November 30, 2007

Ms. Jo Strang
Associate Administrator for Safety

Mr. Grady Cothen
Deputy Associate Administrator for
Safety Standards and Program Development

Docket Clerk
Office of the Chief Counsel

Federal Railroad Administration
1200 New Jersey Ave. SE
Third Floor West
Washington, DC 20590.

Dear Ms. Strang and Mr. Cothen,

Ohio Central Railroad System Positive Train Control Informational Filing [49 CFR § 236.913 (j)] and Waiver Request [49 CFR § 211.7]

The Ohio Central Railroad System (OCRS) is initiating a program to demonstrate and implement technology designed to prevent authority limit and over-speed violations in non-signaled Track Warrant Control (TWC) territory and to prevent equipped trains from entering the limits of on-track authority granted to employees without authorization. This technology is identified as Ohio Central Railroad Positive Train Control ("OCRS PTC").

Ohio Central Railroad (OCRS) is requesting a waiver and permission to start the process for a Positive Train Control System, to be installed on the Southern Lines of OCRS. The purpose of this letter is to outline to the Federal Railroad Administration (FRA) the process OCRS believes is necessary to accomplish the various tasks. Some current Operating Rules may be suspended, amended, or changed, and relief from 49 CFR 236 parts A-G is requested per Attachment 3. The Superintendent of Operations through his directives will execute or amend any changes to the Operating Rules. This letter will also serve as a waiver request. An amended filing will be executed with concurrence of the FRA Test Monitor and/or FRA designee denoted as Task 2e. Per your letter of April 30, 2007, 49 CFR 236.913(j) has been referenced and has been followed for this submission.

Program Description

The Ohio Central Railroad Positive Train Control system (OCRS PTC) will consist of a processor-based train control system, located on the locomotive, utilizing two (2) monitors (LCD) and two (2) keypads, one for each of the crewmembers. Information to and from the OCRS PTC system will be from a computer assisted dispatching (CAD) system located at Coshocton, OH, via the company owned VHF radio network.

The OCRS PTC system consists of both the onboard computer (OBC), called Train Sentinel® utilized by the train crews, and a computer-aided dispatching (CAD) system being utilized by the train dispatchers. Train Sentinel® will be installed on two (2) locomotives for the demonstration. Train Sentinel® will not be used for controlling trains through the use of enforcement during Task 1. In the event an unsafe condition is detected or predicted by Train Sentinel®, information to the

47849 Paper Mill Rd.
Coshocton, OH 43812
Phone (740)-622-8092

crewmembers will be provided through visual alerts on the Train Sentinel® screens and audible alarms, ringing buzzers. Train crews will acknowledge delivered information through the OBC so that V&V analysis can be performed.

OCRS and Quantum Engineering are committed to the established mandates for a Positive Train Control system:

1. Protection of limits of movement authorities (train-to-train collisions)
2. Protection of overspeeds and train handling
3. Protection of men and equipment working on track

The OCRS is comprised of various lines that make up three (3) operating divisions:

- Northern Lines
- Pittsburgh Lines
- Southern Lines
  - Columbus and Ohio River Railroad Company (CUOH)
    - C&N Subdivision (Columbus, OH to Newark, OH) This territory is Track Warrant Control (TWC) with no signals or automatics switches. This territory is 34.4 miles long and entails an operation of 4-6 freight trains a day. This territory does not operate any passenger trains.

The project outlined in this Information Filing pertains to the C&N subdivision.

Program Plan

The Program Plan will be divided into various Tasks for project tracking.

- Task 1 will be conducted in 4 parts:
  - Task 1a – Informational Filing and Waiver Request from the Federal Railroad Administration (Attachment 4)
  - Task 1b –Validation and Verification (V&V) of the operations and onboard track map of Train Sentinel® by OCRS/QEI personnel, with no train crew involvement and no classroom training. Initial validation (1a) will be conducted by use of a hi-rail vehicle operated by OCRS supervisory personnel. No waivers will be necessary for this phase. Items included in this task are:
    - Validation of communications between the office and locomotives and identification of any "black holes" in the communications network
    - Validation of the Train Sentinel® onboard map for accuracy and graphical clarity.
    - Validation of milepost and fields devices for accuracy.
    - FRA Test Monitor assistance and involvement with complete V&V of this task.
  - Task 1c – Submittal of the Demonstration Test Plan that will entail all of the tasks outlined within this letter and proposed dates for their execution. (Attachment 1)
  - Task 1d – training for train dispatchers and C&N train crews on the operation and use of Train Sentinel® and execution and delivery of electronic data between the office to designated "equipped" locomotives. Crewmembers will operate the system under OCRS qualified locomotive mentors. Each crewmember (LCD) screen will display a placard

reading "Test Purposes Only. Do Not Use This Information for Movement Instructions." This is an operational parallel mode and records will be kept for 2 weeks on the Q - CAD to Train Sentinel® message interface for message integrity of the two (2) locomotives. Items included in this task, in no particular order, are:

- Training of mentors and train crews (engineers and conductors) for operating Train Sentinel® over the C&N SD by qualified QEI instructors/engineers. This process is a train-the-trainer function. Training criteria is outlined under Attachment 6 of this document.
- Validation of documents delivery to the Train Sentinel® onboard systems (2 week validation period should generate approximately 125-150 messages, dependent on train traffic at that time.) Requested process of message validation at PCRC is noted in Attachment 7.
- Validation of Train Sentinel® generated messages to the office (2 week validation period should generate 50 – 100 messages, dependent on train traffic at that time)
- Training of crewmembers in the functions of Train Sentinel® by the OCRS road Foreman of Engines.
- Training train dispatcher of their role in the execution of electronic movement authorities by OCRS Supervisors, supported by QEI personnel.
- Train dispatcher recognition of Train Sentinel® generated messages to the office by OCRS Supervisors, supported by QEI personnel.
- Validation of Permanent Speed Restriction and active Temporary Speed Restrictions.
- Validation of proper Train Sentinel® posting of all Form B activities to the train crews.
- Validation of proper Train Sentinel® posting of all Form F activities to the train crews.
- FRA Test Monitor assistance and involvement with complete V&V of this task. (OCRS has submitted to the FRA 8 mandatory tests to be demonstrated to the FRA that were validated at PCRC and will be validated on OCRS. These 8 tests fill the requirements of the 3 PTC mandates.)
- Train crews assisted by OCRS and/or QEI on-the-job mentors and trains operate <u>without</u> enforcement, only audible alarms (bells) and visual indications (LCD) of a pending problem will be available.
- Waiver invocation or relief of 49 CFR 220 Rules that mandate the train crews to verbal read-back of the digital delivery of messages to the locomotive. This is a work load issue for the train crews as well as the train dispatchers.

❖ Task 2 will be conducted in 5 parts:

- Task 2a – Train any additional C&N crews – No waivers requested.
- Task 2b – Continue to operate the 2 equipped locomotives <u>without</u> enforcement
- Task 2c – Notify FRA Test Monitor of enforcement demonstration in the test territory.
- Task 2d – Conduct enforcement testing with FRA Test Monitor

- Task 2e – File an amended Informational Filing with FRA Test Monitor and/or FRA designee, seeking concurrence to provide full locomotive enforcement on the C&N subdivision.

- Task 3 will be conducted in 4 parts:
  - Task 3a – Operate 2 locomotives with full enforcement on C&N under revenue service. Under this task, revenue service will be established and no data collection will be performed, except to fulfill completions of any Product Safety Plan items that are referenced as post-implementation or quantative extrapolation of data. No additional training will be necessary for the train crews during or after this task as the train control system is fully loaded at the time of training. The duration of this item is endless, as revenue service will dictate actual operations from that point. Train dispatchers will continue to maintain a service performance log for any anomalies with the system and report these to the OCRS PTC Safety Committee.
  - Task 3b – Submit PSP
  - Task 3c – Approval of PSP
  - Task 3d – Request continuation from FRA, to implement PTC beyond the C&N subdivision on additional Southern Lines territory.

The information required to be included in this filing, as per 49 CFR 236.913(j)(1-7), is as follows:

(j-1) A complete description of the product:

The OCRS Positive Train Control System, Train Sentinel®, is a communications-based train control system that was designed to enhance safety by precisely managing the movements of locomotives and trains in real time. The OCRS Positive Train Control safety enhancements are achieved through a communications-based system that monitors train crew activity for compliance to movement authorities granted by the CAD system and enforcement of speed restrictions, both temporary and permanent, also generated by the CAD system, for Train Sentinel® equipped trains. Enforcement is only active upon non-compliance with the track warrant authority or an attempted speed violation.

Train Sentinel® provides the train crews with a graphic monitor as well as text representation of all authorities and speed restrictions and also provides the train crew with a braking profile that is updated in real time. Whenever a train is attempting to operate outside this safe stopping distance envelope, Train Sentinel® first warns the train crew (audible and visual) of the condition and, if no action is taken to place the train within this safe braking envelope, Train Sentinel® will initiate a penalty application of the brakes and force the train to a complete and safe stop while notifying the dispatcher of the occurrence. At a minimum a P2A response (full service brake application at a service rate), followed by an emergency request to the EOT, which will become an emergency application if the EOT responds, will be available. Dynamic brakes are not used. The train dispatcher will also be informed through the message interface of the train in emergency.

Train Sentinel® can embody the full range of PTC functions; however, various features can be deployed which are customer specific. Two examples of customer specific features: the threshold for alarms on overspeeds, as an example, + 3 MPH over Maximum Authorized Speed (MAS) if the speed is greater than 21 MPH, and +1 MPH when the train speed is 20

MPH and below, and how to handle the train interaction with a Form B authority. OCRS is a Track Warrant Control (TWC) application. There are no wayside devices present in the track structure with which to communicate at this time and this feature will not be used. Train Sentinel® utilizes periodic digital communications interface with the office system. This means that when CAD or Train Sentinel is operating, only pertinent information is delivered to either side. Once a valid track authority is delivered, confirmed, and accepted, the message is stored as the limits of the authority without the need for additional communications.

(j-2) An operational concepts document:

Please refer to the attached OCRS Concept of Operations (CONOPS) for further definition of the operational concepts. (Attachment 2)

(j-3) A complete description of the specific test procedures, including the measures that will be taken to protect trains and on-track equipment:

Please refer to the Test Plan, Attachment 1 to the letter. Train Sentinel® will be installed on the two (2) locomotives. Systems will be checked and certified by OCRS Mechanical personnel and Quantum engineers to ensure the components have been installed correctly and are ready for operation. The connection from Train Sentinel® to the P2A valve will not be installed in order to inhibit the enforcement feature.

OCRS is presently dispatching all trains through the CAD office component as "unequipped" i.e., Train Sentinel® onboard equipment is not turned on or not installed. Currently, the train dispatcher's instructions are read to crews over voice radio and then train crews will respond with a read-back for compliance to the instructions, again using the voice radios with TWC rules (see 49CFR 220 rules set).

Track map data, train position, and general communication coverage will all be reviewed to assure they are within performance parameters that allow Train Sentinel® to detect and predict unsafe operating conditions. The majority of trains on OCRS are operated by OCRS train crews, but there is some joint trackage arrangements with RJ Corman and W&LE on the north end of the Railroad. The foreign crews will be informed of the new Bulletins, but will not be affected by the directions. These crews will not use the designated PTC locomotives and will continue to operate as TWC, unequipped. The same process will apply as today with no impact on the operation.

(j-4) An analysis of the applicability of the requirements of subparts A through G of this part to the product that will not apply during testing;

OCRS does not believe any relief from these sections are necessary, and can comply with all pertinent parts that now apply on the OCRS. (Attachment 3)

(j-5) The date testing will begin:

The V&V applicable to Tasks 1a and 1b will commence on September 24, 2007 and will not need any waivers as this part of the demonstration will occur with OCRS supervisory personnel in Hi-rail vehicles. Moving to Task 1c will require waivers and a preliminary Task Plan is included in this document under Attachment 1.

(j-6) The location of the demonstration:

The OCRS is comprised of 7 operational subdivisions. For the initial Task 1 and Task 2, only the C&N subdivision will be utilized to demonstrate the communications reception capabilities for each environment and operate Train Sentinel® without enforcement.

(j-7) A description of any effect the demonstration will have on the current method of operation:

The OCRS Positive Train Control system is designed for both equipped and unequipped trains. On a daily basis, OCRS operates foreign trains with OCRS train crews that will not be equipped with the onboard Train Sentinel® product. Flexibility of this system allows for the operation of both equipped and unequipped and therefore the current method of operation will not be impaired or safety degraded for the activity of either type of trains. Current application of OCRS Operating Rules will preclude any changes to track occupancy during or after the testing. The process will remain the same.

The Ohio Central Railroad stands ready to provide any additional information or clarification needed to expedite approval of this application. We would appreciate an accelerated review of this application to allow for any additional changes necessary to comply with the scheduled Task 1c. Ohio Central Railroad is committed to this product as a means to enhance safety throughout its railroad.

Sincerely;

William A. Strawn, II

President

The Ohio Central Railroad System

Attachments:

1) Proposed Test Plan
2) CONOPS
3) 49 CFR 236 parts A through G - Requirements Analysis
4) Waiver Request for Relief of Demonstration (Task 1a)
5) Train Sentinel Keyboard Matrix
6) Training Manual for Train Sentinel®
7) PCRC TWC Messages

Ohio Central Railway System

Implementation Testing Plan

49 CFR 236.907 (17)

"A complete description of all initial implementation testing procedures necessary to establish that safety-functional requirements are met and safety-critical hazards are appropriately mitigated"

[Attachment 1]

Positive Train Control

Train Sentinel® PTC

By Quantum Engineering, Inc.

Table of Contents

Introduction

The Train Sentinel® PTC being installed on the OCRS uses identical hardware and base GCOR operating rules software as the system installed on the Panama Canal Railway by Quantum Engineering. A group of user specific configurable options such as how Form 'B' work authorities are handled and the specific points at which penalty applications are initiated have been, in some cases, modified and are unique to the OCRS installation.

Per the provisions of 49 CFR 236 Part H the full body of V&V testing data performed in association with the Panama Canal Railway Corporations (PCRC) application will be submitted with this test plan and as an attachment to the OCRS PSP submissions. OCRS stands ready to duplicate any particular test that FRA feels is needed. OCRS proposes to conduct a series of eight acceptance tests on its property to verify that the system meets as a minimum the three functional 'performance based' provisions of Part H:

- Train to train collisions
- Authority limits and over speed enforcement
- Prevention of Train to MOW collisions

Inherent in this set of field tests is the concept that in order to work properly most/all of the individual subsystem features tested in the full body of the base Panama data will have had to have functioned properly in order to get an acceptable result.

Two years of Post Implementation test data in Panama in daily revenue service will be included as part of the OCRS PSP. This data demonstrates that no new hazards were introduced as a result of application of Train Sentinel® and that the MTTHE of the composite system including all its subsystems is at least two years and 500,000 train miles.

It is OCRS's intention to incorporate the result of the eight filed tests into our final PSP submission. OCRS is proposing to perform a three month 100% capture of all communications between the office system and the onboard Train Sentinel® to verify that what was meant to be sent by the dispatcher was received and verified by the crew. A Post implementation test similar to the one performed in Panama will be conducted on OCRS notifying FRA immediately of any anomalies not consistent with the design or functionality of the system. Any proposed alterations in response to a newly discovered anomaly will be documented and immediately sent to the FRA.

Instructions for Completion of Quantum Test Plan, Form #397/A

The **purpose** of the test plan form is to prescribe the scope, resources and schedule of the testing activities; to identify the items being tested, the features to be tested, the testing tasks to be performed, the personnel responsible for each task, and the risks associated with this plan.

If some or all of the content of a section is in another document, then a reference to that material may be listed in place of the corresponding content. The referenced material must be attached to the test plan or available to the users of the plan.

1. Test plan identifier: Specify a unique identifier assigned to this test plan.

QTP xxxx-cccc-nnnn, where

QTP =	Quantum Test Plan
xxxx =	The Product model (Q) number or series.
cccc =	Customer identifier (e.g. QTP 1920-BNSF-nnnn) [an additional contract number may be included, if required]
nnnn =	Sequential number (e.g. QTP 1920-PCRC-0001) [an additional subdivision number may be included, if required]

4. Other Documents/Cross-Reference: Supply references to the following documents, when they exist, are required at the highest level test plan:

a) Project authorization;
b) Project plan;
c) Quality assurance plan;
d) Configuration management plan;
e) Relevant policies;
f) Relevant standards.

In multi-level test plans, each lower-level plan must reference the next higher-level plan.

5. Test item(s): Identify the test item(s) including their version/revision level. Also specify characteristics of their transmittal media that impact hardware requirements or indicate the need for logical or physical transformations before testing can begin (e.g. programs must be transferred from tape to disk).

Supply references to the following test item documentation, if it exists:

a) Requirements specification;
b) Design specification;
c) Users guide;
d) Operation manual;
e) Installation guide.

6. Features to be tested: Identify all features and combinations to be tested. Identify the test design specification associated with each feature and each combination of features.

7. Features not to be tested: Identify all features and significant combinations that will not be tested and the reasons.

8. Approach: Describe the overall approach to testing. For each major group of features or feature combinations, specify the approach that will ensure that these feature groups are adequately tested. Specify the major activities, techniques and tools that are used to test the designated groups of features.

Specify the minimum degree of comprehensiveness desired. Identify the techniques that will be used to judge the comprehensiveness and testing effort (e.g. determining which statements have been executed at least once). Specify any additional completion criteria (e.g. error frequency).

Identify significant constraints on testing such as test item availability, testing resource availability, and deadlines.

(Form 397/A—Reverse)

QTP-1920-OCRS-01 Braking Descending Ruling Grade

Quantum Engineering, Inc.

DESIGN REVIEW / VERIFICATION / VALIDATION

Ref: Procedure QOP 7.3-01 and QOP 7.3-02

Project – QPN:	1920	Page #:	1
Project Name:	OCRS Train Sentinel	Date:	9/24/07

❒ **Review** ☒ **Verification** ☒ **Validation** ☒ **See Attached**

Subject – Including Revision Level

Hardware:	OBC Train Sentinel	Rev:	A
Software:	1920 OP System	Rev/Release:	C

Test Description (or Test Plan Document No.QTP-1920-OCRS-01 Rev. A ; **or** ❒ Description attached):

Braking Tests on OCRS Descending Ruling Grade.

Results:

Expected: Test result will be the stopping distance measured in feet plus or minus from the front of the locomotive relative to an identifiable track feature (MP1).

Tests will be run for the three primary FRA scenarios at three strategic speeds over the OCRS C&N ruling grade (descending). In conjunction with this live brake test detection scenarios will be tested QTC-1920-OCRS-08, QTC-1920-OCRS-02, QTC-1920-OCRS-07

Feet to Stop Point

Scenario	14,000 Tons Train Speed		5,000 Ton Train Speed	
	15 MPH	40 MPH	15 MPH	40 MPH
End of Authority				
Speed Compliance				
From 'B' Compliance				

Test **Performed by** – Name: _____ Title _____ Date _____

Approval: _____ Title _____ Date _____

Quantum Engineering, Inc.

Test Plan

1. Quantum Test Plan Identifier

QTP-1920-OCRS-01

Rev. A

Ref. QOP 7.3-01 and QOP7.3-02

Sheet 1 of 1

2. **Project, system, sub-system or customer:** OCRS

3. This plan is intended to meet the requirements of OCRS-VV-01	5. Unit Under Test (Test Item) Identification:
Document title and/or No: OCRS acceptance test.	**UUT Description:** **UUT Model or part No.**
Doc. revision:	**UUT H/W revision:**
Doc. section/Paragraph:	**Software part No.** 89017, 89008 **S/W version: A**
4. **Other Doc. cross-reference:** H-3, QTP-1920-PCRC-01	**UUT Serial Number:**
6. **Features to be tested:** The braking calculation safety envelope and stopping distances will be tested under various scenarios.	7. **Features *not* to be tested:** The logic and detection that would dictate a stop is needed at the prescribed location.

8. **Approach/Description of test set-up:** A track location will be specified and various train stop scenarios executed. In every case TS will be allowed to initiate a penalty application. The braking calculation will stop the train short of the designated mile post or track feature (MP1).

9. **Required testing equipment & tools:** Approximately 10 miles of protected track, a TS equipped locomotive, loaded train, event recorder, communications recorder, laptops and test programs at the locomotive and dispatch stations.

10. **Item pass/fail criteria:** Train stops 100% of the time before crossing MP1.

11. **Test suspension criteria:** Violation at MP1, traffic interrupting testing.	12. **Test resumption requirements** (& which activities must be repeated): Restart test segment from the beginning.

13. **Test deliverables:** ❑ Work Order Form 115; ☒ Review/Validation/Verification Form 280; ☒ Test report; ☒ Video;
☒ Data (describe); ❑ Other (specify):

14. **Test Tasks/Procedure** (may be referenced by document number and revision level):
Simulate various scenarios at 15, and 40 MPH and at different train weights. (5,000T nominal) Simulate:
1. An end of authority at MP1.
2. A slow order beginning at MP1.
3. A form B beginning at MP1.

The train will be issued an appropriated movement authority using MP1 as the absolute compliance point. For the same train 3 speed ranges will be executed. Then the movement authority type is changed (6 tests) then the train set will be changed (2) for a total of 12 tests.

15. **Environmental needs:** Daylight, at least one rain day of testing is desirable.

16. **Responsibilities:** Dispatcher will protect the test track segment. The train crew will operate the train and ensure train handling safety.

17. **Staffing and training needs:** Train Sentinel qualified train crew and dispatcher. Quantum test engineer and product development technician. Video camera operator to record stopping distances.		
18. **Schedule:** Set up test – 1 day, 5 tests per day if dedicated track, 1 per day under traffic. Total of 18 tests.		
19. **Risks and contingencies:** Flat wheels or excessive wear. Derailment or interference with traffic.		
20. **Proposed by** (originator): W. Bolla **Date:** 9/24/07		
21. **Remarks:** Scheduling will need to be closely coordinated so revenue trains will be allowed to move unimpeded during testing.		
22. ❑ Plan approved Date: ❑ Plan approved with changes noted	By:	

QTP-1920-OCRS-02 Limits of Authority

Quantum Engineering, Inc.

DESIGN REVIEW / VERIFICATION / VALIDATION

Ref: Procedure QOP 7.3-01 and QOP 7.3-02

Project – QPN:	Q 1920	Page #:	1
Project Name:	OCRS Train Sentinel	Date:	9/24/07

❒ **Review** ☒ **Verification** ☒ **Validation** ☒ **See Attached**

Subject – Including Revision Level

Hardware:	OBC – Train Sentinel	Rev:	A
Software:	Q 1920 OP System	Rev/Release:	A

Test Description (or Test Plan Document No. **QTP-1920-OCRS-02** Rev. A ; **or** ❒ Description attached):

Test the detection and system reaction to the limits of authority.

Verify Train Sentinel recognizes the limits of authority and initiates a penalty brake application if no control response is detected after alarming the crew to decelerate preventing a violation of the present valid movement authority.

Results:

Expected:

Train Sentinel will decelerate the train with the crews assistance and never cross the boundary of authority. Without crew intervention Train Sentinel will set a penalty break application and preven the train from violating the block boundary. When a valid extension of the present movement authority is received it will seamlessly extend the authority boundary after crew acknowledgement

Actual Results:

Test **Performed by** – Name:	_____	Title	_____	Date	_____
Approval:	_____	Title	_____	Date	_____

Quantum Engineering, Inc.

Test Plan

1. Quantum Test Plan Identifier

QTP-1920-OCRS-02

Rev. A

Ref. QOP 7.3-01 and QOP7.3-02

Sheet 1 of 1

2. **Project, system, sub-system or customer:** OCRS

3. This plan is intended to meet the requirements of OCRS-02	5. Unit Under Test (Test Item) Identification:
Document title and/or No: OCRS Acceptance Test.	**UUT Description:** **UUT Model or part No.**
Doc. revision:	**UUT H/W revision:**
Doc. section/Paragraph:	**Software part No.** 89017, 89008 **S/W version:** A
4. **Other Doc. cross-reference:** H-7, H-8, QTP-1920-PCRC-05	**UUT Serial Number:**
6. **Features to be tested:** Train Sentinel recognizes limits of authority and starts penalty brake application if no control response is detected after alarming the crew to a deceleration requirement.	7. **Features *not* to be tested:** Full brake application and train stopping.

8. **Approach/Description of test set-up:** Train Sentinel must recognize the limits of authority and prevent the train from violating the limits of the valid authority. As the train approaches a limit the speed will be reduced in steps to stop the train before the authority is breached. If the crew fails to reduce speed an alarm will be sounded and unless a control signal is detected a penalty application will be initiated. Test to verify end of movement authority. Verify a new authority can be issued extending the old one.

9. **Required testing equipment & tools:** Train Sentinel equipped locomotive, test train, track segment, event recorder, laptop computers to read OBC condition and the dispatch office system. Brake application indicator panel. (indicates penalty braking call for without actually energizing the brake system)

10. **Item pass/fail criteria:** Train Sentinel decelerates the train and prevents the authority from being violated.

11. **Test suspension criteria:** Clear up of test train for revenue traffic to pass.	12. **Test resumption requirements** (& which activities must be repeated): Restart test segment.

13. **Test deliverables:** ❑ Work Order Form 115; ☒ Review/Validation/Verification Form 280; ☒ Test report; ☒ Video;
❑ Data (describe); ❑ Other (specify):

14. **Test Tasks/Procedure** (may be referenced by document number and revision level):

1. Receive a valid Movement Authority for two blocks.
2. Accelerate to track speed.
3. Dispatch will not send an additional authority to extend the authority in the first two tests.
4. Run the train to the end of the authority:
   a) Observe deceleration sequence as prompted and stop the train following the OBC recommendations.
   b) Do not respond to the deceleration and observe the alarm and simulated brake application prior to a projected authority violation.
   c) Extend the movement authority to the next block during the deceleration operation and confirm train is allowed to resume track speed and cross into the next block.

15. **Environmental needs:** Daylight. Traffic protection on two adjoining blocks of railroad		
16. **Responsibilities:** Dispatcher to protect train movement. Crew to assure safe movement of all test trains.		
17. **Staffing and training needs:** Train Sentinel qualified dispatcher and train crew. Quantum product development engineer and technician.		
18. **Schedule:** 1 day with no interruptions, 3 days with clear ups for traffic.		
19. **Risks and contingencies:** Dispatcher must provide absolute protection on at least two blocks.		
20. **Proposed by** (originator): W. Bolla **Date:** 9/24/07		
21. **Remarks:**		
22. ❑ Plan approved Date:9/24/07 ❑ Plan approved with changes noted	By: Bob Griffin	

QTP-1920-OCRS-03 Road Work Consist Changes

Quantum Engineering, Inc.

DESIGN REVIEW / VERIFICATION / VALIDATION

Ref: Procedure QOP 7.3-01 and QOP 7.3-02

Project – QPN:	Q 1920	Page #:	1
Project Name:	OCRS Train Sentinel	Date:	9/24/07

❒ **Review** ☒ **Verification** ☒ **Validation** ☒ **See Attached**

Subject – Including Revision Level

Hardware:	OBC – Train Sentinel	Rev:	A
Software:	Q 1920 OP System	Rev/Release:	A

Test Description (or Test Plan Document No. **QTP-1920-OCRS-03** Rev. A ; **or** ❒ Description attached):

Pick up and set out tonnage (road work) changes are accurately reflected vs the predicted braking distance.

Verify the initial consist data, pick-up and set out on line-of-road will alter the train weight and be interpreted correctly by the brake algorithm and result in safe train stops.

Results:

Expected:

The correct consist information will be confirmed by the crew, dispatcher, and will be used by Train Sentinel on the locomotive. Brake curve calculations will be updated by changes in train mass as they are verified by the crew and dispatcher resulting in consistent stops short of the required stopping location.

Tons	# Engines	Speed	Stop Distance
500		40	
2000		40	
4000		40	
6000		40	
8000		40	
10000		40	
14000		40	

Actual:

Test **Performed by** – Name: _____ Title _____ Date _____

Approval: _____ Title _____ Date _____

Quantum Engineering, Inc.

Test Plan

1. Quantum Test Plan Identifier

QTP-1920-OCRS-03

Rev. A

Ref. QOP 7.3-01 and QOP7.3-02

Sheet 1 of 1

2. **Project, system, sub-system or customer:** OCRS

3. This plan is intended to meet the requirements of OCRS 03	5. Unit Under Test (Test Item) Identification:
Document title and/or No: OCRS Acceptance Test.	**UUT Description:** **UUT Model or part No.**
Doc. revision:	**UUT H/W revision:**
Doc. section/Paragraph:	**Software part No.** 89017, 89008 **S/W version:** A
4. **Other Doc. cross-reference:** H-16, H-17, H-93, H-94, H-95, QTP-1920-PCRC-11	**UUT Serial Number:**
6. **Features to be tested:** Initial set up of consist data, pick-up and set-outs on line-of-road of cars will alter train weight and could introduce inaccuracies in the braking algorithm. Testing will assure the braking model will adjust to changes in train weight as the train varies in size.	7. **Features *not* to be tested:** Work order data function. Accuracy of crew or dispatcher consist information.

8. **Approach/Description of test set-up:**
A change in the mass of the train, incorrect start data missing pickup or set-outs of cars will alter the performance of the braking algorithm. Worst case would occur where the train was actually heavier than reported. Testing will verify the initial consist data is correctly received from the dispatcher. Testing will also assure that changes in the consist input by the train crew are used in the braking algorithm in a timely way and will be used to compute a safe stopping distance requirement.

9. **Required testing equipment & tools:** An equipped locomotive and test train. Laptop computer to monitor communication.

10. **Item pass/fail criteria:**
The correct consist information is confirmed by the crew, dispatcher, and reaches the Train Sentinel OBC on the locomotive. The braking algorithm correctly interprets train consist initialization and on going changes and re-configures the train dynamic braking envelope using the most current train mass data.

11. **Test suspension criteria:** Clear up for revenue trains.	12. **Test resumption requirements** (& which activities must be repeated): Restart the test from consist initialization.

13. **Test deliverables:** ❑ Work Order Form 115; ☒ Review/Validation/Verification Form 280; ☒ Test report; ☒ Video;
❑ Data (describe); ❑ Other (specify):

14. **Test Tasks/Procedure** (may be referenced by document number and revision level):

1. Test train in yard, system initialized, and crew requests a movement authority.
2. Dispatcher responds with a proposed authority including consist data (# cars and weights) including a predetermined absolute stopping location.
3. Crew verifies consist and acknowledges acceptance of the movement authority.
4. Accelerate the train to track speed and allow a penalty application as the train moves toward the known

stop. 5. Verify Train Sentinel stops short to the absolute stop location. 6. Move train to the start location and add 50% more train tonnage. 7. Report the train make-up change to dispatch and verify the communication cycle to update braking algorithm. 8. Repeat step 5. (two tests)
15. **Environmental needs:** Daylight and clear visibility.
16. **Responsibilities:** Dispatcher to protect train movement. Train crew to assure safe train movement.
17. **Staffing and training needs:** Train Sentinel qualified crew and dispatcher. Quantum test engineer and technician.
18. **Schedule:** Two days testing - without clearing up for revenue traffic.
19. **Risks and contingencies:** Slid flat wheels or minor chance of a derailment from braking action.
20. **Proposed by** (originator): W. Bolla **Date:** 9/24/07
21. **Remarks:**

22. ❑ Plan approved Date: ❑ Plan approved with changes noted	By:	

QTP-1920-OCRS-04 Block Rollup & Back Up Protection

Quantum Engineering, Inc.

DESIGN REVIEW / VERIFICATION / VALIDATION

Ref: Procedure QOP 7.3-01 and QOP 7.3-02

Project – QPN:	Q 1920	Page #:	1
Project Name:	OCRS Train Sentinel	Date:	9/24/07

❒ **Review** ☒ **Verification** ☒ **Validation** ☒ **See Attached**

Subject – Including Revision Level

Hardware:	OBC Train Sentinel	Rev:	A
Software:	Q 1920 OP System	Rev/Release:	A

Test Description (or Test Plan Document No. QTC-1920-OCRS-04 Rev. A ; **or** ❒ Description attached):

Block rollup and back up protection.

Safe continuous block roll up will occur as a Train Sentinel equipped train traverses its movement authority.

