision sensors to capture georeferenced data, with a date and time stamp, of PTC critical assets using a data collection approach specified by the individual railroad. Examples of data collection approaches may include use of dedicated data collection vehicles or use of data collection devices mounted to track vehicles that collect data opportunistically throughout normal operations. For circumstances where georeferenced data cannot be collected opportunistically, the system will also support targeted data collection. The proposed TDAS will be capable of recording whether raw audit data was collected from targeted raw audit data collection or opportunistically.

The georeferenced data initially collected can be validated against the track database and stored as reference data, in addition to the reference data defined within the track database itself. If the proposed TDAS is designed to use additional reference data along with the track database, the additional reference data must be validated prior to being used as TDAS reference data; the system cannot identify the difference between a failed audit and bad reference data. The amount of reference data stored is dependent on the users' operation of the system.

The audit data may be processed (i.e., compared against reference data) in the field or in the back office, depending on the specific implementation of the system. However, regardless of the implementation, all georeferenced data collected in the field will be transferred to a centralized database in the back office to retain records of raw audit data collected. The raw audit data is transferred to the track data auditing process management component and stored in the TDAS's database using a set of standard defined interfaces.

The comparison of raw audit data against reference data can be done manually or with automated data processing software using a variety of methods, including machine vision algorithms, depending on the specific implementation of the system. Additionally, the system may be implemented such that comparison is performed in the field in real-time or post-processed in the back office. In the case where data is processed in the field, either by trained field personnel or automated comparison software, the raw audit data collection component will interface directly to the data comparison component. In the case where data is processed in the back office, the data comparison component will interface with the track data auditing process management component to perform audits using raw data stored in the database.

Once the comparison of data is complete, the audit results and status will be communicated through the reporting interface to the railroad systems that provide reporting and alerting, based on the specific railroad implementation. The results and status will be stored in the TDAS database and will be used to track the audit status of each PTC critical asset and can be accessed through the track data auditing process management user interface.

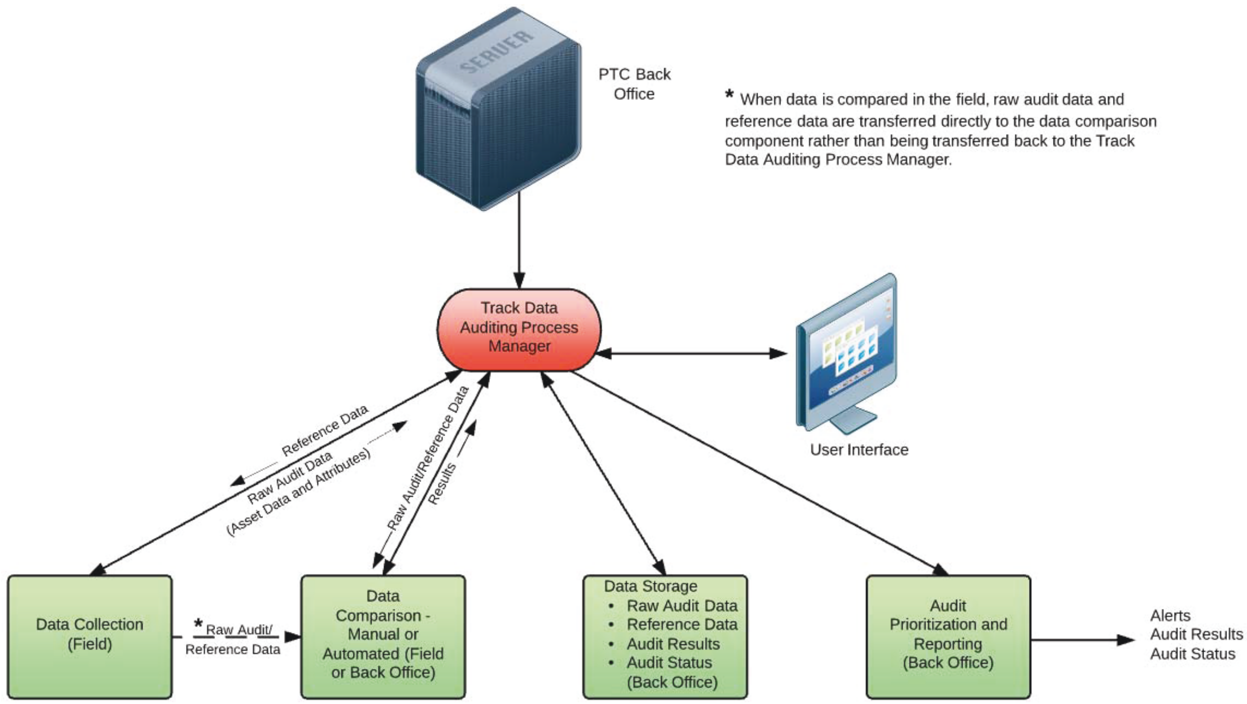

Figure 1. Track Data Auditing System

2. Current Process

This section provides background on the ITC PTC system and track database, as well as an overview of the current process for auditing/validating the track database, including definition of the users and their interactions.

2.1 Background

The Rail Safety Improvement Act of 2008 (RSIA '08) requires the implementation of interoperable PTC on rail lines over which intercity passenger or commuter transportation is regularly provided or over which poison- or toxic-by-inhalation hazardous materials are transported, and any additional lines identified by the U.S. Secretary of Transportation. PTC is defined within RSIA '08 as a system designed to prevent:

- Train-to-train collisions
- Overspeed derailments
- Unauthorized incursions into established work zones
- Movement of a train through a mainline switch in the improper position

The scope of PTC implementation covers approximately 60,000 miles of the national railroad network and is requiring significant capital expenditure.

To achieve interoperability, the largest Class I freight railroads established the ITC standards, which specify requirements for an interoperable PTC system, including system segment requirements, interface requirements, human-machine interface (HMI) standards, messaging standards, as well as standards for track data and track database format.

The system defined by the ITC standards is currently designed as an overlay system, providing enforcement of movement authorities and speed limits defined by an underlying method of operation, such as centralized traffic control (CTC) or track warrant control (TWC). In the ITC system, movement authorities and speed limits are transmitted digitally to a computer onboard the locomotive. The onboard computer tracks the train speed and location relative to the defined authority and speed limits and calculates the estimated stopping distance of the train on a regular, periodic basis. The system alerts the train crew of any impending speed or authority violations and automatically initiates a penalty brake application if the train is predicted to exceed the limits of its authority or allowable speed.

The onboard computer tracks its position and speed using Global Positioning System (GPS) and locomotive tachometer, and a database defining the characteristics of the track and the locations and critical attributes of all PTC critical assets. Track databases are unique for each rail line; however to support the ITC system, each railroad must define their track database according to the ITC database format. A PTC track database is a collection of geographical information that specifies track layout information such as track geometry, and locations and critical attributes of PTC critical assets. For a PTC system to function properly, the information provided in the track database must accurately represent the characteristics of the asset in the field. The PTC track database file is created in accordance with the ITC Geographic Information System (GIS) logical model, used by the ITC PTC onboard application system.

The life cycle of a track database consists of four stages; survey, generation, validation, and maintenance.

- Survey – Prior to generating a track database, a survey of the PTC critical assets must be conducted. A number of methods have been and can be utilized for this survey. For example, a number of railroads have used airborne and mobile mapping, using Light Detection and Ranging (LiDAR) as the baseline for the railroad's PTC track database. This technology provides high resolution results that can be used for surveying and geospatial applications. While some railroads use airborne and mobile mapping, others rely on their field personnel to collect data to develop the track database baseline.
- Generation - The track database is generated, per the PTC track data model, using the collected GIS survey data.
- Validation - The track database is validated to ensure the location and critical attributes of each PTC critical asset, defined in the track database, matches the characteristics in the field, within the required accuracy.
- Maintenance - Once the track database has been established, ongoing maintenance of the track database is performed, including updating the track database with known changes and auditing the track database to ensure changes are captured.

Validating and maintaining the track database is currently a manual, time consuming process. Track databases are not updated until PTC critical assets are visually inspected, surveyed, and documentation is submitted and verified.

Location of PTC critical assets within the track databases can change as a result of various factors such as:

- Construction: Construction activities could include modifying track alignment and the removal or placement of PTC critical assets including switches, signals, mileposts and speed signs.
- Track maintenance: When maintaining track, there may be circumstances that require a PTC critical asset to be relocated.
- Accidental/unintentional changes: Accidental/unintentional changes could be attributed to natural disasters (i.e. wind, tornados, floods, etc.), unintentional changes resulting from track inspection or maintenance, or other similar circumstances.
- Theft or vandalism: Theft and vandalism can entail the removal of a PTC critical asset that may be removed or relocated.

The track database requires regular management and timely updates to ensure safe rail operations; otherwise safety and efficiency could be compromised.

Not all field assets are considered to be critical to the operation of PTC systems. In addition to the location of field assets, there are critical attributes associated with the field assets that may be critical to the ITC system. Asset types and critical attributes that may be critical to the ITC system include:

- Track centerline points
- Integer mileposts, milepost signs

    - Sign text
- Signals
    - Direction of signal
    - Type of signal
    - Signal graphic
- Crossings, grade crossings
- Switches
    - Turnout leg
    - Switch orientation
- Permanent speed restrictions, speed signs
    - Sign text
- The beginning and ending limits of track detection circuits in non-signaled territory
- Clearance point locations for every switch location installed on the main and siding tracks
- Clearance/fouling points
- Inside switches equipped with switch circuit controllers
- Method of operation signs
    - Sign text
- Derails

It may not be necessary to audit every instance of the above assets. For example, derails would only be audited if they act as a clearance point. The specific assets that would be audited will be specified in each PTC track database.

Catastrophic failures in the operation of PTC systems can potentially be caused by inaccuracies when identifying critical infrastructure component types and locations.

FRA has mandated that assets that are critical to PTC systems must be geolocated to a horizontal precision of less than 2.2 meters to provide the accuracy necessary to safely warn or stop a locomotive. The horizontal requirement is interpreted as an "along track" geolocation of a point on a line perpendicular to the track "alignment", a line which runs from the center of the PTC critical asset to the center of the track, at top of rail track height. The location in the track file is the location (as measured/geolocated) of the point along the track centerline adjacent to the PTC critical asset. The point georeferenced and placed in the track database for the PTC critical asset is the point along the centerline of the track at top of rail height adjacent to the PTC critical asset. The geolocated PTC critical feature is ascribed a XY (lat/lon or northing/easting) GIS location along the centerline of the track and not that of the actual location of the PTC critical asset.

2.2 Current Process Objectives and Description

The objective of the audit process is to ensure that changes to the track database are identified such that the track database can be updated to accurately represent the features in the field.

The track database validation and maintenance life cycle stages are important steps in verifying and managing the PTC critical assets within a track database. When validating and maintaining track databases, the railroads verify that PTC critical assets meet the required accuracy and ensure that known changes to the track database are captured and updated. By periodically revalidating each track database, the railroads can identify changes that have not been reported and update the track database accordingly.

In general, each railroad adheres to a similar process of revalidating and maintaining track databases. However, they do not currently have an industry standard system or process in place to accomplish these tasks.

In general, major changes to the track databases, e.g., resulting from large construction projects, are reported to the PTC data group. The changes are then surveyed and the track database is updated and validated. However, smaller changes run the risk of not being reported in a timely manner. Methodologies are being developed independently by each railroad to manage when PTC critical assets were last validated, and how often the assets need to be revalidated. The current process is to audit/revalidate track databases periodically to ensure PTC critical assets in the field align with the track database. Generally, this task is accomplished by deploying PTC field personnel to operate a hi-rail vehicle to each PTC critical asset and verify the location meets the required accuracy. If a PTC critical asset fails the audit/revalidation, the field team reports the failure and the process of surveying and updating the track database is followed.

2.3 User Classes/Involved Personnel

There are various groups of users within the current process each with a different role, skill level, work activity, and mode of interaction. The specific personnel that carry out these functions may differ between railroads, but the following general user classes can be defined for the current process:

- Field survey team – Responsible for surveying and providing PTC critical asset and GIS information (i.e., coordinate information) to the appropriate personnel
- PTC track data team – Responsible for generating, updating, and maintaining the track database
- PTC field validation team – Responsible for validating the track database, including revalidation as part of the audit process

2.4 User Interaction

Users interact and are manually involved with every part of the existing audit/revalidation process. Figure 2 shows the interaction of the current users within the process of auditing/validating PTC critical assets that exist in a track database.

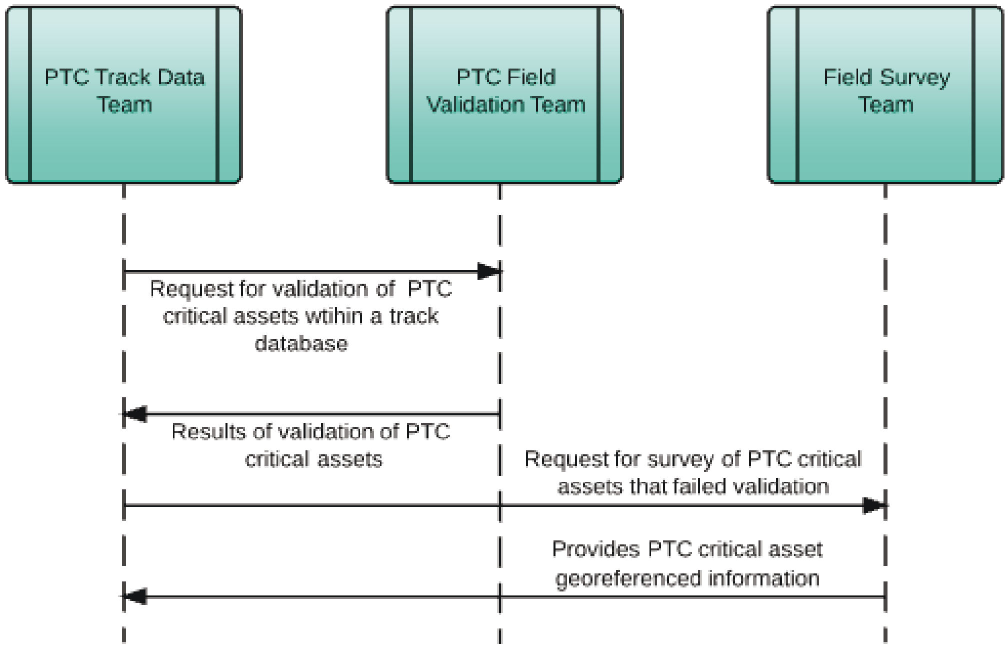

Figure 2. Current Process User Interaction

- The PTC track data team requests that the PTC field validation team validate PTC critical assets within a track database.
- The PTC field validation team operates a hi-rail vehicle to each PTC critical asset or use mobile GPS validation equipment to verify the location within the track database matches the actual field location within the required accuracy.
- The results of the validation process are reported back to the PTC track data team.
- The PTC track data team dispatches a field survey crew to survey locations and critical attributes of any PTC critical assets that failed the audit/validation process.
- The field survey team will provide the PTC track data team with the updated georeferenced information for each failed PTC critical asset.
- The PTC track data team updates the track database with the new information for each PTC critical asset.
- The above procedure is repeated until all PTC critical assets within the track database have been validated.