Results:

Expected:

The train length estimates generated by the dispatch/office system are accurate to plus or minus100 feet. Train Sentinel automatically issued a block cleared message to dispatch when it calculated the train should be clear of the trailing block. The block was not released in the office system until the dispatcher contacted the crew and received confirmation from the crew that the train cleared the block. After the clear block was established the train attempted to back into the block and was alerted to stop before violating its authority. A penalty brake application was set stopping the rear of the train short of the block boundary.

Test **Performed by** – Name:	_____	Title	_____	Date	_____
Approval:	_____	Title	_____	Date	_____

Quantum Engineering, Inc.

Test Plan

1. Quantum Test Plan Identifier

QTP-1920-OCRS-04

Rev. A

Ref. QOP 7.3-01 and QOP7.3-02

Sheet 1 of 1

2. **Project, system, sub-system or customer:** OCRS

3. This plan is intended to meet the requirements of OCRS-04	5. Unit Under Test (Test Item) Identification:
Document title and/or No: OCRS Acceptance Test	**UUT Description:** **UUT Model or part No.**
Doc. revision:	**UUT H/W revision:**
Doc. section/Paragraph:	**Software part No.** 89017, 89008 **S/W version:** A
4. **Other Doc. cross-reference:** H-39, H-40, QTP-1920-PCRC-18	**UUT Serial Number:**
6. **Features to be tested:** Continuous block roll up will occur as the Train Sentinel equipped train traverses its movement authority.	7. **Features *not* to be tested:** Verification that train length or changes in train length are updated correctly.

8. **Approach/Description of test set-up:**

Release of the block after the end of the train clears the block will be tested. After initialization a movement authority will be requested spanning at least three blocks. As the end of the test train leaves the first block, verify a block clear message is sent to dispatch by Train Sentinel. Verify the train was clear when the request was made. Verify the cleared request is sent to the crew from dispatch. Verify the crew response is received at dispatch before the block is designated 'released' in the office system.

9. **Required testing equipment & tools:** Laptops at dispatch and on the locomotive to monitor communications. Train length measurement equipment.

10. **Item pass/fail criteria:** The train length received by the Train Sentinel OBC for the dispatcher / office system is accurate to ± 100 feet. Train Sentinel recognizes the end of train should be clear of the block and messages dispatched. The block is not released in the office system until the crew confirms the rear of their train is in the clear.

11. **Test suspension criteria:** Clear for revenue train to pass.	12. **Test resumption requirements** (& which activities must be repeated):

13. **Test deliverables:** ❑ Work Order Form 115; ☒ Review/Validation/Verification Form 280; ☒ Test report; ❑ Video;
❑ Data (describe); ❑ Other (specify):

14. **Test Tasks/Procedure** (may be referenced by document number and revision level):
1. Initialize the system and request a movement authority.
2. Measure the length of the train; verify it is within 100 feet of the dispatch systems estimate.
3. Proceed at track speed through the first block.
4. Position an observer at the block boundary and record the time the end of train passes the observer.
5. Verify the time that Train Sentinel generated the block clear message received at dispatch.
6. Verify the train crew receives a clear pending message for confirmation.
7. Verify the crew's confirmation is received at dispatch before the block status is cleared to 'available' at

dispatch. 8. Stop the train after the block is released by the office system and back into the clear block. Verify TS will not allow violation of the cleared block by the test train.		
15. **Environmental needs:** Daylight, clear visibility		
16. **Responsibilities:** Train Crew to assure safe train operations, Dispatcher will protect the test train and railroad.		
17. **Staffing and training needs:** Train Sentinel certified train crew and dispatcher, Quantum Test Engineer and Technician.		
18. **Schedule:** One day of set up and two days of testing – uninterrupted.		
19. **Risks and contingencies:** Dispatcher must protect test train and railroad from revenue traffic.		
20. **Proposed by** (originator): W. Bolla 9/24/07	**Date:**	
21. **Remarks:**		
22. ❑ Plan approved Date: 9-24-2007 ❑ Plan approved with changes noted	By: Bob Griffin	

QTP-1920-OCRS-05 Digital Communications Integrity

Quantum Engineering, Inc.

DESIGN REVIEW / VERIFICATION / VALIDATION

Ref: Procedure QOP 7.3-01 and QOP 7.3-02

Project – QPN:	Q 1920	Page #:	1
Project Name:	OCRS Train Sentinel	Date:	9/24/07

❒ **Review** ☒ **Verification** ☒ **Validation** ☒ **See Attached**

Subject – Including Revision Level

Hardware:	OBC Train Sentinel	Rev:	A
Software:	Q 1920 OP System	Rev/Release:	A

Test Description (or Test Plan Document No. QTC-1920-OCRS-05 Rev. A ; **or** ❒ Description attached):

Communications Integrity Test

Test the integrity of the digital communication. As many of the 78 macros as practical will be transmitted and received to verify the information that was sent is received and interpreted as intended. Not all macros are used routinely. Some are reserved.

Results:

Expected:

100% correspondence between the instructions sent by the dispatcher and the information received at the Train Sentinel OBC for execution.

Actual:

Test **Performed by** – Name:	_____	Title	_____	Date	_____
Approval:	_____	Title	_____	Date	_____

Quantum Engineering, Inc.

Test Plan

1. Quantum Test Plan Identifier

QTP-1920-OCRS-05

Rev. A

Ref. QOP 7.3-01 and QOP7.3-02

Sheet 1 of 1

2. **Project, system, sub-system or customer:** OCRS

3. This plan is intended to meet the requirements of OCRS-05	5. Unit Under Test (Test Item) Identification:
Document title and/or No: OCRS Acceptance Test	**UUT Description:** **UUT Model or part No.**
Doc. revision:	**UUT H/W revision:**
Doc. section/Paragraph:	**Software part No.** 89017, 89008 **S/W version:** A
4. **Other Doc. cross-reference:** H-41, QTP-1920-PCRC-19	**UUT Serial Number:**
6. **Features to be tested:** The integrity of the transmitted data and macros will be verified. The information that was sent is what was received and was interpreted as intended.	7. **Features *not* to be tested:** Message encryption and security measures.

8. **Approach/Description of test set-up:**

Each of the 78 macros in the system ICD manual will be transmitted by the dispatcher and received by an OBC test bed and verified to assure that what was sent is what is received. A series of dispatcher commands will be executed at the office system level, transmitted to TS. The command will be captured on a laptop computer and compared against what was sent from the office system and the dispatcher's original intention.

9. **Required testing equipment & tools:** Laptop computers and communications recording devices to capture and display the communications stream taking place between the dispatcher and the crew.

10. **Item pass/fail criteria:** 100% correspondence between Train Sentinel OBC and Engesis Office

11. **Test suspension criteria:** The digital radio will function without a problem.	12. **Test resumption requirements** (& which activities must be repeated): Restart the macro sequence again from the beginning of the test.

13. **Test deliverables:** ❑ Work Order Form 115; ☒ Review/Validation/Verification Form 280; ☒ Test report; ❑ Video;
❑ Data (describe); ❑ Other (specify):

14. **Test Tasks/Procedure** (may be referenced by document number and revision level):
1. Initialize the system.
2. From dispatch send a test message sequence containing the macro being tested.
3. Record the message as initiated by the dispatcher.
4. Record the message as received and decoded by the OBC/ data radio.
5. Verify that the instructions given were those received.
6. Record the results.
7. Re-initialize the system for the next test.
8. Loop until all macro commands are tested.

15. **Environmental needs:** none
16. **Responsibilities:** A qualified dispatcher will operate the office system. A qualified test Engineer or crew member will operate Train Sentinel at the test bed.
17. **Staffing and training needs:** Train Sentinel qualified dispatcher, Quantum Test Engineer and Technician.
18. **Schedule:** One day set up.
19. **Risks and contingencies:**
20. **Proposed by** (originator): W. Bolla **Date:** 9/24/07
21. **Remarks:** Post implementation communications testing will record 100% of communications activity both at the office and onboard TS for a minimum of three months after the system is fully deployed.

22. ❑ Plan approved Date: 09-24-07 ❑ Plan approved with changes noted	By: Bob Griffin	

QTP-1920-OCRS-06 Forms & MOW Procedures

Quantum Engineering, Inc.

DESIGN REVIEW / VERIFICATION / VALIDATION

Ref: Procedure QOP 7.3-01 and QOP 7.3-02

Project – QPN:	Q 1920	Page #:	1
Project Name:	OCRS Train Sentinel	Date:	9/24/07

❒ **Review** ☒ **Verification** ☒ **Validation** ☒ **See Attached**

Subject – Including Revision Level

Hardware:	OBC Train Sentinel	Rev:	A
Software:	Q 1920 OP System	Rev/Release:	A

Test Description (or Test Plan Document No.**QTC-1920-OCRS-06** Rev. A ; **or** ❒ Description attached):

Forms will be accurately displayed to the crew onboard and imbedded for enforcement in the movement authority.

Verify that Form ‘A’ and Form ‘B’, when entered by the dispatcher are interpreted correctly by the system and that the information is transmitted to the crew and imbedded in the active Movement Authority and will be enforced by Train Sentinel.

Results:

Expected:

Form ‘A’ and Form ‘B’ were displayed to the crew for verification as submitted to the dispatcher. I all cases the Form content displayed to and verified by the crew was 100% the same as the Form given to the dispatcher for input to the Office system.

In the case of the Form ‘A’, the crew was advised to decelerate so that when they reached the beginning milepost of the Temporary Speed Restriction, the train was operating at prescribed speed. When the EOT passes the end of the Temporary Speed Restriction the train is allowed to accelerate back up to normal track speed (MAS).

For the Form ‘B’, the EIC will be informed that a train is about to enter the limits of the Form B Zone. The EIC will talk to the train crew and inform the train crew of the authorized speed through

the Form B limits. The train crew will enter the designated speed. Train Sentinel will update the speed table graph and enforce the accepted speed as the MAS through the limits. When the EOT has cleared the work limits the train is allowed to resume normal track speed. Test **Performed by** – Name: _____ Title _____ Date _____
Approval: _____ Title _____ Date _____

Quantum Engineering, Inc.

Test Plan

1. Quantum Test Plan Identifier

QTP-1920-OCRS-06

Rev. A

Ref. QOP 7.3-01 and QOP7.3-02

Sheet 1 of 1

2. **Project, system, sub-system or customer:** OCRS

3. This plan is intended to meet the requirements of OCRS-06	5. Unit Under Test (Test Item) Identification:
Document title and/or No: OCRS Acceptance Test	**UUT Description:**
	UUT Model or part No.
Doc. revision:	**UUT H/W revision:**
Doc. section/Paragraph:	**Software part No.** 89017, 89008 **S/W version:** A
4. **Other Doc. cross-reference:** H-50, H-83, QTP-1920-PCRC-22	**UUT Serial Number:**
6. **Features to be tested:** Form 'A' and Form 'B', when entered by the dispatcher are interpreted correctly by the system and the information is transmitted to the crew and is imbedded in the active movement and will be enforced by the Train Sentinel.	7. **Features *not* to be tested:** The origin and accuracy of the original Forms data.

8. **Approach/Description of test set-up:**
Form data is received from the Engineering and/or Operating, by train dispatchers and entered into the system by the train dispatcher. The CAD system must interpret the information on the form and incorporate it into the Movement Authority sent to the train so it can be enforced by Train Sentinel as well as send the form in a human readable format so the crew can read and act upon it.

9. **Required testing equipment & tools:** Laptop computers at the OBC and the office computer. An equipped locomotive. Test track and route.

10. **Item pass/fail criteria:** The content of the information received by the OBC and displayed to the crew will be 100% identical to that entered on the original form. The content of the original forms will be 100% enforced by Train Sentinel.

11. **Test suspension criteria:** Loss of communications, Clearing up for revenue traffic.	12. **Test resumption requirements** (& which activities must be repeated): Restart the test segment for the form in question.

13. **Test deliverables:** ❑ Work Order Form 115; ☒ Review/Validation/Verification Form 280; ☒ Test report; ☒ Video;
❑ Data (describe); ❑ Other (specify):

14. **Test Tasks/Procedure** (may be referenced by document number and revision level):

1. Initialize the TS system.
2. Enter the test Form 'A' Temporary Speed Restriction covering a section of the test track.
   - Request a Movement Authority over the test track segment.
   - Verify the Form 'A' is displayed to the train crew as written.
   - Verify Train Sentinel OBC was sent a valid Movement Authority with the Temporary Speed Restrictions embedded at the proper locations.
   - Verify that Train Sentinel prompts the train crew to slow the train at the correct location and allows a resumption of track speed after the restriction is passed.
3. Enter a test Form 'B' – Work Zone.
   - Request a Movement Authority over the test track segment.
   - Verify the Train Sentinel OBC was sent a valid Movement Authority with the Form B displayed on the Train Sentinel OBC.
   - Verify that the train will not enter the Form B limits unless the train crew has entered a speed limit designated by the EIC.
   - Verify that Train Sentinel has updated the train profile for the correct speed conditions outlined

by the EIC. ▪ Verify that after contacting the EIC the train is allowed to continue through the work zone at the speed specified by the EIC. ▪ Verify that after clearing the work zone the train is allowed to continue at track speed.		
15. **Environmental needs:** Daylight, Clear visibility.		
16. **Responsibilities:** Train Crew to protect safety of the train operation. Dispatcher to protect the railroad and other trains.		
17. **Staffing and training needs:** Train Sentinel qualified train crew and dispatcher.		
18. **Schedule:** One day set up. One day for testing with no interruptions.		
19. **Risks and contingencies:** Dispatcher to protect test rail segment from revenue traffic.		
20. **Proposed by** (originator): W. Bolla 9/24/07	**Date:**	
21. **Remarks:**		
22. ❑ Plan approved Date: 9/24/07 ❑ Plan approved with changes noted	By: Bob Griffin	

QTP-1920-OCRS-07 Over Speed

Quantum Engineering, Inc.

DESIGN REVIEW / VERIFICATION / VALIDATION

Ref: Procedure QOP 7.3-01 and QOP 7.3-02

Project – QPN:	Q 1920	Page #:	1
Project Name:	OCRS Train Sentinel	Date:	9/24/07

❒ **Review** ☒ **Verification** ☒ **Validation** ☒ **See Attached**

Subject – Including Revision Level

Hardware:	OBC Train Sentinel	Rev:	A
Software:	Q 1920 OP System	Rev/Release:	A

Test Description (or Test Plan Document No.**QTC-1920-OCRS-07** Rev. A ; **or** ❒ Description attached):

Over speed detection and enforcement.

Validate the overspeed detection and enforcement function. Validate the accuracy of the speed input used in speed enforcement activities. Validate the positional accuracy so Tran Sentinel knows where to start and stop speed enforcement activities

Results:

Expected:

For the permanent speed limit test Train Sentinel warned the crew at 1 mph over the speed limit and then set the brakes when the overspeed reached 5 mph.

For the Form ‘A’ test the Train Sentinel will decelerate the train prior to entry into the Form ‘A’ territory.

For the restricted speed test the train is brought to restricted speed prior to the front of the train entering the speed zone. When the train went 1 MPH over restricted speed, enforcement took place.

Actual:

Test **Performed by** – Name: _____ Title _____ Date _____

Approval: _____ Title _____ Date _____

Quantum Engineering, Inc.

Test Plan

1. Quantum Test Plan Identifier

QTP-1920-OCRS-07

Rev. A

Ref. QOP 7.3-01 and QOP7.3-02

Sheet 1 of 1

2. **Project, system, sub-system or customer:** OCRS

3. This plan is intended to meet the requirements of OCRS-07	5. Unit Under Test (Test Item) Identification:
Document title and/or No: OCRS Acceptance Test	**UUT Description:** **UUT Model or part No.**
Doc. revision: A	**UUT H/W revision:**
Doc. section/Paragraph:	**Software part No.** 89017, 89008 **S/W version:** A
4. **Other Doc. cross-reference:** H-62, H-67, QTP-1920-PCRC-25	**UUT Serial Number:**
6. **Features to be tested:** Train Sentinel will have all the necessary inputs; speed, position, location, speed limit information and awareness of the crew's control inputs to recognize excess speed and initiate action to control it.	7. **Features *not* to be tested:**

8. **Approach/Description of test set-up:** In order to enforce speed correctly, Train Sentinel must have accurate speed inputs, know where it is on the railroad and know that the crew is not attempting to control speed. A section of test track will be used to test compliance with permanent speed limits; a Form 'A' temporary speed restriction and Form 'B' designated speeds.

9. **Required testing equipment & tools:** Laptop computer on board the locomotive to verify computer code set points. Equipped locomotive, brake simulation panel. (A light that activates in lieu of the P2A valve activating). If incorporated as part of a live brake test no panel will be used.

10. **Item pass/fail criteria:** Verify the speed accuracy is better than one mile per hour. Verify the position accuracy is within 30 feet of the actual position.

11. **Test suspension criteria:** Clear up for revenue trains.	12. **Test resumption requirements** (& which activities must be repeated): Restart the test segment from the beginning.

13. **Test deliverables:** ❑ Work Order Form 115; ☒ Review/Validation/Verification Form 280; ☒ Test report; ☒ Video;
❑ Data (describe); ❑ Other (specify):

14. **Test Tasks/Procedure** (may be referenced by document number and revision level):

1. Initialize Train Sentinel on the test train. Request a Movement Authority over the test territory.
2. The Movement Authority will be constructed to contain a Form 'A' reducing the track speed to 25 mph at an identifiable track location MP 10 and a section of restricted speed at MP 25.
3. The train will accelerate and attempt to exceed track speed. Verify the speed is not >1 MPH.
4. Attempt to exceed track speed by 5 mph. Verify the crew is warned to slow down at one mph over track speed. Verify the brakes will be set at 5 mph over track speed if no control input is made.
5. Measure train speed at MP 9.5. Observe train crosses into the Form 'A' territory at MP 10. Observe attempted deceleration action by Train Sentinel, crew alarm, and simulated brake application.
6. Approach MP 25 at track speed. Observe Train Sentinel decelerate the train to restricted speed. Verify crew warning and subsequent penalty brake action if no control inputs are made.

15. **Environmental needs:** Daylight, clear visibility.		
16. **Responsibilities:** Train crew to assure safe train operation. Dispatcher to protect the railroad, test train, and revenue trains during testing.		
17. **Staffing and training needs:** Train Sentinel qualified train crew and dispatcher. Quantum Engineering test engineer and Technician.		
18. **Schedule:** One day set up, one day testing.		
19. **Risks and contingencies:** Train over speeds must be constructed in a safe manner.		
20. **Proposed by** (originator): W. Bolla 9/24/07	**Date:**	
21. **Remarks:**		
22. ❑ Plan approved Date: ❑ Plan approved with changes noted	By:	

QTP-1920-OCRS-08 Controlled Track Access & Restricted Speed

Quantum Engineering, Inc.

DESIGN REVIEW / VERIFICATION / VALIDATION

Ref: Procedure QOP 7.3-01 and QOP 7.3-02

Project – QPN:	Q1920	Page #:	1
Project Name:	OCRS Train Sentinel	Date:	2/24/07

❒ **Review** ☒ **Verification** ☒ **Validation** ☒ **See Attached**

Subject – Including Revision Level

Hardware:	OBC Train Sentinel	Rev:	A
Software:	1920 OP System	Rev/Release:	

Test Description (or Test Plan Document No. **QTP 1920-OCRS-08** Rev. B ; **or** ❒ Description attached):

Restricted speed and controlled track access enforcement.

Operations within yard limits will be conducted after initialization of the system. Without a track Movement Authority the locomotive will be accelerated to 16 MPH on a clear safe track. Train Sentinel will warn the crew and set the brakes at 16 MPH. Without receiving a track Movement Authority the locomotive will proceed to and attempt to enter Controlled track at Restricted Speed. Train Sentinel will warn the crew and stop the locomotive.

Results:

Expected:

Restricted speed will be enforced. Train will be stopped before entering Controlled territory without a Movement Authority.

Test Performed by – Name:	_____	Title	_____	Date	_____
Approval:	_____	Title	_____	Date	_____

Quantum Engineering, Inc.

Test Plan

1. Quantum Test Plan Identifier

QTP-1920-OCRS-08

Rev. B

Ref. QOP 7.3-01 and QOP7.3-02

Sheet 1 of 1

2. **Project, system, sub-system or customer:** OCRS

3. This plan is intended to meet the requirements of OCRS-08	5. Unit Under Test (Test Item) Identification:
Document title and/or No: OCRS acceptance test	**UUT Description:** **UUT Model or part No.**
Doc. revision: B- numbering change	**UUT H/W revision:**
Doc. section/Paragraph:	**Software part No.** 89017, 89008 **S/W version:** Rev. A
4. **Other Doc. cross-reference:** M-1.2, H-126, QTP-1920-PCRC-47	**UUT Serial Number:**
6. **Features to be tested:** Restricted speed is enforced. Train will be stopped before entering controlled territory without authority.	7. **Features *not* to be tested:** System initialization.

8. **Approach/Description of test set-up:** Operations within yard limits will be conducted after initialization of the system. Without a track movement authority the locomotive will be accelerated to 16 MPH on a clear safe track. TS will warn the crew and set the brakes at 16 MPH. Without receiving a track movement authority the locomotive will proceed to and attempt to enter controlled track at restricted speed. TS will warn the crew and stop the locomotive.

9. **Required testing equipment & tools:** On board event recorder. Locomotive. Imbedded memory for TS system readout. Laptop computer for data download. Factory diagnostics and analysis software.

10. **Item pass/fail criteria:** 1. Locomotive comes to a complete stop for 30 seconds after penalty application. 2. Locomotive stopped prior to entering controlled territory.

11. **Test suspension criteria:** TS allows overspeed or controlled track entrance w/o authority	12. **Test resumption requirements** (& which activities must be repeated): Trace malfunction and rerun test.

13. **Test deliverables:** ❑ Work Order Form 115; ☒ Review/Validation/Verification Form 280; ☒Test report; ❑ Video;
☒ Data (describe); ☒ Other (specify): Recorded data files. Processed data.

14. **Test Tasks/Procedure** (may be referenced by document number and revision level):
1. Power up TS and acquire a GPS location fix.
2. Secure yard running track long enough to safely accommodate test.
3. Accelerate train beyond restricted speed.
4. Verify alarm and brake application.
5. Verify after train stops system can not be reset for 30 seconds.
6. Verify dispatch is sent a brake application message.
7. Move train toward controlled territory boundary with out a movement authority.
8. Verify train is alarmed and stopped prior to entering controlled territory.

15. **Environmental needs:** Clear protected yard track – flagged. Dispatcher protected first block onto controlled territory.

16. **Responsibilities:** Dispatcher for track safety. Train crew for locomotive operations and safety.		
17. **Staffing and training needs:** Train crew has completed TS system training. Quantum will supply a test engineer and a product development technician.		
18. **Schedule:**		
19. **Risks and contingencies:** Over speed in yard must be planned and controlled. Track must be protected by dispatcher or flagman.		
20. **Proposed by** (originator): W. Bolla **Date:** 9/24/07		
21. **Remarks:**		
22. ❑ Plan approved Date: 9/24/07 ❑ Plan approved with changes noted	By: Bob Griffin	

QTP-1920-OCRS-09 On Board Track Map

Quantum Engineering, Inc.

DESIGN REVIEW / VERIFICATION / VALIDATION

Ref: Procedure QOP 7.3-01 and QOP 7.3-02

Project – QPN:	1920	Page #:	1
Project Name:	OCRS Train Sentinel	Date:	11/27/07

❒ **Review** ☒ **Verification** ☒ **Validation** ☒ **See Attached**

Subject – Including Revision Level

Hardware:	OBC Train Sentinel	Rev:	A
Software:	1920 OP System	Rev/Release:	C

Test Description (or Test Plan Document No.QTP-1920-OCRS-01 Rev. A ; **or** ❒ Description attached):

V&V of C&N Train Sentinel Track Map data base. An imbedded track map is used by the system to locate features, permanent speed limits, and control points on the physical railroad. A hybrid system using GPS positioning, updating the axle generator wheel revolution dead reckoning system yields a very accurate series of rolling fixes during train operation. Some track map features such as marked mile posts and grade crossings can be readily identified by visual inspection and will be used as a basis to verify they are correctly mapped within the accuracy range of commercial GPS. Other track features such as unmarked block boundaries, switch fouling point locations, and intermediate milepost locations are generated by the system, without actual GPS coordinates residing in the system and can not be readily located visually.

Results:
Expected: Test results will verify visible track map features are accurate to within the published L1 GPS standard. i.e. +/- 10 meters 90% of the time. It will later be demonstrated in tests that this level of resolution combined with active dead reckoning, allows Train Sentinel to satisfy performance based tests conducted by OCRS and witnessed by the FRA.

Actual:

Test **Performed by** – Name:	_____	Title	_____	Date	_____
Approval:	_____	Title	_____	Date	_____

Quantum Engineering, Inc.

Test Plan

1. Quantum Test Plan Identifier

QTP-1920-OCRS-09

Rev. A

Ref. QOP 7.3-01 and QOP7.3-02

Sheet 1 of 1

2. **Project, system, sub-system or customer:** OCRS

3. This plan is intended to meet the requirements of OCRS-VV-09	5. Unit Under Test (Test Item) Identification:
Document title and/or No: OCRS acceptance test.	**UUT Description:** **UUT Model or part No.**
Doc. revision:	**UUT H/W revision:**
Doc. section/Paragraph:	**Software part No.** 89017, 89008 **S/W version: A**
4. **Other Doc. cross-reference:**	**UUT Serial Number:**
6. **Features to be tested:** Train Sentinel onboard imbedded track map. Verify that location Lat/Log are within acceptable limits for features presently mapped.	7. **Features *not* to be tested:** Track curvature and elevation components. Position augmentation with dead reckoning axle drive utilization. No axle drive is available for Hi-Rail.

8. **Approach/Description of test set-up:** A portable Train Sentinel unit will be applied to a Hi-Rail vehicle. A set of paper OCRS track maps and associated GPS coordinates used to generate the map data base loaded in the Train Sentinel unit will be available. The vehicle will proceed to an identifiable feature. The TS data display will be checked and the programmed GPS coordinates of visible features will be verified against an independent GPS device. Data will be recorded on the attached spread sheet. (Attachment 1)

9. **Required testing equipment & tools:** A portable Train Sentinel unit correctly installed in an OCRS Hi-Rail vehicle. An independent GPS position receiver. A laptop computer to read position coordinates from TS and record data. Video recording device - optional.

10. **Item pass/fail criteria:** For the track map – visible mapped features will be within the published GPS specification of +/- 10 meters 90% of the time to pass.

11. **Test suspension criteria:** Equipment failure GPS unit. Consistently bad satellite fixes due to atmospheric conditions or poor satellite positioning. Clearing track for revenue trains.	12. **Test resumption requirements** (& which activities must be repeated): Restart test segment from the beginning after equipment is rebooted or retake individual feature fixes at a different time when GPS reception is more favorable.

13. **Test deliverables:** ❑ Work Order Form 115; ☒ Review/Validation/Verification Form 280; ☒ Test report; ☒ Video;
☒ Data (describe); ❑ Other (specify):

14. **Test Tasks/Procedure** (may be referenced by document number and revision level):

1. Check out equipment on board Hi-Rail.
2. Contact the dispatcher for track possession of C&N subdivision.
3. Hi-Rail to the first track feature on the Track Map Verification test sheet sequence i.e. 'Begin ECY1'. (Attachment 1)
4. Verify TS is showing the beginning of the ECY1 block, check proper position reading TS GPS coordinate off the laptop, then record the coordinates shown on the independent GPS device.
5. Repeat until all visible features are checked.

15. **Environmental needs:** Daylight, favorable atmospheric conditions for GPS.		
16. **Responsibilities:** Dispatcher will protect the test track segment. An OCRS officer will operate the Hi-Rail vehicle and ensure test crew safety.		
17. **Staffing and training needs:** Quantum test engineer and an OCRS operating officer will perform tests. FRA representative to witness the test.		
18. **Schedule:** Set up test – 1 day, pre-test briefing by QEI Engineering 8:00 AM 12/11/07. Testing to start immediately after the briefing.		
19. **Risks and contingencies:** Interference passing revenue traffic.		
20. **Proposed by** (originator): W. Bolla **Date:** 11/27/07		
21. **Remarks:** Scheduling will need to be closely coordinated so revenue trains will be allowed to move unimpeded during testing.		
22. ☒ Plan approved Date: 11/28/07 ❑ Plan approved with changes noted	By: Tom Hickenlooper, QEI; OCRS:	

CONCEPT OF OPERATIONS

(CONOPS)

[PSP § 236.907 (a) (3)]

[Attachment 2]

Ohio Central Railroad
Positive Train Control (PTC)

Revision History

Version	Date	Comment	FRA Status
1.0	11/13/2006	Preliminary Draft from PCRC, reformatted	
1.1	11/13/2006	Preliminary Draft from PCRC, detailed with OCRS requirements	
1.2	2/5/2007	OCRS CONOPS draft, assignment of territory for demonstration	
1.3	5/8/2007	OCRS CONOPS draft, verbiage cleanup	
1.4	5/13/2007	OCRS CONOPS draft, verbiage cleanup	
1.5	5/18/2007	OCRS CONOPS draft, verbiage cleanup	
1.6	5/21/2007	OCRS CONOPS draft, verbiage cleanup	
1.7	9/11/2007	OCRS CONOPS, draft for FRA (preliminary review)	
1.8	9/13/2007	OCRS CONOPS, draft for FRA	
1.9	10/19/2007	OCRS CONOPS, draft for FRA	
1.10	11/28/2007	OCRS CONOPS, draft for FRA	

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1 SCOPE

Pursuant to the Final Rule §236.907 (a)(3) this system level Concept of Operations (CONOPS) document is developed as a joint venture between the Ohio Central Railroad and Quantum Engineering. This document is a subset of the Product Safety Plan (PSP) and contains a description of the product functional characteristics and how various components within the system are controlled.

This document follows the guidelines of IEEE "Guide for Information Technology System definitions – Concept of Operations (ConOps) Document" IEEE Std. 1362-1998, approved March 19, 1998 by the Software Engineering Standards Committee of the IEEE Computer Society.

The scope of the Ohio Central Railroad (OCRS) Positive Train Control (PTC) project will encompass delivery, installation, implementation, and testing of a revenue service Positive Train Control System. Revenue service is defined as a system that has passed all required functional and safety tests. This process will also ensure all appropriate regulatory approvals have been received.

The OCRS PTC project will include the installation of a new Quantum – Computer Assisted Dispatching (Q–CAD) System. This installation will involve a migration of the current Ohio Central Railroad System from their existing system. It will also include the installation of Train Sentinel® on-board locomotive computer (OBC) systems.

1.1 Identification

This document establishes a "System" Concept of Operations for the Positive Train Control system to be implemented on the OCRS Railroad. The OCRS PTC project will entail two major components, the Quantum Engineering Train Sentinel® on-board computer system and the Computer Assisted Dispatching (Q–CAD) system. The OCRS PTC will utilize the current OCRS data radio network to provide interfaces between the locomotive and the office during the project phase.

It is expected that the Federal Railroad Administration (FRA) will use this CONOPS as a description of the OCRS PTC system. In compliance with the FRA Final Rule, this document will satisfy §236.907 (a)(3).

1.2 Document Overview

In conjunction with a System Requirements Specification, this CONOPS will describe functional and operational characteristics of the OCRS PTC system. Hardware and software components will not be covered in this document, but will be provided in subsequent line items associated with the FRA Final Rule §236.907.

This document is being generated through a combination of efforts with project teams associated with the Ohio Central Railroad and Quantum Engineering. This document will demonstrate the components and their interactions to provide OCRS a safer railroad environment as well as satisfy the mandated requirements identified for a PTC project.

The FRA may use this System CONOPS as a complete high-level description for the OCRS project.

In complying with the IEEE System Definition for a Concept of Operations (CONOPS), this document will be segmented into the following sections:

1. Scope
2. Referenced Documents
3. Current System
4. Justification for and nature of changes
5. Concepts for the proposed system
6. Operational scenarios
7. Summary of impacts
8. Analysis of the proposed system

1.3 System Overview

As identified by the PTC Working Group, the primary purpose of a PTC system is to increase railroad safety by providing the safety functions:

- Enforcement of authority limits
- Enforcement of speed restrictions
- Protection of track force work limits (men and equipment)

It has further been defined that the following additional safety functions might be included in some PTC systems:

- Provide warning of on-track equipment operating outside the limits of authority.
- Receiving and acting upon hazard information in a more timely or more secure manner (e.g. compromised bridge integrity, wayside detector data).
- Generating data for transfer to highway users to enhance warning at highway-rail grade crossings.