3. Nature and Justification of Changes

The need for enhancement of the current process for PTC track data auditing is discussed within this section. This includes identification of the key deficiencies of the current process, justification for changes to that process, user expectations for the new system, and finally, desired functions of the new system.

3.1 Current Process Deficiencies and Limitations

A standard, universal PTC track data audit process is not currently being employed by railroads operating the ITC PTC system. Absent this standard process, each railroad would need to engineer their own solution to ensure that PTC critical assets are audited on a regular basis. Audits may be performed at irregular intervals due to manual audit tracking, scheduling and prioritization.

Depending on the approach used, the current auditing/validation process can be a manual, time consuming process. Auditing PTC critical assets, utilizing current processes, can present a number of challenges:

- Providing access to and time on track, while avoiding disruption of train movement and schedules.
- Assigning needed resources, including rail vehicles and field crews, to perform the auditing/validation.

Finally, there is not currently an industry standard method for tracking and reporting of audit status and there is no alerting for critical assets that need to be re-audited. The timeliness of reporting of critical assets that have failed an audit is dependent on manual communication between the various users.

3.2 Justification of Changes to Current Process

Based on the deficiencies of the current process, described above, a structured and standardized auditing process is needed to:

- Optimize the time and resources required to audit PTC critical assets
- Reduce the potential for human error and inaccuracies in the process
- Manage the audit processes according to an established audit frequency
- Provide timely alert and reporting capability

Potential improvements over the current process include:

- Reduced operational impacts
- Improved safety
- Improved system efficiency
- Improved scheduling of audits

- Improved tracking of audit status
- Improved reporting capability
- Standardized process

3.3 User Needs/Expectations

The users need an intelligent auditing system that:

- is efficient and is an effective long-term solution,
- integrates with current railroad processes and systems,
- is flexible in terms of level of automation and other functions in each individual implementation,
- regularly assesses the audit status of PTC critical assets,
- tracks PTC critical assets and alerts the user of failed audits,
- alerts the user when an audit result has been identified as "insufficient data" a predefined number of times,
- alerts the user when a PTC critical asset has not been audited within a specified period of time,
- allows users to access records of raw audit data collected and audit history,
- is cost-effective, and
- can be managed internally or outsourced.

3.4 Desired System Functions

The need for a more structured and standardized approach for auditing PTC track data and maintaining track databases has been established to help ensure that the location of PTC critical assets in the field correlate with the information in the track database. The goal is to have each track database audited on a regular, periodic basis. New capabilities and functions are required in order to meet this need. The following is a list of functions desired within the new system:

- The system will be capable of collecting and storing raw audit and reference data, through either an automated or manual process, from a variety of data collection sensor types.
- The system will be capable of transmitting and receiving data through various methodologies, including wireless or cellular connections, between the field and back office components.
- The system will include a user configurable audit schedule that will identify when each PTC critical asset needs to be audited, and when alerts are provided.
- The system will be capable of prioritizing audits of PTC critical assets that are closer to exceeding the audit expiration dates within the audit schedule.

- The system will be able to perform both opportunistic and targeted raw audit data collection of PTC critical asset data and will provide alerts if data is not collected based on defined dates within the audit schedule.
- The system will be able to generate geospatially referenced data or relative referenced data for each PTC critical asset.
- The system can be configured to provide alerts to the user for scheduling of targeted raw audit data collection based on a set number of inconsistent or insufficient audit results for a given PTC critical asset.
- The system will provide reporting and alerts intended to be provided to appropriate personnel within the railroad. The reporting component of the system will provide information related to audit status, including audit results and audit schedules.
- The system will be able to retract alert messages if the conditions for the alert are no longer present. For example, if an updated audit results in a “pass” after an alert has been sent for a failed audit, or if sufficient raw audit data becomes available to complete an audit due to the audit data refresh date being reached.

4. Proposed System Concepts

The high-level objectives, approach, scope, and user classes are defined within this section. Further details of the proposed system are provided in subsequent sections.

4.1 Proposed System Objectives and Approach

The objectives of the TDAS are to:

- standardize the PTC track data audit management, prioritization, and record keeping processes to the extent possible while maintaining the flexibility needed;
- improve the efficiency of and reduce the number of resources required for PTC track data auditing;
- allow for incremental increase in the level of automation; and
- be flexible in the method of implementation.

The approach is to implement a PTC track data auditing system that allows for various levels of implementation and automation. These various levels will allow the railroads to choose a system implementation that will best meet their needs. Once the standard architecture is established, and the system reporting and audit scheduling and prioritization parameters are set up, some of the various levels within this approach include:

- automating the raw audit data collection process
- automating the audit data comparison process
- implementing the audit data comparison function in either the back office or in the field

The flexibility allows not only for each railroad to find the solution that best fits their needs, but also allows for a phased approach to developing and implementing the system, allowing for initial deployment of the system to gain some of the benefits, with subsequent incremental increase in the level of automation of the various system functions. The phased approach will be discussed in further detail in Section 5.

The proposed system will create an effective system process that may reduce the amount of track time necessary to complete audits by equipping data collection vehicles or track vehicles with machine vision sensors. This should allow the audits to be conducted without adding any additional delays to operations.

Furthermore, the TDAS will establish a common architecture with a standardized, yet flexible, implementation methodology for managing the process of PTC track data auditing. Although the TDAS will establish a common architecture to be used by all railroads, it is envisioned that there will not be a centralized system, but rather each railroad will implement their own TDAS.

The efficiency of the auditing process may increase since the prioritization of audits will no longer be a manual process and the notification of audit results will be reported in a more structured and timely manner.

4.1.1 Scope

The system scope includes the management and performance of the audit portion of the track database auditing component of track database maintenance, as specified in Section 2.1. It is assumed that the track database has previously been established and validated; these functions are not intended to be handled by the TDAS. The system is based on the assumption that PTC critical assets were, at the time of validation, at the locations defined in the track database. The TDAS is intended to be used for auditing as ongoing maintenance of track databases, defined by the ITC data model, is performed, although, it may be used for auditing of track databases otherwise defined, depending on the specific design and implementation of the system.

Additionally, investigation of failed audits and PTC critical asset maintenance are outside the scope of the system. The TDAS is not conceived to identify the location of missing PTC critical assets, in other locations, or PTC critical assets not identified in the track database.

The intent is to provide reporting and alerting capabilities, which the railroad can use to make decisions relating to audit scheduling, and develop plans for handling exceptions in cases where audit data is insufficient or not being collected in a timely manner.

4.2 User Classes/Involved Personnel

The user classes for the proposed system are similar to the user classes defined for the current process, although the roles of the personnel, work activity, and mode of interaction will change with the new system. The titles of the user classes and the responsibilities of each class can be individualized per each railroad's need and organizational structure, but the intent here is to define the basic functional user categories. The following user classes can be defined for the proposed system:

- PTC Track Data Team
    - Determine railroad configurable parameters of the TDAS
    - Oversee TDAS and the auditing process
    - Oversee system initialization for new or updated track databases
    - Manage alerts, failed audits, and other anomalies
- Audit Data Collection Team
    - Manage collection of raw audit data
    - Oversee transfer of raw audit data to the TDAS database
    - Schedule targeted collection of raw audit data, as appropriate/required
    - Perform raw audit data collection (if/when raw audit data collection is done manually)
    - Compare raw audit data against reference data (if processing of data is done manually in the field)
- Audit Comparison Team
    - Compare raw audit data against reference data (if processing of data is done manually in the back office)

    - Oversee processing of raw audit data against reference data (if processing of data is done automatically)

- TDAS maintenance team
    - Implement updates or changes to TDAS
    - Perform TDAS routine maintenance

5. System Architecture and Operational Scenarios

This section describes the proposed architecture of the TDAS and how that architecture changes based on the specific operational scenario(s) selected for implementation.

5.1 System Architecture

The proposed TDAS architecture is shown in Figure 3. The system is comprised of a manager component, which facilitates data collection, data storage, data comparison, audit prioritization, and reporting activities.

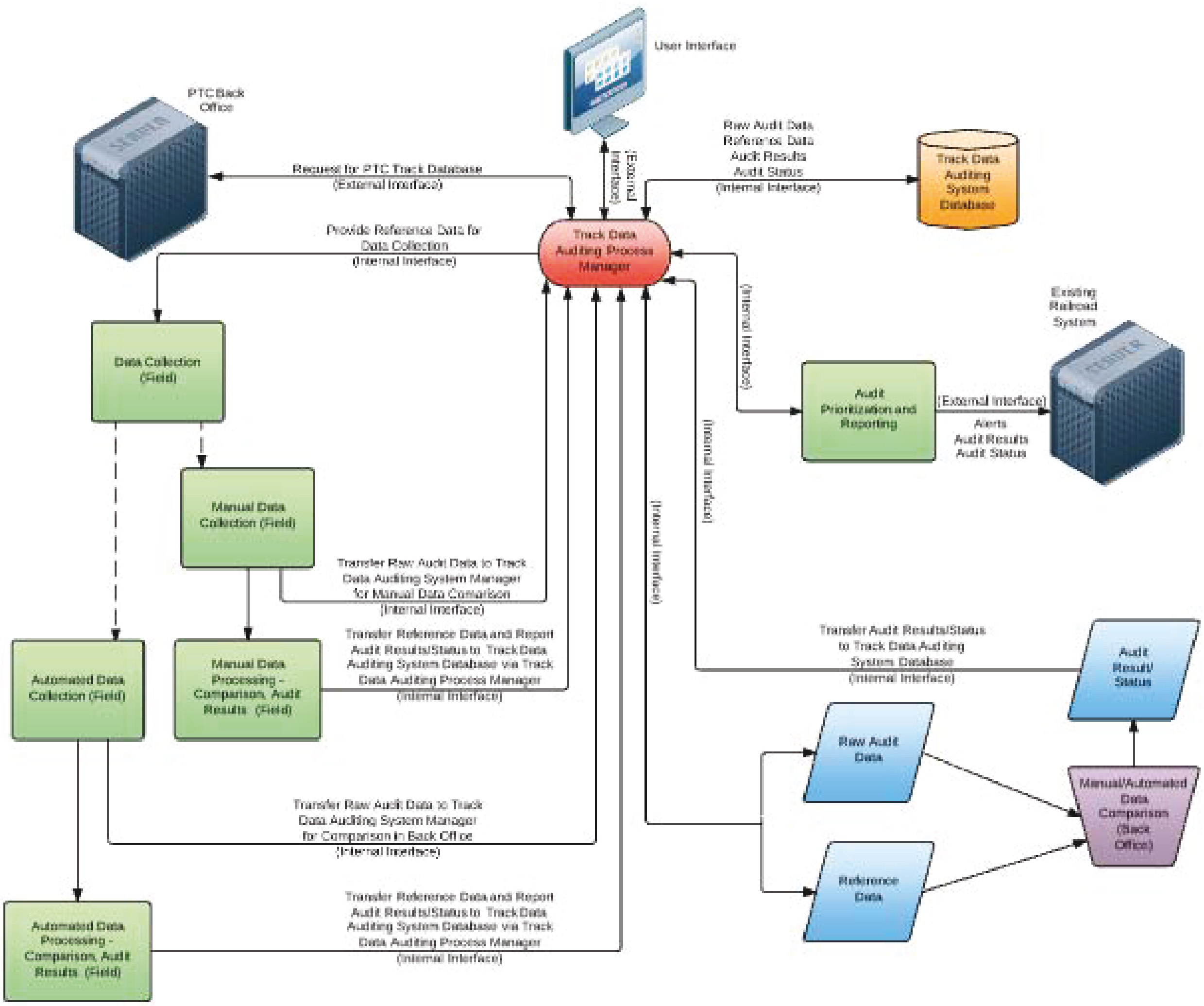

Figure 3. TDAS Architecture

5.1.1 Track Data Auditing Process Manager

The track data auditing process manager is the backbone of the TDAS. It manages all of the data transfer between the PTC back office and TDAS components, and also manages all interfaces to users and other external systems.

To support the raw audit data collection process, the process manager provides the reference data to the data collection component needed for collecting raw audit data and loads raw audit data from the data collection component into the TDAS database.

To support the audit comparison process, the process manager provides the raw audit data and associated reference data to the data comparison component and saves the audit results to the TDAS database.

Finally, the process manager provides the audit results and status information through the reporting component of the system to the appropriate railroad systems.

5.1.2 Data Collection

The collection of raw audit data can be a manual or an automated process. The audit data collection team or automated data collection system is provided with the reference data, from the TDAS process manager, necessary to identify the PTC critical assets and verify their location. This reference data may include:

- PTC critical asset location (i.e., GPS coordinates, station/offset)
- PTC critical asset type
- PTC data source ID

Depending on how the system is implemented, additional data could be provided to the audit data collection team or automated data collection system.

The audit data collection team or automated data collection system collects and provides raw audit data to the TDAS process manager, which may include:

- PTC critical asset location (e.g., GPS coordinates, station/offset)
- PTC data source ID
- Georeferenced PTC critical asset image data that is date and time stamped (used for image comparison)

There are a variety of potential methods for implementing the automated data collection process. Some design considerations that need to be addressed are:

- How the image will be taken
    - The automated data collection system may be implemented on a number of different vehicle types, ranging from locomotives to track inspection vehicles to dedicated track database data collection vehicles. The type of vehicle that is chosen may affect other aspects of the automated data collection system.
    - The track database contains information as to where along the track the PTC critical asset is expected. The track database may not indicate the direction of the

PTC critical asset location. The PTC critical assets may be located between rails, perpendicular to rail, on adjacent tracks, or span across multiple tracks above rail. Furthermore, some PTC critical assets and their critical attributes are directionally specific. Therefore, images may need to be taken in a range of directions from the data collection vehicle to obtain information in one pass without having to traverse in both directions. Forward, rear, and upward facing cameras will likely be best for object recognition and unique identification. Side looking cameras will provide the least location ambiguity.