For Task 1c of the test program (outlined in the Informational Filing) anticipated for the OCRS PTC system, the locomotive onboard computer (OBC) will only provide alerting (audible and visual) criteria to the train crew. In Task 2 (c-e), whenever a train is attempting to operate outside this safe stopping distance envelope, Train Sentinel® first warns the train crew (audible and visual) of the condition and, if no action is taken to place the train within this safe braking envelope, Train Sentinel® will initiate a penalty application of the brakes and force the train to a complete and safe stop while notifying the dispatcher of the occurrence. At a minimum, should a penalty condition occur, a P2A response (full service brake application at a service rate), followed by an emergency request to the EOT, which will become an emergency application if the EOT responds, will

be generated. After repeated braking tests initiated by Train Sentinel® it is the opinion of the Vendor and OCRS that an EOT initiated emergency application from the rear of the train has had a favorable effect on in train forces. This is justified by prior experience with the mechanical forces of the train's brakes to be pulled to a stop rather than the compression of the weight of the train moving toward the front end of the train with a front-end application. Dynamic brakes are not used. The train dispatcher will also be informed through the message interface of the train in emergency.

The system will be implemented to optimize train operations by automating many dispatching, train crew, and Maintenance-of-Way (MOW) functions. The OCRS objective will be to develop data on the corridor for improving throughput without changing track speed requirements.

For this program, the OCRS PTC functions to be implemented are as follows:

- Use of the current OCRS VHF radio network.
- Electronic delivery of movement authorities with defined limits, speed restrictions, and MOW worker limits, supplemented by submission of the PSP.
- Use of GPS on the head-end and rear-end to ascertain proper train configuration as well as develop location report data for the office.
- Ability for Q–CAD to distinguish between equipped or operating and non-equipped or non-operating or not equipped trains and off track equipment. Q–CAD will provide functionality through the HMI to assist the train dispatcher in this process.
- Ability of Q–CAD to interrogate the OBC to ensure the database version control is the same in order to execute authorities.

The Quantum Train Sentinel® system is a locomotive on-board computer system that when used correctly, should generate to improved safety and efficiency of train operations. This Concept of Operations is also the basis for the initial program system activities such as the functional and performance analyses. By providing an overall description of how the Quantum Train Sentinel® system supports the railroad's mission, this document also serves as a tool for providing the necessary strategic implementation vision for railroads.

The Quantum Train Sentinel® system has the potential to significantly reduce rule infractions associated with train movement authorities, over-speeds, and to reduce accident rates.

This document describes the description of operations of the integrated modules of the Quantum Train Sentinel® System. It should be noted that each of these modules builds upon the other to ensure safety compliance. The document focuses on the safety dimensions and economic benefits that the railroad should realize if the system is implemented.

The strategy identified in this process will provide improvements in the safety and efficiency of railroad operations, in the near future, without commitment of large up-front

expenditures of a traditional PTC system or a fixed installation of Centralized Traffic Control (CTC). This strategic approach includes two building components: precise GPS position data and a communications conduit supporting five modular components. These modules provide (1) authority limit approach alerts, authority limit encroachment warnings and proximity alerts, (2) on-board delivery and future enforcement of authorities and speed restrictions, (3) on-board displays, and (4) an on-board braking system to prevent over-speed / authority violations.

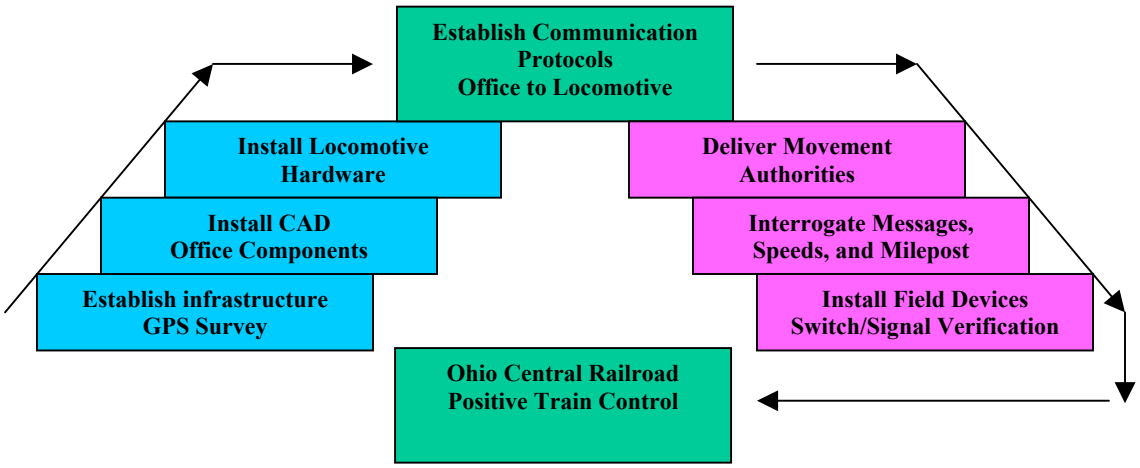

Figure: 1.3-1 OCRS Migration Path

Any event that will cause loss of system operation will result in the engineer being notified by the audible/visual indications on the locomotive LCD display screen, and the train dispatcher through the network. Fail-safe technology is applied to the on-board systems such that a failure of the on-board computer or locomotive control system will automatically bring the vehicle to a stop prior to the end of the last delivered authority.

The five Quantum Train Sentinel® modules enforce the safety requirements of a predefined strategy, composed of the 3 FRA mandates for a PTC system. All the modules are based on managing train speed. Operations within authorized parameters are allowed at the maximum authorized speed. Exceptions requiring a reduced speed or a Stop are managed by forcing the crew to reduce the speed to the maximum authorized speed at the conflict point. This strategy alerts the engineer to the speed reduction required and allows the engineer to maintain train control by slowing within the acceptable limits. ***Failure to do so will stop the train.*** The system is supported by an on-board track database. The track database includes layout information, (multiple tracks, switches, etc.), grades, curvature, milepost references, signal locations, speed limits, and highway crossings. This database provides all the information required to safely and efficiently authorize and monitor movements. Configuration control is managed at the central office and the current

subdivision database is provided to the on-board computer via a laptop computer with serial communications technology. Future enhancements will include the ability of the Q–CAD server, through a WAN to update track database information when needed. The Quantum Train Sentinel® System includes environments for Software/Database Validation. The software/database validation environment provides the ability to load and validate the operation of Software Release and Railroad database updates with no adverse effect on operation and safety. This rational management philosophy ensures current data is on-board without detrimental impact to rail operations.

Functional Capabilities of PTC

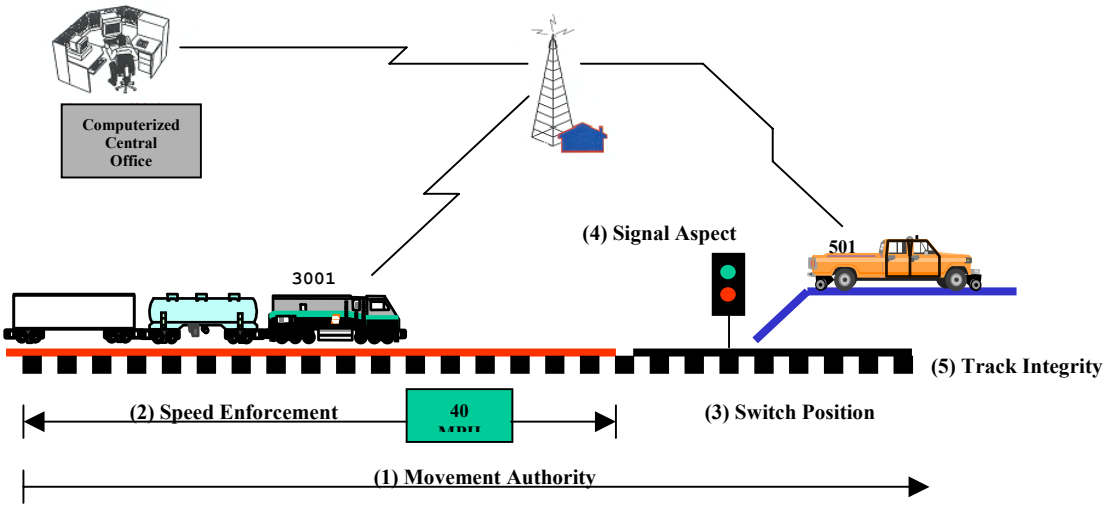

Figure 1.3-2 Function Capabilities of PTC

Quantum Train Sentinel® has been developed as a fail-safe system. The system will also adhere to the specifications outlined in the Final Rule that address safety-critical.

> "The term "safety-critical" is intended to apply to any function or system the correct performance of which is essential to the safety of personnel and/ or equipment, or the incorrect performance of which could cause a hazardous condition, or allow a hazardous condition which was intended to be prevented by the function or system to exist. An example of the latter would be a system that does not constitute any part of the method of operation, but maintains safe system operation should any one of the safety-critical functions be omitted or not performed correctly (*e.g.*, human error)."

Quantum Train Sentinel® will also address those concerns established in the Final Rule about human factors and their interface to the users of the office and on-board products.

> "The goals of human factors requirements and concepts in product design are to enhance safety, increase the effectiveness and efficiency of work, and reduce human error, fatigue, and stress. Since the implementation of any new system, subsystem or component can directly or indirectly change the nature of tasks that humans perform, both negative and positive consequences of implementation should be considered in design. FRA believes that these principles need to be adequately addressed early in the product development stage rather than at the end of it."

The dispatcher issues authorities and restrictive information for maintenance personnel and trains and communicates electronically applicable restrictions that must be obeyed in order to maintain safe operations (e.g., speed and operating restrictions) within their assigned territories. Since this requires the maintenance and exchange of a significant amount of data, railroads support the dispatcher through a Computer Assisted Dispatching (Q–CAD) system. The computerized dispatch systems contain conflict checking and "fail safe" mechanisms to ensure that movement authorities, restrictive information, and authority forms such as Work Between's are produced in a safe and efficient manner. This means that all safety critical functions will be identified and implemented in a fail-safe manner as defined in IEEE-1483. The dispatching system utilizes procedures that ensure the dispatcher activities and HMI interfaces to the dispatching equipment are performed safely and efficiently.

The on-board systems continuously check the vehicle location comparing it to the track it is authorized to occupy. Warnings and braking algorithms will be applied whenever the locomotive approaches the end of existing limits, or whenever the vehicle speed exceeds that authorized for the track segment it now occupies. Fail Safe operations allows a train to operate to the end of its authorized limits in the event of a system failure. Any time that the network telemetry signal to the locomotive is lost for a prescribed period of time (user selectable) it will only be allowed to continue to operate to the last limit of authority. Once telemetry communication has been re-established, the locomotive will continue with its normal operations. Similarly, if any of the locomotive control equipment or the GPS system malfunctions, and system integrity cannot be assured, the result will be either a complete shutdown, or reduced capability as determined by the kind of failure experienced. The locomotive engineer and the dispatcher will be notified by the audible/visual indications.

2 APPLICABLE DOCUMENTS

The following documents were used in the preparation of this document.

a) Ohio Central Railroad System, Timetable No. 2, Southern Lines, effective Thursday July 5, 2005.

b) Columbus & Ohio River Railroad, Timetable No. 3, effective Thursday July 5, 2005.

c) Ohio Central Railroad, Timetable No. 4, effective Thursday July 5, 2005.

d) Ohio Southern Railroad, Timetable No. 4, effective Thursday July 5, 2005.

e) Ohio Central Railroad System, Standard Operating Procedures, effective July 1, 2005.General Code of Operating Rules, Fourth Edition, effective April 2, 2000

f) U.S. Department of Transportation, Federal Railroad Administration, 49 CFR Parts 209, 234, and 236. Final Rule for *Standards for Development and Use of Processor-Based Signal and Train Control Systems*, printed March 7, 2005 and effective June 6, 2005. Federal Docket No. FRA-2001-10160.

g) IEEE STD 1362-1998: "Guide for Information Technology System definitions – Concept of Operations (ConOps)" dated March 19, 1998.

OCRS CONOPS	**IEEE STD 1362-1998**
1 Scope	1 Scope
2 Applicable documents	2 Referenced documents
3 Current system or situation	3 Current system or situation
4 Justification for and nature of changes	4 Justification for and nature of changes
5 Concepts for the proposed system	5 Concepts for the proposed system
6 Operational scenarios	6 Operational scenarios
7 Summary of impacts	7 Summary of impacts
8 Analysis of the proposed system	8 Analysis of the proposed system
9 Glossary - Acronyms	9 Notes
10 Glossary - Terms	10 Appendices
11 Blowfish Encryption	11 Glossary

h) MIL-STD-498, Software Development and Documentation

i) ANSI/ASQC A3 Quality System Terminology

j) IEEE STD 729-1983, Glossary of Software Engineering Terminology

k) IEEE Standard 14483-2000, "IEEE Standard for Verification of Vital Function in Processor Based Systems Used in Rail Transit Control", IEEE VT Society, 5 April 2000.

l) IEEE Standard 1016.1-1993, "Guide to Software Design Descriptions", IEEE Computer Society, 30 August 1993.

m) ATCS Specification 110 (Environmental)

n) ATCS Specification 140 (Recommended Practices and Safety Assurance)

o) ATCS Specification 320 (Locomotive Displays and Controls)

3 CURRENT SYSTEM

This section describes the OCRS territory, as it exists today, including the infrastructure and operation. It will also detail some enhancements to the field that will be added as the test program is implemented.

3.1 Background, Objectives, and Scope

The Ohio Central Railroad dispatching office is located at Coshocton, OH. The office consists of one train dispatcher per shift. The existing dispatcher system is manual block sheets that rely heavily on the dispatcher for safety and efficiency of the railroad operation. Presently, there is not a computer assisted dispatching system available to the train dispatcher.

The train dispatchers are responsible for management of track use, ensuring that trains are routed safely and efficiently, and for ensuring the safety of personnel working on and around the track structure. These are complex tasks that require integrating multiple sources of information (e.g., information from train schedules, manually developed paper track state sheets, and radio communication with multiple personnel.

The train dispatchers must project into the future, by estimating ETA's, and balancing the demands placed on track use by workers involved in track repair, with operational requirements for train schedules and customer commitments. Heavy reliance on voice communication is required today for safe and efficient management of the railroad operation. Train crews and maintenance employees are responsible for accurately copying, and interpreting authorities and restrictive information from the dispatcher. A complex system of receiving, copying, and repeating instructions is currently in place. Accuracy in the copying, and repeat process is safety-critical to the operation. Accuracy in the implementation of the voice communicated data is safety-critical. Errors in the transmission process, the transcription process, or the implementation process are prone to human error, which can have catastrophic results.

3.2 Operational Policies and Constraints

The current rules are provided to employees at Ohio Central Railroad are:

- OCRS Operating Rules
- OCRS General Operation Instructions

Principle constraints to the current operation are the train dispatchers are afforded no computerized means to conduct their work. All work is performed by manually prepared block sheets and therefore represent a potential for human factor conditions that may result in negative consequences.

3.3 Description of the current system

In this non-signaled territory, there is no computerized system to assist the train dispatcher in the execution of their duties. This manual system relies manually prepared block sheets and voice radio communication between train dispatchers and train crews, or dispatchers and maintenance personnel. Field personnel must occasionally wait for extended periods to receive or return authorities, to obtain location data for other field equipment and how it will affect their on-track possibilities. Trains and MOW can be granted "joint" authorities, or shared block authority.

The train dispatcher is responsible for all operations of traffic over the territory. In the process of planning the traffic operation, the train dispatcher must determine meet and pass locations. In the planning process, the dispatcher is responsible for train delay over the territory. During heavy traffic periods the plan that was arranged earlier may not be the optimal plan in order to minimize the delay to trains. For this reason, trains may experience unnecessary delays.

The OCRS Operating Rules are used to manage the movement of trains, and the integration of field equipment. Rules training, written testing, operational testing, and on-the-job-training are used to maintain current awareness and compliance with rules governing operation.

Human error (dispatcher, train crew, field personnel) is the predominant risk associated with the current system. The current system is prone to human error from incorrectly hand written train sheets, verbal miscommunication, misunderstanding, and misinterpretation.

3.3.1 Dispatcher System

The existing dispatcher system consists of a computerized assisted dispatcher (CAD) system, referred to as Quantum – CAD or Q – CAD. The basis of this system is Track Warrant Control or TWC.

3.3.2 Locomotive System

The engineer operates the locomotive based on train handling and operating rules. Train crews are responsible for accurately copying, and interpreting authorities, and restrictive information from the dispatcher. A complex system of receiving, copying, and repeating instructions is in place. Accuracy in the copying, and repeat process is safety-critical to the operation. Accuracy in the implementation of the voice communicated data is safety-critical. Errors in the transmission process, the transcription process, or the implementation process are prone to human error, which can have catastrophic results.

3.3.3 Communication System

The entire territory has voice radio coverage. Restrictions are faxed or printed at origin stations, and picked up by a crewmember prior to departure. Authorities, and restrictions initiated following the train's departure are issued verbally following GCOR procedures, and OCRS practices.

A communication data radio provides communications from fixed or mobile sites to a central office. It can be used for sending and receiving messages, position reporting, data logging, or other custom applications. There are times when cellular phones are used to transmit a track warrant or other important information between the dispatcher and train crews. The existing VHF radio network will be employed to electronically transmit track warrant and other pertinent information between the office environment and on track equipment for the proposed system.

3.3.4 OCRS Territory

The Ohio Central Railroad System is a network of ten railroads that operate almost 500 miles of railroad throughout the East Central and North-Eastern Ohio and in the Pittsburgh, Pennsylvania area. The Ohio Central is divided into three divisions, Northern Lines, Southern Lines and Pittsburgh Lines.

The lines are made up of three (3) operating divisions:

Northern Lines –

- Youngstown & Austintown Railroad (YARR)
- Warren & Trumbull Railroad (WTRM)
- Youngstown Belt Railroad (YB)
- Mahoning Valley Railway (MVRY)
- Ohio & Pennsylvania Railroad (OHPA)

Pittsburgh Lines –

- The Pittsburgh & Ohio Central Railroad (POHC)
- Aliquippa & Ohio River Railroad (AOR)

Southern Lines –

- Ohio Central Railroad, Inc. (OHCR)
- Ohio Southern Railroad, Inc. (OSRR)
- Columbus and Ohio River Railroad Company (CUOH)
  - C&N subdivision – Demonstration Territory

Division/Subdivision	Total Length	TWC	Yard Limits
East Columbus to Newark C&N SD (CUOH)	**34.4**	**31.5**	**2.9**
Total in Miles	**34.4**	**31.5**	**2.9**

Figure 3.3.4 Demonstration Territory

3.4 Modes of operation for the current system

The current Ohio Central Railroad is composed of Track Warrant Control Territory (TWC). The demonstration territory will operate with 2 types of conditions:

- Track Warrant Control Territory (TWC)
    1. Track Warrant Control for mainline operations with Positive Train Control for trains equipped with Train Sentinel®; and,
    2. Track Warrant Control for mainline operations in an unequipped state with verbal authorities.
- Manual oversight of yard and industry tracks

3.5 User classes and other personnel involved

The following railroad workers will be involved in the operation of the OCRS PTC project:

- Train crews
    - Engineers
    - Assistant Engineers
    - Conductors
    - Brakemen
- Train Dispatchers
    - Regular assigned
    - Extra board
- Mechanical forces
    - Electricians
    - Service track personnel
- Engineering forces
    - Road masters
    - Track inspectors
- Office personnel
    - Chief dispatchers
    - Service planning personnel
    - Operating rule personnel
    - System administrators

4 JUSTIFICATION FOR AND NATURE OF CHANGES

The Ohio Central Railroad Positive Train Control system will be based on proven railroad technologies that use current operating principles developed as safety-critical components. OCRS is implementing this system to ensure future safety requirements are met with state-of-the-art computer systems. Train Sentinel® and Q–CAD are mature, operational systems, that have been extensively tested on the PCRC and are production ready for the OCRS demonstration territory. The system being implemented is the same system, office and Train Sentinel®, as currently being operated on the Panama Canal Railroad. The use of the same technology, already in full revenue service, will provide OCRS with a proven safety operation.

4.1 Justification of changes

The objectives of the OCRS PTC are to provide an additional level of safety to the existing operations, while supporting all on-going operating conditions. The OCRS PTC will:

- Provide user-friendly, graphical interfaces that provide the user with easy to comprehend information.
- Provide efficiency of operations to train and roadway maintenance.
    - Line capacity enhancement
    - Improved service reliability
    - Faster over-the-road running times without additional speed increases to facilitate better train management.
    - More efficient use of cars and locomotives (due to real-time location information)
    - Larger “windows” for track maintenance
    - Reduction in locomotive failures (due to real-time diagnostic data)
- Prevent, to the extent practical, those actions explicitly not permitted by the operating rules.
- Permit the operations of failed, or non-communicating equipped trains to revert to the native TWC operation,
- Enforce authority limits, speed limits, and applicable Roadway Worker limits.

Current Computer Assisted Dispatching systems fail to provide a sufficient feedback mechanism to the users, which allow the system to detect whether the system and/or dispatcher response is in correspondence to the instructions provided, and to inform or make corrective actions when necessary. Most current systems do not offer such operational benefits and often leave safety in the hands of the dispatcher, locomotive crews, and MOW work crews, which allows room for human error. The OCRS PTC project will analyze all the human factor aspects of the interfaces between all parties to the

process.

The OCRS PTC system will provide the mechanism that will significantly improve safety, and efficiency. OCRS PTC provides accurate and timely feedback to dispatchers and train crews in the control of trains by relaying location information and train status to the dispatcher automatically from the onboard equipment. The OCRS PTC can present the Q–CAD system and human operators with improved information for decision-making that will achieve safety goals by detecting any failures and potential violations in a timely manner.

OCRS PTC is designed with safety-critical functions. Any action, or failure to act, which would put the safety of the public, trains, crews, MOW residing on the track (unequipped), and/or track operations at risk will cause a warning to the crew and dispatcher, and if no action is taken, the train brakes shall be activated.

4.2 Description of desired changes

OCRS PTC is designed to provide safety and efficiency gains. The system is comprised of a Quantum – Computer Aided Dispatch (Q–CAD) system (office portion), Train Sentinel® on-board system (OBC and digital display), a communications conduit (VHF data radio), and GPS location technology.

The OCRS PTC system will be the same system as provided the Panama Canal Railroad and therefore it is not projected at this time that any system process changes, personnel changes, operational changes, or support changes will be necessary.

The OCRS PTC system will integrate train dispatchers and on-board equipment with a communication network that provide OCRS with the tools to:

Create a Q–CAD management environment for movement planning that will enable dispatchers to automatically coordinate and manage train movements, integrate MOW, and access information and reports regarding train performance with the strategic plan.

- Electronically deliver authorities, speed restrictions, and additional messaging between Q–CAD and the on-board system.
- Efficiently and safely maintain database version control through a secure data conduit, between Q–CAD and the OBC.
- Alert train crews to authority limits
- Alert train crews to speed restrictions
- Stop locomotives/trains prior to exceeding authority/speed limits
- Alert MOW of authority limits and possible violations
- Provide an HMI environment for the user to facilitate additional avenues of information through user interfaces.

The anticipated approach for the OCRS PTC project is to maximize the safety benefits while minimizing risk. The system is designed to address (and mitigate) the hazards that produce accidents under a current TWC operation by supplementing the operations with a PTC environment.

4.3 Priorities among changes

The OCRS PTC design will address the need to increase safety, capacity, reliability, and efficiency. Several of the subsystems are integrated to provide the benefits. The system provides the following safety functions:

- Alerting and enforcement of authority limits
- Alerting and enforcement of speed restrictions
- Protection of MOW limits

There are three unique areas that comprise OCRS PTC that can be considered essential to the success of the project. These include:

4.3.1 VHF Data Radio

The VHF Data Radio conduit provides communications from fixed or mobile sites to the dispatching center. It can be used for sending and receiving messages, position reporting, data logging, or other custom applications. Each device on the VHF Data Radio network (locomotives, hi-rails, signals, switches, wayside detectors) has telemetry equipment that provides status and position reports. The VHF Data Radio network provides the foundation for electronic delivery of safety critical information between the Q–CAD office, the on-board system, the GPS location system, as well as between the on-board systems and wayside devices.

4.3.2 The Q–CAD system

OCRS PTC is also designed to encompass a broad range of tools to improve the safety and efficiency of the OCRS operation. The Q–CAD system will automatically coordinate and manage train movements and access information and reports regarding train performance, composition and scheduling. In addition the Q–CAD system will provide a vital check for all safety critical authorities, speed restrictions, and MOW items generated by Q–CAD and delivered to the on-board systems.

The office system is essential to the OCRS PTC design and implementation. The Q–CAD system will provide for the OCRS operations:

- Track Warrant Control (TWC) with Positive Train Control (PTC) for equipped locomotive operations.
- Track Warrant Control (TWC) for unequipped locomotive operations.
- Train message delivery process, electronic or manual
- Synchronized databases between office Q–CAD and OBC

4.3.3 The On-Board Computer

The on-board computer systems are designed to increase the effectiveness, efficiency, and a higher level of safety for the train crew. The system includes an on-board computer and a location determination system. The system includes a Human Machine Interface (HMI) for the train crew. A VHF Data Radio on-board provides the link through the network to the dispatching center.

The primary task of the locomotive segment is to provide a visual and audible notification of a pending violation. If this is ignored the secondary task is to protect the public, train, crews, and track infrastructure by stopping the train to prevent any violations of the movement authority or speed restrictions. If the safe braking distance is about to be violated, the crew will be alerted. Failure to respond by slowing the train will result in a penalty brake application at the service rate that will be applied to stop the train. Temporary speed restrictions are combined with civil speed restrictions that are resident in the OBC to determine the lowest applicable speed restriction for the train for each section of track. The system alerts the crew to approaching speed limits, and failure of the engineer to control the train by slowing for the restriction will result in a full service brake application to stop the train.

4.4 Changes considered but not included

Under the OCRS PTC project, it will not be determined if there is anything to contribute to this line item until the project has been completed. An option that has been considered is the interface between the locomotive and highway-rail grade crossing. The locomotive OBC could interrogate the device to ensure compliance before entering the crossing. This would benefit public safety in that the train could react prior to the encounter if the crossing gates were not activated properly.

Quantum Engineering has already developed a “Train Sentinel®” package to be used for MOW forces. These devices will not provide enforcement, but will provide the same level of message exchange between the office and field to ensure reliable information is transmitted to the field as will be done with the on-board systems.

Quantum Engineering also has a portable “Train Sentinel®” to be used for foreign line locomotives used on OCRS on a temporary trackage right basis. These devices will provide enforcement with the same level of message exchange between the office and field to ensure reliable information is transmitted to the field as will be done with the on-board systems. This device will also entail GPS locations and proximity locations for trains in the general area.

5 CONCEPTS FOR THE PROPOSED SYSTEM

OCRS PTC efficiencies will be achieved through the integration of the various subsystems. The Q–CAD subsystem will encompass a broad range of tools that permit the train dispatcher to monitor and control the entire network, and to have full software backup in the event of a hardware failure. The ability to perform database replication and backup to a different site assures business continuity. The Q–CAD system enables the train dispatcher to automatically coordinate and manage train movements, monitor the operation of signaled and non-signaled territories, and access information and reports regarding train performance, composition, and scheduling.

The Q–CAD system provides a "point and click" environment for the dispatcher to execute, Positive Train Control (equipped), Track Warrant Control (unequipped), train bulletin/message functions, an FRA acceptable train sheets, and dispatcher transfers.

For the project, the OCRS territory defined for the project will be TWC territory. The other functionality will also be provided as mandated through OCRS personnel. OCRS PTC safety enhancements are achieved through a communication-based train control system that enforces movement authority and speed restrictions for communicating with equipped trains. Maintenance vehicles may also be included in the delivery mechanism, but enforcement can only be provided through audible notification. The electronic delivery of authority, and restriction data replaces the voice communicated equivalent and eliminates transposition errors, miscommunication, misunderstanding, and the time consuming repeat process.

With the OCRS PTC operation, equipped trains will be issued electronic movement authorities and Track Bulletin information. With the equipped locomotives, these active authorities and restrictions will contain an enforcement flags that will define enforceable limits of movement and speed. Significant safety is obtained by not authorizing overlapping authorities to directional trains and maintenance vehicles except in situations where work is to be performed. Failed equipped locomotives will revert to verbally issued TWC directives.

Under a full deployment, the controlling locomotive of a train consist has track topography, track characteristics, and civil/permanent speed restrictions resident in the OBC. The OBC database is under configuration control. Specific bulletin types will be delivered from the Q–CAD system prior to departure from the originating terminal. This is completed prior to departure to provide a route "view" of the restrictions to the train crew.

The locomotive will receive an incremental authority as it traverses its route and the proper bulletins will be appended to each authority. Each individual restriction will have a unique identifier. Machine to machine, and human acknowledgement will assure the correct receipt of the relevant information. The locomotive segment confirms the locomotive's location, via the location segment, and enforces authority and speed limits by monitoring the train's location and speed, providing alerts to the locomotive operator of impending restrictions, or limits, and applying the brakes to stop the train if necessary to prevent a violation.

5.1 Background, objectives, and scope

The Ohio Central Railroad is a network of ten Class III Common Carrier railroads providing freight service throughout Eastern and Northeastern Ohio. While each railroad is an independent corporation they are commonly controlled and managed. As a smaller Class III, OCRS is interested in developing alternative means to facilitate traffic throughput over their network. With a CTC system, the human is still responsible for the activities on the locomotive. Failure to stop at a signal or switch or slow for a speed restriction is purely a manual effort.

OCRS is interested in a PTC project that can be implemented on a small scale and provide its management with the necessary information for defining the future of its railroad. The demonstration will be operated on TWC territory and has a relatively low volume of though traffic as well as local traffic. Train traffic will average 4-6 trains a day. While the Federal Railroad Administration and the National Transportation Safety Board have promoted the use of PTC as a mode of operations, OCRS will approach this demonstration as a means to provide practical and achievable results from the project.

5.2 Operational policies and constraints

OCRS Operating Rules will be used to manage trains over the territory and the interrelationship of MOW forces on the track. As expected, no additions or deletions to the OCRS Operating Rules will be necessary in order to maximize the ability to perform under the PTC or equipped train mode.

5.3 Description of the proposed system

Proper use of the OCRS PTC System should provide safety and efficiency gains that are not quantified at this time. The entire system is comprised of the Q–CAD Dispatcher Control System, Quantum Engineering's "Train Sentinel® System" and GPS technology. There is also a need for a communications conduit, which will be the current VHF radio network.

Track Configuration

Under the OCRS – Positive Train Control System, implementing the PTC concept requires that operational objectives will be achieved through a thorough understanding of the railroad operation. PTC track sections are initiated with an emphasis on diverging routes from the main track operations. Another consideration is establishment of track sections where hi-rails are permitted to enter and exit track locations. Yards tracks will not be controlled through PTC operations, but speed will be monitored and enforced. The size of the track sections will be determined based on the operation.

System Environment

The system provides locomotive on-board and office safety functions designed to prevent a locomotive/train from violating its authority and speed limit and thereby eliminating train collisions. The system backbone includes a database derived from a Global Positioning System survey of the rail infrastructure, and a communication infrastructure. System

implementation of the OCRS PTC should enhance safety far sooner and more economically than could be done through a conventional in-cab safety system or through existing or developing technical alternatives (not quantified at this time). The objective of the OCRS – Positive Train Control System development is to increase the safety of train operations to a level approaching that attainable through a Positive Train Control (PTC) system without the expense of the specialized hardware and software required for a traditional Automatic Train Control (ATC) system. Another objective of the OCRS PTC should be the protection of the train and crew by taking human factors into play and assisting or alerting the crew to abnormalities in the operation.

The fundamental difference between the previous and current alternatives is the fact that the components of the OCRS PTC System are in revenue service use today within the rail industry. As a result, the focus will be on integrating the system components and analyzing the rules implications necessary to implement the system on OCRS.