- When the data will be captured
    - GPS provides data at 1.0 second or 100 millisecond intervals. As vehicle speed increases, there is an increasing chance that the image could be missed if not triggered with sub-second accuracy. In order to time the image collection, dead reckoning may be utilized. Alternatively, a simple least squares calculation of the distance between the current location and the location where the asset is documented to be placed can be performed. As this function approaches a minimum value, the proximity to the asset becomes known. The calculation may be made real time by the TDAS onboard processor. As the asset distance reaches a threshold, an image burst may be commanded. Ideally, the asset will be found in the center of the center image of the burst. Generally, 3 images should suffice. Many imagers allow for single images, and 3, 5, 10 and 20 image bursts. The images may be sequenced at 24, 25, 30, 60 or 120 frames per second rates. The onboard processor may adjust the triggering of the image collection to account for latency factors. The calculation may take into account the vehicle velocity in making the adjustments. The vehicle velocity is easily calculated by comparing the least squares (delta latitude, delta longitude) distance covered in a 1.0 second (or, if available, 100 ms) time interval between GPS updates.
- How many images are necessary
    - An asset may be imaged at 50 feet in front of the vehicle for archival of the condition and unique identification of an asset. This image data will be useful for manual data comparison in the back office, or for manual review if the data comparison is performed onboard. Additionally, a burst set of 3 images looking outward from the side of the vehicle should be sufficient for determining the asset location along the line of track. Stereo imaging techniques may need to be implemented. With 3 images, the object should be imaged in the center of the middle image. The object may be observed in the side of the pre-approach image and the opposite side of the post approach image. The additional images allow data collection for an object that may be offset within limits from its reported location. If it is unknown which side of the vehicle the asset will be, burst images will have to be taken looking outward from both sides of the vehicle. Eight images per asset may be a good initial estimate. With refinement, this may reduce to two images per asset, knowing the side of the track, and finding a good place to image for identification the asset, and an image collected as the asset is adjacent to a side looking imager.
- Image resolution

- Two levels of resolution may be required. When approaching an object a higher resolution image may be collected in order to facilitate object classification and unique identification. As the system is utilized, it will become known where in the forward looking imager the asset will be found at the trigger time. As this becomes known, only the portion of the image called the "region of interest" needs to be acquired from the imager. This is a feature available in some higher-end cameras. If available, a high resolution fixed optics camera may suffice. Alternatively a lower resolution camera with a command able pan/tilt mechanism would also suffice. A side looking imager, which is utilized to locate the geolocation of the asset, would not need to be of a high resolution. For this imager, the centroid of the object's vertical axis is all that needs to be determined. The object would need to be seen in the central portion of one of the burst images, in order to determine a bound of locations for the asset with sufficient accuracy to meet the overall error budget for the pass/fail criteria (e.g., 2.2 meter or as derived from vendor or other requirements) to be evaluated for the asset.

- Accuracy of geolocation information
    - The overall system accuracy is met if error contributions allocated to sub-contributors are met. A Root Sum Square (RSS) addition of various errors meeting the pass/fail criteria (e.g., 2.2 meter or as derived from vendor or other requirements) may equal 1 meter Root Mean Square (RMS) error budgets to be allocated for Imaging Geometry Uncertainty, Global Navigational Satellite System (GNSS) (GPS + GLONASS, for instance) and latency/timing errors. Notionally, a 1 meter Circular Error of Probability (CEP) (95%) accurate GNSS receiver will be required to support an overall 2.2 meter total error budget. Final allocations may be adjusted.
    - A GPS/GLONASS GNSS receiver utilizing L1 GPS signals and Satellite-based Augmentation System (SBAS) Wide Area Augmentation System (WAAS) corrections may provide a 1 meter CEP (95%) error allocation budget, and may be of sufficient precision for the TDAS system. There are several environmental influences that can prevent this level of accuracy. OmniStar VBS or RTX subscription or RTK network may eliminate occasional disruptions in loss of accuracy.

PTC critical asset image data will be collected, potentially from a variety of machine vision sensor types. These machine vision sensors can produce a variety of data types, as shown in Figure 4.

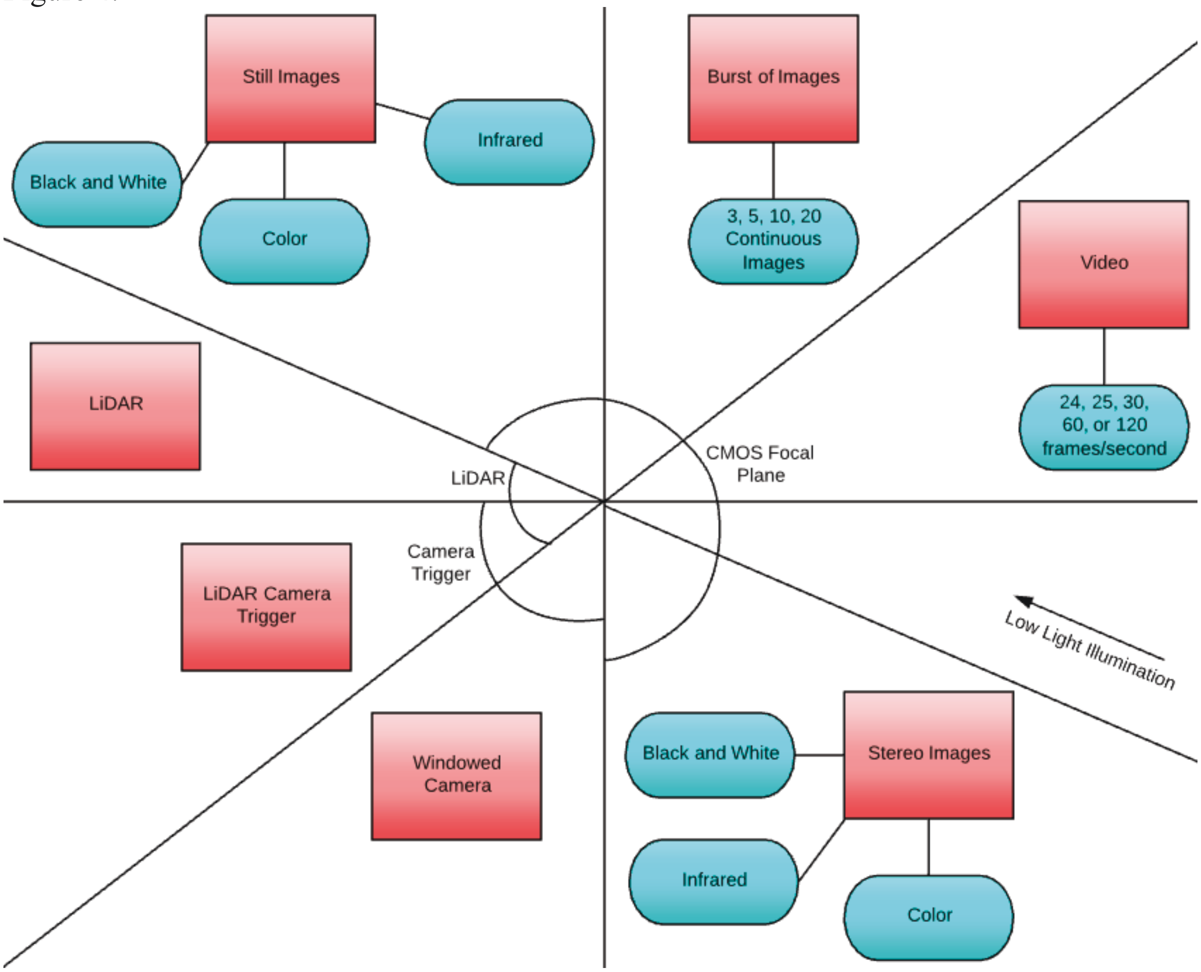

Figure 4. Machine Vision Sensor Types

The machine vision sensor data can potentially consist of:

- Still images
  - Color, black/white, infrared
- Burst images
  - Series of rapid succession images used to capture objects in motion
    - Usually captures 3, 5, 10, or 20 images
- Video
  - 24, 25, 30, 60, or 120 frames per second
- Stereo images
  - An image that provides a 3-dimensional visual impression
    - Color, black/white, and infrared
- Windowed cameras
  - Windowing increases the readout speed and achieves the maximum frame rate
- LiDAR
- LiDAR camera trigger

5.1.3 Data Comparison

As with data collection, data comparison can be a manual or automated process. Unlike the data collection function, the data comparison function can take place in the field or in the back office. The system will include an interface that will allow the transfer of raw audit data and reference data to the automated data comparison component. The system will also need to include a user interface that will allow the audit comparison team to manually compare images of PTC critical assets or identify the PTC critical asset types.

If automated data comparison is to be utilized, the data processing methodology used will have an impact on the overall system design. Specifically, a flexible processing methodology that is chosen will affect how the data is collected and what data is stored by the system.

One technique for data processing is to collect image data and compare the image against a reference image to determine if the object has moved from the reference image. This would require that georeferenced image data be date and time stamped, and be available so that the raw audit image can be compared to the reference data. If this comparison is done in the field, the georeferenced reference image must be available on board the data collection vehicle.

Another possible image processing technique is image recognition. In this technique, the data collection system would capture an image of the asset and the data comparison component would use the features of the asset to identify the asset type. A georeferenced image might not be needed with this technique, but the raw audit data returned to the TDAS could include the asset type determined by the image recognition methodology.

In addition to determining the data processing technique used, it must be determined who/what will process the data and where the processing will take place. As mentioned earlier in this document, one of the objectives of the system is to allow a phased approach to incrementally increase the level of automation. This incremental approach is detailed in the operational scenarios described in section 5.2.

5.1.4 Audit Dates, Prioritization, Alerting and Reporting

The TDAS is responsible for providing notifications regarding audit status, audit results, audit alerts, and when audits need to be scheduled. The TDAS is not conceived to handle scheduling of audits; the development of an auditing schedule will be handled on an individual railroad basis.

5.1.4.1 Audit Date, Audit Expiration Date and Data Comparison Prioritization

The audit date and audit expiration date are set for each asset each time that asset is audited. When the audit is completed (i.e., when the raw audit data is compared against the reference data and it is confirmed that the asset location information in the track database matches the actual location within the required accuracy), the audit date and audit expiration date are set as follows:

- The audit date is set to the raw audit data collection date (i.e., the date the raw audit data that was used in the data comparison was collected)
- The audit expiration date is set to a railroad-configurable number of days past the audit date

- The audit window associated with the audit expiration date can vary based on PTC critical asset type and the territory in which the assets are located.

If data comparison is performed in the back office, the TDAS process manager continuously updates the priority of each asset, based on the asset audit expiration date.

Figure 5, illustrates the data comparison process described in this section.

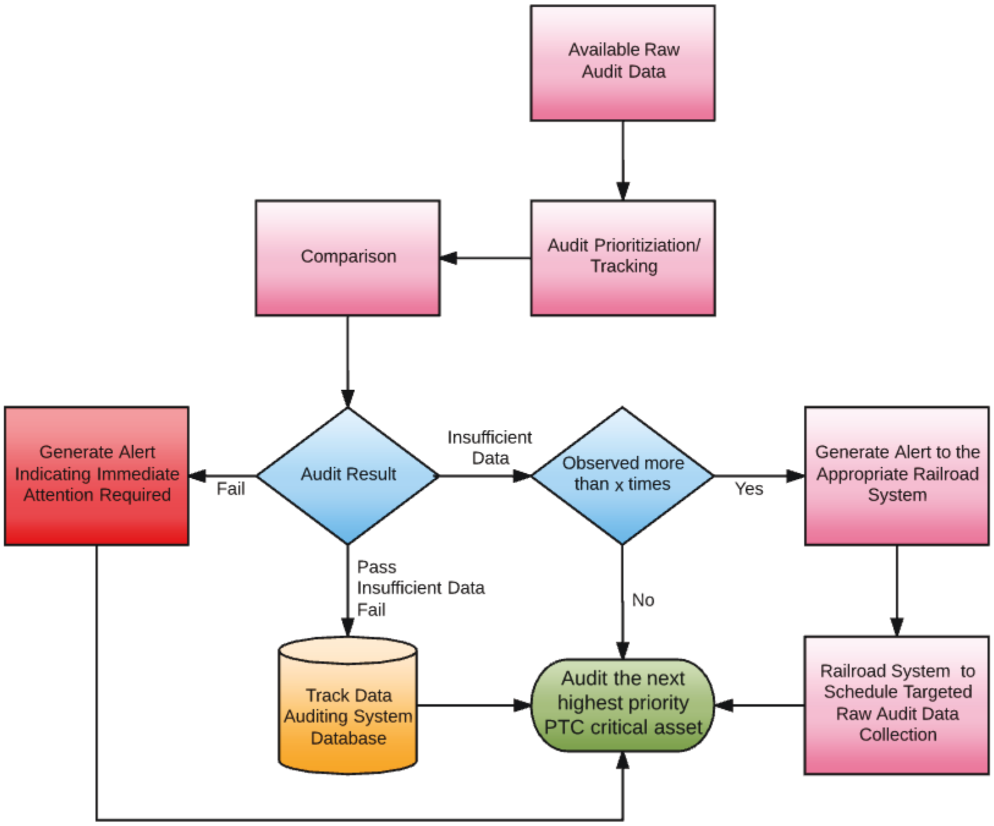

Figure 5. Data Comparison Prioritization

The asset that is closest to reaching its audit expiration date will have first priority, followed by the asset that is next closest to reaching its audit expiration date, and so on for each asset. The data comparison component will attempt to audit the highest priority asset first. If there is no new raw audit data available for the highest priority asset, or if the only new raw audit data available has previously been identified as insufficient for data comparison, the data comparison component will attempt to audit the next highest priority asset. If the raw audit data has been identified as insufficient for data comparison, the system will generate an alert and send an INSUFFICIENT_DATA message. As each asset is audited, the TDAS process manager again updates the priorities and the process continues in this manner. If the audit expiration date is reached and raw audit data has not been collected, the system will generate an alert and send an AUDIT_EXPIRED message.

If an audited asset is identified to be greater than 1.5 meters of its identified location in the PTC track database, putting the asset at risk of exceeding the FRA mandated horizontal precision of less than 2.2 meters, the system will send an ASSET_LOCATION_CLOSE_TO_EXCEEDING LIMITS message. The system can be configured such that, if an audit results in a failure, the

TDAS will interface with the appropriate railroad systems to support various levels of alerts and send an AUDIT_FAIL message. The alert levels will be railroad configurable and may be based upon PTC critical asset types and territory (e.g., depending on territory, a failed audit of a signal may have a higher priority than a failed audit of a milepost sign).

If data comparison is performed in the field, the data comparison prioritization does not apply, as the data comparison for each asset can be performed at the time of data collection.

5.1.4.2 Audit Data Refresh Dates and Data Collection Alerting

In addition to the audit date and audit expiration date described above, the TDAS will also maintain an audit data refresh date, as shown in Figure 6, to monitor the risk that new raw audit data may not be available in time to audit the asset prior to the audit expiration date. The audit data refresh date is the date beyond the latest raw audit data collection date at which a notification will be sent indicating new raw audit data is needed.

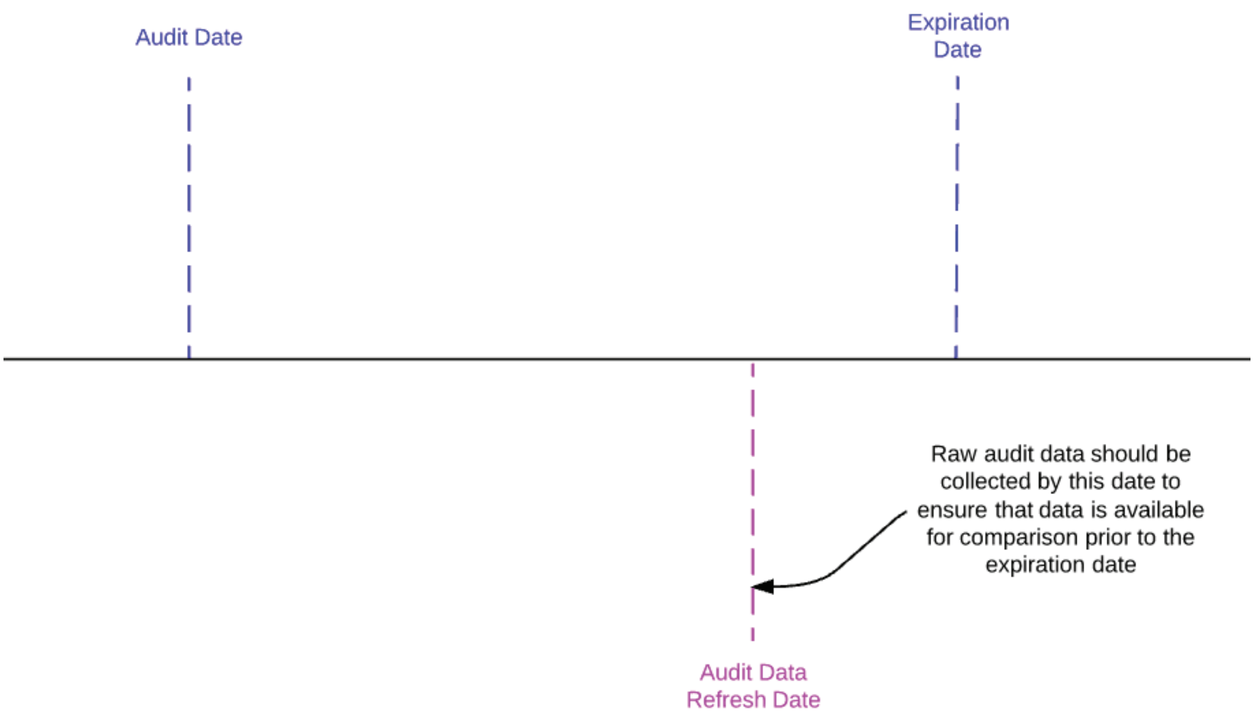

Figure 6. Audit Data Refresh Date

The railroad will establish the number of days following the last raw audit data collection date to set the audit data refresh date. When raw audit data has not been collected within the configurable number of days, the system will generate an alert and send an AUDIT_DATA REFRESH_DATE_REACHED message. When raw audit data is compared against reference data, the collection date will become the audit date, as shown in Figure 7. The audit expiration date for the subsequent audit will be referenced from the new audit date rather than the collection date.

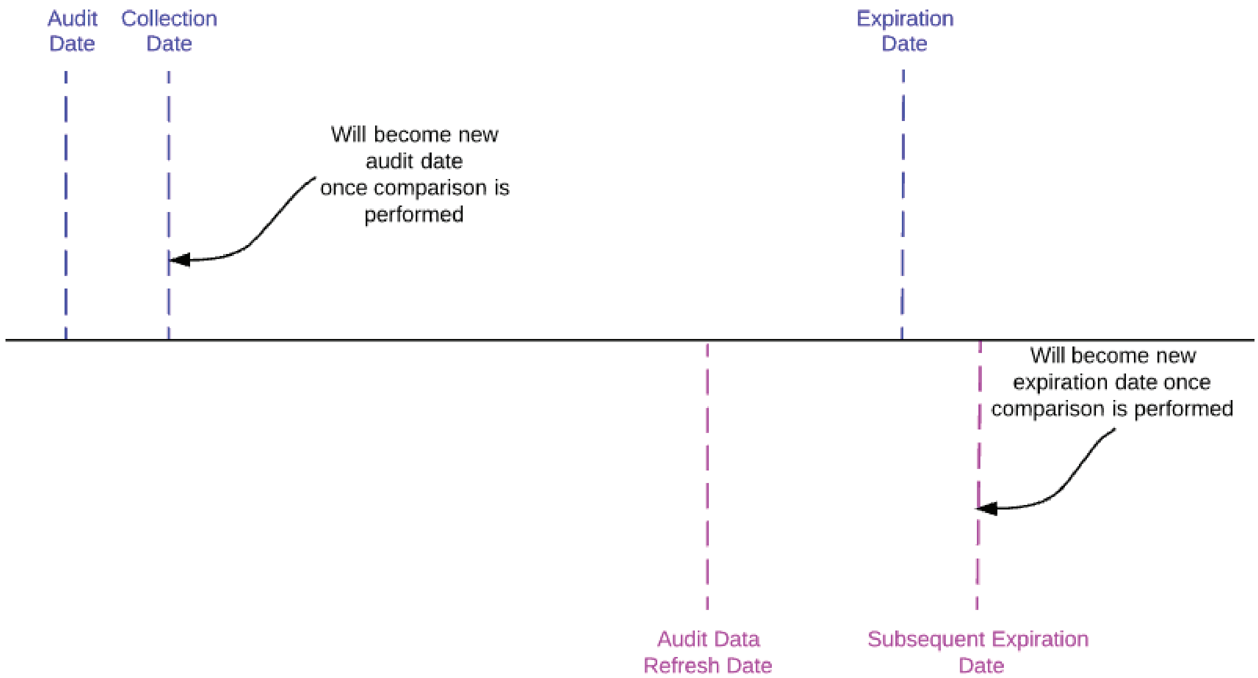

Figure 7. Critical Dates and Data Collection

When new raw audit data has been collected, the audit data refresh date is used to ensure that raw audit data is available for the subsequent audit. For this reason, it is possible to have the audit data refresh date after the audit expiration date, as shown in Figure 8.

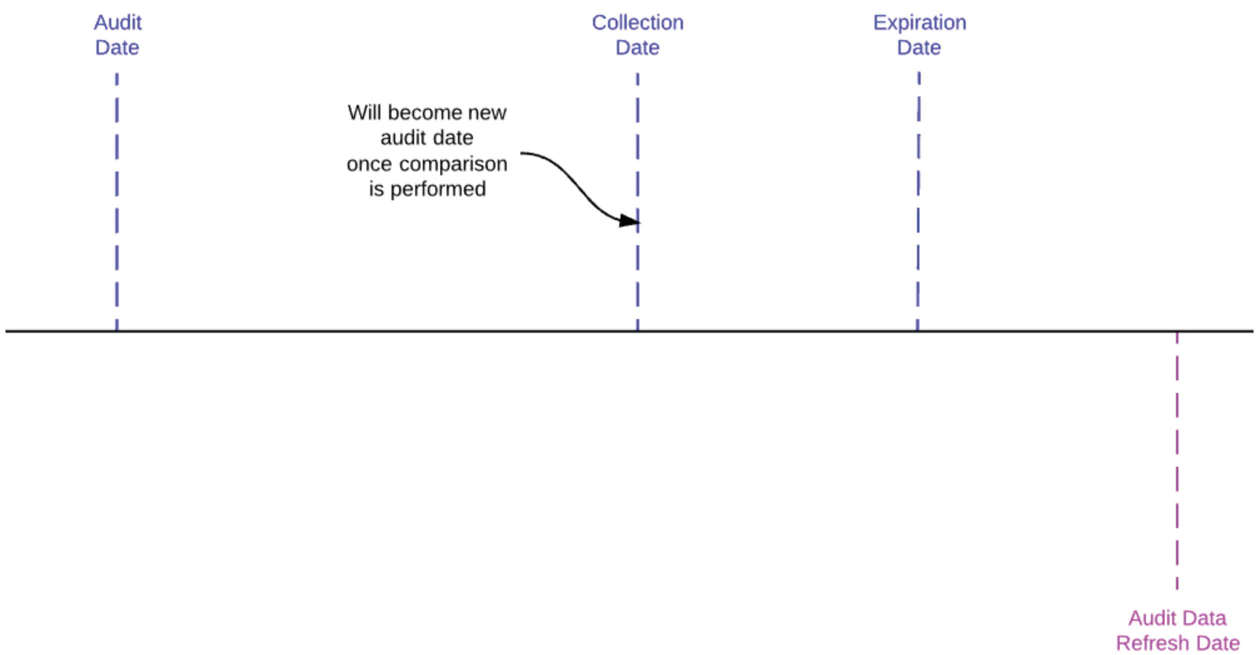

Figure 8. Subsequent Audit

It is assumed that the data comparison will be prioritized for the raw audit data collected so that the data is compared prior to reaching the audit expiration date. An alert for collection of new raw audit data for the subsequent audit will not be required until after the audit data refresh date has been exceeded.

5.1.4.3 Retraction of Alerts

After an alert has been generated, the TDAS will be capable of sending a retraction message, for specific PTC critical assets:

- If an AUDIT_DATA_REFRESH_DATE_REACHED message has been sent and new raw audit data becomes available and not deemed insufficient, the TDAS will send an AUDIT_DATA REFRESH_DATE_REACHED retraction message.
- If an INSUFFICIENT_DATA message has been sent and new raw audit data becomes available and not deemed insufficient, the TDAS will send an INSUFFICIENT_DATA retraction message.
- If an AUDIT_FAIL message has been sent and an updated audit results in a "pass", the TDAS will send an AUDIT_FAIL retraction message.
- If an AUDIT_FAIL message has been sent and an updated, track database has been provided to the system that rectifies the need for the initial alert, the TDAS will send an AUDIT_FAIL retraction message.
- If an AUDIT_DATA_REFRESH_DATE_REACHED message has been sent and an updated, track database has been provided to the system, which will update the audit date, the audit data refresh date, and the audit expiration date, the TDAS will send an AUDIT DATA REFRESH DATA_REACHED retraction message.
- If an AUDIT_EXPIRED message has been sent and an updated, track database has been provided to the system, which will update the audit date, the audit data refresh date, and the audit expiration date, the TDAS will send an AUDIT_EXPIRED retraction message.

5.1.4.4 Reporting

The role of the reporting component is to provide data to the users of the system. The information that will be reported includes:

- Audit results
- Audit status
- Audit alerts

The TDAS will provide an interface to the reporting component so that the railroad can develop custom reports based on data available from the system. The Track Data Auditing Manager will provide a user interface for the user to configure what data is reported and at what frequency. Reports can be configured to be delivered on a regular basis, such as a daily report for audit status. Reports can also be configured to be provided on an event driven basis such as a report of a failed audit, which would need to go out immediately after the audit comparison is completed.

If an alert has been generated or a failed audit has been reported, the railroad systems will have the capability of reporting additional information pertaining to the PTC critical asset's audit status for traceability. Given the flexibility in implementing the system, what information and how it is provided will be railroad configurable. Additional information provided back to the TDAS may include:

- The date set for targeted raw audit data collection for a PTC critical asset that an alert was generated as a result of insufficient or failed audit results, or for a PTC critical asset reaching its audit data refresh date or audit expiration date.
- Updates regarding errors identified in baseline data.
- Details concerning PTC critical assets removed from track databases.

5.1.5 Data Storage

The role of the data storage component is to store all data associated with auditing the PTC critical assets and the results of the auditing process. The Track Data Auditing Process Manger will provide a user interface that will allow a user to access all information (i.e., audit status) related to PTC critical assets. Depending on the implementation of the system, the data storage component may need to accommodate a large amount of data for each PTC critical asset. The TDAS will be an image-based system in which the images may need to be retained for use in the auditing process and for traceability of previous audits.

5.2 Operational Scenarios

One of the key objectives of the TDAS is to allow for flexibility in implementation and, as a result, the architecture has been conceived to be modular and will allow for future expansion. Due to this modular nature, there are various implementation options for the TDAS. This section outlines how the components and functions of the system can be implemented in the field or back office and considers whether the data collection and processing are accomplished in a manual or automated fashion.

Figure 7 illustrates the proposed implementation options (operational scenarios) for the TDAS. The elements common to all operational scenarios are discussed and each individual operational scenario is described in further detail in the subsections that follow.

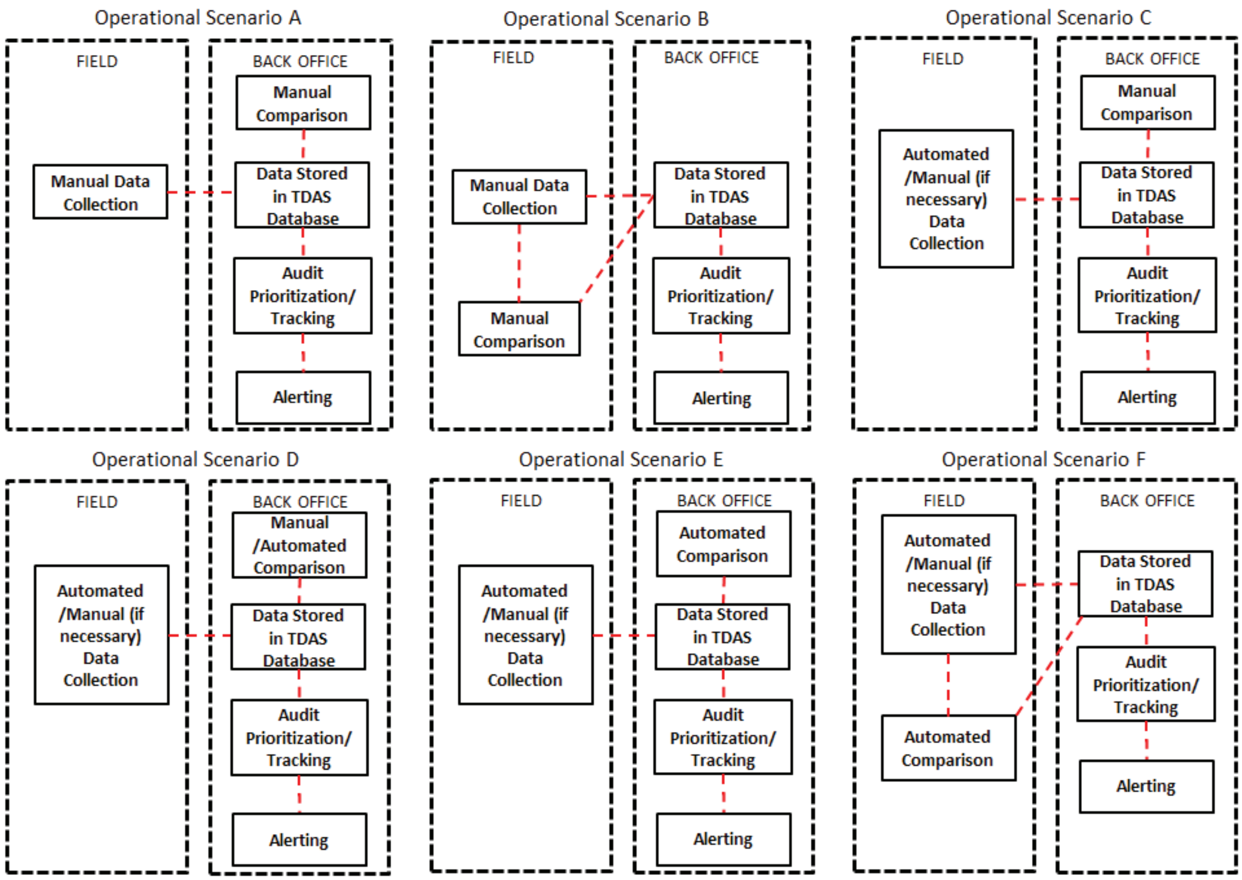

Figure 9. Operational Scenarios

The primary component of the TDAS is the process manager and it is common to all operational scenarios. The role of this component is to oversee and manage the communications between the primary functions of the system.