The proposed safety enhancements include:

- Digital delivery of authorities and restrictions (in conjunction with PSP submittal)
- Authority limit enforcement
- Speed Limit enforcement

System Fallback

When equipped locomotives are given electronic movement instructions, the operations will be Track Warrant Control operations. The train dispatcher view of the system is block oriented, but instructions are delivered by milepost. Most limits of authority will be to a switch or a published milepost location. Any roll-up will occur through the same noted physical locations. If the operation involves unequipped, non-communicating, or failed equipment, the fallback will be to Track Warrant Control. The fallback operations utilized with the OCRS will be as simple as the following:

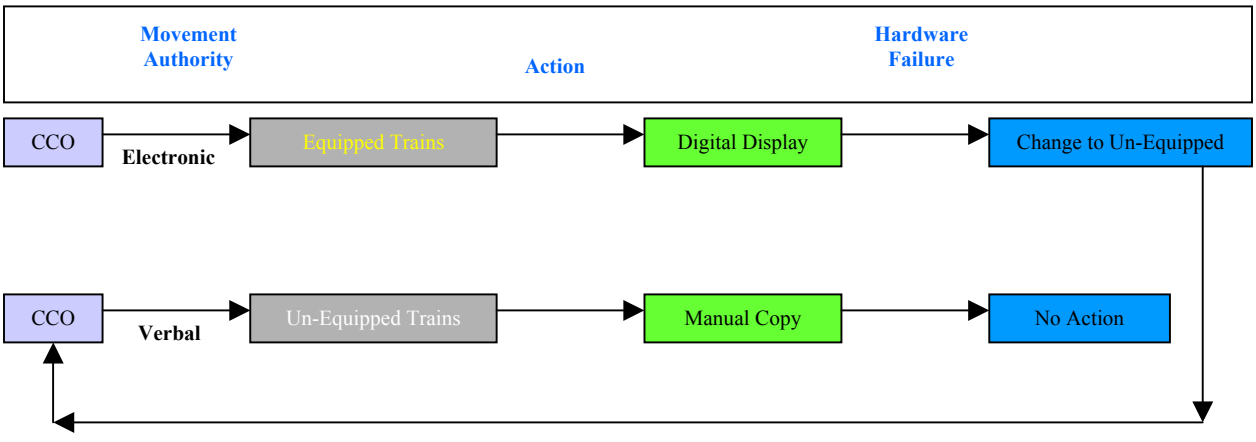

Figure 5.3 System Fallback

System Architecture

The system architecture is comprised of the following:

- The railroad database
- GIS
- Key data systems

The Railroad Database

Electronic authorities are granted to, and electronic speed restrictions apply to the location of these attributes along the track. Therefore accurate location of these attributes within the database, and configuration management practices pertaining to database changes affect the safe operation of trains. Attributes include but are not limited to station signs, milepost signs, switches, signals, speed signs, highway grade crossings, failed-equipment wayside detectors, locomotives, vehicles, grade and curvature.

To obtain the location accuracy required by the proposed GIS applications, working with Quantum Engineering, OCRS supervisory personnel will assist in providing a mapping survey that employs a GPS receiver.

OCRS and Quantum Engineering will utilize the commercial application of the L1 - the primary L-band carrier used by GPS satellites to transmit satellite data. OCRS PTC will utilize the L1 standard of 10 meters accuracy and demonstrate this level of accuracy meets the performance based functionality proposed in 49CFR236 part H. There are no parallel tracks on OCRS controlled territory that exceed this system's resolution.

The Quantum safety case for not using the FRA prescribed 2.2 meters accuracy is that the design of the system does not reflect the need for such finite accuracy. The design of database dictates that a train will have to stop prior to its encounter with a "device." Whether this will be a switch, station sign, or milepost marker does not prescribe the need for the 2.2 meters. As an example:

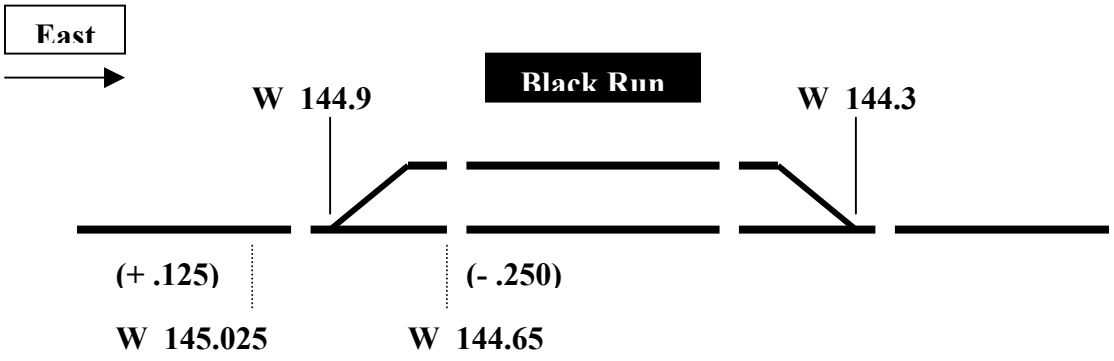

Figure 5.3 GPS Accuracy Description

If a train is heading east toward the siding (Figure 5.3), Black Run, the system will not enforce a braking curve to the switch, it will enforce a stop at the fouling point (W 145.025 or 660 feet from the switch). If the train is running against the switch, or westbound, the braking curve is enforced to the fouling point (W 144.65 or 1320 feet from the switch). The figures used are examples, with each device having its own topography and Train Sentinel® is tabled to reflect the OCRS railroad's conditions for safe fouling points. The need to stop the train at 2.2 meters does not justify the safety requirements that Quantum Engineering has built into the system to provide a level of safety that protects the train and crew with these additional safety parameters.

Train Sentinel® has not been designed to bring the nose of a locomotive to the switch point. Even with the most finite GPS, topographical errors may be evident or a point may exist where there is no GPS available (jungles, tunnels, mountains, etc.). Therefore, the design to a safe point, or in this example a fouling point, determines a safe perspective for stopping.

A railroad may utilize an equipped hi-rail vehicle or locomotive with mapping systems and GPS receivers to capture infrastructure changes.

Geographic Information System

The project will utilize a data repository to house a database that accurately reflects the assets and the asset's attributes correctly. A Geographic Information System (GIS) is the necessary utensil to accomplish this purpose. GIS is comprised of a computer system that records, stores, and analyzes database information about the features that make up the infrastructure of the railway.

Key Data Features Overview

The key data features, that will make up the data model which will be built to house the assets or objects identified in the infrastructure, will consist of many standards attributes that will be reflected in different columns of the database. Each of these assets or database objects will have physical properties to describe them, as well as geographic features to help relate their position with regards to the earth. These objects are identified in the table below:

5.3.1 Train Sentinel®

5.3.1.1 Locomotive Equipment

The Quantum Train Sentinel® on-board computer system consists of several distinct task based subsystems. These systems have checks and balances to achieve maximum fault tolerance. Of primary importance is the monitoring of conditions between the on-board computer (OBC) and the power/braking control system. In addition, the monitoring of various input/output capabilities of the computer insures data integrity.

5.3.1.2 On-Board Computer (OBC)

The Train Sentinel® system utilizes an on-board computer (OBC). The OBC is the central processing center on the locomotive. It integrates all information to and from the locomotive, and commands the various subsystems to perform the necessary functions to insure a fail-safe system. The On-Board Computer (OBC) insures each equipped locomotive operates within designated areas in a safe and controlled manner. The system integrates the dispatcher office with various wayside devices, and on-board computer (OBC) and Global Positioning Systems (GPS) technology to determine the location of the equipped locomotive and to ensure routes are safely lined for approaching locomotives/trains, and that authority to occupy upcoming track is on-board.

Fail-safe operations is applied to the on-board systems such that a failure of the on-board computer or locomotive control system will automatically bring the vehicle to a safe stop. Various parameters of the locomotive are monitored as well as those systems necessary to move and safely stop the locomotive. Should any of these items exceed safe levels, the locomotive is halted, and movement requests denied. The locomotive on-board systems continuously check its current location comparing it to not only what track it is allowed to occupy, but also which near-by tracks it is not authorized to occupy. Braking algorithms will be applied whenever the locomotive approaches the end of existing limits, or whenever the train speed is anticipated to exceed that authorized for the track segment it now occupies.

5.3.1.3 Locomotive Display

The Train Sentinel® Locomotive Segment includes a Human Machine Interface (HMI) for the train crew. The flat panel display is ruggedly designed to withstand typical locomotive vibration and temperature extremes, and environmental conditions such as dirt, dust, and diesel exhaust, and has push-button keys for operator input. The display utilizes user-friendly concepts of display flexibility and easily understood control inputs. The HMI displays necessary operating information to the crew; train status, commands, consist information, authorities, restrictions, and topographic information. All indicators and pertinent authority information is viewable on the flat panel screen(s). The display has a sub-screen to indicate the status of the GPS system, the current status of the locomotive/train speed coupled with a track warrant pictorial, showing where the locomotive/train is in relation to existing speed and authority limits. Displays are presented in both text and graphics. The display shows the relative stopping distance, in feet, from the present location to the stopping point based on the relative deceleration. An audible warning is contained within the flat panel to alert the operator should the train approach the authority limit, or attempt to exceed the boundary condition of the brake/stopping profile.

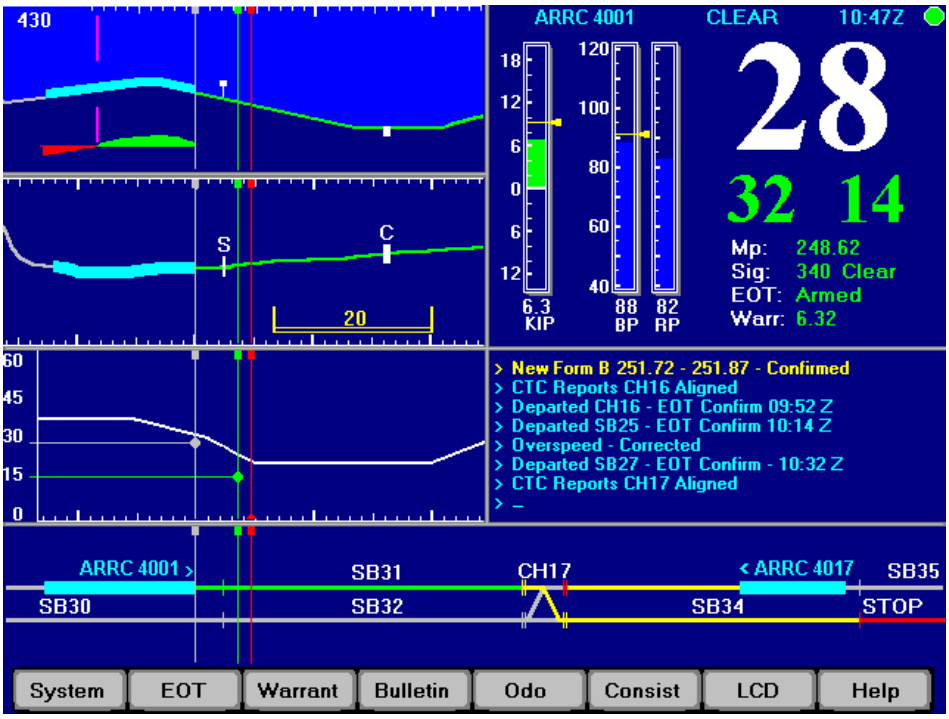

Figure 5.3.1.3 Locomotive Display

5.3.1.4 GPS/Internal Navigation System

The on-board Train Sentinel® System relies on two inputs for position data. The primary system is the inertial navigation system employing the end of axle generator. This is supported and corrected by the secondary global positioning system (GPS) and a map-matching algorithm that further defines and verifies the correct location of the locomotive. If the system loses GPS or is unable to correlate the GPS data to a location within the known limits of the territory, the system reverts to the inertial navigation mode, notifying the crew and dispatcher that the system is operating in a degraded mode. In the event of a complete failure of the navigation system the OBC will declare a fault condition and stop the train, or force the manual operation of the train, in a default or fallback mode requiring verbally transmitted authorities, and signal indications of a traffic control system until the anomaly is cleared.

5.3.1.5 Recording Train Sentinel® Events

Train Sentinel® keeps available all delivered information that has been transmitted to the train crew. This is part of the HMI for stored data and can be access by the train crew. All of the messages sent by Quantum – CAD (movement authorities, train statistics, track bulletins, etc.) and all the information and message acknowledgements sent by the train crew are keep in a database of Q – CAD. The retention of this information is logged on the servers indefinitely for use at any time.

5.3.1.6 Locomotive Control System

The locomotive control system is comprised of a number of locomotive inputs to determine the operation of the locomotive and whether the locomotive can continue operation. Such items as brake pipe pressure, speed, throttle position, and alerter function are monitored on a continuous basis to insure proper locomotive operation under the given authority. In addition, the locomotive control system employs a braking subsystem tied into the existing locomotive piping and utilizing locomotive resident hardware (e.g., a P2A valve) to induce a penalty application of the brakes if the system determines either the authorized speed has been, or will be exceeded, or the limit of authority will be exceeded if a brake application is not made. The locomotive control system will operate under a concept that if power is lost to the control system, all power applications to the locomotive (throttle setting, excitation, etc.) will immediately cease and a brake application at the service rate will be made. In this type of failure, the engineer can regain manual operation of the locomotive by placing the locomotive in the unequipped or cutout mode. When placed in an unequipped or cutout position, a message is immediately transmitted, if possible, to the dispatching center, informing that the Train Sentinel® system on-board the locomotive is under manual control, forcing a verbal delivery of authorities and speed restrictions to that locomotive.

5.3.1.6.1 Power Braking System (PBS)

The power/braking system will have multiple inputs generated by the computer, and multiple outputs fed to the computer. The power braking sub-system will have a power supply separate from that used by the computer. The power/braking sub-system will utilize a "gravity-default" design such that if power is lost, full service brake application is automatic, and the ability to apply power to the locomotive will be removed.

In the event any failure of this system occurs, locomotive operation is halted and a message, if possible, is sent to the dispatcher giving notification of the event. The engineer may take manual control of the locomotive. However, when the engineer does so a message is transmitted, if possible, to the dispatcher advising that a manual locomotive is operating within the Train Sentinel® equipped subdivision. The "failed and/or cut out" locomotive is uniquely identified to the dispatcher via the dispatch system. The locomotive engineer will be required to contact the dispatcher for approval to cut out PTC (required in 236.567) because some failures may be of a nature that when cut out, no transmission will occur.

5.3.1.6.2 Power Braking System (PBS) CPU Monitor

The CPU integrity line is used by the PB sub-system as an input. The PB sub-system will allow the computer to control the locomotive only when the CPU integrity line indicates the on-board computer is fully functional.

5.3.1.6.3 PBS Air Pressure Monitor

Air pressure transducer measurements are forwarded to the on-board computer to insure all air pressures exist at levels insuring safe operation. If the EOT brake pipe pressure falls below approximately 60 psi, the train crew is notified of the problem to take corrective action.

5.3.1.6.4 Braking Algorithm

The Train Sentinel® on-board computer (OBC) will be employed to determine the stopping distance necessary to always stop short of the limit of authority, including Form B track bulletins, and speed restrictions both temporary and permanent. This algorithm incorporates detailed consist data and track profile data to improve the accuracy of the calculation. The train consist data is electronically generated to Train Sentinel® before the electronic Track Warrant is generated. The train dispatcher is responsible for sending this information. If the train crew enters the information first, the dispatcher has to approve the train consist data before it is loaded into the OBC. The algorithm that determines safe braking distance is instrumental to maintaining present levels of productivity. By knowing the train makeup (loads, empties, tonnage, locomotives), track location, and speed of the train at all times, the onboard computer will constantly update Train Sentinel® as to the relative stopping distance needed for each train.

In the interest of crew safety, audible and visual warnings are always given at or before the time of enforcement brake application. In cases of predictive enforcement, the engineer is allowed time to take corrective action following the warning before enforcement braking occurs. If the engineer has not taken appropriate action within a specified number of seconds after the warning, braking is applied. In cases of reactive enforcement, the system initiates braking simultaneously with the warning, although the time lag between the application of braking and its effects allow for a de facto alert to the crew that the train is going to be stopped.

5.3.2 Train Sentinel® Operational Description

Train Sentinel® operations can be divided into the major functions that are used to manage the movement of trains. The Description of Operations is organized according to these major functions:

- Locomotive Initialization.
- Train Initialization.
- Train Movements.
- Speed Restrictions.
- Train Termination.

5.3.2.1 Locomotive Initialization

Each Train Sentinel®-equipped locomotive undergoes initialization in order to ensure that all necessary data (e.g., latest version of track profile) is on board and matches the master track database prior to departure. The onboard track map will be validated with Q-CAD for the proper version. A reliable message delivery protocol is used to establish with a high level of confidence that the track profile on board each OCRS – Positive Train Control System, Train Sentinel®-equipped locomotive is error free, complete, and up-to-date.

5.3.2.2 Train Initialization

At various times, typically before a train's departure, the OCRS – Positive Train Control system will be given dynamic train data. This will include the Q–CAD system, and the locomotive on-board computer (OBC). This dynamic train data will be used to allocate track, as appropriate, based on the Q–CAD supplied movement authorities. The dynamic train data includes the following:

- Train ID.
- Locomotive consist (quantity and types).
- Train consist (quantity and types).
- Planned consist changes (adding/deleting locomotives, car pickup/setouts).
- Displayable Authorities and Bulletins.
- Movement Authorities.
- Speed Restrictions.

Before departing, a train must be defined with a locomotive consist and movement authority generated by the Q–CAD system; but, the OCRS – Positive Train Control System, Train Sentinel® system, will be designed to handle receipt of additional and changing train data throughout the life of the train.

OCRS and Quantum Engineering intends to comply with the daily inspection of the Train Sentinel® onboard equipment as outlined in 49 CFR section 236.587, in the following manner:

1) Each CRT display (engineer/conductor) has an icon displaying whether the GPS satellite signal is available. If unavailable the system is inoperative and the train will be operated as unequipped.
2) Each CRT display (engineer/conductor) has an icon displaying whether the Communications Module is connected to the VHF data network. If unavailable the system is inoperative and the train will be operated as unequipped.
3) Each day a test of system operation of the P2A will be performed, using the Train Sentinel® onboard equipment. The test person or engineer can invoke the dumping of the P2A using the soft keys and menu used for this purpose. Prior to attaching the locomotives on the train consist, the P2A shall be commanded to dump from Train

Sentinel®, with the automatic brake in release and the independent brake released. If the P2A does not create a penalty brake application onboard the train consist the Train Sentinel® system shall be deemed inoperative.

4) A written record of the daily inspection/test will be kept onboard the locomotive showing date/time/tester name and status of the test.

Compliance to this rule will be followed by OCRS Operating personnel:

§ 236.587 Departure test

(a) The automatic train stop, train control, or cab signal apparatus on each locomotive, except a locomotive or a multiple-unit car equipped with mechanical trip stop, shall be tested using one of the following methods:
  (1) Operation over track elements;
  (2) Operation over test circuit;
  (3) Use of portable test equipment; or
  (4) Use of onboard test device.

(b) The test shall be made on departure of the locomotive from its initial terminal unless that apparatus will be cut out between the initial terminal and the equipped territory. If the apparatus is cut out between the initial terminal and the equipped territory the test shall be made prior to entering equipped territory.

(c) If a locomotive makes more than one trip in any 24-hour period, only one departure test is required in such 24-hour period.

(d) (1) Whoever performs the test shall certify in writing that such test was properly performed. The certification and the test results shall be posted in the cab of the locomotive and a copy of the certification and test results left at the test location for filing in the office of the supervisory official having jurisdiction.

(2) If it is impractical to leave a copy of the certification and test results at the location of the test, the test results shall be transmitted to either (i) the dispatcher or (ii) one other designated individual at each location, who shall keep a written record of the test results and the name of the person performing the test. These records shall be retained for at least 92 days.

5.3.2.3 Train Movements

Authority granted by the Q–CAD system is required for a locomotive/train/MOW to occupy a track. Once the authority is received on board, the system will permit the engineer to operate the locomotive/train over the authorized track. The system may receive authority from the dispatcher system for each Train Sentinel® equipped train. The dispatching system generates a movement authority, a Work Between, or another form of authority for a train, which specifies the route for which the train has authority. The on-board displayable authority is a textual, and graphical representation of the train's authority. The authority is passed from the dispatching system without modification to the Train Sentinel® Locomotive Segment and made available to the crew via the Locomotive HMI.

Train Sentinel® has a representation of the railroad's track in the on-board database. The Q–CAD system allocates track to all trains, unequipped and Train Sentinel®-equipped trains with respect to their movement authorities. The Train Sentinel® on-board system, using the track profile, allocates track based on the received authority. A single train may occupy a track section, also referred to as an occupation block. In special situations, a dispatcher may place more than one train in the same track segment using a joint authority.

Loss of communications from the wayside (base station or wayside device) to the locomotive for a prescribed period of time (railroad selectable and factory programmable) will result in the locomotive/train being able to operate to the last limit of authority, only. Once communication has been reestablished, the locomotive will be allowed to continue, with the current movement authority or with a new one delivered after the restoration of communications. The Q–CAD system maintains a database of allocated track and will not release the tracks to available usage unless a valid Track Warrant, dispatcher actions, or automatic Train Sentinel® roll-up has occurred (See Glossary – Rollup). Unless there is a positive indication by the train crew, train dispatcher, or Train Sentinel® roll-up, the territory behind the train will remain as part of the authority for the train, no overlaps can occur. This activity will preclude any locomotive operating into the path of another, even if a most catastrophic event occurs which would render the digital communications system totally inoperative. In this case, operations would revert back to Track Warrant Control (TWC) operation without the Train Sentinel® system.

5.3.2.3.1 Displayable Authorities

The OCRS – Positive Train Control system has the capability to accept the following displayable authorities:

A Train Movement Authority (TWC) is used in non-signaled territory to authorize a train to occupy the main track within designated limits. The train must travel in the direction specified only, unless authorized by bi-directional authority for the purpose of performing work.

Train movement authorities can overlap when two or more trains are authorized with a "Work Between," between two specific points at Restricted Speed, or when directional trains are authorized to move through another train's "Work Between" area at Restricted Speed. Rear end flag protection is not required within "Work Between" limits for directional moves. Rear end flag protection is not required due to the Operating Rules specifying that in a "Work Between" with both entities as an indication of an overlap condition, both entities must maintain speeds of less than 15 MPH and operate, looking out for the other entity at ½ the range of vision.

With a Directional Movement Authority, when a reverse move is performed, with permission of the train dispatcher, by a train with Train Sentinel®, the logic is reversed in the system to analyze the rear of the train so as to not violate the rear limit authority active at the time. The system will alarm the train crew of a violation of the rear authority limit, if the train crew does not correct the train handling.

The following Operating Rules have been extrapolated from the OCRS Operating Rules to clarify this section concerning flagging requirements:

6.2.7 Movement at Restricted Speed	When a train or engine is required to move at Restricted Speed, movement must be made at a speed that allows stopping within half the range of vision short of: • Train • Engine • Railroad car • Men or equipment fouling the track • An obstruction • Stop signal, or • Derail or switch lined improperly The crew must keep a lookout for broken rail and not exceed 15 MPH unless authorized by special instructions
6.4 Reverse Movements	Make reverse movements on the main track at Restricted Speed and only within the limits a train has authority to occupy the track.
6.4.1 Permission for Reverse Movements	Obtain permission from the train dispatcher before making a reverse movement.

14.3 Operating with Track Warrants	A Track Warrant authorizes a train or engine to occupy the main track within designated limits. However, the train or engine must not foul a switch at either end of the limits where an opposing train may use the same switch to clear the main track. The train or engine must move as follows: 1. Proceed from one point to another in the direction the Track Warrant specifies. When a crewmember informs the train dispatcher that the entire train has passed a specific point, Track Warrant authority is considered void up to that point. or **2.** If authorized to "WORK BETWEEN" two specific points, the train or engine may move in either direction between those points without flag protection.
14.4 Occupying Same Track Warrant Limits	Only one train can occupy the same or overlapping limits of a Track Warrant except when: 1. Two or more trains are authorized to "WORK BETWEEN" two specific points at Restricted Speed within the overlapping

	limits, or, 2. Trains are moving through the limits of another train authorized to "WORK BETWEEN" two specific points, and Track Warrants have instructed all trains to move at Restricted Speed within the overlapping limits. Flag protection is not required within these limits. Where Track Warrant authority includes yard limits, the terms of Rule 6.13 (Yard Limits) apply, but Track Warrant instructions must be followed.
14.5 Protecting Men or Equipment	Men or equipment may receive a Track Warrant in the same manner as trains to occupy or perform maintenance on the main track without other protection. A Track Warrant must not be issued to protect men or equipment within the same or overlapping limits with a train unless All trains authorized are notified of the men or equipment and have been instructed to move at Restricted Speed. Also, a Track Warrant must inform the employee in charge of men or equipment about the trains. If the track is not safe for trains to move at Restricted Speed, the employee must protect the track with red flags according to Rule 5.4.7 (Display of Red Flag or Red Light).

Note that Train Sentinel® does not enforce train separation in a joint "Work Between" limit, but does enforce Restricted Speed (15 MPH). At Restricted Speed it is not necessary to enforce train separation in overlapping track areas due to the Operating Rules.

Train Sentinel® stores all of its' delivered Movement Authorities and these are available for review on the OBC screen at any time by the train crew. Each locomotive with Train Sentinel® cannot see or review messages assigned to another entity, but Train Sentinel® will display movement authority information that is applicable to other equipped trains within its' vicinity. The Current Movement Activity window will display the current (and next, if issued) Movement Authority under which the train is currently operating. The crew may review more detailed information about specific instructions or authorities by use of the OBC screen.

However, Train Sentinel® can receive and display the locomotive number, location, and speed of any Train Sentinel® equipped train in the vicinity. This information is updated as the other train moves. The incumbent train cannot tell what movement authorities are on the other trains but can see the intended movement within the vicinity of the incumbent train.

All of the displayable authorities described above are available for display on board the locomotive. The Current Movement Activity window will display the current (and next, if issued) movement authority under which the train is currently operating. The crew may

view more detailed information about specific instructions or authorities by selecting the Movement Authority Summary window.

In all cases on OCRS the method of operations remains TWC.

When Train Sentinel® is active for equipped operations the method of delivering TWC authorities will be by digital communications to the OBC with display to the crew on the locomotive's LCD screens.

When Train Sentinel® is not active for equipped operations the method of TWC authority delivery will be by voice radio per 49CFR220.61.

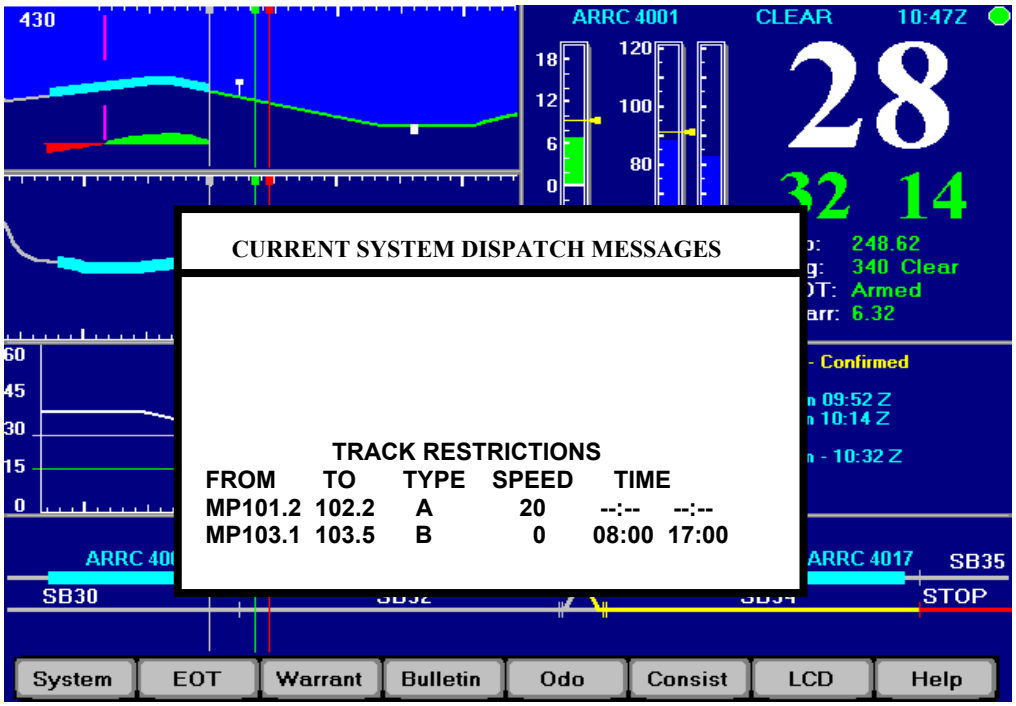

Figure 5.3.2.3.1 Authority Displays

5.3.2.3.2 Movement Authorities

The OCRS – Positive Train Control System protects trains and maintenance personnel and equipment by allocating the track on which the dispatching system has authorized them to travel, or work. The allocation is accomplished through TWC and are allocated in accordance with operational parameters identified by the railroad. Main Track and any sidings that are considered "controlled track" and as such require authorization for occupancy. Switches can be a dispatchable component of the track architecture. Track is allocated to the trains and equipment via Train Movement Authorities, TWC Authorities and Work Between Authorities that identify the individual track segments the train or equipment is allowed to traverse.

Movement authorities in non-signaled territory are based on authority types (TWC), along with specific operational rules. The dispatching system applies the rules, as appropriate,

when generating an authority for the train. The dispatching system generated rules are based on the rules of train operation and include the following:

- Forward Moves.
- Reverse Moves.
- Following Moves.
- Bi-directional Moves.
- Clear of Main.

5.3.2.3.3 Authority Enforcement

A primary goal of the OCRS – Positive Train Control System is to improve safety by enforcing movement authorities such that no actual violation of an authority occurs. The Train Sentinel® System predicts an imminent violation, alarms the train crew of the potential violation, and can prevent it from occurring. This is referred to as predictive enforcement. However, there are some scenarios where Train Sentinel® cannot prevent an authority violation. An enforcement that is initiated after the violation has occurred is referred to as a reactive enforcement. An example of this is a temporary speed restriction delivered to the train after the train has already entered the track that the speed restriction resides. Train Sentinel® will not force a train into emergency if the train is on top of the newly delivered restriction. But the train crew will have the information displayed on Train Sentinel® display.

The Quantum Train Sentinel system treats all potential violations of limits of authority or speed restrictions, both temporary Form A, B, or permanent speed restrictions, as an over speed condition. The onboard equipment creates a braking profile for all speed conditions based on train consist and actual train speed. A braking curve is presented in real time to the train crew via the onboard display. As long as the train is operated at a speed at or below the braking curve maximum authorized speed threshold, no action is taken by Train sentinel. However, if the braking curve envelope is exceeded, Train Sentinel first warns the crew of the "overspeed" condition. If the crew takes no action to place the train into compliance with the braking curve, in other words does not reduce train speed to at or below the specified braking curve speed for that location, train Sentinel will cause a penalty brake application and stop the train, also notifying the dispatcher automatically of the event.

In the case of a limit of authority, the braking curve is gradually reduced from maximum authorized speed to "0" MPH at the limit of authority based on the train consist and train speed. As the train approaches the limit of authority the braking curve is reduced. As long as the train is operated at or below the braking curve threshold no action is taken. Should the train exceed this braking curve the crew is first warned of the overspeed condition and if no action is taken to place the train in compliance with the braking curve, the train is placed into a penalty application and brought to a stop also advising the dispatcher.

In the case of permanent or temporary speed restrictions, the braking curve will show a gradual reduction into the start of the speed restriction. If the train crew exceeds the braking curve speed, the crew is first warned and if no action is taken the train is given a penalty brake application to stop the train and advise the dispatcher.

The Train Sentinel® Locomotive Segment will notify the crew of a pending enforcement action, if possible. If the crew initiates a full service brake application during the pre-enforcement warning time, the pre-enforcement audible and textual warnings would terminate and the penalty application would be averted. After the initiation of the enforcement and the accompanying enforcement warning, prompt action by the crew may not be sufficient to avert the enforcement action. The Train Sentinel® system may not have sufficient time to determine that the braking actions of the crew will prevent a violation, so the penalty action may occur regardless of their action.

5.3.2.3.4 Train-to-Train Positive Train Control

Train Sentinel® employs a radio telemetry OCRS – Positive Train Control system. Information will flow between locomotives and the dispatching office to provide a master file of all train locations. This system will periodically transmit position location as well as other locomotive specific information to any train in proximity to another train. Proximity warning is achieved through the use of location reporting data. Algorithms within the Train Sentinel® system keep track of all train movements and will warn each engineer of a possible conflict. Train Sentinel® will, if necessary, stop any train(s) that is in danger of colliding. Should this occur, the dispatcher would be notified via the telemetry system through use of an automatic messaging protocols.

5.3.2.4 Speed Restrictions

The on-board Train Sentinel® System receives speed restriction information from the Q–CAD dispatching system for each equipped train. The speed restriction information includes restrictions derived from Form A and Form B bulletins issued to the train. The bulletin is passed from the Q–CAD system dispatching segment to the Train Sentinel® on-board computer and made available to the crew via the Locomotive LCD screen. The dispatcher system generates all speed restriction for the train, which specifies the actual speed restriction and the limits where the speed restriction is effective. The Train Sentinel® system uses the dynamic speed restriction, along with any existing permanent track and/or train speed restrictions and enforces to the lowest speed restriction. Form F (free form) bulletins are also issued via the Q–CAD system but do not provide information that can be used for enforcement.

The Train Sentinel® system has a representation of the railroad's track in the on-board computer of each locomotive. Using this track profile, the on-board computer manages all the current speed restrictions for the train based on the train's location.

The train dispatcher can enter the appropriate information into Q–CAD, using a Form A or a Form F, to relay (transmit) to Train Sentinel® for the train crew to acknowledge and be aware of their responsibilities under the following 2 sections:

PART 234_GRADE CROSSING SIGNAL SYSTEM SAFETY

Subpart C Response to Reports of Warning System Malfunction

Sec. 234.105 Activation failure.

(3) If there is not an appropriately equipped flagger or uniformed law enforcement officer providing warning to highway traffic at the crossing, each train must stop before entering the crossing and permit a crewmember to dismount to flag highway traffic to a stop. The locomotive may then proceed through the crossing, and the flagging crewmember may reboard the locomotive before the remainder of the train proceeds through the crossing.

Sec. 234.107 False activation.

(2) If there is not an appropriately equipped flagger providing warning for each direction of highway traffic, or if there is not at least one uniformed law enforcement officer providing warning, trains with the locomotive or cab car leading, may proceed with caution through the crossing at a speed not exceeding 15 miles per hour. Normal speed may be resumed after the locomotive has passed through the crossing. In the case of a shoving move, a crewmember shall be on the ground to flag the train through the crossing.

Train Sentinel® has the capability to react to highway-rail grade crossing failures by 2 primary methods:

1. By a Form A or For F initiated by Q–CAD, which results in a "zero" speed at the crossing intercept. (prior non-verbal alert to train crew)
2. By interrogation of the grade crossing device by Train Sentinel® prior to the encounter with the crossing, if it device is equipped to communicate.

The train crews will be responsible for the compliance to Sec. 234.105 Activation failure and Sec. 234.107 False activation, as they do currently.

5.3.2.4.1 Bulletin Speed Restrictions

The on-board Train Sentinel® system will handle track bulletins from the Q–CAD system. Form A and Form B are used to effect additional speed restrictions. Form A bulletins typically instruct the train to travel at less than the normally authorized speed due to track condition, such as unstable ballast due to water erosion or extremely high temperatures in an area. This is normally a temporary condition. Form B bulletins are intended to protect maintenance of way crews and their equipment while performing repairs on or around the track. The Train Sentinel® system has the capability to accept the following displayable bulletins:

- Form A
- Form B
- Form F

Note that various railroad may provide additional bulletin formats that can be added to the system.

Two options exist to provide bulletin information to trains. The options include an initial bulletin that includes all speed restriction that the train will encounter during the crew's tour of duty, or the dynamic delivery of bulletins matching the authority limits generated to the train. However, occasionally a need arises to notify the crew about a new bulletin, one not listed in the current bulletin.

Unlike permanent speed restrictions imposed by the timetable, speed restrictions derived from Form A and Form B bulletins can be voided. When a bulletin is voided or expires, a configuration option within Train Sentinel® determines the enforcement behavior for a train already within the limits of the bulletin. The configuration option either immediately ends enforcement, or continues to enforce the restriction until the train clears the limits.

OCRS will allow the track foreman, holding the Form B, to issue a speed directly to the train crewmembers that input the dictated speed into the Train Sentinel® onboard computer, which then allows for the train to travel at this new speed, but never over the Maximum Authorized Speed for that track section. When this action is taken by the train crew, the information is relayed to the Q–CAD system and recorded.

Form F bulletins are often used to convey safety information, such as notification of stumbling hazards or other similar information, to the crew. Train Sentinel® will display this information for convenient reference by the crew. Form F Bulletins can also be used for Grade Crossing malfunctions, with speed and milepost. The speed will be set at a zero (0) speed for a Stop and Flag conditions.

All of the bulletins described above are available for display on-board the locomotive. The crew may view detailed information about specific instructions or bulletins by selecting the Track Bulletin button on the display.

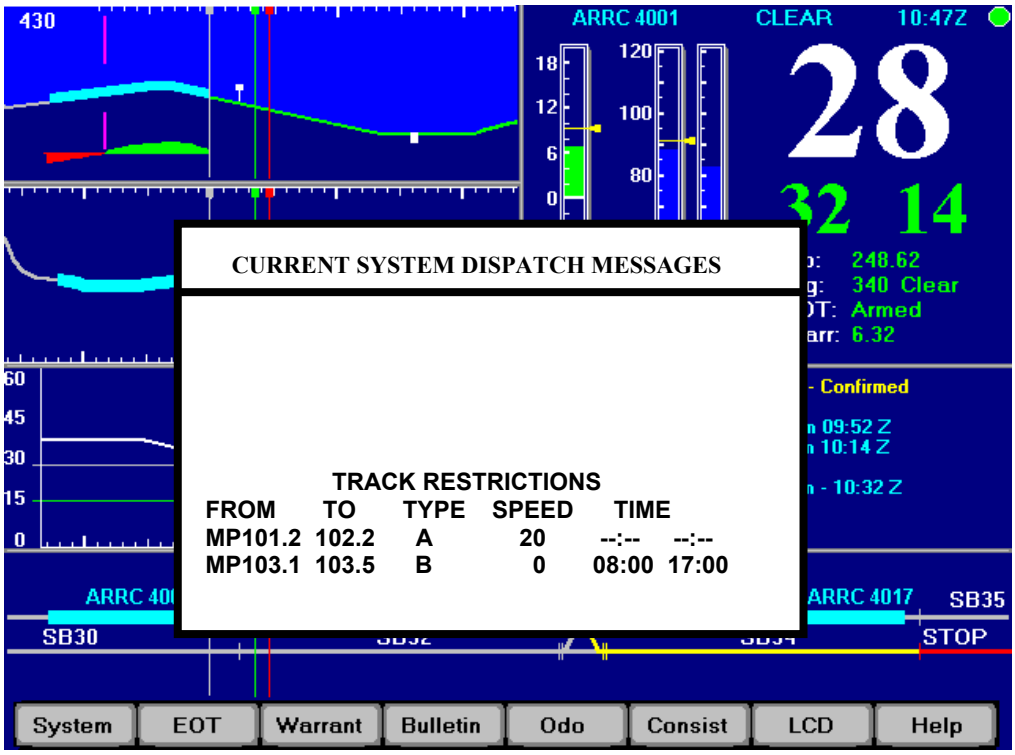

Figure 5.3.2.4.1 Bulletin Speed Restrictions

5.3.2.4.2 Timetable Derived Speed Restrictions

Train Sentinel® OBC enforces various speed restrictions derived from the railroads timetable, including permanent and temporary speed restrictions, restrictions based on the direction of travel, train type, the train's gross weight, and combinations of the above. The Train Sentinel® system can also enforce restrictions due to the presence of a specific car in the consist, such as a car containing hazardous material or restricted to speed restrictions.

The locomotive HMI current movement activity window will display a geographically sequenced list of speed restrictions under which the train is currently operating.

5.3.2.4.3 Speed Enforcement

The locomotive Train Sentinel® system initiates penalty enforcement when such action is required to bring the train into compliance with an upcoming restriction. Enforcement once initiated, continues until the train is completely stopped. In addition, the Train Sentinel® Locomotive Segment will initiate penalty enforcement on a train that has violated the current speed restriction. Speed violations that are minor or of brief duration can be exempted from enforcement by properly configuring the speed tolerance table. Whenever a train is enforced and stopped due to any type of violation, Train Sentinel® sends a message to the dispatcher identifying this condition.

5.3.2.5 Train Termination

From the perspective of the Train Sentinel® system, train "termination" refers to the train reaching its ultimate destination. Once the train is terminated, the system will always provide protection against locomotives not assigned to any train from entering the main track.

Similar to train termination, a Train Sentinel®-equipped train can also exit PTC controlled track, perhaps to enter an industry. Train Sentinel® will not manage the movements of the train or monitor its movements once a train has exited mapped track. The on-board Train Sentinel® equipment will be in a state waiting for initialization and authority to move upon the train's return to regulated PTC track. Note that a Train Sentinel® equipped train leaving the main track, with its entire train, into an industry track, will void its movement authority when Reports Limits Clear is executed by the train crew. The train will not be able to re-enter regulated PTC track until a request is made to the train dispatcher for access to controlled track.

5.3.2.6 Field Operations Description - Communications

Communications between the locomotive and the dispatching system will be periodic. The locomotive will report location to the dispatcher system on a periodic basis (TBD) without prompts from the dispatcher system. The locomotive will always respond to the periodic message generated by the dispatching system. The vast majority will be a "heartbeat", insuring the communications pathways are fully functional. The dispatcher system generated "heartbeat" message will contain only the existing authority number for that locomotive.

Data contained in the reply message will be dependent upon the nature of the message generated by the dispatching office. In response to the issuance or removal of authorities, the locomotive reply message will contain all existing authorities maintained in the locomotive on-board computer. In reply to a dispatcher system generated "heartbeat" message, the locomotive will respond with existing authority number, location, direction, and speed.

Any time that the telemetry signal from the wayside to the locomotive is lost for a prescribed period of time (user selectable and factory programmable) the locomotive will only be allowed to continue to operate to the last limit of authority in the on-board computer. Once telemetry communication has been reestablished, the locomotive/vehicle will continue.

5.4 Modes of operation

For the OCRS test project, the primary mode for mainline operation will be Track Warrant Control (TWC) utilizing a Positive Train Control (PTC) with Train Sentinel as the onboard device for crew information. There will also be Yard Limit territory, under the direction of local forces or train crews. The test project does not have any Centralized Traffic Control (CTC) territory. All sidings will be under the control of the train dispatcher. The fallback for equipment failures or operation involving non-equipped entities will be TWC. For

unequipped trains, the movement authorities will appear as today, as Track Warrant Control (TWC).

5.5 User classes and other involved personnel

The implementation of the OCRS Positive Train Control System will involve many employees representing various crafts. Quantum Engineering will provide OCRS with technical expertise for any of the listed areas. In other areas, QEI engineers and support personnel will provide train-the-trainer instruction to OCRS personnel. An example of the allocation of employees as previously shown is as follows:

- Installation of Train Sentinel® on locomotives
  - OCRS, Mechanical, Electrical
- Installation of Q–CAD in the office
  - OCRS, Communications, Signals
- Training personnel on trouble-shooting Train Sentinel®
  - OCRS, Mechanical, Electrical
- Training personnel on trouble-shooting Q–CAD
  - OCRS, Communications, Signals
- Training train crews on Train Sentinel®
  - OCRS, Engineers, Conductors, Brakemen, Pilots
- Communications between Office and Locomotive
  - OCRS, Communications
- Verbal Communications from Office to Locomotive
  - OCRS, Communications, Train Crews
- Verbal Communications from Office to Engineering Work forces
  - OCRS, Communications, Engineering

6 OPERATIONAL SCENARIOS

6.1 Introduction

This section will describe the step-by-step description of how the proposed system will operate and interact with its users and its external interfaces under a given set of circumstances. The scenarios will be described in a manner that will allow the users to gain an understanding of how all the various parts of the proposed system function and interact. The scenarios will tie together all parts of the system, the users, and other entities by describing how they interact. The outlined scenarios will also describe what the system will not do for the project.

The proposed Quantum PTC System works in conjunction with existing Methods of Operation to protect against the consequences associated with human error. This approach provides for "stand-by safety compliance" for train operations while retaining the existing functionality of the train or maintenance crews. Because the Quantum PTC system continues as an "oversight" operation, a failure or deactivation of the system has the effect only of suspending the safety-provided enhancements without compromising existing systems and/or operating rules. Train and maintenance crews remain the focal point for compliance of operating rules and movement authorities with the added benefit of Quantum PTC as an additional layer of compliance.

6.2 Test Territory

The proposed OCRS PTC project will be initiated in the new Track Warrant Control (TWC) territory. The primary purpose of this territory will be to test the functionality and reliability of the VHF radio network to deliver the electronic messages from the office to the locomotive. The test is also to provide OCRS with the means to increase throughput within the assigned territory without the need for increasing track speed. Currently the means of transacting business on the territory is through a labor-intensive verbal exchange of information between the dispatcher and the train crews.

It is the goal of this project to decrease the verbal interaction of the dispatchers and train crews and increase train throughput. Another factor will be the electronically delivered authorities that are interrogated by the on-board computers for compliance and at the same time deliver the information to the crews without a mechanical means of recordkeeping. Some of the benefits for the project will be to decrease over-the-road time for train crews, thereby reducing train delay; improved safety for train crews and maintenance-of-way personnel; and increase track capacity without compromising safety.

6.3 Mode of Operations – TWC with Equipped Locomotives

6.3.1 Rules Applicable Only in TWC with Equipped Locomotives

The newly implemented Operating Rules will define the rule applications to be used for the OCRS PTC project. The primary application of these rules will be through the use of Rule 9. The use of Rule 6.13 Restricted Speed defines the use of tracks within Yard Limits and apply to speed control of the trains within Yard Limits.

With this project there will be likelihood that trains will be operating within the corridor that are equipped with Train Sentinel® and not equipped with Train Sentinel®. In order to keep traffic moving within the OCRS operational parameters, this mix of traffic will have unique characteristics that will prevail. When the term equipped is designated, it is understood that the on-board computers are fully communicating with the office. When the term non-equipped is implied, this locomotive may be unequipped or have a failed or non-communicating situation. It should also be understood that a maintenance-of-way vehicle that is on the track will be considered non-equipped, unless the vehicle is provide with an on-board portable device that will electronically communicate with the office.

6.3.2 Movement Authorities

The TWC Authority function enables the dispatcher to issue an authority for train movement or maintenance-of-way (MOW) or on-track equipment (OTE) movement in non-signaled (Track Warrant Control) territory, if equipped. This function gives the dispatcher the capability to issue a new authority, recall any unreleased authority, releases all or part of an existing authority, extend an existing authority, or perform a meet/pass.

The train dispatcher will perform an entrance/exit for each movement authority. Tabling within Q–CAD will identify locomotives that are equipped or unequipped. The train dispatcher will list each locomotive in the train consist for the train sheet. When the dispatcher enters a train into tracking, Q–CAD will validate the locomotive as to being equipped or unequipped. With the execution of the entrance/exit, the dispatcher will be displayed with a completed route or a read-back form will appear for the unequipped train.

For unequipped, non-communicating or failed equipment, two (2) types of authorities will govern train activity for movement on the territory:

- ***"Directional"*** Block – A block that may be occupied by only one train at a time. Granted in non-signaled territory and can be used against the current of traffic. Granted for one specified direction. This is the normal single direction movement authority for operating trains. (Equipped/Unequipped trains)
- ***"Joint"*** Block – The block granted to maintenance of way for unscheduled work or for placing two trains in the same block with the following train creeping to the rear end of the train ahead. Speed enforcement will be governed at restricted speed, but Train Sentinel® will interrogate train location for equipped entities. (Equipped/Unequipped trains)

6.4 Train Initiation

The initial request for a train to enter into TWC territory using the OCRS PTC system is primarily determined by:

- Equipped train status
    - On-board computer (OBC) through GPS knows the actual position of the locomotive
    - Track databases determine compliance to instructions

- The train crew will enter the command to initialize Train Sentinel® positioning by keying into the keypad a 3 – 2 – 1. This will notify Q–CAD of a pending train departure.
- When this function is performed Q–CAD will send to Train Sentinel®, train consist information.
- When the train dispatcher is prepared to allocate movement instructions, those instructions will be delivered to the locomotive and a pending route displayed on Train Sentinel®.
- The train crew will have to acknowledge the displayed Track Warrant information before a departure from Yard Limits can be active.
- After Q–CAD has acknowledged the train crew response; Train Sentinel® will generate an additional screen with the limits of the Track Warrant for the crew to read verbally over the radios.
- The train is now ready to depart Yard Limits or non-controlled track.
- Human factors are involved for alerts and compliance

- Non-equipped train status
  - Verbal communication is initiated for every event, in either direction, train-to-office or office-to-train
  - Human factors cannot be determined for compliance

An Example of an Execution of a Request to Enter TWC Territory, with Train Sentinel® (Example)

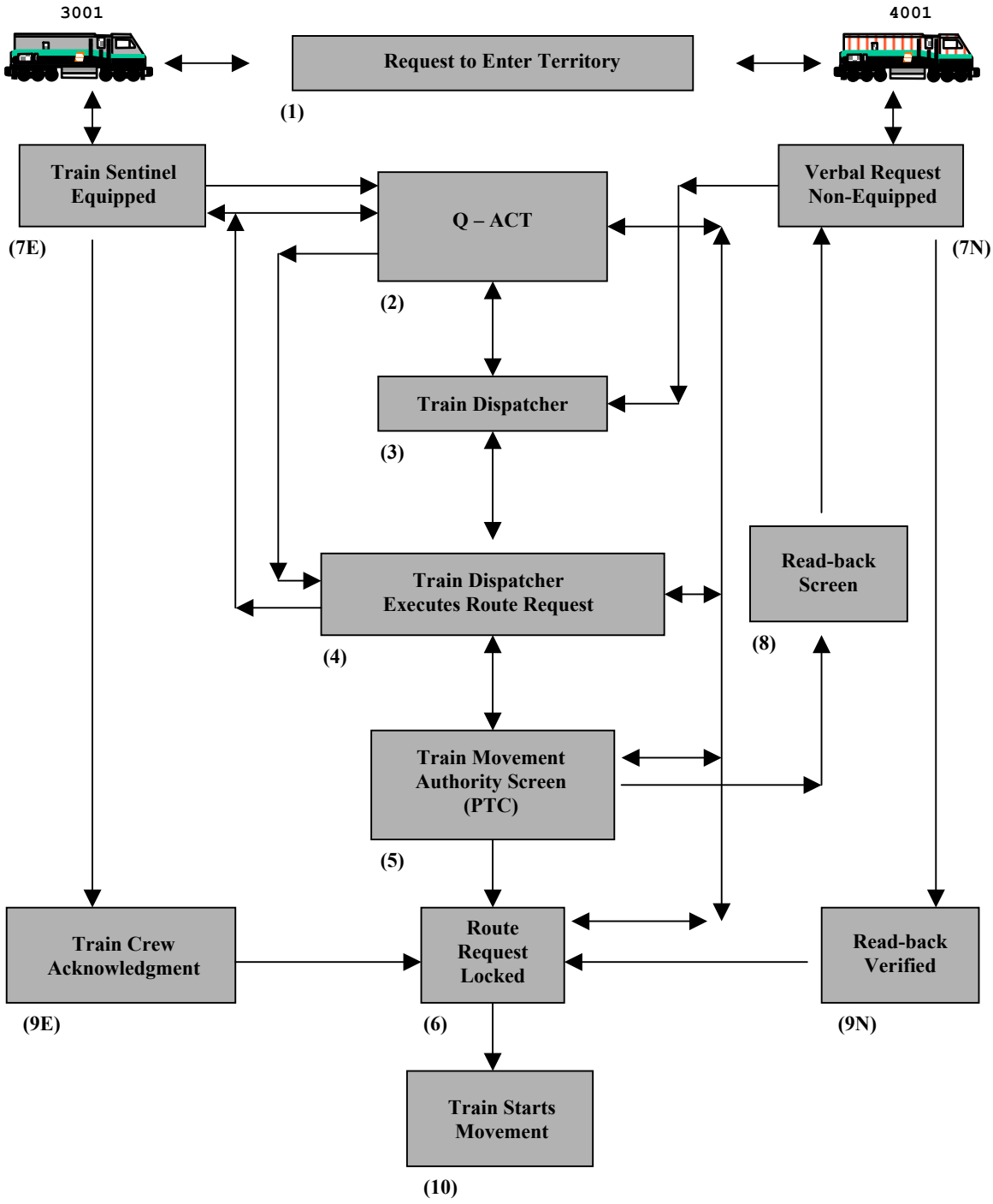

Figure 6.4 Enter TWC Territory

6.5 Operational Scenario – Process of a train to start a movement

This section will outline an example of the process to start a train movement:

From the example noted in Figure 6.4, the following scenario will apply:

- Equipped Trains
    - Train is ready to depart and needs to request entry into PTC designated territory. (1)
    - Locomotive engineer will depress a function key on Train Sentinel® for a request to enter the track.
    - The message is transmitted via the communication media from the locomotive (7E) to the office, Q–CAD (2).
    - Q–CAD notifies the train dispatcher (3) of a pending request for entry into PTC territory. The station designator on the trackline overview display will display a small "yellow arrow" under the station name to show the dispatcher of a pending request.
    - For initial entry onto a track, the dispatcher will designate a starting track (4) that provides the system with a single PTC block for a starting point.
    - The message is relayed from Q–CAD (2) to Train Sentinel® (7E). Also included in this message will be any pertinent instructions for the block, speed restrictions, Form B activity, etc.
    - The train crew will hear an audible alarm of a pending incoming message and the train crew will acknowledge (7E/9E) that message through the HMI interface provide with Train Sentinel® (7E).
    - The acknowledged message is then sent from Train Sentinel® (7E) to Q–CAD (2), and the trackline overview display (6) will display the train on the starting track with a designated occupancy.
    - The dispatcher will then use the mouse to provide the system and train with a route for the train to operate. (Entrance/Exit)
    - This "from" and "to" location is then sent from Q–CAD (2) to Train Sentinel® (7E), along with any pertinent instructions for the block, speed restrictions, Form B activity, etc.
    - Again the crew will acknowledge the route established for the train.
    - Once the acknowledgment has reached the office, the trackline overview (2) display will turn green for the route designated in the request.
    - Train Sentinel® (7E) has also stored the route in its database and has established parameters for movement, based on grade, curvature, speed restrictions, Form B activity, etc.

- Train Sentinel® displays a "read back" screen to the train crew who will read back the track warrant to the dispatcher. Once concurrence with the "read back" the train can initiate the track warrant.
- The train begins to operate over the designated route (10).
- At any time Train Sentinel® determines that track is no longer needed, Train Sentinel® (7E) will send to Q–CAD the position of the rear of the train for the cleared territory, automatically, and the Q–CAD system will roll-up the territory behind the train, thereby releasing available tracks to the train dispatcher.
- At this juncture, two conditions will apply:
  - If the train <u>is in</u> automatic, the next territory in the route, will be delivered to the train automatically and the cleared OS information will be passed back to Q–CAD.
  - If the train <u>is not</u> in automatic, the dispatcher will have to progressively dictate the future route through Q–CAD manually, and the system will automatically roll up the cleared territory behind the train.
  - In either case, the train crew will acknowledge all transmissions that pertain to future route information. Q–CAD will also incrementally deliver the restriction information with each subsequent exchange of information.

- Non-equipped Trains
  - Train is ready to depart and needs to request entry into TWC territory. (1)
  - The train crew has picked up the hard copies of the restrictions, Track Bulletins and messages for the route at the on-duty starting point.
  - Locomotive engineer will verbally call the train dispatcher to identify where the train is located and where it needs to enter the track.
  - The train dispatcher (3) will acknowledge the train and select an entry track and display the TWC Movement Authority screen in Q–CAD. Once the dispatcher has identified the track, Q–CAD will interrogate the system to determine that the train is non-equipped and a pop-up read-back form will appear for the train crew to manually write/read the track warrant and acknowledgement, and the dispatcher to follow along to ensure compliance.
  - This initial track allocation will designate that the train is now shown on a single TWC block.
  - The dispatcher will then use the mouse to provide the system and train with a route for the train to operate, while verbally transmitting the information to the train crew. (Entrance/Exit)

- The pending request will have the track turned to yellow awaiting confirmation by the dispatcher that the read-back has been performed correctly.
- After completion of the read-back and "OK" confirmation, the track will turn to green and the dispatcher may also provide the train crew with any changes to their original track bulletins.
- The train can now move.
- Any subsequent block information and changes to their track bulletins will be transmitted verbally and copied by the train crew.
- This exchange will be performed until the train has been terminated at its destination.
- At this juncture, only one condition will apply:
  - The train is basically handled as a manual process for all activities;
    - Future movement instructions
    - Changes to track bulletin information
    - Exceptions in route
    - Clearing blocks behind the train
    - All verbally transmitted and repeated

6.6 Train Termination

Once the equipped train has reached its destination, if there is a working GPS end-of-train device on the train, an automatic Report Limits Clear is initiated, thereby releasing the current Track Warrant. The train can now operate in the yard with Restricted Speed. Any movement within the yard is allowed, such as, doubling of trains, shoving cars, moving locomotives to the shops, etc. There is no shutdown of Train Sentinel® in order to protect the locomotive from accessing controlled track. If the locomotive is moved toward controlled track, audible alarms will be sounded and if no response is made the locomotive will be automatically stopped prior to entry into controlled track.

6.7 Hardware Failures

If any module becomes disabled for any reason the train crew will notify the train dispatcher and the dispatcher will advise the train crew to perform a cutout procedure. This involves the removal of a breakaway warning tag on the Control Module and flipping a single switch to the "off" position to disable Train Sentinel®. Once this occurs the train will be operated as an unequipped train and receive verbal authorities from the train dispatcher.

7 SUMMARY OF IMPACTS

This section will describe the operational impacts of the proposed system on the Ohio Central Railroad. It will also describe the temporary impacts on users and the support and maintenance organizations during the period of time when the new system is being installed and trained on.

This information is provided in order to allow all affected areas of the project to prepare for the changes that will be brought about by the new system and to allow for planning of the impacts on OCRS, Quantum Engineering, and the support maintenance organizations during the transition to the new system.

7.1 Operational impacts

The Operational impacts for the new system will require minor changes for the Railroad. The installation and maintenance of the Train Sentinel® components will entail an appropriate level of training, but the magnitude of any change will be small.

These impacts may include, but not be limited to, the following:

- Operations with a new office computer system. This has already been accomplished with some changes already implemented;
- Changes in procedure with respect to equipped entities. The ability to execute movement authorities to equipped trains is already resident in Q–CAD. The toggle to change the locomotive from unequipped to equipped has already been exercised by the train dispatchers.;
- HMI training for dispatchers and train crews. Train dispatchers have already been shown the difference between the equipped and unequipped. Train crews will receive the necessary training when the test project begins on the C&N;
- Use of new computer screens to detail more information to the system. Current software deliverables will occur within the next 2 months to improve train sheet reporting and customer designed inquiries to Q–CAD;
- Changes in quantity, type, and timing of data to be input into the system. Equipped trains will deliver more timely data to the system, thereby eliminating the need to ask trains to clear up territory. Train Sentinel® will provide screens for the train crews to enter data that they currently do not perform and that information will be delivered to Q–CAD;
- Changes in data retention requirements and extraction of data.

7.2 Organizational impacts

The organizational impacts to this project will be minimal with no expected changes for the proposed system. The railroad is small and entails only one train dispatcher position per shift, but working 3 shifts a day.

These impacts may include the following:

- Modification of responsibilities. Dispatchers will sometimes be required to initiate new software through periodic cycles. This is a simple process that all dispatchers have already performed. There is no signal maintainer or IT specialist to oversee the Q–CAD operation. QEI engineers have remote access to the Q–CAD servers, l with password protection, to analyze any problems in the system, if needed;
- Training or retraining users. OCRS is a small railroad and frequently new hires and vacations will present a lost opportunity to have every employee trained on every aspect of Train Sentinel® or Q–CAD at the same time. OCRS has supervisory personnel that will identify employees who require additional training and ensure total compliance to system operations will be satisfied;
- Changes in skill levels of personnel. If any new systems are made available for train crews utilizing Train Sentinel® or train dispatcher using Q-CAD, additional training will be performed to increase the skill levels of employees. Efficiency testing is another means to accomplish this task in both the office and onboard the locomotive.

8 ANALYSIS OF THE PROPOSED SYSTEM

This section provides an analysis of the benefits, limitations, advantages, disadvantages, and alternatives and trade-offs considered for the proposed PTC system.

8.1 Summary of improvements

This subsection provides a qualitative summary of the benefits to be provided by the proposed system. For the purposes of this document and the size and nature of operations for the Ohio Central Railroad, a quantitative analysis will not be performed. This summary includes the items listed below, as applicable.

- *New capabilities.* Additional new features or functionality.
    - Quantum Train Sentinel® and the Q–CAD provide OCRS with a higher level of operational opportunities. Q–CAD has been developed to emulate as close as possible the functionality of the current system. The training involved with the new system will not entail a radical change to their current processes. More information will need to be provided to the Q–CAD System.
- *Enhanced capabilities.* Upgrades to existing capabilities.
    - Q–CAD will provide a means to provide more data to the System in order for the train dispatcher to become a better decision maker. The more dramatic improvements will be in the interface between the train crews and the train dispatchers. The use of verbal communications will not be as evident as it exists in the current system. Information will be relayed electronically between the two parties. Train crews will have a visual display of authorities and current locomotive conditions (speed, grade, curvature, braking curve, etc.).
    - After the train dispatcher has initiated a movement authority to the train and the train crew has acknowledged the assigned route, Train Sentinel® will generate from the system another screen that the train crew will read verbally over the radio that depicts the assigned route (milepost to milepost).
- *Deleted capabilities.* Unused, obsolete, confusing, or dangerous capabilities removed.
    - At this time there are no deleted capabilities other than the rule change (April 2007) from Direct Train Control (DTC) to TWC and eliminating the manual block sheets and progressing to the current Q–CAD system. All of the on-board components are *New Capabilities*.
- *Improved performance.* Better response time, reduced storage requirements, improved quality, etc.
    - These include improved line capacity with a more disciplined combination of train pacing and more predictive train location enhancements. The Q–CAD system operates in an environment that provides fast response time to

dispatcher actions. The system is operated within a hot stand-by configuration for automatic fail-over if something should happen to the primary processors. Backup UPS units are also available.

The Quantum Engineering solution of improvements proposed for the Ohio Central Railroad Positive Train Control System integrates dispatcher and on-board equipment with a dedicated communication network that should:

- Ensure system availability, with minimum down-time, even for software upgrades (The system availability can be measured from the PCRC operation in Panama which has had one failure of one LCD screen in the past 3 years)
- Efficiently, non-intrusively, and safely maintain, configure and input database updates (Conops Section 5.3.2.1)
- Alert locomotive crews to authority limits (Conops Section 5.3.2.3.1)
- Alert locomotive crews to speed restrictions (Conops Section 5.3.2.4)
- Stop locomotives/trains prior to exceeding authority/speed limits (Conops Sections 1.3, 4.2, 5.3.1.2, 5.3.1.6)
- Provide an efficient, intuitive user environment through the appropriate use of user interfaces. (Conops Section 5.3.1.3)
- Provide for equipment failures or loss of communications while trains or equipment are active on the territory. (Conops Section 5.3, subcategory System Fallback, Figure 5.3)

8.2 Disadvantages and Limitations

This subsection provides a qualitative summary of the disadvantages and/or limitations of the proposed system.

Disadvantages may include the need to retrain personnel for new processes, rearrange work areas, or change to a new style of user interface. Limitations may include features desired by users but not included, degradation of existing capabilities to gain new capabilities, or greater-than-desired response time for certain complex operations.

8.3 Alternatives and trade-offs considered

At this time, all parties on the project have not identified “Alternatives and trade-offs” for this project. Based on the size of the railroad, number of trains, and personnel involved, everything identified has been straightforward and is being implemented. The use of the PTC environment should be based on the culture of the railroad to support the change from verbal to electronic communications. That may be the largest trade-off.