The primary functions in each of the following operational scenarios are:

- Data collection
- Data comparison
- Data storage
- Audit prioritization and tracking
- Alerting

How the data is collected and compared varies based on the operational scenario chosen to be implemented by an individual railroad. Given the flexibility in implementing the system, along with available machine vision technology, there are various approaches that can be implemented in the field to collect raw audit data, as well as various approaches to comparing the data either in the field or back office.

The track data auditing process manager will monitor which PTC critical assets need to be audited based on the audit status, audit data refresh dates and the audit expiration dates, as described previously. The track data auditing process manager will provide the reference data that is needed by the audit data collection team or the automated data collection system to collect the raw audit data. The audit data collection team or the automated data collection system will collect the raw audit data associated with each PTC critical asset. Collected raw audit data will be transferred to a centralized database in the back office in all operational scenarios to retain records of all raw audit data collected. There are various ways to transmit and receive data between the field and the back office (e.g. wi-fi, cellular, MDM server, Ethernet connection, etc.); how exactly this is done and what data is transmitted is dependent on the details of the operational scenario and the implementation. In the majority of operational scenarios, raw audit data will be collected opportunistically during normal operation. However, there may be times that the data collection system will have to be scheduled for targeted raw audit data collection. This might be required for those assets that sensor mounted vehicles do not pass frequently. It might also be required when sensor view is degraded due to inclement weather or obstructed, e.g., by other rolling stock.

The data will then be compared through either a manual or automated process that can be performed either in the field or in the back office. The operational scenarios described in the following subsections provide further detail regarding the methodologies for collecting and comparing data in each operational scenario.

Once the comparison of data is complete, the track data auditing process manager will store the raw audit data, reference data, audit status, and audit results in the TDAS database. Tracking, alerting, and audit prioritization will be performed in the back office for all operational scenarios. The TDAS will interface the appropriate railroad systems to support scheduling, alerts, and provide access to audit results and audit status.

The six operational scenarios, described in the following subsections, describe the high level operations of the system.

5.2.1 Operational Scenario A

In Operational Scenario A, as shown in Figure 8, data collection and comparison are manual processes that require personnel to gather the raw audit data in the field and manually compare the raw audit data against reference data in the back office.

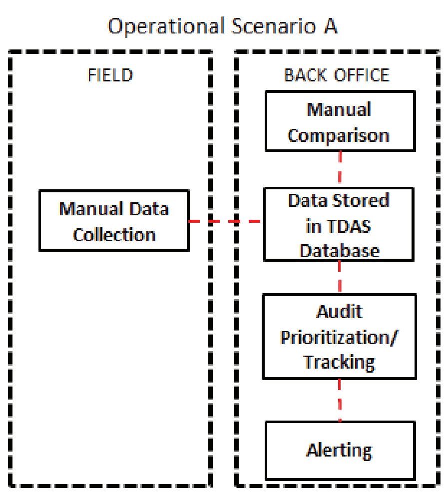

Figure 10. Operational Scenario A

Using the GPS coordinates in the reference data provided, the audit data collection team will locate each PTC critical asset. The audit data collection team will collect the raw audit data necessary to complete the comparison of audit data in the back office. The audit data collection team will transfer the raw audit data to the Track Data Auditing process manger so that the comparison of raw audit data against reference data can be completed using a manual process.

5.2.2 Operational Scenario B

In Operational Scenario B, as shown in Figure 9, data collection and comparison are manual processes that require personnel to gather the raw audit data and manually compare the raw audit data against reference data in the field.

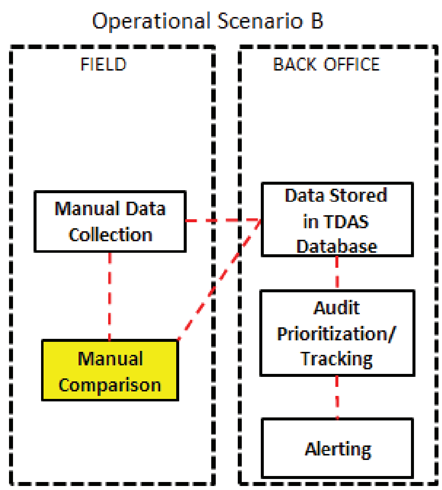

Figure 11. Operational Scenario B

Using the GPS coordinates in the reference data provided, the audit data collection team will locate each PTC critical asset. The audit data collection team will collect the raw audit data necessary to complete the comparison of raw audit data against reference data, using a manual process, in the field. Once the comparison of data is complete, the audit data collection team will transfer the raw audit data, reference data, and audit results through the user interface to the Track Data Auditing process manger, and the track data auditing process manager will store the data in the TDAS database. Data collection/comparison is prioritized based on the temporal proximity to the audit data refresh date.

5.2.3 Operational Scenario C

In Operational Scenario C, as shown in Figure 10, raw audit data is collected opportunistically during normal operation. This is accomplished through an automated process utilizing any of a variety of machine vision sensors to capture georeferenced data of PTC critical assets. Manual data collection may be used on an exception basis when targeted raw audit data collection has been scheduled or for hard-to-capture assets. The raw audit data will be manually compared against reference data in the back office.

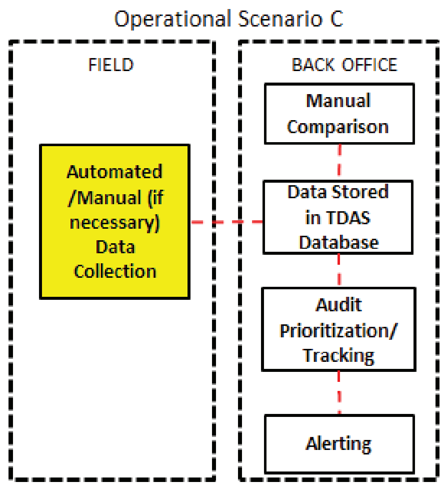

Figure 12. Operational Scenario C

Using the GPS coordinates in the reference data provided to the data collection vehicle, the onboard data collection system will collect the raw audit data necessary to complete the comparison of audit data in the back office as it passes each PTC critical asset location. The onboard data collection system will transfer the raw audit data through an interface to the Track Data Auditing process manger, either in real time or when practical, so that the comparison of raw audit data against reference data can be completed in the back office using a manual process.

5.2.4 Operational Scenario D

In Operational Scenario D, as shown in Figure 11, raw audit data is collected opportunistically during normal operation. This is accomplished through an automated process utilizing any of a variety of machine vision sensors to capture georeferenced data of PTC critical assets. Manual data collection may be used on an exception basis when a targeted raw audit data collection has been scheduled or for hard-to-capture assets. The raw audit data will be compared against reference data in the back office through a combination of manual and automated processes.

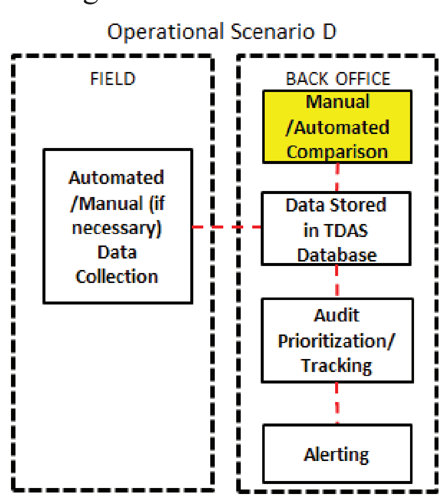

Figure 13. Operational Scenario D

Using the GPS coordinates in the reference data provided to the data collection vehicle, the onboard data collection system will collect the raw audit data necessary to complete the comparison of audit data in the back office as it passes each PTC critical asset location. The onboard data collection system will transfer the raw audit data through an interface to the Track Data Auditing process manger, either in real time or when practical, so that the comparison of raw audit data against reference data can be completed in the back office using a manual or automated process. Automated data processing software will be utilized to automatically compare the raw audit data against reference data for certain PTC critical assets, while others will be compared manually.

This operational scenario may be used because certain assets may be difficult to compare automatically, or the cost of developing the processing software for certain PTC critical assets might limit the number of assets that can be practically compared automatically. It may be easier and more cost effective to continue to compare certain PTC critical assets manually. Manual comparison will be required to confirm the audit results from the automated processing software until sufficient confidence in the software is achieved. Periodic manual comparison, for quality assurance, may be necessary to verify the automated processing software continues to work correctly throughout the life of the system.

5.2.5 Operational Scenario E

In Operational Scenario E, as shown in Figure 12, raw audit data is collected opportunistically during normal operation. This is accomplished through an automated process utilizing any of a variety of machine vision sensors to capture georeferenced data of PTC critical assets. Manual data collection may be used on an exception basis when a targeted raw audit data collection has been scheduled or for hard-to-capture assets. The raw audit data will be automatically compared against reference data in the back office.

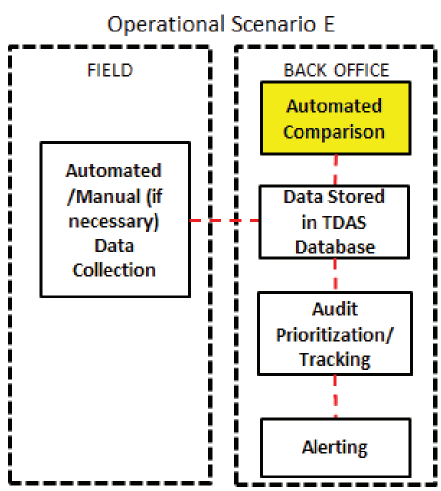

Figure 14. Operational Scenario E

Using the GPS coordinates in the reference data provided to the data collection vehicle, the onboard data collection system will collect the raw audit data necessary to complete the comparison of audit data in the back office as it passes each PTC critical asset location. The onboard data collection system will transfer the raw audit data through an interface to the Track

Data Auditing process manger, either in real time or when practical, so that the comparison of raw audit data against reference data can be completed in the back office using an automated process. The automated process will utilize automated data processing software to perform the comparison for all PTC critical assets. Manual comparison will be required to confirm the audit results from the automated processing software until sufficient confidence in the software is achieved. Periodic manual comparison, for quality assurance, may be necessary to verify the automated processing software continues to work correctly throughout the life of the system.

5.2.6 Operational Scenario F

In Operational Scenario F, as shown in Figure 13, raw audit data is collected opportunistically during normal operation. This is accomplished through an automated process utilizing any of a variety of machine vision sensors to capture georeferenced data of PTC critical assets. Manual data collection may be used on an exception basis when a targeted raw audit data collection has been scheduled or for hard-to-capture assets. The raw audit data will be automatically compared against reference data in the in the field.

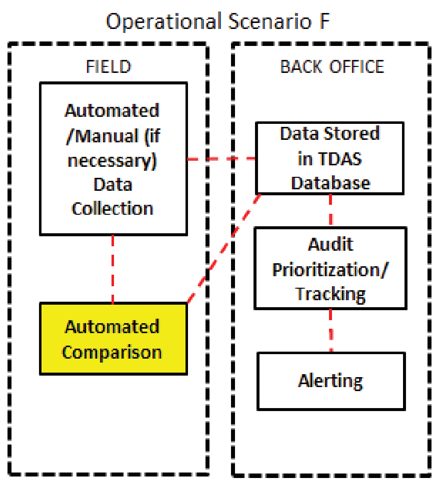

Figure 15. Operational Scenario F

Using the GPS coordinates in the reference data provided to the data collection vehicle, the onboard data collection system will collect the raw audit data necessary to complete the comparison of audit data as it passes each PTC critical asset location. Comparison of raw audit data against reference data will be performed, using an automated process, in the field. The automated process will utilize automated data processing software for all PTC critical assets. Once the comparison of data is complete, the onboard data collection system will transfer the raw audit data, reference data, and audit results through an interface to the Track Data Auditing process manger, either real time or when practical. Once the transfer of data has been completed, the track data auditing process manager will store the data in the TDAS database.

5.3 Phased Implementation Approach

The system architecture and operational scenarios are designed to allow for a phased implementation approach that incrementally increases the level of automation of the auditing functions in each development/implementation phase. One of the fundamental concepts behind the architecture of the system is to provide flexibility in implementation and support incremental improvement through phased development and implementation.

By implementing Operational Scenario A or B, the railroad can establish a standardized process for data collection, data comparison, audit status tracking, alerting, and prioritization, using the standard architecture of the TDAS, without incurring the additional cost of automatic data collection and comparison functions. If Operational Scenario A or B is initially executed, a railroad can incrementally implement automated data collection in the field as described in Operational Scenario C. This would allow the railroad to distribute the cost of implementing automated data collection across their entire network by allowing them to purchase and mount machine vision sensors to a data collection vehicle over an extended period of time rather than acquiring the equipment and cost at one time. If the railroad decides to implement the system as described in Operational Scenario D, to automatically compare data, machine vision algorithms can be incrementally developed and added to the TDAS, beginning with a single PTC critical asset type (e.g., switch). Once the machine vision algorithm for comparing this particular PTC critical asset is completed and validated, the development of algorithms for other PTC critical assets will continue. The PTC critical assets may need to be prioritized when developing the automated routines, e.g., based on which PTC critical asset types are the most prevalent and thus require the most manual effort for comparison, or based on which PTC critical assets are more difficult or time-consuming for manual comparison. Some assets may not be worth moving to an automated process as the PTC critical asset may only exist in a few locations. This would allow the vendors and/or railroads to focus on a given PTC critical asset type to ensure that the developed machine vision algorithm is accurate and reliable when executing the automated data comparison function. The process of incrementally adding machine vision algorithms may continue until a railroad develops a fully automated process of comparing data as described in Operational Scenario E. Operational Scenario E would reduce the manpower needed to complete the comparison function of the system thus reducing system operating costs and the potential for human error. In Operational Scenarios C, D, and E, the data comparison function is performed in the back office, but the comparison of data may not take place immediately. In Operational Scenario F, data comparison for each PTC critical asset can be performed at the time of data collection. Therefore, reporting of audit status and results can occur in a timelier manner.