9 GLOSSARY - ACRONYMS

ACT	Advanced Control of Trains
ATC	Automatic Train Control
Q–CAD	Computer Aided Dispatch System developed by Quantum
CONOPS	Concepts of Operations
DTC	Direct Train Control
ECN	Engineering Change Notice
GCOR	General Code of Operating Rules
GIS	Geographic Information System
GPS	Global Positioning System
HMI	Human-Machine Interface
OCRS PTC	PTC project on the OCRS railroad
OBC	On-Board Computer
PBS	Power Braking System
PTC	Positive Train Control
SBD	Safe Braking Distance
SPR	System Problem Report
TWC	Track Warrant Control

10 GLOSSARY – DEFINITION OF TERMS

Absolute Signal

A block or interlocking signal without a number plate, or designated by an "A" marker.

Acknowledgment, Machine-to-Machine

Computer-generated message, sent from a Train Sentinel®-equipped locomotive to the Q–CAD Dispatching System, confirming that a digital message has been received on board.

Authority

Authority to occupy a main track or other controlled track, generated by a dispatch system or by the dispatcher using a dispatch system, conveyed through signal indications in CTC and, track warrant, track and time, or other means, and supplied to the Train Sentinel® system as the basis for an enforceable authority.

Authority Enforcement

Quantum – Positive Train Control system capability of preventing a violation of movement authority through an automatic full service application of train brakes to stop the train before a violation occurs; under certain conditions, capability of stopping a train following detection of an authority violation.

Authority Limits

Segment of controlled track defined by mileposts or station names, over which a train has authority to occupy and move on a main track.

Automatic Train Control

A system to enforce compliance with cab and wayside signal indications. If the train exceeds a predetermined speed for a given signal indication and speed is not reduced at a sufficient rate, brakes are automatically applied.

Bi-directional Authority

Authority for a train or maintenance vehicle to occupy a specified main track or controlled siding and move in either direction within designated limits.

Block

A length of track between consecutive block signals or between a block signal and the end of block system limits. Designated by timetable of a block in non-signaled territory.

Block Signal

A fixed signal at the entrance of a block that governs trains entering and using that block.

Brake Pipe Pressure

The amount of air pressure supplied to the brake pipe from the locomotive air compressor, expressed in pounds per square inch.

Braking Curve

Dynamic calculation of the point at which full-service braking must be applied for a train to be stopped within its movement limits or for its speed to be reduced short of a speed restriction limit. This may be portrayed graphically as a curve plotting train speed against distance remaining to the enforcement reference point; used in triggering braking for predictive enforcement.

Braking Distance

Distance required to stop a train, measured from the point at which a full-service (P2A) application of braking begins; projected by the onboard computer through a calculation based on train speed, weight, and length, consist detail, brake pipe pressure, track gradient, and other possible inputs.

CAD (Quantum – CAD System or Q–CAD)

Computer-Aided Dispatching system, a computer hardware and software system that automates some dispatching functions and provides information support for dispatching.

Cleared Route

One or more consecutive blocks in CTC territory over which a train is authorized to move, as by signal indication.

Communications Infrastructure

Basic installations and facilities, such a railroad's communication radio base stations, on-board communication devices, required to support data communications for the Quantum – Positive Train Control System.

Communications Outage

Loss of data communications over a limited geographic area, as through a failed radio base station, or on-board communication device.

Controlled Track

Track on which occupancy and movement by a train engine or on track equipment require authority issued through some method of train control. (main track and/or sidings)

Crossing

Point of intersection at grade between two tracks belonging to the same or different railroads.

Crossing Move

Movement of a train through a railroad crossing at grade or gauntlet track.

Centralized Traffic Control (CTC)

A block system that uses block signal indications to authorize train movements.

Dark Territory

Railroad tracks not equipped with signals; also known as *Non-ABS, DTC or TWC*.

Database Speed Restriction

Enforceable speed limit defined in a database and associated with train attributes, with track location, or with a combination of train attributes and track location.

Directional Authority

Movement authorities that are generated in one direction only. Reverse movements can only be made prior to informing the dispatcher for authority.

DTC

Direct Train Control, an alternative to Track Warrant Control in dark territory.

Effective Date

Date on which a track bulletin restriction takes effect, designated in a track bulletin line item or heading.

Effective Time

Time at which a track bulletin restriction takes effect, designated in a track bulletin line item.

End-of-Train Interface

Electromechanical means of monitoring end-of-train brake pipe pressure and train integrity through systems installed in the locomotive cab.

Enforceable Authority

Computer-readable authority defining limits of train movements that are subject to a Positive Train Control System enforcement.

Enforceable Speed Limit

At any given location, the nominal maximum speed at which a train can move before invoking a response from the onboard enforcement function; may differ from the actual speed limit, as in the case of an enforceable speed limit dictated by signal aspect, and from the actual speed at which enforcement braking is triggered, which may reflect a margin of overspeed tolerance.

Enforcement Braking

Automatic application of full service to stop a train either before it violates its authority limits or an upcoming speed limit (*predictive* enforcement) or in response to a detected violation of authority limits or a current speed limit (*reactive* enforcement).

Equipped Train

Train equipped with the onboard communications, computing, and location-tracking systems required for Quantum – Positive Train Control System functions; required equipment includes data radio, onboard computer, location-tracking device (such as GPS receiver), and a computer interface with the braking and throttle systems.

Fail Safe

A design philosophy applied to the design of a system, subsystem, or component. The applied philosophy causes the system, subsystem, or component to revert and maintain with very high probability to a state reasonably believed to be safe in the event of any design fault or hardware failure, to a very high degree of reliability. A fail-safe design philosophy is typically applied to the implementation of *safety critical* functions.

Flag Protection

A method of manually protecting the rear end or head end of a train to prevent collision, in accordance with GCOR Rule 6.19.

Following Move

Authorized movement by a train constrained by another train ahead moving on the same track in the same direction.

Form A

Track bulletin item establishing a temporary speed limit over a specified track segment.

Form B

Track bulletin item establishing protection for men or machines on track within specified limits and limiting train movement within the limits to restricted speed or another speed negotiated with the maintenance foreman.

Form F

Track bulletins for delivery of free-form information to the train crew.

Forward Move

Authorized movement to a specified limit ahead of a train, conferred by signal indication in CTC territory, or by track warrant item 2 or 3, or track and time, or other means.

Global Positioning System

A satellite-based radio navigation system deployed and operated by the Department of Defense, providing highly accurate three-dimensional position, velocity, and time data; input to Train Sentinel® train location tracking.

Head-End-Only Speed Restriction

Timetable speed restriction in effect for a train until the train's leading engine moves past the far limit of the restriction.

Human Machine Interface (HMI)

Interface between human operator and Q–PTC equipment that identifies necessary operations information.

Interlocking

An arrangement of signals and signal appliances, either manually or automatically controlled, interconnected so that their movements occur in a proper and safe sequence. Interlocking may be operated manually or automatically.

Joint Authority

Movement authorities issued to multiple trains, to a combination of trains and track forces or multiple maintenance crews with the same or overlapping limits.

Limit, Speed

Maximum speed in force for a train at a given track location.

Limits, Authority

Segment of track, defined by mileposts or location names, over which a train has authority for occupancy and movement.

Limits, Speed Restriction

Segment of track, defined by mileposts or station names, over which a train is subject to a specified speed restriction.

Location Tracking

Quantum – Positive Train Control System through which an equipped train's location is determined for train control and enforcement purposes; also known as *positioning*.

Main Track

A track extending through yards and between stations that must not be occupied without authority or protection.

Main Track Permission

Method of train control, closely resembling track warrant control, authorizing track occupancy within designated yard limits subject to Main Track Permission rules.

Manual Input Function

On-board Train Sentinel® function requiring a manual input by a train crew member in order to initiate a data request or transaction, acknowledge a digital message, or provide information on train movement to the Quantum – Positive Train Control System. (See Attachment 5 of the Information Filing)

Meet

Opposing trains authorized to move past one another at a designated location, where one train clears the main track onto a siding while the other holds to the main.

Non-controlled Territory

Tracks on which trains are free to move with Timetable Special Instructions authorization.

Non-equipped Train

Train not equipped with the onboard communications, computing, and location-tracking systems required for Positive Train Control functions.

Non-signaled Territory

Track without signals, over which train movements are governed by timetable, track warrants, or operating rules (Dark Territory).

Normal Switch Position

Position of a switch such that a train moving on the main track through the switch remains on the main track.

OCRS PTC

A Positive Train Control system that has been implemented on the Ohio Central Railroad.

On-board Computer (OBC)

Computer installed on an equipped train and used for running on-board Train Sentinel® functions, including location tracking, authority and speed limit enforcement, and various display and input functions.

Opposing Train

Train authorized to move toward a given train on the same track but in the opposite direction, requiring a meet.

Overlapping Authorities

Movement authorities issued to multiple trains, multiple maintenance crews, or a combination of trains and maintenance crews having the same or overlapping limits.

Partial Clearance

Manual or automatic process whereby a train's authority is released behind the train after the train passes, making the track available for other traffic. (Roll up)

Pass

One train passing another train moving in the same direction at a designated location, where one train clears the main track onto a parallel track, while the other holds to the main.

Passing Train

Train authorized to move past a given train, which is required to wait on a parallel track.

Position, Rear-End

Location of a train's rear end, calculated by subtracting the train length from the head-end position, or obtained from a GPS device on the rear of train.

Position, Head-End

Location of a train's lead locomotive as determined by a wheel tachometer or a GPS device.

Position Report

Message sent from an on-board computer to the dispatcher office indicating the current train location, speed, and direction.

Positioning

A QEI PTC function by which an equipped train's location is determined for train control purposes; also known as *location tracking*.

Power Braking System (PBS)

Train Sentinel® subsystem used to stop Train Sentinel®-equipped locomotive using a full brake application.

Predictive Enforcement

Application of enforcement braking to prevent violation of authority limits or violation of an upcoming speed limit.

Pre-enforcement Alert

Textual message, accompanied by an audible alert, warning the train crew of an impending application of enforcement braking unless the engineer acts to take control of the train.

Protection

Prevention of train collisions through various measures, such as block signals, flagging, or the intervention by the Quantum – Positive Train Control System.

Q–CAD

The Computerized Aided Dispatch System (Q–CAD) used by the train dispatcher and operation personnel to operate trains through Advanced Control of Trains. The dispatcher workstation.

Quantum – Positive Train Control (Q–PTC)

Dispatcher office, on-board, wayside and data radio network segments integrated to provide safety and efficiency gains in railroad operations.

Reactive Enforcement

Application of enforcement braking to stop a train that has violated a current speed limit or authority limits.

Release of Limits

Relinquishment by a train crew of all or a portion of their authority limits.

Restricted Speed

Speed that allows stopping within half the range of vision short of a train, engine, railroad car, men or equipment fouling the track, a stop signal, a derail, or an improperly lined switch, not in excess of 20 mph, in accordance with GCOR Rule 6.27; enforced as a 20 mph speed limit in Quantum – Positive Train Control System operations.

Revocation of Authority

Action by the Train Sentinel® system to shorten a train's authority in response to a new constraint, such as a signal changing to *Stop*.

Reverse Movement

Train movement in the direction opposite of the authorized direction.

Reverse Switch Position

Position of a switch such that a train moving on the main track through the switch leaves the main track.

Rollup

Manual or automatic process whereby a portion of a train's movement authority is released behind the train after the train passes an identifiable point, making the released track available for other traffic. (Partial Clearance) This process does not void or cancel a movement authority with the shrinking of the authority behind the train.

Rollup Location

Location to which a train's authority has been reported as a partial clearance of territory or rolled up, milepost or station.

Safety Overlay

A safety overlay allows for proven control methods (Track Warrant Control) to be the primary means of protection involving movement authorities and speed restrictions while providing digitally generated warnings and enforcements to the locomotive.

Siding

A track connected to the main track and used for meeting or passing trains. Under PTC Rules all tracks are considered controlled for the dispatcher use.

Speed Enforcement

Quantum – Positive Train Control System capability of preventing violations of speed limits through an automatic application of braking either in anticipation of or in response to over speeding.

Spur Track

A short track connected to a main track, often serving an industry location.

System Problem Report (SPR)

Reports used to document and trace a problem or change requirement initiated by either the vendor or the railroad.

TBD

To Be Determined.

TBS

To Be Specified.

Threat Alert

Textual message accompanied by an audible signal alerting the train crew to a threatening condition, such as an absolute signal ahead that has changed to *Stop*, or a train in the vicinity in violation of its authority.

Track Bulletin

A notice of conditions affecting train movement, including speed restrictions for designated limits, authority for a maintenance crew to work on or about the track.

Track Database

Database containing locations and attributes of track over which trains are subject to location tracking and enforcement.

Track Warrant

Standardized form used to authorize the movement of trains or track forces on a main track within specified limits in a territory subject to Track Warrant Control (TWC), as designated in the timetable.

Train Control Speed Restriction

Enforceable speed limit derived from temporary movement instructions generated through the dispatcher system, as through a track warrant or track bulletin, or from timetable train handling instructions and the train consist.

Train Movement Authority

Authority for movement given to a train in a specified manner. Primarily pertains to non-signaled territory.

Train Sentinel® System

Refers to the locomotive on-board railroad safety system developed by Quantum Engineering, Inc.

TWC

Track Warrant Control, a method of authorizing train movements or protecting track forces on a main track within specified limits in a territory so designated in the timetable.

Unconditional Authority

Movement authority effective immediately upon issuance, not contingent on fulfillment of any condition.

Visible Authority

Movement authority issued to the human operators of a train, by means of signals, track warrant, or other visible instrument, as distinct from the computer-readable enforceable

authority, which is not displayed to the human and may differ in extent from the visible authority.

Voiding

Cancellation of an authority or restriction through action of the dispatcher, acknowledged by a train crewmember.

11 CRC-32 AND BLOWFISH ENCRYPTION

11.1 CRC-32 Messaging

Quantum Engineering employs CRC-32 to insure data is not corrupted and then transmits data to and from the wayside to locomotive, using a 128-byte blowfish encryption technique. To date the blowfish encryption has not been cracked. The encryption key can be frequently changes and therefore ensures that the messaging cannot be spoofed. Additionally, Quantum employs a "time to live" embedded in each message. In order to send a valid message to a unique location, the message header that contains information specific to the train or wayside where the message is being sent, also needs a "time to live" message that is derived from the GPS satellite clock. If this part of the message is incorrect, the complete message is discarded and a new message is requested. For more information about the blowfish algorithm, please refer to the appendix for blowfish.

11.2 Blowfish[1] Encryption

In cryptography, **Blowfish** is a keyed, symmetric block cipher, designed in 1993 by Bruce Schneier and included in a large number of cipher suites and encryption products. Blowfish provides a good encryption rate in software and no effective cryptanalysis of it has been found to date. However, the Advanced Encryption Standard now receives more attention.

Schneier designed Blowfish as a general-purpose algorithm, intended as a replacement for the aging DES and free of the problems associated with other algorithms. At the time, many other designs were proprietary, encumbered by patents or kept as government secrets. Schneier has stated that, "Blowfish is unpatented, and will remain so in all countries. The algorithm is hereby placed in the public domain, and can be freely used by anyone."

Notable features of the design include key-dependent S-boxes and a highly complex key schedule.

The algorithm

Blowfish has a 64-bit block size and a key length of anywhere from 32 bits to 448 bits. It is a 16-round Feistel cipher and uses large key-dependent S-boxes. It is similar in structure to CAST-128, which uses fixed S-boxes.

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[1] Wikipedia, Bruce Schneier, 1993
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11.5 Blowfish Example

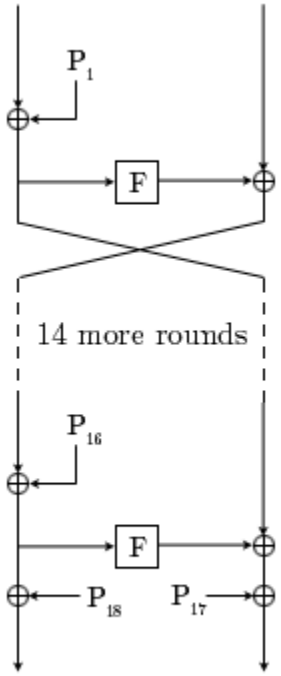


Figure 11.5 Blowfish Example

11.6 The Feistel Structure of Blowfish

The algorithm keeps two subkey arrays: the 18-entry P-array and four 256-entry S-boxes. The S-boxes accept 8-bit input and produce 32-bit output. One entry of the P-array is used every round, and after the final round, each half of the data block is XORed with one of the two remaining unused P-entries.

The function splits the 32-bit input into four eight-bit quarters, and uses the quarters as input to the S-boxes. The outputs are added modulo 2^{32} and XORed to produce the final 32-bit output.

Since Blowfish is a Feistel network, it can be inverted simply by XORing P_{17} and P_{18} to the ciphertext block, then using the P-entries in reverse order.

Blowfish's key schedule starts by initializing the P-array (Figure 11.2) and S-boxes with values derived from the hexadecimal digits of pi, which contain no obvious pattern (see nothing up my sleeve number). The secret key is then XORed with the P-entries in order (cycling the key if necessary). A 64-bit all-zero block is then encrypted with the algorithm as it stands. The resultant ciphertext replaces P_1 and P_2. The ciphertext is then encrypted again with the new subkeys, and P_3 and P_4 are replaced by the new ciphertext. This continues,

replacing the entire P-array and all the S-box entries. In all, the Blowfish encryption algorithm will run 521 times to generate all the subkeys - about 4KB of data is processed.

11.7 Cryptanalysis of Blowfish

There is no effective cryptanalysis on the full-round version of Blowfish known publicly as of 2006, although the 64-bit block size is now considered too short, because encrypting more than 2^{32} data blocks with it can begin to leak information about the plaintext in most modes of operation due to the birthday attack. While the short block size does not pose any serious concerns for routine consumer applications like e-mail, Blowfish may not be suitable in situations where large plaintexts must be encrypted, as in data archival.

In 1996, Serge Vaudenay found a known-plaintext attack requiring 2^{8r+1} known plaintexts to break, where r is the number of rounds. Moreover, he also found a class of weak keys that can be detected and broken by the same attack with only 2^{4r+1} known plaintexts. This attack cannot be used against the full 16-round Blowfish; Vaudenay used a reduced-round variant of Blowfish. Vincent Rijmen, in his Ph.D. thesis, introduced a second-order differential attack that can break four rounds and no more. There remains no known way to break the full 16 rounds, apart from a brute-force search.

11.8 Blowfish in practice

Blowfish is one of the fastest block ciphers in widespread use, except when changing keys. Each new key requires pre-processing equivalent to encrypting about 4 kilobytes of text, which is very slow compared to other block ciphers. This prevents its use in certain applications, but is not a problem in others. In one application, it is actually a benefit: the password-hashing method used in OpenBSD uses an algorithm derived from Blowfish that makes use of the slow key schedule; the idea is that the extra computational effort required gives protection against dictionary attacks.

In some implementations, Blowfish has a relatively large memory footprint of just over 4 kilobytes of RAM. This is not a problem even for older smaller desktop and laptop computers, but it does prevent use in the smallest embedded systems such as early smartcards.

Blowfish is not subject to any patents and is therefore freely available for anyone to use. This benefit has contributed to its popularity in cryptographic software.

Analysis of OCRS PTC with Subparts A-G [§ 236.907 (a) (14)]

An analysis of the applicability of the requirements of subparts A-G of this part to the OCRS PTC system that may no longer apply or are satisfied by the product using an alternative method, and a complete explanation of the manner in which those requirements are otherwise fulfilled (see Sec. 234.275 of this chapter and Sec. 236.901);

Description of Proposed Waivers and Justification for Relief

Relief is requested from the requirements of the regulations listed below, identified by CFR part, section number and heading. Testing Programs will be conducted in compliance with the OCRS RSPP and with the procedures set forth in the "Standards for Development and Use of Processor-based Signal and Train Control Systems" also known as the Final Rule, as published in the Federal Register March 7, 2005, pages 11052 to 11101, Volume 70, No. 43.

Regulations not specifically cited in this application are considered, where appropriate, to be applicable to OCRS PTC system. The following requirements are being requested to be waived or suspended for any testing of the OCRS PTC system. This product is in revenue service in Panama.

Summary of Proposed Waivers and Justification for Relief

OCRS has reviewed the following information and will or has already complied with the following line items based on prior conditions (e.g., ISO-9001, various Mil Specs, etc.):

Subpart A – Rules and Instructions, All systems

Line Item	OCRS Response
General	
§236.1 Plans, where kept.	**N/A for the test and development of this portion of the project.** Plans will be included in the Operations and Maintenance manual, listed in the PSP as 49 CFR 236.919
§236.2 Grounds.	**OCRS will comply with this section** Each circuit, the functioning of which affects the safety of train operations, shall be kept free of any ground or combination of grounds which will permit a flow of current equal to or in excess of 75 percent of the release value of any relay or other electromagnetic device in the circuit, except circuits which include any track rail and except the common return wires of single-wire, single-break, signal control circuits using a grounded common, and alternating current power distribution circuits which are grounded

	in the interest of safety.
§236.3 Locking of signal apparatus housings.	**OCRS will comply with this section** Signal apparatus housings shall be secured against unauthorized entry.
§236.4 Interference with normal functioning of device.	**OCRS will comply with this section** The normal functioning of any device shall not be interfered with in testing or otherwise without first taking measures to provide for safety of train operation that depends on normal functioning of such device.
§236.5 Design of control circuits on closed circuit principle.	**OCRS will comply with this section**
§236.6 Hand-operated switch equipped with switch circuit controller.	**N/A for this project** There are no hand-operated switches with switch circuit controllers connected to the point, or with facing-point lock and circuit controller on this demonstration territory.
§236.7 Circuit controller operated by switch-and-lock movement.	**N/A for this project**
§236.8 Operating characteristics of electromagnetic, electronic, or electrical apparatus.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no signal apparatus, the functioning of which would affect the safety of train operation.
§236.9 Selection of circuits through indicating or annunciating instruments.	**N/A for this project**
§236.10 Electric locks, force drop type; where required.	**N/A for this project**
§236.11 Adjustment, repair, or replacement of component.	**OCRS will comply with this section**
§236.12 Spring switch signal protection; where required.	**N/A for this project**
§236.13 Spring switch; selection of signal control circuits through circuit controller.	**N/A for this project**
§236.14 Spring switch signal protection; requirements.	**N/A for this project**
§236.15 Timetable instructions.	**OCRS will comply with this section**
§236.16 Electric lock, main track releasing circuit.	**N/A for this project**
§236.17 Pipe for operating connections, requirements.	**N/A for this project**
§236.18 Software Management Control Plan	**OCRS will comply with this section**
Roadway Signals and Cab Signals	

§236.21 Location of roadway signals.	**N/A for this project**
§236.22 Semaphore signal arm; clearance to other objects.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no semaphore signal arms.
§236.23 Aspects and indications.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no signal aspects.
§236.24 Spacing of roadway signals.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, the spacing of roadway signals is not applicable.
§236.25 [Reserved]	**N/A for this project**
§236.26 Buffing device, maintenance.	**N/A for this project**
Track Circuits	
§236.51 Track circuit requirements.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no track circuits for providing broken rail protection, switch circuits, fouling point derails, or automatic stop cab signal applications.
§236.52 Relayed cut-section.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no track circuits.
§236.53 Track circuit feed at grade crossing.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no track circuits
§236.54 Minimum length of track circuit.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no track circuits
§236.55 Dead section; maximum length.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no track circuits
§236.56 Shunting sensitivity	**N/A for this project** On the Ohio Central Railroad and in

	particular the demonstration territory, there are no shunting capabilities.
§236.57 Shunt and fouling wires	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no shunting capabilities.
§236.58 Turnout, fouling section.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no track circuits.
§236.59 Insulated rail joints.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no insulated rail joints.
§236.60 Switch shunting circuit; use restricted.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no switch shunting circuits.
Wires and Cables	
§236.71 Signal wires on pole line and aerial cable.	**N/A for this project**
§236.72 [Reserved]	**N/A for this project**
§236.73 Open-wire transmission line; clearance to other circuits.	**N/A for this project**
§236.74 Protection of insulated wire; splice in underground wire.	**OCRS will comply with this section** Insulated wire shall be protected from mechanical injury. The insulation shall not be punctured for test purposes. On the Ohio Central Railroad and in particular the demonstration territory, a splice in underground wire is not applicable.
§236.75 [Reserved]	**N/A for this project**
§236.76 Tagging of wires and interference of wires or tags with signal apparatus.	**OCRS will comply with this section**
Inspections and Tests; All Systems	
§236.101 Purpose of inspection and tests; removal from service of relay or device failing to meet test requirements.	**N/A for this project**
§236.102 Semaphore or searchlight signal mechanism.	**N/A for this project**
§236.103 Switch circuit controller or point detector.	**N/A for this project** On the Ohio Central Railroad and in

	particular the demonstration territory, there are no switch circuit controllers, circuit controllers, or point detectors operated by hand-operated switches or by power-operated or mechanically-operated switch-and-locks.
§236.104 Shunt fouling circuit.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no shunting capabilities.
§236.105 Electric lock.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no electric locks.
§236.106 Relays.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no relays.
§236.107 Ground tests.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no track circuits.
§236.108 Insulation resistance tests, wires in trunking and cables.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no track circuits.
§236.109 Time releases, timing relays and timing devices.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, there are no track circuits.
§236.110 Results of tests.	**N/A for this project** OCRS will comply with the section of 49 CFR 236.587 of this section. The balance of the testing required in this section is not applicable due to the OCRS and in particular the demonstration territory have no track circuits and signal aspects.

Subpart B—Automatic Block Signal Systems

Line Item	OCRS Response
Standards	
§236.201 Track-circuit control of signals.	**N/A for this project**

	On the Ohio Central Railroad and in particular the demonstration territory, have no track-circuit control of signals.
§236.202 Signal governing movements over hand-operated switch.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, have no track-circuit control of signals.
§236.203 Hand operated crossover between main tracks; protection.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory have no hand-operated crossovers between main tracks that provide track circuit protection.
§236.204 Track signaled for movements in both directions, requirements.	**N/A for this project**
§236.205 Signal control circuits; requirements.	**N/A for this project**
§236.206 Battery or power supply with respect to relay; location.	**N/A for this project**
§236.207 Electric lock on hand-operated switch; control.	**N/A for this project**

Subpart C—Interlocking

Line Item	OCRS Response
Standards	
§236.301 Where signals shall be provided.	**N/A for this project**
§236.302 Track circuits and route locking.	**N/A for this project**
§236.303 Control circuits for signals, selection through circuit controller operated by switch points or by switch locking mechanism.	**N/A for this project**
§236.304 Mechanical locking or same protection effected by circuits.	**N/A for this project**
§236.305 Approach or time locking.	**N/A for this project**
§236.306 Facing point lock or switch-and-lock movement.	**N/A for this project**
§236.307 Indication locking.	**N/A for this project**
§236.308 Mechanical or electric locking or electric circuits; requisites.	**N/A for this project**
§236.309 Loss of shunt protection; where required.	**N/A for this project**
§236.310 Signal governing approach to home signal.	**N/A for this project**

§236.311 Signal control circuits, selection through track relays or devices functioning as track relays and through signal mechanism contacts and time releases at automatic interlocking.	N/A for this project
§236.312 Movable bridge, interlocking of signal appliances with bridge devices.	N/A for this project
§236.313 [Reserved]	N/A for this project
§236.314 Electric lock for hand-operated switch or derail.	N/A for this project
Rules and Instructions	
§236.326 Mechanical locking removed or disarranged; requirement for permitting train movements through interlocking.	N/A for this project
§236.327 Switch, movable-point frog or split-point derail.	N/A for this project
§236.328 Plunger of facing-point lock.	N/A for this project
§236.329 Bolt lock.	N/A for this project
§236.330 Locking dog of switch-and-lock movement.	N/A for this project
§236.331–236.333 [Reserved]	N/A for this project
§236.334 Point detector.	N/A for this project
§236.335 Dogs, stops and trunnions of mechanical locking.	N/A for this project
§236.336 Locking bed.	N/A for this project
§236.337 Locking faces of mechanical locking; fit.	N/A for this project
§236.338 Mechanical locking required in accordance with locking sheet and dog chart.	N/A for this project
§236.339 Mechanical locking, maintenance requirements.	N/A for this project
§236.340 Electromechanical interlocking machine; locking between electrical and mechanical levers.	N/A for this project
§236.341 Latch shoes, rocker links, and quadrants.	N/A for this project
§236.342 Switch circuit controller.	N/A for this project
Inspection and Tests	
§236.376 Mechanical locking.	N/A for this project
§236.377 Approach locking.	N/A for this project
§236.378 Time locking.	N/A for this project
§236.379 Route locking.	N/A for this project
§236.380 Indication locking.	N/A for this project

§236.381 Traffic locking.	N/A for this project
§236.382 Switch obstruction test.	N/A for this project
§236.383 Valve locks, valves, and valve magnets.	N/A for this project
§236.384 Cross protection.	N/A for this project
§236.385 [Reserved]	N/A for this project
§236.386 Restoring feature on power switches.	N/A for this project
§236.387 Movable bridge locking.	N/A for this project

Subpart D—Traffic Control Systems

Line Item	OCRS Response
Standards	
§236.401 Automatic block signal system and interlocking standards applicable to traffic control systems.	N/A for this project
§236.402 Signals controlled by track circuits and control operator.	N/A for this project
§236.403 Signals at controlled point.	N/A for this project
§236.404 Signals at adjacent control points.	N/A for this project
§236.405 Track signaled for movements in both directions, change of direction of traffic.	N/A for this project
§236.406 [Reserved]	N/A for this project
§236.407 Approach or time locking; where required.	N/A for this project
§236.408 Route locking.	N/A for this project
§236.409 [Reserved]	N/A for this project
§236.410 Locking, hand-operated switch; requirements.	N/A for this project
Rules and Instructions	
§236.426 Interlocking rules and instructions applicable to traffic control systems.	N/A for this project
Inspection and Tests	
§236.476 Interlocking inspections and tests applicable to traffic control systems.	N/A for this project

Subpart E—Automatic Train Stop, Train Control and Cab Signal Systems

Line Item	OCRS Response

Standards	
§236.501 Forestalling device and speed control.	**OCRS will comply with this (b-1) of this section** Part (b-2) implies a signal aspect of which is not applicable to the OCRS and in particular the demonstration territory.
§236.502 Automatic brake application, initiation by restrictive block conditions stopping distance in advance.	**OCRS will comply with section**
§236.503 Automatic brake application; initiation when predetermined rate of speed exceeded.	**OCRS will comply with section**
§236.504 Operation interconnected with automatic block-signal system.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, operations interconnected with automatic block-signal system are not applicable.
§236.505 Proper operative relation between parts along roadway and parts on locomotive.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, proper operative relation between parts along roadway and parts on locomotive are not applicable.
§236.506 Release of brakes after automatic application.	**OCRS will comply with section**
§236.507 Brake application; full service.	**OCRS will comply with section**
§236.508 Interference with application of brakes by means of brake valve.	**OCRS will comply with section**
§236.509 Two or more locomotives coupled.	**OCRS will comply with section**
§236.510 [Reserved]	**N/A for this project**
§236.511 Cab signals controlled in accordance with block conditions stopping distance in advance.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, cab signals controlled in accordance with block conditions stopping distance in advance are not applicable.
§236.512 Cab signal indication when locomotive enters block where restrictive conditions obtain.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, cab signal indications when locomotive enters block where restrictive conditions are evident is not applicable.
§236.513 Audible indicator.	**OCRS will comply with (b) of this section.**

	On the Ohio Central Railroad and in particular the demonstration territory, part (a), signal aspects are not applicable.
§236.514 Interconnection of cab signal system with roadway signal system.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, cab signal applications are not applicable.
§236.515 Visibility of cab signals.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, cab signal applications are not applicable.
§236.516 Power supply.	**OCRS will comply with section**
Rules and Instructions; Roadway	
§236.526 Roadway element not functioning properly.	**N/A for this project**
§236.527 Roadway element insulation resistance.	**N/A for this project**
§236.528 Restrictive condition resulting from open hand-operated switch; requirement.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, restrictive conditions resulting from an open hand-operated switch associated with a circuit controller are not applicable.
§236.529 Roadway element inductor; height and distance from rail.	**N/A for this project**
§236.530 [Reserved]	**N/A for this project**
§236.531 Trip arm; height and distance from rail.	**N/A for this project**
§236.532 Strap iron inductor; use restricted.	**N/A for this project**
§236.533 [Reserved]	**N/A for this project**
§236.534 Entrance to equipped territory; requirements.	**OCRS will comply with this section**
Rules and Instructions; Locomotives	
§236.551 Power supply voltage; requirement.	**OCRS will comply with this section**
§236.552 Insulation resistance; requirement.	**OCRS will comply with this section**
§236.553 Seal, where required.	**OCRS will comply with this section**
§236.554 Rate of pressure reduction; equalizing reservoir or brake pipe.	**OCRS will comply with this section**
§236.555 Repaired or rewound receiver coil.	**N/A for this project**
§236.556 Adjustment of relay.	**N/A for this project**

§236.557 Receiver; location with respect to rail.	**N/A for this project**
§236.558–236.559 [Reserved]	**N/A for this project**
§236.560 Contact element, mechanical trip type; location with respect to rail.	**N/A for this project**
§236.561 [Reserved]	**N/A for this project**
§236.562 Minimum rail current required.	**N/A for this project**
§236.563 Delay time.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, delay time of automatic train stop or train control systems shall not exceed 8 seconds and the spacing of signals to meet the requirements of Sec. 236.24 shall take into consideration the delay time, is not applicable.
§236.564 Acknowledging time.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, acknowledging the time of intermittent automatic train-stop device shall be not more than 30 seconds, is not applicable.
§236.565 Provision made for preventing operation of pneumatic brake-applying apparatus by double-heading cock; requirement.	**N/A for this project**
§236.566 Locomotive of each train operating in train stop, train control or cab signal territory; equipped.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, the locomotive from which brakes are controlled, of each train operating in automatic train stop, train control, or cab signal territory shall be equipped with apparatus responsive to the roadway equipment installed on all or any part of the route traversed, and such apparatus shall be in operative condition, is not applicable.
§236.567 Restrictions imposed when device fails and/or is cut out en route.	**OCRS will comply with this section**
§236.568 Difference between speeds authorized by roadway signal and cab signal; action required.	**N/A for this project**
Inspection and Tests; Roadway	
§236.576 Roadway element.	**N/A for this project**
§236.577 Test, acknowledgement, and cut-in circuits.	**OCRS will comply with this section**

Inspection and Tests; Locomotive	
§236.586 Daily or after trip test.	**OCRS will comply with this section**
§236.587 Departure test.	**OCRS will comply with this section**
§236.588 Periodic test.	**OCRS will comply with this section**
§236.589 Relays.	**N/A for this project**
§236.590 Pneumatic apparatus.	**OCRS will comply with this section**

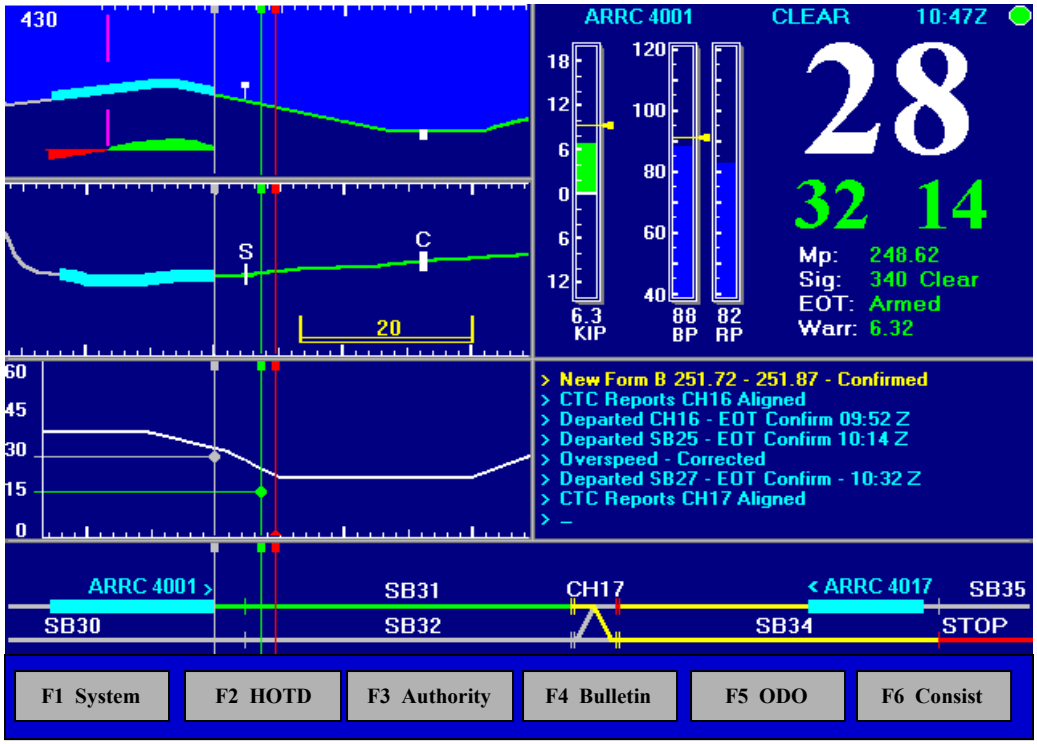
Subpart F—Dragging Equipment and Slide Detectors and Other Similar Protective Devices

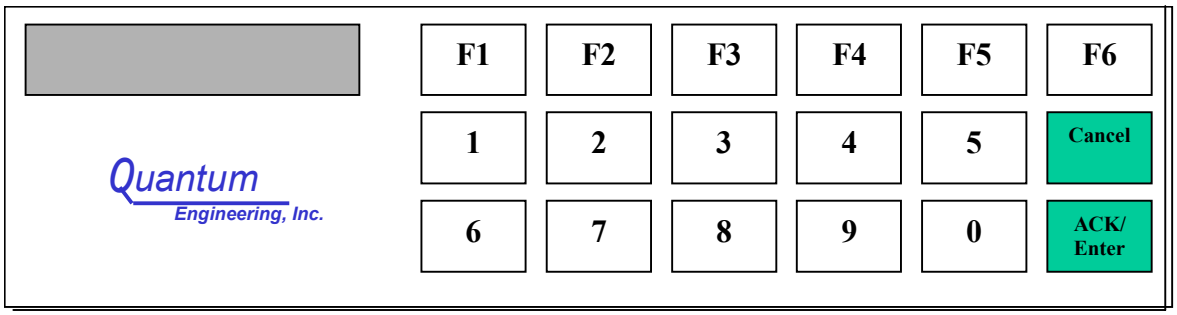
Line Item	**OCRS Response**
Standards	
§236.601 Signals controlled by devices; location.	**N/A for this project** On the Ohio Central Railroad and in particular the demonstration territory, signals controlled by devices used to provide protection against unusual contingencies, such as landslides, dragging equipment, burned bridges or trestles and washouts shall be located so that stopping distance will be provided between the signal and the point where it is necessary to stop the train, is not applicable.

Subpart G—Definitions

Line Item	**OCRS Response**
Definitions	
§236.700 Definitions	**OCRS will comply with this section for all noted definitions that apply**
§236.701 Application, brake; full service *through* §236.838 Wire, shunt.	**OCRS will comply with this section**

The following represent a list of commends that can be executed from the Train Sentinel keypad located on the locomotive.





1. System
   1.1. Test
      1.1.1. Outputs
         1.1.1.1. Horn — Test the horn output (run sequence)
         1.1.1.2. Bell — Test the bell output (toggle)
         1.1.1.3. Penalty — Test the P2A valve
         1.1.1.4. –
         1.1.1.5. –
         1.1.1.6. Back
      1.1.2. Comms
         1.1.2.1. HOTD
            1.1.2.1.1. 1200 — Transmit 1200 Hz tone

1.1.2.1.2.	1800	Transmit 1800 Hz tone.
1.1.2.1.3.	Emergency	Send emergency dump command
1.1.2.1.4.	Off	Turn off all tests.
1.1.2.1.5.	–	
1.1.2.1.6.	Back	
1.1.2.2.	Disp	Engesis dispatch RF test.
1.1.2.3.	–	
1.1.2.4.	–	
1.1.2.5.	–	
1.1.2.6.	Back	
1.1.3.	GPS	View the GPS status.
1.1.4.	–	
1.1.5.	–	
1.1.6.	Back	
1.2. LCD		
1.2.1.	Backlight	Adjust the backlight level
1.2.2.	Contrast	Adjust the contrast
1.2.3.	Scale	Set the display scale
1.2.4.	–	
1.2.5.	–	
1.2.6.	Back	
1.3. Setup		
1.3.1.	Time	Adjust the time units of display
1.3.2.	Zone	Set the current time zone.
1.3.3.	–	
1.3.4.	–	
1.3.5.	–	
1.3.6.	Back	
1.4. –		
1.5. –		
1.6. Back		
2. HOTD		
2.1. Arm		Arm the EOTD
2.2. Disarm		Disarm the EOTD
2.3. Set Code		Set the EOTD ID Code
2.4. EOT Position		Check the EOT position, if available
2.5. Test		Run a communications test
2.6. Back		
3. License		
3.1. Current		Show the Engesis Dispatch messages
3.1.1.	First	Go to the first
3.1.2.	Previous	Go to the previous
3.1.3.	Next	Go to the next

- 3.1.4. Last — Go to the last (default)
- 3.1.5. –
- 3.1.6. Back

3.2. Request

- 3.2.1. Enter — Request to enter controlled track
- 3.2.2. Exit — Request to operate manually (exit)
- 3.2.3. W&T — Request Work and Time
- 3.2.4. Lead — Request Lead Loco Change
- 3.2.5. –
- 3.2.6. Back

3.3. –

3.4. Select

- 3.4.1. Head — Set the head-end occupancy
- 3.4.2. EOT Blk — Set the EOT occupancy
- 3.4.3. EOT Pos — Set the EOT position
- 3.4.4. –
- 3.4.5. –
- 3.4.6. Back

3.5. Report EOT / Last Car — Report the ID of a passing EOT/Car

3.6. Back

4. Bulletin
   - 4.1. Form B — Permission to enter Form B received
   - 4.2. Cancel — Cancel (last car clear)
   - 4.3. List — List all in advance
   - 4.4. –
   - 4.5. –
   - 4.6. Back

5. Odo
   - 5.1. Count up
   - 5.2. Count down
   - 5.3. Stop
   - 5.4. –
   - 5.5. –
   - 5.6. Back

6. Consist
   - 6.1. Setup — Set the initial consist completely
   - 6.2. Pickup — Picked up cars (locos)
   - 6.3. Drop — Set aside cars (locos)
   - 6.4. –
   - 6.5. –
   - 6.6. Back

Train Sentinel®

Training Manual

Prepared for

Ohio Central Railroad

Quantum Engineering, Inc.

Quantum Engineering, Inc.
Orange Park, Florida

Revision History

Version	Date	Comment	FRA Status
1.0	4/21/2007	Preliminary Draft from PCRC, reformatted	
1.1	11/5/2007	Updated Train Sentinel® Manual	

Table of Contents

1. Introduction

Quantum Engineering and the Ohio Central Railroad (OCRS) have worked jointly to produce a System Training Plan that is consistent with the U.S. Government Final Rule §236.907 (a) (12) of the Product Safety Plan (PSP). The production of a Training Plan by the various participants will ensure a safe operation. The training requirements shall address normal and abnormal operation of the system.

This Training Plan will also incorporate other applicable items noted in the Final Rule:

- 49 CFR 236.927 Training specific to locomotive engineers and other operating personnel
- 49 CFR 217.9 – Program of operational tests and inspections; recordkeeping
- 49 CFR 236.921 Training and qualification program, general
- 49 CFR 236.921(a)(5) OCRS PTC Safety Committee[1] will solicit and make recommendations for the hierarchy of training from the Supervisory level to the worker level for all crafts involved with the PTC process. The OCRS PTC Safety Committee will provide names of the Direct Supervisors prior to the start of training.
- 49 CFR 236.923 Task analysis and basic requirements

This Training Plan will specify a complete description of the specific training necessary to ensure the safe and proper operation of the Train Sentinel® system. Quantum Engineering, working with OCRS, will document the training requirements necessary for OCRS personnel to ensure safe operation of the Train Sentinel® system. These training requirements will address installation, normal and abnormal operation, repair, modification, and testing of the system, and will be developed jointly by the Vendor and the OCRS. The PSP will identify the intended audience for each training requirement. This Manual is intended for the use of train crews.

[1] The OCRS PTC Safety Committee will be composed of Bill Strawn, President OCRS, Len Wagner, VP Operations, Denny Varian Superintendent of Operations, the road foremen of engines, a designated QEI project leader and a QEI engineer, a designated MOW Supervisor, and one designated locomotive engineer and one conductor.

2. Training Milestones

2.1 Training Plan

A Training Plan will be generated listing the planned subject matter to be supplied with an estimated schedule. A draft Training Plan will be made available to OCRS early in the training development cycle to be used for planning purposes. The final Training Plan will be provided to OCRS one (1) month prior to start of testing.

The Training Plan will include the following information for each course:

- Course overview. (Engineers and Conductors oriented)
- Course objective. (Engineers and Conductors oriented)
- Target Audience for whom the course is intended. (Engineers and Conductors oriented)
- Course outline and schedule.

2.2 Training Documents

There will be a Training Document milestone for the Ohio Central Railroad. The Training Documents delivery from Quantum Engineering provides for any updates covering the additional functionality provided by each new release, and the integration of their module in Quantum's Positive Train Control System.

2.3 Training Documentation

- Operations Manuals and User Guides
- Maintenance Manuals and Maintenance Guides
- Technical and Administrative Training

2.4 User Training

When appropriate, there will be a User Training milestone for Quantum Engineering and OCRS with each release. User Training will occur after Training Documents have been reviewed by the OCRS PTC Safety Committee. The delivery for subsequent releases will be update courses covering the additional functionality provided by those releases.

3. Training Course

3.1 Introduction

Course Syllabus

Quantum – Computer Assisted Dispatching

Course Description: This course provides experienced locomotive train crews with a basic skill sets for the use of the Train Sentinel® system. This Train Sentinel® system will incorporate all of the information necessary to perform the daily functions of the train crews using the system. The course is also intended to demonstrate the application of critical thinking and decision making within the system as it applies to the OCRS rail operation. Emphasis is placed on preparing train crews that can deal clearly, rationally, and creatively within a diverse workforce and dynamic workplace. This course will equip train crews with concrete skills in critical thinking and decision making that will allow them to identify and solve operational problems, as well as provide corporate strategic direction.

Assignments. This module will be followed for all assignments for the course:

ASSIGNMENTS
Introduction to Train Sentinel®
Introduction to Use of the Various Forms/Menus
Operating Trains – Initial and on-the-road
Interfaces with Train Sentinel® and Q – CAD
Handling train as non-equipped train
Handling train with malfunctioning equipment

3.2 Overview

3.2.1 Course Description

This course provides experienced train crews with basic skill sets for the use of the Quantum Engineering's Train Sentinel® system. This Train Sentinel® Training Manual will incorporate all of the information necessary to perform the daily of a train crew on the system. The course is also intended to demonstrate the application of critical thinking and decision making within the system as it applies to the OCRS rail operation. Emphasis is placed on preparing train crews that can deal clearly, rationally, and creatively within a diverse workforce and dynamic workplace.

All material for this course will follow the outline as prescribed by the U.S. Government Final Rule Section §236.927 Training Specific to Locomotive Engineers and Other Operating Personnel. This section will propose minimum training requirements for train crews and other operating personnel who interact with locomotive processor-based train control systems. "Other operating personnel" is intended to refer train crews; engineers, conductors, brakemen, pilots, and flagmen.

3.2.2 Topics and Objectives

The following will outline the Objectives of this course:

- Classroom training will be provided to employees responsible for issuing or communicating mandatory directives.
    - Including instructions concerning the interface between computer-aided dispatching systems and processor-based train control systems as applicable to the safe movement of trains and other on-track equipment.
    - Including operating rules that pertain to the locomotive control system, with the provision for moving unequipped trains and trains on which the train control system has failed or been cut out en route.
- Instructions for control of trains and other on-track equipment when the Train Sentinel® system fails.
- Practical exercises or simulations and operational testing under part 217 to assure that personnel are capable of providing for safe operations as well as alternative operation methods (fallback).

3.2.3 Training Process

The following will outline the Training Process of this course:

- Classroom training (approximately 4 hours for 8 crew members)
- Actual operation (1-2 days after training), on-the-job with coaches/mentors as observers
- Follow-up training in classroom for reinforcement training, if necessary

- Actual operations (1-2 days after training), on-the-job with coaches/mentors as observers
- Certified as compliant with all aspects of the System

3.3 Course Material Learning Objectives

Initialization
- Start-up
- Activation
- Train Information

Departure
- Initial Movement Authority
- Subsequent Movement Authorities

Enroute
- Train Sentinel LCD components
- Keypad usage
  - Alarms
- Braking Curve
- Subsequent Movement Authorities
- Roll-up of Territory
- Additional Information

Arrival
- Trip Completion

Equipment Malfunction
- Complete
- Partial

3.4 Introduction to Train Sentinel®

- Background of previous systems
- System development
- Strategy used for Human Machine Interfaces (HMI)
- Train Sentinel® Display Unit
- Train Sentinel® Keypad

3.5 Introduction to Use of Various Forms/Menus

- Use of device menus and background menus
- Use of pull-down or pop-up menus

4. TRAIN SENTINEL®

4.1 Training Outline

Purpose:	The purpose of this module is to familiarize train crews with the Quantum Train Sentinel® onboard computer components. This module must be presented in conjunction with the Training Simulator for hands-on knowledge.
Materials:	Must be conducted with the Training Simulator
Time:	4 hour
Overview:	In this module the train crews will learn all about the Train Sentinel® System. The train crews will be shown how to observe, acknowledge, and send information with the Train Sentinel® system.
Performance objectives & measures:	Objectives: train crews must be able to interpret operating conditions, read, and understand information on Train Sentinel®. The train crews must also be able to utilize all of the function keys and their implication. The train crews must be able to demonstrate the ability to accomplish these tasks taking into account any appropriate safety implications for their use. Measures: train crews will demonstrate the hands-on activities that relate to the Train Sentinel® operation.
Content:	The instructor will provide during this module the following processes: • What is the Train Sentinel® process • What are the major/minor components • Train crew responsibilities • Train Sentinel® loss of communications or failure operations
Prompt:	The instructor will discuss each of the items and conditions evident for Train Sentinel® operations as well as the processes to manage train operations utilizing Train Sentinel® methods.
Perform:	Instructor will guide the train crews through the process and then the train crews will perform the response. Train crews will be shown the cut-out warning tag for the Control Module.
Practice:	Train crews will navigate the screens to practice where the various screens and function keys are located and how they are used. Train crews will achieve 100% compliance during this portion of training.

4.2 Purpose and Scope

This system level description document is developed as a joint venture between Quantum Engineering and OCRS personnel. The Positive Train Control System will be used as a basis for improved safety and efficiency of train operations. The document is also the basis for the initial program system activities such as the functional and performance analyses. By providing an overall description of how the Quantum – Positive Train Control System supports the railroad's mission, this document also serves as a tool for providing the necessary strategic implementation vision for railroads. The migration path is as follows:

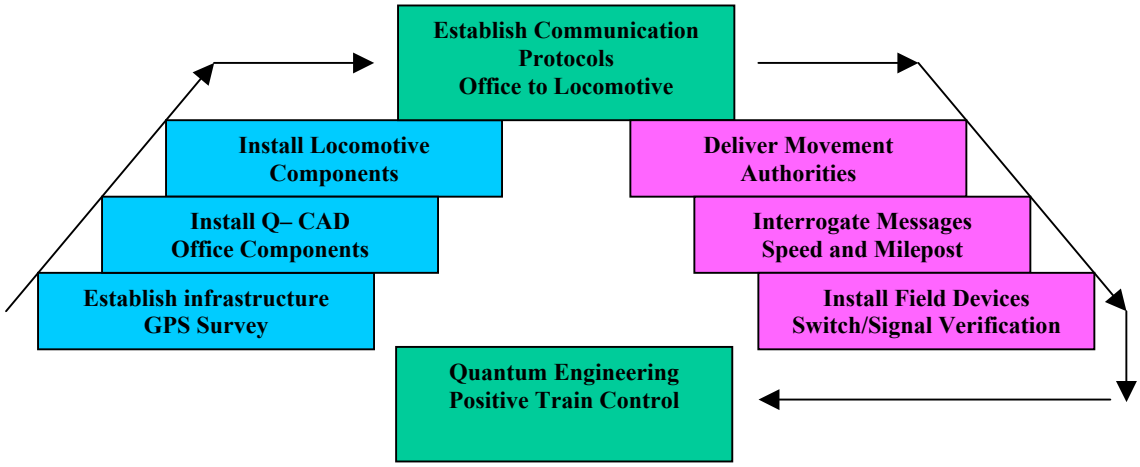


Figure 4.2 Steps to Completion

The system follows a well-defined migration path and has the potential to significantly reduce rules infractions associated with authority and speed violations, and to reduce accident rates. The development is expected to enhance safety far sooner and more economically than could be accomplished through a conventional in-cab safety system or through existing or developing alternatives. The migration plan provides impressive economic returns at each level of implementation by, pacing trains for fuel conservation, reducing human induced accidents, and offsetting train control investments.

4.3 System Overview

The technology used is a mix of mature, proven products, technology applied from other industries, the PCRC revenue service, and research developments with high potential for success. This strategic approach includes building block infrastructure components. These modules provide authority limit approach alerts, authority limit violations warnings, proximity alerts, on-board delivery and enforcement of authorities and speed restrictions, on-board displays, on board display of train performance, switch position monitoring (future), operator alertness capability, and an on-board braking systems to prevent speed / authority violations. The capability of providing on-board pacing speed and/or the desired time of arrival at the next significant event location can be provided by integrating the on-board system with an office traffic planner that can be provided in the future.

Any event that will cause loss of system operation will result in the operator being notified by the audible/visual indications on the cab interactive display screen, and the dispatcher through the network. The system will always fail safely.

The five Quantum Train Sentinel® modules enforce the safety requirements of a predefined strategy. All the modules are based on managing train speed. Operations within authorized parameters are allowed at the maximum authorized speed. Exceptions requiring a reduced speed or a Stop are managed by forcing the crew to reduce the speed to the maximum authorized speed at the conflict point. This strategy alerts the engineer to the speed reduction required and allows the engineer to maintain train control by slowing within the acceptable limits. ***Failure to do so will stop the train.*** The system is supported by an on-board track database. The track database includes layout information, (multiple tracks, switches, etc.), grades, curvature, milepost references, signal locations, speed limits, and highway crossings. This database provides all the information required to safely and efficiently authorize and monitor movements. Configuration control is managed at the central office and the current subdivision database can be provided to the on-board computer via a VHF data radio at crew change locations, if necessary. The Quantum Train Sentinel® System includes environments for Software/Database Validation. The software/database validation environment provides the ability to load and validate the operation of Software Release and Railroad database updates with no adverse affect on operation and safety. This rational management philosophy ensures current data is on-board without detrimental impact to rail operations.

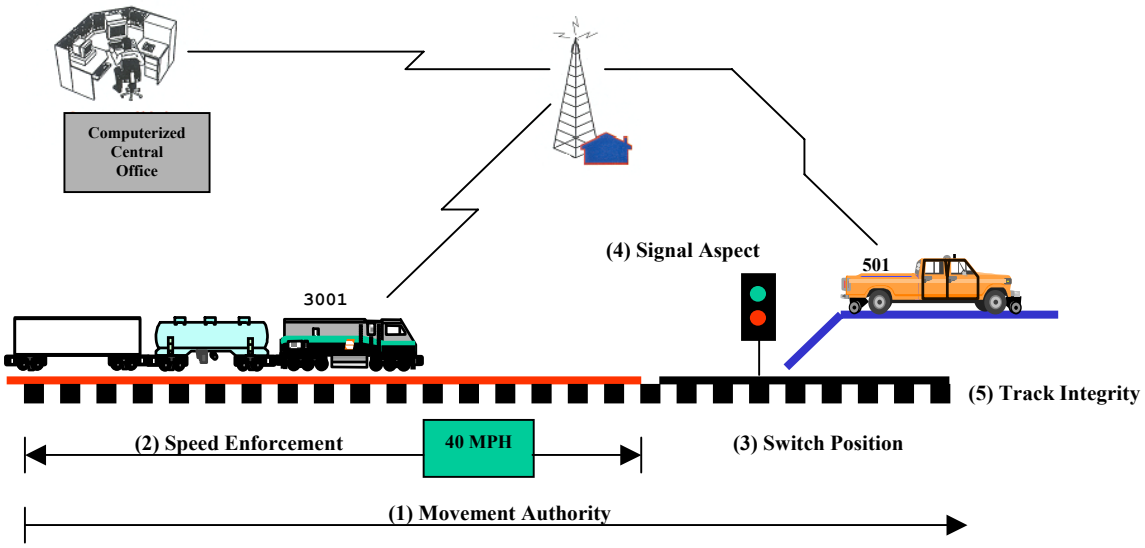


Figure 4.3 Example of interface with devices

The on-board systems continuously check the vehicle location comparing it to the track it is authorized to occupy. Braking algorithms will be applied whenever the locomotive approaches the end of existing limits, or whenever the vehicle speed exceeds that authorized for the track segment it now occupies. Fail Safe design allows a train to operate to the end of its authorized limits in the event of a system failure.

A hierarchical approach to train control is used as an example of a railroad. Train dispatchers, supervisors, and remote users are networked together internal to the existing train control system and via an interface to provide optimal efficiency. Train dispatchers are responsible for the safe and efficient movement of trains and the integration of maintenance personnel on their territory. Operation supervisory staff both internal to the dispatching centers and remote across the network has the capability of monitoring activity of selected dispatchers, terminals, and corridors. Each dispatcher is assigned a territory to operate.

Each dispatcher issues authorities and restrictive information for maintenance personnel and trains and communicates electronically applicable restrictions that must be obeyed in order to maintain safe operations (e.g., speed and operating restrictions) within their assigned territories. Since this requires the maintenance and exchange of a significant amount of data, railroads support the dispatcher through Quantum's Computer-Assisted Dispatching (CAD) system (Q – CAD). The computerized dispatch systems contain conflict checking, and "fail safe" mechanisms to ensure that signal requests, train movement authorities, restrictive information, and authority forms such as Work Between are produced in a safe and efficient manner. The dispatching system utilizes procedures and HMI that ensures that dispatcher activity and interfaces to the dispatching equipment are performed safely and efficiently.

The on-board systems continuously check the vehicle location comparing it to the track it is authorized to occupy. Warnings and braking algorithms will be applied whenever the locomotive approaches the end of existing limits, or whenever the vehicle speed exceeds that authorized for the track segment it now occupies. Fail Safe design allows a train to operate to the end of its authorized limits in the event of a system failure. Any time that the network telemetry signal to the locomotive is lost for a prescribed period of time (user selectable) it will only be allowed to continue to operate to the last limit of authority. Once telemetry communication has been re-established, the locomotive will continue with its normal operations. Similarly, if any of the locomotive control equipment or the GPS system malfunctions, and system integrity cannot be assured, the result will be either a complete shutdown, or reduced capability as determined by the kind of failure experienced. The locomotive engineer and the dispatcher will be notified by the audible/visual indications.

4.4 Concept of Operations

The Quantum – Positive Train Control System is designed to provide safety and efficiency gains. The system is comprised of the Q – CAD Dispatcher Control System, Quantum Engineering, Inc "Train Sentinel® System", and GPS technology. The preponderance of benefits (safety and economic) identified in PTC is believed achievable through this approach at an affordable cost.

The Quantum – Positive Train Control System integrates dispatcher, on-board equipment, and wayside devices with a communication network and provides the tools to:

- Implement a cost effective Communications-Based Positive Train Control System
- Ensure system availability,
- Efficiently, non-intrusively, and safely maintain, configure and input database updates
- Alert locomotive crews to train movement authority limits
- Alert locomotive crews to speed restrictions (temporary and permanent)
- Stop locomotives/trains prior to exceeding authority/speed limits
- Interrogate switches in a locomotive/trains route when operating in non-signal territory.
- Interrogate track integrity circuits in a locomotive or trains route.
- Provide an efficient, intuitive user environment through the appropriate use of user interfaces.

4.5 System Environment

The Positive Train Control system provides safety functionality in three (3) distinct areas. These areas include locomotive on-board computers and office environment (Q – CAD) designed to prevent a locomotive/train from violating its authority and speed limit and thereby reducing train collisions. The third major component is the communications conduit which allows the free exchange of data in a timely manner to be processed in the office as well as the field. The system also includes a Global Positioning System (GPS) survey of the rail and wayside infrastructure. The system implementation is expected to enhance safety far sooner and more economically than could be done through a conventional in-cab safety system or through existing or developing technical alternatives. The proposed safety enhancements include:

- Digital delivery of authorities and restrictions
- Authority limit enforcement
- Speed Limit enforcement

4.6 Major Segments of the System

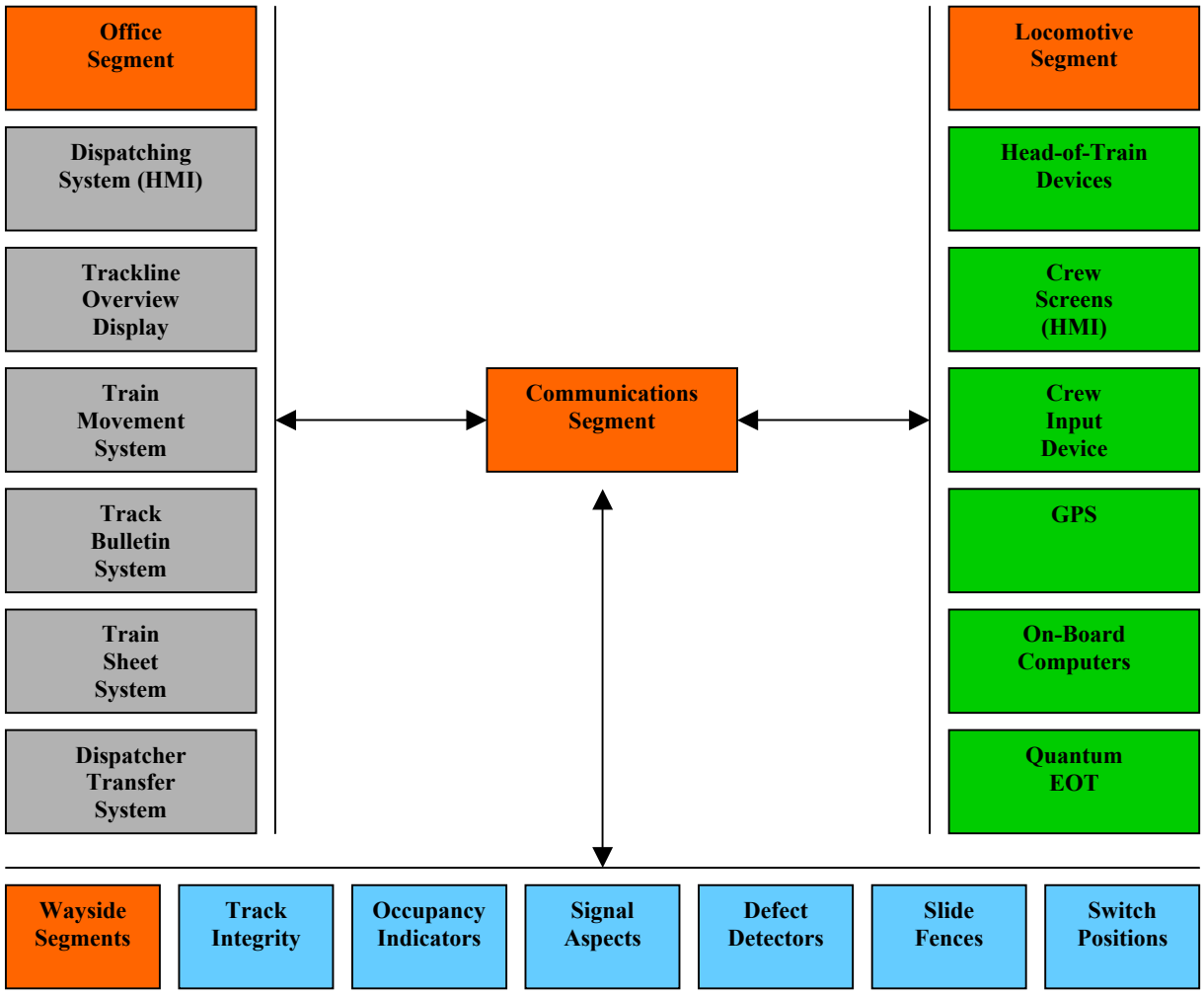


Figure 4.6 Examples of Devices

The Quantum Engineering approach is to integrate known technology, with mature applications and selected developments to maximize the safety benefit while minimizing the developmental risk. The system will be designed to address (and mitigate) the hazards that produce accidents under the current control system operation.