6. Audit Initialization and Reference Data Updates

This section describes the process for adding and updating PTC critical asset data into the TDAS, provided that the track database has been created, additional reference data has been collected (if required), and both the track database and the reference data have been validated. The dotted line shown in the diagrams in the following subsections indicate the processes that occur within the TDAS. Elements common to the process for adding or updating PTC critical asset data into the TDAS are discussed and each process is described in further detail below.

6.1.1 Track Database Audit Initialization and Update Overview

There are two ways to initialize or update the TDAS, depending on the type of reference data utilized by the system. The system may be designed to use the track database as the only reference data or it may be designed to use additional reference data (e.g., image reference data), along with the track database. The TDAS will utilize the PTC data source ID from the PTC track database as the unique identifier when collecting and comparing raw audit data. This ID may be a composite ID that could contain the subdivision ID, and the data source ID used to uniquely identify PTC critical assets. Additionally, the track database version will be maintained and used to determine if the information stored within the TDAS is from the most recent track database.

If the track database is to be used as the only reference data, the data source ID for each PTC critical asset will be loaded into the TDAS database and the audit date, audit data refresh data, and audit expiration date will be set, based on the date the track database was validated.

If the system is designed to use additional reference data, the system will determine if reference data is available, utilizing a matching algorithm, for each PTC data source ID from the track database. If reference data is available, the matching algorithm will pair the asset ID with the corresponding asset ID in the reference data for each PTC critical asset. Once the data source ID has been paired with reference data, the audit date, audit data refresh data, and audit expiration date will be set, based on the date the reference data was validated. If reference data is not available, the TDAS will flag the PTC critical asset and will interface the appropriate railroad systems to support alerting and scheduling for the collection of the additional required reference data. In this case, the PTC track database validation date will be utilized to set the audit date, audit data refresh data, and the audit expiration date until additional reference data can be collected.

6.1.2 Track Database Audit Initialization

The Track Database Audit Initialization diagram, shown in Figure 14, illustrates the process for identifying PTC critical asset data for auditing using the TDAS. The TDAS will have an interface to the PTC back office that will allow the user to identify each track database to be audited by the TDAS. For each PTC critical asset, the system will parse the PTC track database and record the PTC data source ID. The system may be designed to use the track database as the only reference data or designed to use additional reference data (e.g., image reference data), along with the track database. Critical dates will be set based on the date the track database was validated or when the reference data was validated.

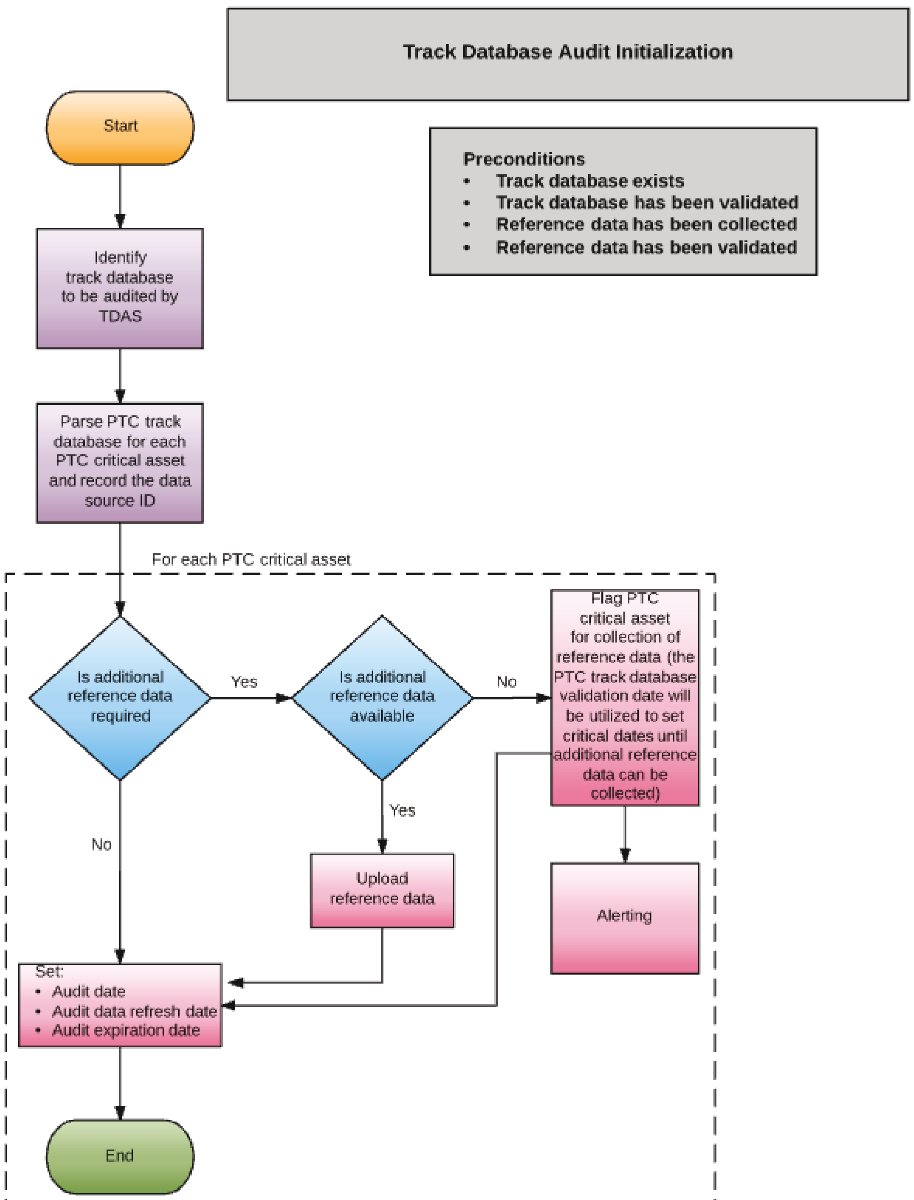

Figure 16. Track Database Audit Initialization

6.1.3 Track Database Audit Update

The Track database audit update diagram, shown in Figure 15, illustrates the process for updating critical asset and audit status data in the TDAS when changes are made to PTC critical asset data in the track database. The system will periodically contact the PTC back office to verify it is utilizing the most up-to-date track database by comparing the track database version number maintained by the TDAS with the version number in the PTC back office. The frequency at which this is done will be railroad configurable. If an updated track database is identified, the updated version of the track database will be compared against the previous track database to identify changes. For each update found, the TDAS will archive the existing reference data, for each PTC critical asset that has been either relocated or removed, and record the updated PTC data source ID. As previously stated, the system may be designed to use the track database as the only reference data or designed to use additional reference data (e.g. image reference data), along with the track database. Critical dates will be set based on the date the track database was validated or when the reference data was validated.

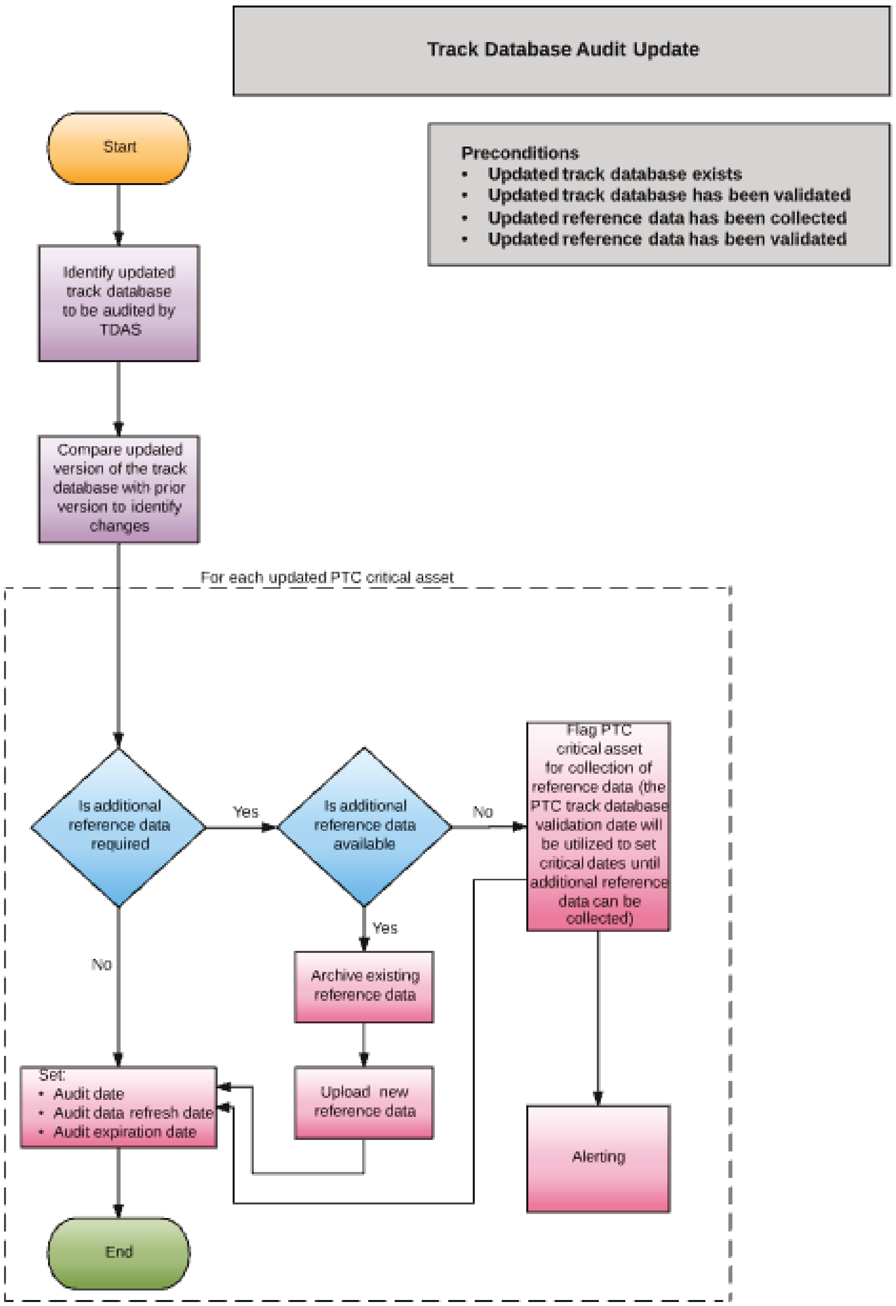

Figure 17. Track Database Audit Update

6.1.4 PTC Critical Asset Reference Data Update

If the system is designed to use reference data in addition to the data contained within the track database, it may be necessary to update the additional reference data at times, even if the track database has not changed. This would be needed for certain types of PTC critical asset feature changes, e.g., an existing signal head replaced with a different type of signal head. This type of change would not require a change to the track database, but the reference data would need to be updated so that an accurate comparison of raw audit data against reference data can be made.

The diagram shown in Figure 16 illustrates the process for updating reference data for the most up-to-date track database. It is assumed that, prior to this process, the additional reference data is collected and validated. The process begins with the user selecting an existing PTC critical asset. The TDAS will prompt the user to select the updated reference data associated with that particular PTC critical asset. The system will archive the existing reference data and upload the new reference data to the database. The system will update the audit date, audit data refresh date, and audit expiration date, based on the date the new reference data was validated.

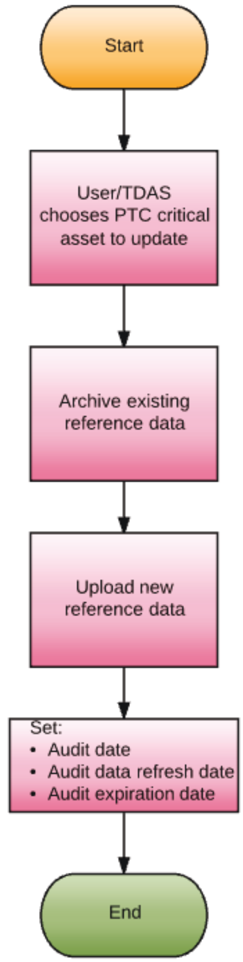

Figure 18. Updating PTC Critical Asset Reference Data

Appendix B. PTC Critical Asset Track Data Auditing System - System Specification

The PTC Critical Asset Track Data Auditing System (TDAS) System Specification document regulated the development and implementation of the TDAS, and focused on defining the high-level system requirements.

PTC CRITICAL ASSET TRACK DATA AUDITING SYSTEM (TDAS)
SYSTEM SPECIFICATION

Transportation Technology Center, Inc.
A subsidiary of the Association of American Railroads
Pueblo, Colorado USA

May 2017

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Jill Gacnik and Jeremy Dasher	5/17	Joseph Brosseau	5/17
	Date		Date
	Date		Date

REVISION RECORD

Revision	Date	Description
1	03/03/17	TTCI Internal Review and Revision
2	04/10/17	TTCI Internal Review and Revision
3	04/15/17	TTCI Internal Review and Revision
4	04/19/17	Advisory Group Review and Revision
5	04/27/17	Advisory Group Review and Revision
6	05/02/17	Final Document

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1. Introduction

This document specifies the system-level requirements for a Track Data Auditing System (TDAS) for auditing of Positive Train Control (PTC) critical asset data specified by the Interoperable Train Control (ITC) data model standards. The system concept that these requirements are based on is documented in the PTC Critical Asset Track Data Auditing System Concept of Operations, Version 1.0.

1.1 Background

PTC is a train control system designed to provide warning and enforcement of the operational limits (e.g., authority and speed limits) of trains. In the United States, an interoperable PTC system is being established and implemented based on Interoperable Train Control (ITC) standards, which specify requirements for an interoperable PTC system.

In the ITC-specified system, the onboard computer tracks its position and speed using Global Positioning System (GPS) and locomotive tachometer, and a database defining the characteristics of the track and the locations and critical attributes of all PTC critical assets. Track databases are unique for each rail line; however, to support the ITC system, each railroad must define their track database according to the ITC-specified data format. A PTC track database is a collection of geographical information that specifies track layout information such as track geometry and locations and critical attributes of PTC critical assets. The PTC track database file is created in accordance with the ITC Geographic Information System (GIS) logical model, used by the ITC PTC onboard application.

For a PTC system to function properly, the information provided in the track database must accurately represent the characteristics of the assets in the field. Validating and maintaining the track database is currently a manual, time consuming process. A concept for enhancing the efficiency and effectiveness of the PTC track data auditing process, through a standardized architecture and incremental increases in the level of automation, has been developed as described in the PTC Critical Asset Track Data Auditing System Concept of Operations, Version 1.0.

1.2 System Purpose

The TDAS establishes a common architecture with a standardized, yet flexible, implementation methodology for managing the process of PTC track data auditing. The TDAS will standardize the PTC track data audit management, prioritization, and record keeping processes, to the extent possible, while maintaining the flexibility needed to support multiple implementation options and migration strategies. The TDAS seeks to improve the efficiency of and reduce the level of resources required for PTC track data auditing, through progressively enhanced levels of automation in the auditing process.

1.3 Scope

It is assumed that the track database has previously been established and validated; these functions are not intended to be handled by the TDAS. The system is based on the assumption that PTC critical assets were, at the time of validation, at the locations defined in the track database. The TDAS is intended to be used for auditing as ongoing maintenance of track databases, defined by the ITC model, is performed.

Additionally, investigation of failed audits and PTC critical asset maintenance are outside the scope of the system. The TDAS is not conceived to identify the location of missing PTC critical assets, in other locations, or PTC critical assets not identified in the track database.

The TDAS is a comprehensive audit process management tool that includes:

- audit management,
- audit prioritization,
- audit reporting,
- archiving of raw audit data and reference data,
- collection of raw audit data,
- processing of raw audit data against reference data,
- and alerting of audit failures.

2. Applicable Documents

The following documents apply to the TDAS to the extent in the text of this specification:

- PTC Critical Asset Track Data Auditing System Concept of Operations.
- The Association of American Railroads, Manual of Standards and Recommended Practices (MSRP) K-6, RP-9511.V1.0, Interoperable Train Control (ITC) Onboard Track Database Field Survey and Validation, 2014.
- The Association of American Railroads, Manual of Standards and Recommended Practices (MSRP), K-5, S9401.V1.0, Electronics Environmental Requirements and System Management, 2014.
- Draft Subdivision File Specification File Format Version, Revision A, August 01, 2016, (assumed to be the next version to be listed in the Association of American Railroads, Manual of Standards and Recommended Practices (MSRP) K-6, S-9503.V1.0, Interoperable Electronic Train Management System ® (I-ETMS) Subdivision File).

3. System Overview

The TDAS is conceived to manage the track data auditing functions for the entire railway network, including data collection, data storage, data comparison, reporting, and audit prioritization. Figure 1 shows a block diagram illustrating the primary components of the TDAS and how they interact.

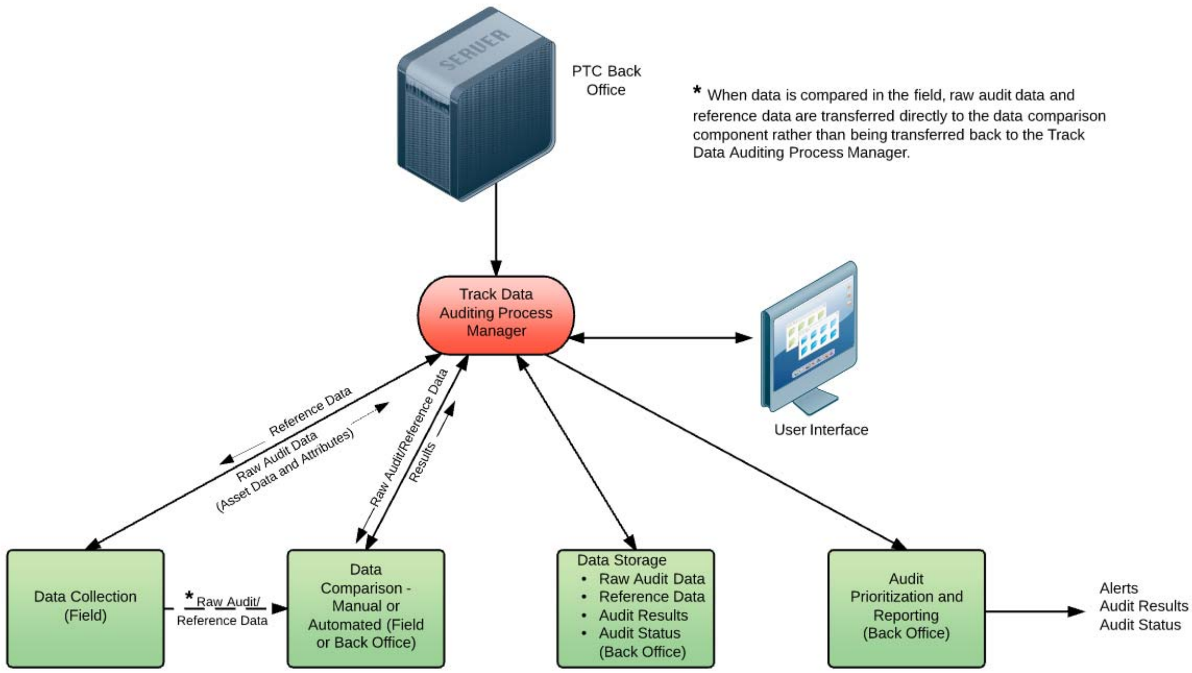

Figure 1. Track Data Auditing System

The track data auditing process management component will interface to the PTC back office, as well as to the TDAS data collection, data storage, data comparison, and audit reporting components. The system is envisioned to utilize any of a variety of machine vision sensors to capture georeferenced data, with a date and time stamp, of PTC critical assets using a data collection approach specified by the individual railroad. Examples of data collection approaches may include use of dedicated data collection vehicles or use of data collection devices mounted to track vehicles that collect data opportunistically during normal operations. For circumstances where georeferenced data cannot be collected opportunistically, the system will also support targeted data collection. The proposed TDAS will be capable of keeping a record of whether raw audit data was collected due to a targeted raw audit data collection or opportunistically.

The georeferenced data initially collected can be validated against the track database and stored as reference data, in addition to the reference data defined within the track database itself. If the proposed TDAS is designed to use additional reference data along with the track database, the additional reference data must be validated. The amount of reference data stored is dependent on the users' operation of the system.

Audit data may be processed (i.e., compared against reference data) in the field or in the back office, depending on the specific implementation of the system. However, regardless of the implementation, all georeferenced data collected in the field will be transferred to a centralized database in the back office to retain records of raw audit data collected. The raw audit data is transferred to the track data auditing process management component and stored in the TDAS database using a set of standard defined interfaces.

Depending on the specific implementation of the system, the comparison of raw audit data against reference data can be done manually or with automated data processing software using a variety of methods, including machine vision algorithms. Additionally, the system may be implemented such that comparison is performed real-time in the field or post-processed in the back office. In the case where data is processed in the field, either by trained field personnel or automated comparison software, the raw audit data collection component will interface directly to the data comparison component. In the case where data is processed in the back office, the data comparison component will interface with the track data auditing process management component to perform audits using raw data stored in the database.

Audit results and status will be communicated through the reporting interface to the railroad systems that provide reporting and alerting. The results and status will be stored in the TDAS database and will be used to track the audit status of each PTC critical asset and can be accessed through the track data auditing process management user interface.

4. Definitions

The following terms are used within this document:

- Audit: process of comparing raw audit data against reference data, and verifying the data corresponds.
- Audit date: date raw audit data is compared against reference data and audit result is produced
- Audit expiration date: date by which a PTC critical asset must be audited, as established by the railroad user.
- Audit data refresh date: date in advance of the audit expiration date at which alert will be generated if raw audit data is not available.
- Audit management: process of tracking audits, performing audits, reporting, and alerting.
- Audit process: overall process of collection raw audit data, comparing raw audit data against reference data, and updating/reporting audit status.
- Audit result: result of the comparison between raw audit data and reference data for an individual PTC critical asset.
    - Pass: location and critical attributes of raw audit data and reference data correspond
    - Fail: location and/or critical attributes of raw audit data and reference data do not correspond
    - Insufficient data: location and/or critical attributes of raw audit data and reference data could not be reliably verified
- Audit Status: information pertaining to the raw audit data collection date, audit date, audit data refresh date, audit expiration date, and result of last audit.
- Geospatial: relative position of objects on the earth’s surface.
- Machine vision sensor: device that can capture georeferenced image data or similar.
- Positive Train Control (PTC): a form of train control where train movement authorities and speed limits are transmitted electronically and automatically enforced to prevent violations.
- PTC critical asset: PTC equipment which if destroyed, degraded, relocated, or otherwise rendered unavailable, would affect the safety, reliability or operability of the railroad

- Raw audit data: data collected during audit process; to be compared against reference data
- Reference data: data used for comparison when conducting an audit (e.g., data contained within the track database, georeferenced data that has been validated against the track database, or relative location information from a referenced object). Data obtained from various sources, validating the location of PTC critical assets, may be used as reference data.
- Raw audit data collection date: date raw audit data was collected
- Track database: onboard track data file, or subdivision file, targeted for use with the onboard system, as defined in MSRP K-6, S-9503.V1.0.

5. Functional Requirements

5.1 Track Database Audit Management Process Initialization and Updates

5.1.1

The TDAS shall obtain a list of all track databases available from the PTC back office when prompted by the TDAS user.

5.1.2

The TDAS shall provide the list of track databases received from the PTC back office to the TDAS user for selection of track databases for audit management by the TDAS.

5.1.3

For each track database selected for audit management, the TDAS shall obtain the most current version of that track database from the PTC back office.

5.1.4

The TDAS shall maintain a reference to the current version of each track database selected for audit management.

5.1.5

The TDAS shall manage auditing for the following types of PTC critical assets and critical attributes, as specified in each track database selected for audit management:

- Track centerline points
- Integer mileposts, milepost signs
    - Sign text
- Signals
    - Direction of signal
    - Type of signal

    - Signal graphic
- Crossings, grade crossings
- Switches
    - Turnout leg
    - Switch orientation
- Permanent speed restrictions, speed signs
    - Sign text
- The beginning and ending limits of track detection circuits in non-signaled territory
- Clearance point locations for every switch location installed on the main and siding tracks
- Clearance/fouling points
- Inside switches equipped with switch circuit controllers
- Method of operation signs
    - Sign text
- Derails

5.1.6

The TDAS shall retain the following reference information for every PTC critical asset in each track database selected for audit management:

- Subdivision ID
- Subdivision File Revision Number
- Data Source ID
- PTC critical asset type

5.1.7

The TDAS shall use the PTC data source ID from the PTC track database as the unique identifier when collecting and comparing raw audit data.

5.1.8

The TDAS shall maintain the following current audit status data for every PTC critical asset in each track database selected for audit management:

- Audit date
- Audit result
- Audit expiration date

- Raw audit data collection date
- Audit data refresh date

5.1.9

The TDAS shall initialize the audit date for each PTC critical asset to the date when the track database was last validated.

5.1.10

The TDAS shall compare the referenced version of each track database selected for audit management against the current version specified by the PTC back office at a railroad-configurable frequency.

5.1.11

If the current version of a track database selected for audit management specified by the PTC back office is different from the version referenced by the TDAS, the TDAS shall compare the current version of the track database against the version of the track database previously referenced by the TDAS to identify any auditable critical assets that have been added, removed, or modified.

5.1.12

If the current version of a track database selected for audit management specified by the PTC back office is different from the version previously referenced by the TDAS, the TDAS shall archive the following reference information and audit status data associated with each PTC critical asset that was removed or modified:

- Subdivision ID
- Subdivision File Revision Number
- Data Source ID
- PTC critical asset type
- Audit date
- Audit result

5.1.13

If the current version of a track database selected for audit management specified by the PTC back office is different from the version previously referenced by the TDAS, the TDAS shall initialize the following reference information for each PTC critical asset that was added or modified:

- Subdivision ID
- Subdivision File Revision Number
- Data Source ID

- PTC critical asset type

5.1.14

If the current version of a track database selected for audit management specified by the PTC back office is different from the version previously referenced by the TDAS, the TDAS shall set the audit date for each PTC critical asset that was added or modified to the date when the track database was last validated.

5.1.15

If the current version of a track database selected for audit management specified by the PTC back office is different from the version previously referenced by the TDAS, the TDAS shall reset the audit date for each PTC critical asset that was not added, modified, or removed to the date when the track database was last validated, if more recent than the current audit date.

5.1.16

If the current version of a track database selected for audit management specified by the PTC back office is different from the version previously referenced by the TDAS, the TDAS shall update the Subdivision File Revision number for each PTC critical asset that was not added, modified, or removed to the Subdivision File Revision Number of the version of the track database specified by the PTC back office.

5.2 Audit Process Management

5.2.1

When an audit is completed for a PTC critical asset, the audit date for the PTC critical asset shall be updated to the date that the raw audit data used in the audit was collected.

5.2.2

To set the audit expiration date for all PTC critical assets, The TDAS shall allow the user to specify a configurable, global default for the number of days following the last audit.

5.2.3

The TDAS shall allow the user to override the global default and specify a configurable default, for each PTC critical asset type, for the number of days following the last audit to set the audit expiration date.

5.2.4

The TDAS shall allow the user to specify a configurable number of days following the last audit to set the audit expiration date for each individual critical asset that would override the critical asset type default and global default.

5.2.5

To set the audit data refresh date for all PTC critical assets, The TDAS shall allow the user to specify a configurable, global default for the number of days following the last audit.

5.2.6

The TDAS shall allow the user to override the global default and specify a configurable default, for each PTC critical asset type, for the number of days following the last audit to set the audit data refresh date.

5.2.7

The TDAS shall allow the user to specify a configurable number of days following the last audit to set the audit data refresh date for each individual critical asset that would override the critical asset type default and global default.

5.3 Raw Audit Data Collection

5.3.1

The TDAS shall support both automated and manual raw audit data collection methods.

5.3.2

The TDAS shall be capable of capturing georeferenced raw audit data for each PTC critical asset identified in each track database selected for audit management.

5.3.3

The TDAS shall annotate georeferenced raw audit data collected with the collection date and time.

5.3.4

When automated data collection is performed, the TDAS automated data collection system shall be capable of collecting all critical asset location and critical attribute raw audit data for each PTC critical asset in a single pass.

5.3.5

When automated data collection is performed, the TDAS automated data collection component shall be capable of capturing raw audit data at minimum lateral distance of 50 feet on either side of the track centerline.

5.3.6

The TDAS automated data collection component shall be capable of capturing raw audit data at minimum vertical distance of 50 feet above rail.

5.3.7

When manual data collection is performed, the TDAS will provide the user with the reference data for the critical asset for which raw audit data is being collected.

5.3.8

When manual data collection is performed, the TDAS shall allow the user to input raw audit data collected.

5.4 Data Comparison

5.4.1

When performing data comparison, the TDAS shall compare the location and any critical attributes defined in the current track database against those contained in the collected raw audit data.

5.4.2

The TDAS shall support both automated and manual data comparison methods.

See Section 5.3 Reference Data Management for requirements related to using reference data that has been georeferenced for the data comparison process.

See section 5.3 Reference Data Management for requirements related using the track database as the main source of reference data when comparing raw audit data against reference data.

The TDAS will allow for various levels of implementation and automation allowing the railroads to choose a system implementation that will best meet their needs. This may include automating the audit data comparison process and implementing the audit data comparison function either in the back office or in the field.

5.4.3

When automated data comparison is performed, the TDAS automated data comparison component shall compare the location of each PTC critical asset, as determined from the raw audit data collected, against the location of each PTC critical asset, as specified in the current track database.

5.4.4

When automated data comparison is performed, the TDAS automated data comparison component shall audit PTC critical assets based on their location perpendicular to the track centerline as defined in the track database.

5.4.5

When automated data comparison is performed, the TDAS shall generate a "pass" audit result if the PTC critical asset audited can be confirmed to be within a horizontal precision of less than 2.2 meters, with a 95% confidence interval, of its identified location along the track centerline in the PTC track database.

5.4.6

When automated data comparison is performed, the TDAS shall generate a "fail" audit result if the PTC critical asset audited can be confirmed to not be within a horizontal precision of less than 2.2 meters, with a 95% confidence interval, of its identified location along the track centerline in the PTC track database.

5.4.7

When automated data comparison is performed, the TDAS shall generate an "insufficient data" audit result if the PTC critical asset audited cannot be confirmed to be within a horizontal precision of less than 2.2 meters, with a 95% confidence interval, of its identified location along the track centerline in the PTC track database.

5.4.8

When automated data comparison is performed, the TDAS shall generate a "pass" audit result if the critical attribute associated with the PTC critical asset audited can be confirmed to match the critical attribute, with a 95% confidence, identified in the PTC track database.

5.4.9

When automated data comparison is performed, the TDAS shall generate a "fail" audit result if the critical attribute associated with the PTC critical asset audited can be confirmed to not match the critical attribute, with a 95% confidence, identified in the PTC track database.

5.4.10

When automated data comparison is performed, the TDAS shall generate an "insufficient" audit result if the critical attribute associated with the PTC critical asset audited cannot be confirmed to match the critical attribute, with a 95% confidence, identified in the PTC track database.

5.4.11

When manual data comparison is performed, the TDAS shall provide the user with the audit reference data and the raw audit data for manual comparison.

5.4.12

When manual data comparison is performed, the TDAS shall allow the user to enter the audit result as a pass, fail, or insufficient data.

5.5 Data Comparison Prioritization

5.5.1

The TDAS shall prioritize comparison of raw audit data against reference data for PTC critical assets based on audit expiration date, starting with the critical asset closest to reaching its audit expiration date.

5.6 Reporting and Alerting

5.6.1

The TDAS shall send an AUDIT_FAIL message when an audit of a PTC critical asset results in a "fail."

5.6.2

The TDAS shall send a DATA_REFRESH_DATE_REACHED message when the audit data refresh date for a PTC critical asset is reached.

5.6.3

The TDAS shall send an AUDIT_EXPIRED message, when the audit expiration date for a PTC critical asset is reached.

5.6.4

The TDAS shall send an INSUFFICIENT_DATA message when raw audit data has been collected and compared against reference data for a PTC critical asset and the audit result has been “insufficient data” a railroad configurable number of times since the last audit date.

5.6.5

The TDAS shall send an ASSET_LOCATION_CLOSE_TO_EXCEEDING_LIMITS message if the audited PTC critical asset is identified to be greater than 1.5 meters of its identified location along the track centerline in the PTC track database.

5.6.6

If an AUDIT_FAIL message has been sent for a PTC critical asset and an updated audit results in a “pass” for that PTC critical asset, the TDAS shall send an AUDIT_FAIL retraction message.

5.6.7

If an AUDIT+DATA_REFRESH_DATE_REACHED message has been sent for a PTC critical asset and new raw audit data becomes available for that PTC critical asset, the TDAS shall send An AUDIT_DATA_REFRESH_DATE_REACHED retraction message.

5.6.8

If an AUDIT_EXPIRED message has been sent for a PTC critical asset and an audit is completed for that PTC critical asset, the TDAS shall send an AUDIT_EXPIRED retraction message.

5.6.9

If an INSUFFICIENT_DATA message has been sent for a PTC critical asset and new raw audit data becomes available verifying that PTC critical asset’s location and attributes, the TDAS shall send an INSUFFICIENT_DATA retraction message.

5.6.10

The TDAS shall be capable of being queried by railroad systems to obtain the following information for each PTC critical asset contained in each track database selected for auditing:

- Audit history

    - Audit status
    - Reference data
- Current audit status
- Current reference data
- Current critical dates

6. Interface Requirements

6.1 External Interface Requirements

6.1.1

The TDAS shall use point to point communication methods to gain access to the PTC back office for accessing track database data.

6.1.2

The TDAS shall be capable of transmitting and receiving data using wireless or cellular connections, between the field and back office components.

6.1.3

The TDAS shall support railroad systems subscribing to receive critical alert messages.

6.1.4

The TDAS shall support connections initiated by railroad systems for receiving and responding to queries for TDAS data from the railroad systems.

6.1.5

The TDAS shall incorporate a user interface allowing TDAS users to configure and interact with the system.

6.2 Internal Interface Requirements

6.2.1

The data collection component shall initiate the connection to the TDAS process manager component to exchange raw audit data and reference data.

6.2.2

The data comparison component shall initiate the connection to the TDAS process manger component to exchange raw audit data, reference data, and audit status.

6.2.3

The process manager shall initiate the connection to the data storage component to exchange raw audit data, reference data, audit status.

7. Data Storage

7.1.1

The TDAS shall store all reference data, raw audit data and archive data in an internal relational database.

7.1.2

The TDAS database shall meet at least a 3rd normal form standard.

7.1.3

The TDAS database shall store and retain the following data associated with the audit of each PTC critical asset for a configurable number of audits:

- Reference data
- Raw audit data
- Audit status

8. Performance Requirements

8.1.1

The TDAS shall capture quality image(s) at vehicle velocities greater than 0 mph through 79 mph.

9. Security Requirements

9.1.1

An authentication process shall be implemented to allow access into the TDAS.

10. System Effectiveness Requirements

10.1 Maintainability Requirements

10.1.1

The TDAS shall be designed such that personnel, that don’t require a lot of training, can replace failed units.

11. Extensibility Requirements

11.1.1

The TDAS shall be designed and implemented in such a way that the system capabilities can be expanded in the future. Future expansions may include:

- Updated sensors
- Faster processors

- Higher level of accuracy
- Capability of capturing PTC critical assets not defined in the track database
- Enhancing of software

11.1.2

The TDAS shall accommodate future track database format changes.

12. Environmental and Physical Requirements

12.1.1

TDAS components implemented in the field environment shall comply with the environmental requirements as defined in the AAR Manual of Standards and Recommended Practices, Section K-5, Standard S9401.V1.0, "Electronics Environmental Requirements and System Management", revised 2014.

13. Notes

13.1 Acronym/Abbreviation List

AAR	Association of American Railroads
CTC	Centralized Traffic Control
GIS	Geographic Information System
GPS	Global Positioning System
HMI	Human-machine Interface
ITC	Interoperable Train Control
PTC	Positive Train Control
RSIA '08	Rail Safety Improvement Act of 2008
TDAS	Track Data Auditing System
TWC	Track Warrant Control

14. Works Cited

1. OpenEI. (n.d.). Retrieved 10 13, 2016, from en.openei.org: en.openei.org/wiki/Definition:Critical_Assets
2. Rail Safety Improvement Act of 2008, Public Law 110-432, Section 102, 122 Stat. 4852 (2008).
3. The Association of American Railroads, Manual of Standards and Recommended Practices (MSRP) K6, S-9501.V1.0, Table of Contents, 2013.
4. Association, A. R.-o.-W. (2014). *Manual for Railway Engineering.* Lanham: AREMA.

Appendix C.
Request for Information - PTC Track Data Auditing System

A Request for Information was issued to vendors in May 2017 to identify any significant gaps between the Track Data Auditing System (TDAS) requirements and available technology.

55500 DOT Road
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To: Prospective Offerors

Subject: Request for Information – PTC Track Data Auditing System (TDAS)

On behalf of the North American railroad industry, the Transportation Technology Center, Inc. (TTCI), is seeking information regarding a Positive Train Control (PTC) Track Data Auditing System (TDAS). This system will be used to manage the auditing of railroad track data for PTC systems that use the Interoperable Train Control (ITC) data model definition. This effort is being funded by the Federal Railroad Administration (FRA). TTCI is a wholly owned subsidiary of the Association of American Railroads (AAR) with offices located at 55500 D.O.T. Road, Pueblo, Colorado, 81001.

TTCI, under the direction of the FRA, is seeking information pertaining to current and potential products, systems, and/or components that comply with or could satisfy the proposed concepts and functions of the TDAS. The purpose of issuing this Request for Information (RFI) is to determine the availability and viability of products and/or concepts that are capable of satisfying system or individual component functions and requirements defined in the "PTC Critical Asset Track Data Auditing System" Concept of Operations (ConOps) and the system requirements documentation provided.

The RFI has been developed as an open method of assimilating additional information from potential vendors and solution providers. Propriety information should be clearly marked and will not be made public. This is not a Request for Proposal.

Responses to the RFI shall include, but are not limited to, the following information:

- Name, address, phone number and e-mail.
- State of compliance and detailed information regarding how current and potential products, systems, and/or components offered satisfy the functions and requirements of the system, or a component of the system, as defined in the "PTC Critical Asset Track Data Auditing System" ConOps and system requirements documentation dated May, 2017.
- Detailed information as to how current and potential products, systems, and/or components allow for flexibility in implementation, can be implemented using a phased approach, and allow for future expansion.

- ROM cost estimate for the development and implementation of the TDAS audit management component.
- Detailed information regarding capabilities of current and potential products, systems, and/or components for automated data comparison.
    - Rough Order of Magnitude (ROM) cost estimate for development and/or application of automated data comparison algorithms for the TDAS.
- ROM unit cost estimates for current and potential products, systems, and/or components for the TDAS field components:
    - The ROM cost estimate should assume the product, system, and/or component must be capable of auditing PTC critical assets at a minimum lateral distance of 50 feet on either side of the track centerline.
    - The ROM cost estimate should include the maximum lateral distance at which PTC critical assets can be audited without a significant increase in the cost of the product, system, and/or component over the ROM cost estimate included above.
    - The ROM cost estimate should include an estimated cost of the product, system and/or component at the maximum lateral distance practical for the product, system and/or component.
    - The ROM cost estimate should indicate to what extent, if any, automated data comparison, in the field, is included in the estimate.
- Product, system and/or component reliability, availability, and maintainability information.
- Definition of external interfaces beyond or other than those defined in the "PTC Critical Asset Track Data Auditing System" ConOps and system requirements documentation dated May, 2017.

In order to be considered for evaluation, the requested information must be received no later than 4:30 P.M. MT, May 17th, 2017. Request for information shall be delivered electronically to jill_gacnik@aar.com.

This solicitation does not commit or obligate TTCI to pay for any cost incurred in the preparation or submission of the RFI, or to procure or contract for current and potential products, systems, and/or components therein.

Note that the railroad industry utilizing the ITC PTC data model definition are the ultimate end users of the TDAS. Participation, by vendors or solution providers, in this RFI does not explicitly or implicitly guarantee future acquisition of products, systems, and/or components by the end users. Likewise, participation in this project does not explicitly or implicitly represent certification or acceptance of products by the AAR.

We look forward to your response. Should you have any questions, please contact:

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Appendix D.
PTC Track Data Auditing System Trade Table

The PTC Track Data Auditing System (TDAS) trade table identified the most critical TDAS requirements and was used to determine how close a vendor's existing system or existing technology came to meeting the system requirements, or if a vendor had the ability to develop a system to meet the requirements of the TDAS in the future.

Criteria		Number of Vendors
Machine Vision Sensors Mount to a Number of Different Vehicle Types	Can only be implemented on specific vehicles	4
	Cannot be implemented on multiple vehicle types	4
Quality Images Captured at Vehicle Velocities up to 79 mph	Product, system, and/or component collects quality images at vehicle velocities up to 20 mph	2
	Product, system, and/or component collects quality images at vehicle velocities greater than 20 mph, but less than 40 mph	2
	System components currently can collect quality images at vehicle velocities up to 79 mph	4
Machine Vision Sensors to Capture Raw Audit Data in a Range of Directions	Product, system, and/or component cannot capture raw audit data in a range of directions	3
	Product, system, and/or component has the potential to capture raw audit data in a range of directions in the future	4
	Product, system, and/or component currently captures raw audit data in a range of directions	1
Locate PTC Critical Assets within a 2.2 Meter Horizontal Precision	Product, system, and/or component has the potential to confirm the location of a PTC critical asset to be less than 2.2 meters of its identified location along the track centerline in the future	4
	Product, system, and/or component can currently confirm the location of a PTC critical asset to be less than 2.2 meters of its identified location along the track centerline	4
Match Critical Atrributes Associated with the Critical Attributes Defined in the Track Database	Product, system, and/or component has the potential to confirm if the critical attributes associated with an audited PTC critical asset match the critical attribute identified in the PTC back office in the future	8
	Product, system, and/or component can currently confirm the if the critical attributes associated with a PTC critical asset match the critical attribute identified in the PTC back office	0
Automated Data Comparison (Field)	Product, system, and/or component has the potential to automatically compare data in the field in the future	8
	Product, system, and/or component can currently compare data automatically in the field	0
Wireless or Cellular Connection	Product, system, and/or component can currently transmit or receive data through a wireless or cellular connection	7
	Product, system, and/or component has the potential to transmit or receive data through a wireless or cellular connection in the future	1
Complies with MSRP, Section K-5, S9401.V1.0	Product, system, and/or component has the potential to comply with MSRP, Section K-5, S9401.V1.0 in the future	6
	Product, system, and/or component can currently comply with MSRP, Section K-5, S9401.V1.0	2
Audit PTC Critical Assets at a Minimum 50 ft on Either Side of Track Centerline	Product, system, and/or component has the potential to audit PTC critical assets at a minimum lateral distance of 50 feet on either side of the track centerline in the future	3
	Product, system, and/or component can currently audits PTC critical assets at a minimum lateral distance of 50 feet on either side of the track centerline	5
Cost Associated with Minimum 50 ft Distance		$10,000 - $450,000
Maximum Distance on Either Side of the Track Centerline w/out Increase to Cost		50 ft - 600 ft
Maximum Distance on Either Side of the Track Centerline		50 ft - 600 ft
Automated Data Comparison (Back Office)	Product, system, and/or component has the potential to automatically compare data in the back office in the future	8
	Product, system, and/or component can currently compare data automatically in the back office	0
Cost Assoicated with Audit Management Component		$175,000 - $1,500,000
Cost Associated with Development and/or Application of Automated Data Processing Software		$95,000 - $2,100,000

Abbreviations and Acronyms

AG	Advisory Group
AKRR	Alaska Railroad
CN	Canadian National Railway
ConOps	Concept of Operations
CTC	Centralized Traffic Control
FRA	Federal Railroad Administration
GIS	Geographic Information System
GPS	Global Positioning System
HMI	Human-machine Interface
ITC	Interoperable Train Control
LiDAR	Light Detection and Ranging
MPH	Miles Per Hour
NS	Norfolk Southern Railway
PTC	Positive Train Control
RFI	Request for Information
ROM	Rough Order of Magnitude
RSIA	Rail Safety Improvement Act of 2008
TDAS	Track Data Auditing System
TO	Task Order
TTC	Transportation Technology Center
TTCI	Transportation Technology Center, Inc.
TWC	Track Warrant Control
UPRR	Union Pacific Railroad