4.7 System Architecture

The system architecture is comprised of the following:

- The railroad database
- GIS
- Key data systems

4.7.1 The Railroad Database

Electronic authorities are granted to, and electronic speed restrictions apply to the location of these attributes along the track. Therefore accurate location of these attributes within the database, and configuration management practices pertaining to database changes affect the safe operation of trains. Attributes include but are not limited to station signs, milepost signs, switches, signals, speed signs, highway grade crossings, failed-equipment wayside detectors, locomotives, vehicles, grade and curvature.

To obtain the location accuracy required by the proposed GIS applications, working with Quantum Engineering, OCRS will assist in providing a mapping survey that integrates the mapping system with an external GPS receiver.

A railroad may utilize an equipped hi-rail vehicle or locomotive with mapping systems and GPS receivers to capture infrastructure changes.

4.7.2 Geographic Information System

The project will utilize a data repository to house a database that accurately reflects the assets and the asset's attributes correctly. A Geographic Information System (GIS) is the necessary utensil to accomplish this purpose. GIS is comprised of a computer system that records, stores, and analyzes database information about the features that make up the infrastructure of the railway.

4.7.3 Key Data Features Overview

The key data features, that will make up the data model which will be built to house the assets or objects identified in the infrastructure, will consist of many standards attributes that will be reflected in different columns of the database. Each of these assets or database objects will have physical properties to describe them, as well as geographic features to help relate their position with regards to the earth.

4.8 Locomotive On-Board Equipment

The Quantum Engineering locomotive On-Board Computer (OBC) system, called the Train Sentinel® system, consists of several distinct task based subsystems. These systems have checks and balances to achieve maximum fault tolerance. Of primary importance is the monitoring of conditions between the On-Board Computer (OBC) and the power/braking control system. In addition, the monitoring of various input/output capabilities of the computer insures data integrity.

4.8.1 On-Board Computer (OBC)

The Train Sentinel® system utilizes an on-board computer (OBC). The OBC is the central processing center on the locomotive. It integrates all information to and from the locomotive, and commands the various subsystems to perform the necessary functions to insure a fail-safe system. The On-Board Computer insures each equipped locomotive operates within designated areas in a safe and controlled manner. The system integrates the dispatcher office (Q – CAD) with various wayside devices, and on-board computer and Global Positioning Systems (GPS) technology to determine the location of the equipped locomotive and to ensure routes are safely lined for approaching locomotives/trains, and that authority to occupy upcoming track is on-board.

Fail-safe technology is applied to the on-board systems such that a failure of the on-board computer or locomotive control system will automatically bring the vehicle to a safe stop. Various parameters of the locomotive are monitored as well as those systems necessary to move and safely stop the locomotive. Should any of these items exceed safe levels, the locomotive is halted, and movement requests denied. The locomotive on-board systems continuously check its current location comparing it to not only what track it is allowed to occupy, but also which near-by tracks it is not authorized to occupy. Braking algorithms will be applied whenever the locomotive approaches the end of existing limits, or whenever the train speed is anticipated to exceed that authorized for the track segment it now occupies. The locomotive onboard control units are designed with systems insuring operator “alertness-to-duty.” Should the operator fail to respond to the alerter function, the locomotive under control will immediately halt.

4.8.2 Locomotive On-Board Equipment

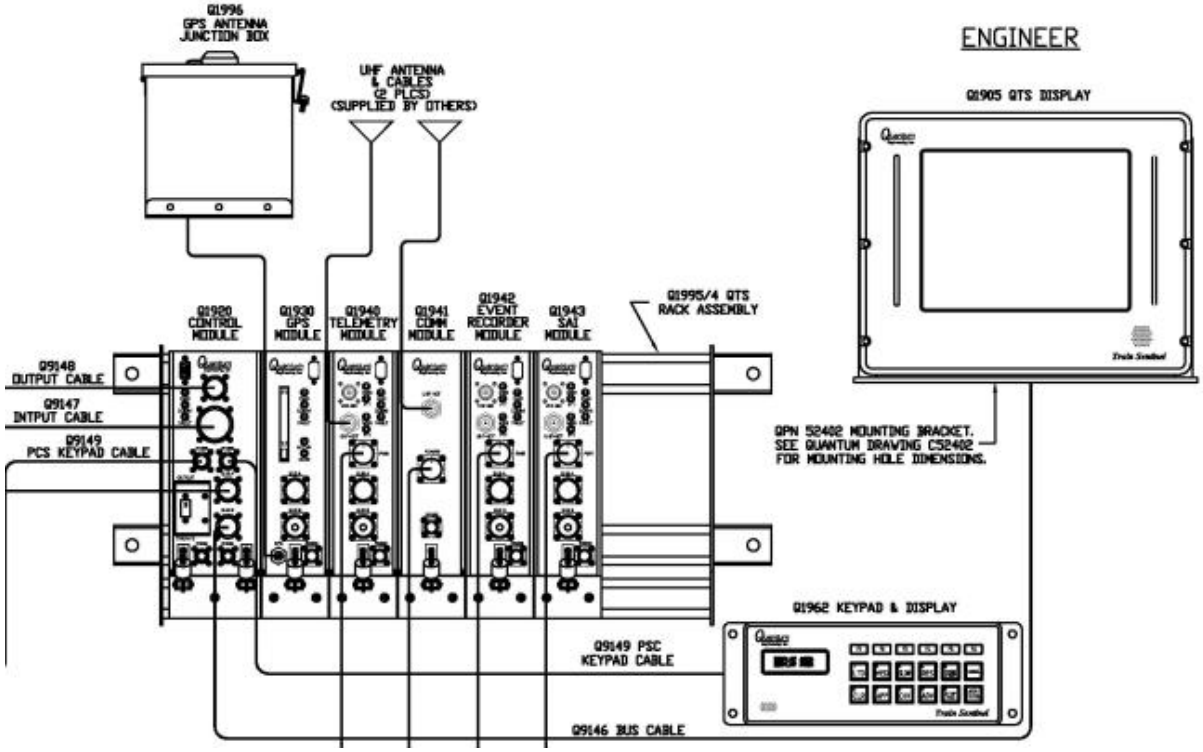


Figure 4.8.2 Typical Train Sentinel® Installation

Primary Control Components

- Control Module
- GPS Module
- Communications Module

Secondary Components

- Event Recorder Module
- Telemetry Module
- "Golden Run" Module (Future)

User Components

- Display
- Keypad

4.8.3 Locomotive Display

The Train Sentinel® Locomotive Segment includes a Human Machine Interface (HMI) for the train crew. The flat panel display is ruggedly designed to withstand typical locomotive vibration and temperature extremes, and environmental conditions such as dirt, dust, and diesel exhaust, and has push-button keys for operator input. Train crews, and a cab committee comprised of management, train crew, and vendors, provided input to the display functionality and in-cab location of displays and equipment. The display utilizes user-friendly concepts of display flexibility and easily understood control inputs. The HMI displays necessary operating information to the crew; train status, commands, consist information, authorities, restrictions, and topographic information. All indicators and pertinent authority information is viewable on the flat panel screen(s). The display has a sub-screen to indicate the status of the GPS system, the current status of the locomotive/train speed coupled with a track warrant pictorial, showing where the locomotive/train is in relation to existing speed and authority limits. Displays are presented in both text and graphics. The display shows the relative stopping distance, in feet, from the present location to the stopping point based on the relative deceleration. An audible warning is contained within the flat panel to alert the operator should the train approach the authority limit, or attempt to exceed the boundary condition of the brake/stopping profile.

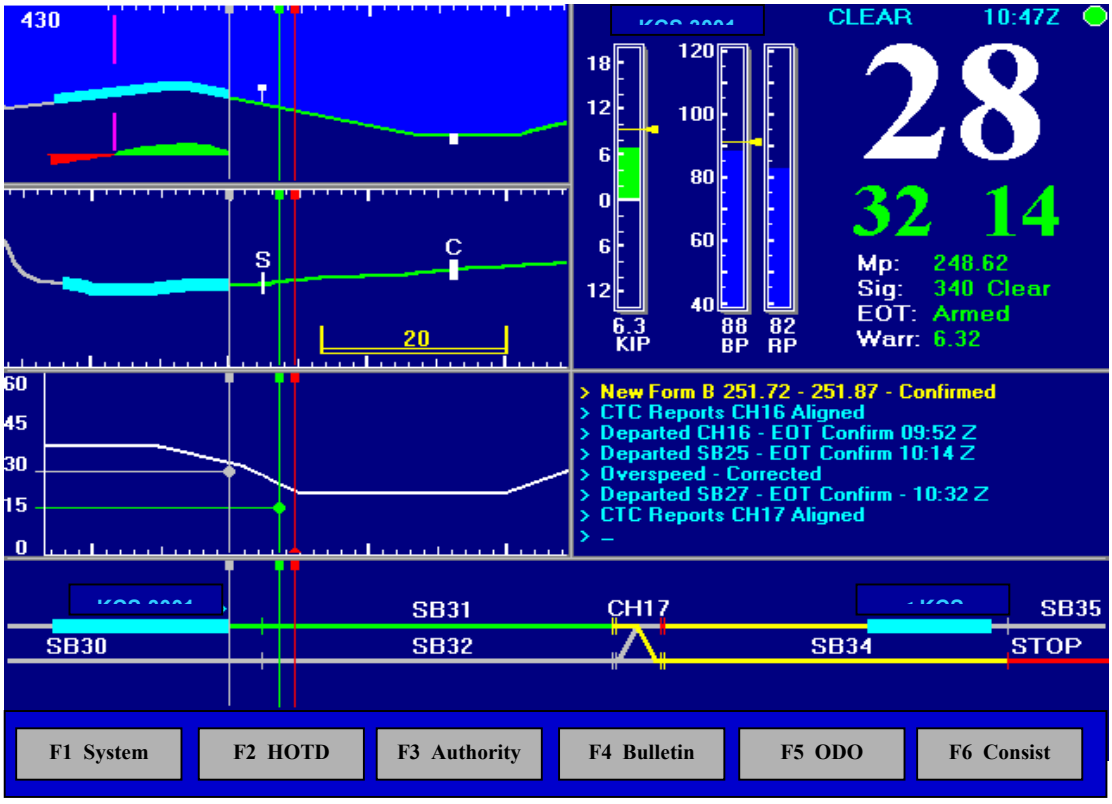


Figure 4.8.3 Examples of Train Sentinel® LCD Screen

4.8.4 GPS/Internal Navigation System

The on-board Train Sentinel® System relies on two inputs for position data. The primary system is the inertial navigation system employing the end of axle generator. This is supported and corrected by the secondary global positioning system (GPS) and a map-matching algorithm that further defines and verifies the correct location of the locomotive. If the system loses GPS or is unable to correlate the GPS data to a location within the known limits of the territory, the system reverts to the inertial navigation mode, notifying the crew and dispatcher that the system is operating in a degraded mode. In the event of a complete failure of the navigation system the OBC will declare a fault condition and stop the train, or force the manual operation of the train, in a default or fallback mode requiring verbally transmitted authorities, and signal indications of a traffic control system until the anomaly is cleared.

If a differential GPS is used, GPS correction generation may be accomplished using the railroad's data radio system by generating the differential corrections at each base station. The correction accuracy is dependent on the accuracy of the base GPS antenna location. Position correction reports are generated once per second based on the deviation from the entered fixed position. The remote position report will then be corrected based on the error reports from the nearest base(s).

4.8.5 Event Recorder

Train Sentinel® has a fully integrated event recorder that will record locomotive operating parameters, as well as track authorities, speed limits and other operating parameters. Several days of operation are available for downloading and review using the playback capability.

4.8.6 Locomotive Control System

The locomotive control system is comprised of a number of locomotive inputs to determine the operation of the locomotive and whether the locomotive can continue operation. Such items as main reservoir pressure, brake pipe pressure and brake cylinder pressure, speed, throttle position, and alerter function are monitored on a continuous basis to insure proper locomotive operation under the given authority. In addition, the locomotive control system employs a braking subsystem tied into the existing locomotive piping and utilizing locomotive resident hardware (e.g., a P2A valve) to induce a penalty application of the brakes if the system determines either the authorized speed has been, or will be exceeded or the limit of authority will be exceeded if a brake application is not made. The locomotive control system will operate under a concept that if power is lost to the control system, all power applications to the locomotive (throttle setting, excitation, etc.) will immediately cease and a brake application at the service rate will be made. In this type of failure, the engineer can regain manual operation of the locomotive by placing the locomotive in the unequipped or cutout mode. When placed in an unequipped or cutout position, a message is immediately transmitted to the dispatching center, informing that the Train Sentinel® system on-board the locomotive is under manual control, forcing a verbal delivery of authorities and speed restrictions to that locomotive.

4.8.7 Power Braking System (PBS)

The power/braking system will have multiple inputs generated by the computer, and multiple outputs fed to the computer. The power braking sub-system will have a power supply separate from that used by the computer. The power/braking sub-system will utilize a "gravity-default" design such that if power is lost, full service brake application is automatic, and the ability to apply power to the locomotive will be removed. In addition, the computer also monitors the power braking system (via a power supply monitor/integrity line) to insure full control of the locomotive is viable and safe.

In the event any failure of this system occurs, locomotive operation is halted and a message is sent to the dispatcher giving notification of the event. The engineer may take manual control of the locomotive. However, when the engineer does so a message is transmitted to the dispatcher advising that a manual locomotive is operating within the Train Sentinel® equipped subdivision. The "failed and/or cut out" locomotive is uniquely identified to the dispatcher via the dispatch system. The locomotive engineer will be required to contact the dispatcher for approval to cut out PTC (required in §236.567) because some failures may be of a nature that when cut out, no transmission will occur.

4.8.8 Power Braking System (PBS) CPU Monitor

The CPU integrity line is used by the PB sub-system as an input. The PB sub-system will allow the computer to control the locomotive only when the CPU integrity line indicates the on-board computer is fully functional.

4.8.9 PBS Air Pressure Monitor

Air pressure transducer measurements are forwarded to the on-board computer to insure all air pressures exist at levels insuring safe operation. If the main reservoir pressure falls below 100 psi, propulsion requests are rejected and locomotive movement is prohibited. In a similar manner, if the brake pipe pressure falls below 80 psi, locomotive movement is denied. If these pressures fall below the minimum value while the locomotive is in motion, all propulsion inputs will be removed and the locomotive and train brakes are applied. The brake cylinder pressure is also monitored to insure proper pressure variations where braking is applied and released by the computer system. Any detected variation in proper operation will result in a removal of all propulsion inputs and full service application of the locomotive and train brakes.

Whenever an on-board decision is made to cease propulsion and apply a full service application of the brakes, a message describing the condition will be transmitted to the dispatcher. Again, the engineer can override this condition and operate the locomotive under a "limp-home" mode of operation under fallback or default procedures. When placed in a non-equipped position, a notice is immediately transmitted to the dispatch center, informing them that the Train Sentinel® system aboard the locomotive is under manual control, forcing a manual track warrant system on that locomotive in the system. The "failed and/or cut out" locomotive is uniquely identified to the dispatcher via the dispatch system.

4.8.10 Braking Algorithm

The Train Sentinel® on-board computer (OBC) will be employed to determine the stopping distance necessary to always stop short of the limit of authority, including Form B track bulletins, and speed restrictions both temporary and permanent. This algorithm incorporates detailed consist data and track profile data to improve the accuracy of the calculation. The train consist data is electronically generated to Train Sentinel® before the electronic Track Warrant is generated. The train dispatcher is responsible for sending this information. If the train crew enters the information first, the dispatcher has to approve the train consist data before it is loaded into the OBC. The algorithm that determines safe braking distance is instrumental to maintaining present levels of productivity. By knowing the train makeup (loads, empties, tonnage, locomotives), track location, and speed of the train at all times, the onboard computer will constantly update Train Sentinel® as to the relative stopping distance needed for each train.

Each time the locomotive accelerates from a zero speed condition, the ability to achieve various speeds based upon throttle and excitation needed to achieve that speed, will be determined. This will permit a classification of tonnage-under-load in one of five groups. When the on-board system determines that a stop command must be made, and this decision is based upon speed, tonnage-under-load classification, and distance from the absolute stopping point, the on-board computer will begin applying brakes.

An alternative methodology of braking algorithm is to examine the distance traveled since the last brake application/modification was made, and the degree of speed reduction, as well as distance traveled during that time. This will yield an indication of effective deceleration. By examining the distance to the absolute stopping point, a decision will be made by the on-board system as to when the need for braking effort is required.

This process will run on a “real-time” basis, continuously measuring braking effort, and the degree of success of that braking effort. Based upon the knowledge of where the locomotive must stop, or what point the locomotive cannot pass, the system will determine when braking effort is required using the resident locomotive hardware.

In the interest of crew safety, audible and visual warnings are always given at or before the time of enforcement brake application. In cases of predictive enforcement, the engineer is allowed time to take corrective action following the warning before enforcement braking occurs. If the engineer has not taken appropriate action within a specified number of seconds after the warning, braking is applied. In cases of reactive enforcement, the system initiates braking simultaneously with the warning, although the time lag between the application of braking and its effects allow for a de facto alert to the crew that the train is going to be stopped.

4.9 Operational Description

Train Sentinel® operations can be divided into major functions which are used to manage the movement of trains. The System is organized according to these major functions:

Locomotive Initialization.

- Train Initialization.
- Train Movements.
- Speed Restrictions.
- Train Termination.

4.9.1 Locomotive Initialization

Each Train Sentinel® equipped locomotive undergoes initialization in order to ensure that all necessary data (e.g., latest version of track profile) is on board and matches the master track database prior to departure. A reliable message delivery protocol will be used to establish with a high level of confidence that the track profile on board each Train Sentinel® equipped locomotive is error free, complete, and up to date.

4.9.2 Train Initialization

At a original departure location, Q – CAD will provide Train Sentinel® with the necessary train composition (loads, empties, tonnage, and length) typically before a train's departure. This dynamic train data will be used to allocate track, as appropriate, based on the Q – CAD movement authorities. The dynamic train data includes the following:

- Train ID.
- Locomotive consist (quantity and types).
- Car consist (quantity and types).
- Planned consist changes (adding/deleting locomotives, car pickup/setouts).
- Displayable Authorities and Bulletins.
- Movement Authorities.
- Speed Restrictions.

Dynamic train data for a specific train may not be available prior to the train's departure. Before departing, a train must be defined with a locomotive consist and movement authority by the Q – CAD system; but aside from that, Train Sentinel® will be designed to handle receipt of additional and changing train data throughout the life of the train.

4.9.3 Train Movements

Authority granted by the Q – CAD system is required for a locomotive/train/MOW to occupy a track. Once the authority is received on board, the system will permit the engineer to operate the locomotive/train over the authorized track. The system may receive authority from the dispatcher system for each Train Sentinel® equipped train. The dispatching system generates a movement authority, a Work Between, or another form of authority for a train, which specifies the route for which the train has authority. The on-board displayable authority is a textual, and graphical representation of the train's authority. The authority is passed from the dispatching system without modification to the Train Sentinel® Locomotive Segment and made available to the crew via the Locomotive HMI.

Train Sentinel® has a representation of the railroad's track in the on-board database. The Q – CAD system allocates track to all Train Sentinel®-equipped trains with respect to their movement authorities. The on-board system, using the track profile, allocates track based on the received authority. A single train may occupy a track section. In special situations, a dispatcher may place more than one train in the same track section using a Work Between, joint authority.

Loss of the communications signal from the wayside (base station or wayside device) to the locomotive for a prescribed period of time (user selectable and factory programmable) will result in the locomotive/train being able to operate to the last limit of authority in the OBC. Once communication has been reestablished, the locomotive will be allowed to continue. Since there are no overlapping authorities generated by the system other than at restricted speed, this precludes any locomotive operating into the path of another at track speed, even if the most catastrophic events occurs would render the digital communications system inoperative. In this case operations would revert back to Track Warrant Control (TWC) operation without the Train Sentinel® system. Enforcement would not be evident under these conditions.

4.9.3.1 Displayable Authorities

The Quantum – Positive Train Control system has the capability to accept the following displayable authorities:

A **Train Movement Authority** (TWC) is used in non-signaled territory to authorize a train to occupy the main track within designated limits. The train must travel in the direction specified only, unless authorized by bi-directional authority for the purpose of performing work. More than one train can hold the same or overlapping authorities if their respective authorities authorize movement in the same direction and if each train is required to provide rear end protection. Note that the last train can be relieved of providing rear end protection if its train movement authority specifies that it is not allowed to foul the limits ahead of any preceding train. Also, train movement authorities can overlap when two or more trains are authorized with a "Work and Time," between two specific points at restricted speed, or when trains are authorized to move through another train's "Work Between" area at restricted speed. Rear end flag protection is not required within "Work

Between" limits. Note that Train Sentinel® does not enforce train separation in a "Work Between" limit, but does enforce speed.

All of the displayable authorities described above are available for display on board the locomotive. The Current Movement Activity window will display the current (and next, if issued) movement authority under which the train is currently operating. The crew may view more detailed information about specific instructions or authorities by selecting the Movement Authority Summary window.

4.9.3.2 Example of the Ohio Central Railroad

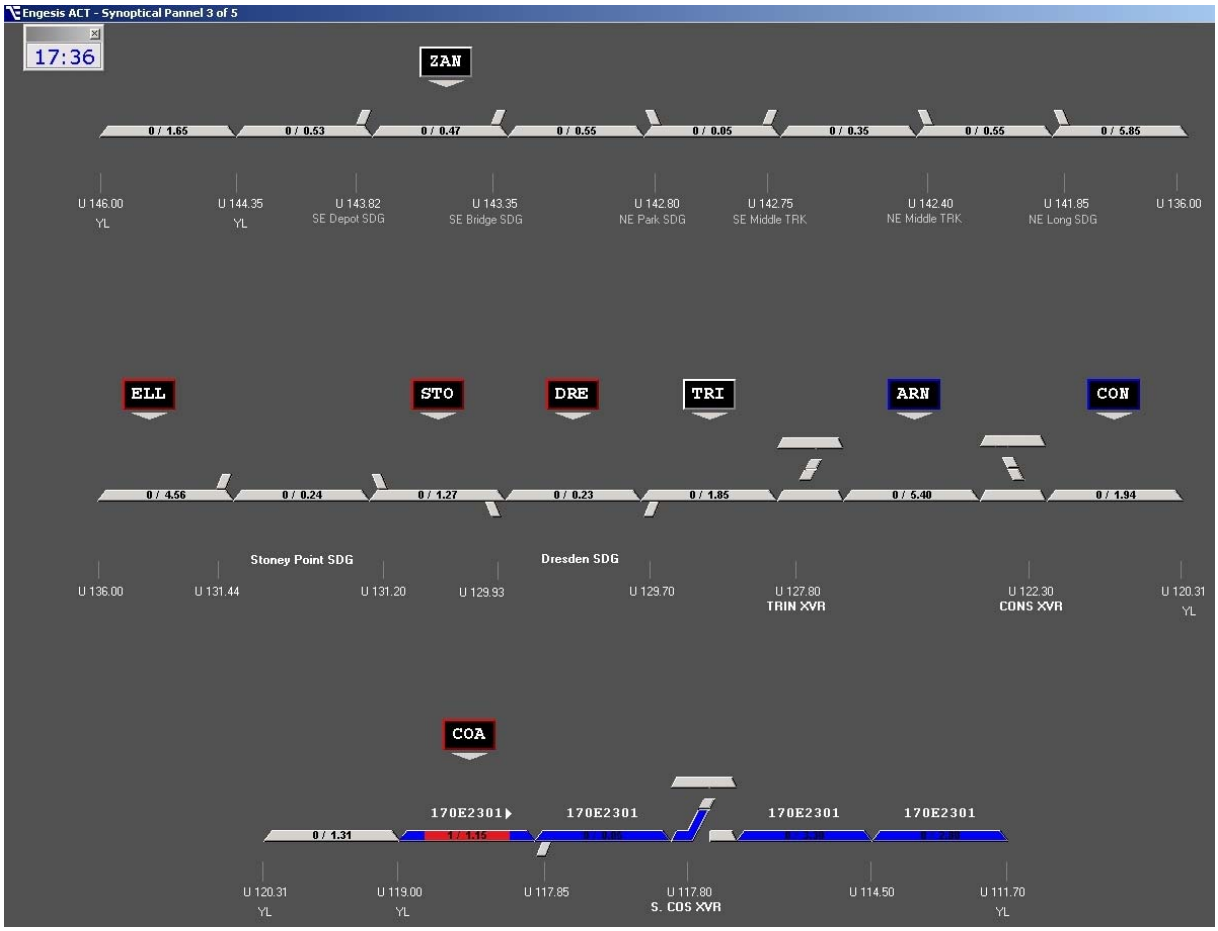


Figure 4.9.3.2-1 Typical Dispatcher Screen

The PTC Authority function enables the dispatcher to issue an authority for train movement or maintenance-of-way (MOW) or on-track equipment (OTE) movement in non-signaled (Positive Train Control) territory. This function gives the dispatcher the capability to issue a new authority, recall and unreleased authority, release all or part of an existing authority, extend an existing MOW authority, or perform a meet/pass (Memorized or Stored).

In non-signaled territory, traditional means using either Direct Train Control, fixed blocks, or Track Warrant Control, variable blocks. Positive Train Control takes the best of both operations to allow for flexibility of train operations. For equipped trains, communicating with the office, the use of the traditional TWC format will apply. For unequipped, the use of TWC will apply with "absolute" protection for trains and equipment.

The concept of Positive Train Control is not intended to increase the overall speed assigned to a particular track, but it is intended to keep trains moving at or near the maximum track speed in order to increase track capacity and train performance.

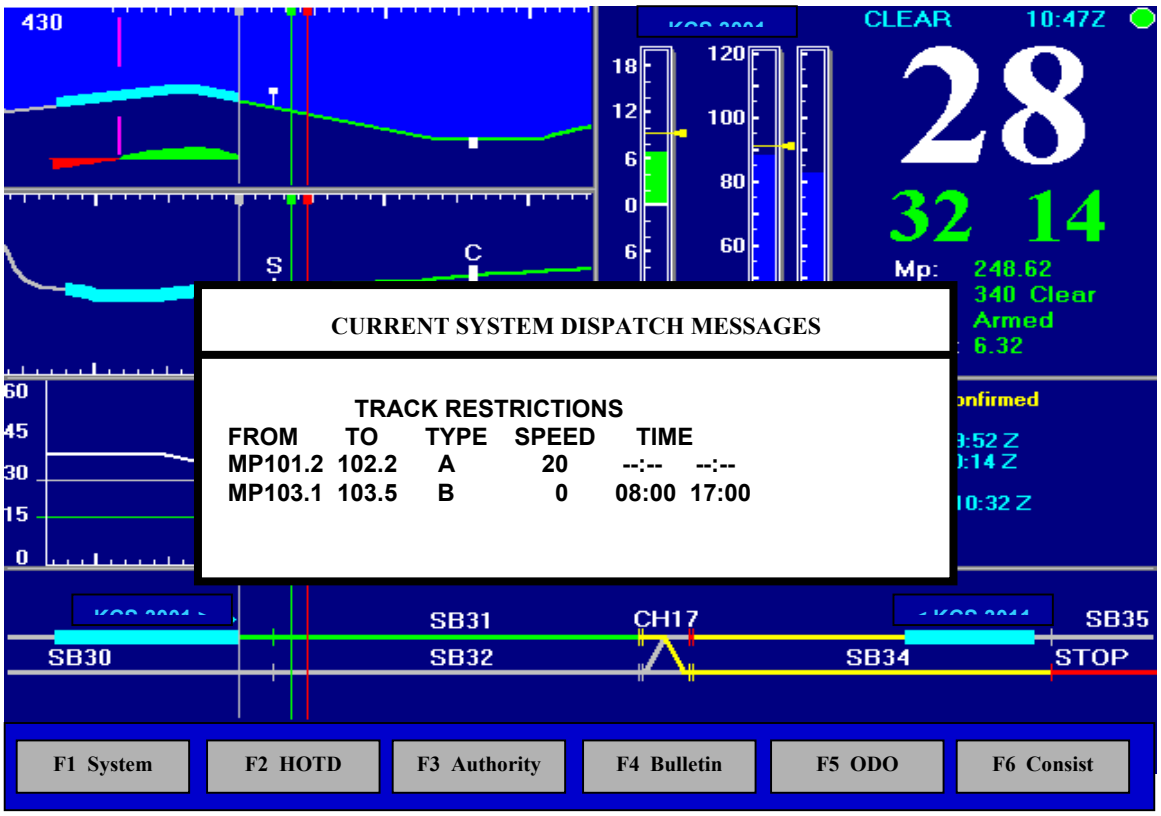


Figure 4.9.3.2-2 Typical Dispatcher Screen with Restrictions

4.9.3.3 Movement Authorities

The Quantum – Positive Train Control System protects the trains and maintenance personnel and equipment by allocating the track on which the dispatch system has authorized them to travel, or work. The allocation is accomplished through fixed blocks that are allocated in accordance with operational parameters identified by the railroad. Main Track and sidings are considered "controlled track" and as such require authorization for occupancy. Track is allocated to the trains via a Train Movement Authority and Work Between Authorities which identify the individual track segments the train or equipment is allowed to traverse.

4.9.3.4 Authority Enforcement

A primary goal of the Quantum – Positive Train Control System is to improve safety by enforcing movement authorities such that no actual violation of authority occurs. The Train Sentinel® System predicts an imminent violation and prevents it from occurring. This is referred to as predictive enforcement. However, there are some scenarios where Train Sentinel® cannot prevent an authority violation. An enforcement that is initiated after the violation has occurred is referred to as a reactive enforcement. An example of this is a dropped signal that may occur as the train approaches.

The Train Sentinel® Locomotive Segment will notify the crew of a pending enforcement action, if possible. If the crew initiates a full service brake application during the pre-enforcement warning time, the pre-enforcement audible and textual warnings would terminate and the penalty application would be averted. After the initiation of the enforcement and the accompanying enforcement warning, prompt action by the crew may not be sufficient to avert the enforcement action. The Train Sentinel® system may not have sufficient time to determine that the braking actions of the crew will prevent a violation, so the penalty action may occur regardless of their action.

4.9.3.5 Train-to-Train Avoidance System

Train Sentinel® employs a radio telemetry collision avoidance system. Information will flow between locomotives and the dispatching office to provide a master file of all train locations. This system will periodically transmit position location as well as other locomotive specific information to any train in proximity to another train. Proximity warning is achieved through the use of location reporting data. Algorithms embedded in the Train Sentinel® system keep track of all train movements and will warn each engineer of a possible conflict. Train Sentinel® will, if necessary, stop any train(s) that is in danger of colliding. Should this occur, the dispatcher would be notified via the telemetry system through use of an automatic messaging protocol.

4.9.4 Speed Restrictions

The on-board Train Sentinel® receives speed restriction information from the Q – CAD system for each equipped train. The speed restriction information includes restrictions derived from Form A and Form B bulletins issued to the train. The bulletin is passed from Q—CAD, dispatch segment to the Train Sentinel® on-board computer and made available to the crew via the Locomotive HMI. The dispatcher system generates a speed restriction for a train, which specifies the actual speed restriction and the limits where the speed restriction is effective. The Train Sentinel® system uses the dynamic speed restriction, along with any existing track and/or train speed restrictions and enforces to the lowest speed restriction.

4.9.4.1 Bulletin Speed Restrictions

The on-board Train Sentinel® system will handle track bulletins from the Q – CAD system. Form A and Form B track bulletins are used to affect additional speed restrictions. Form A bulletin typically instructs the train to travel at less than the normally authorized speed due to track condition, such as unstable ballast due to water erosion or extremely

high temperatures in an area. Form B bulletins are intended to protect maintenance of way crews and their equipment while performing repairs on or around the track. Form F bulletins are intended to provide additional free-form information to the train crew. The Train Sentinel® system has the capability to accept the following displayable bulletins:

- Form A
- Form B
- Form F

Two options exist to provide bulletin information to trains. The options include an initial bulletin that includes all speed restriction that the train will encounter during the crew's tour of duty, or the dynamic delivery of bulletins matching the authority limits generated to the train. However, occasionally a need arises to notify the crew about a new bulletin, one not listed in the warrant for bulletins.

Unlike permanent speed restrictions imposed by the timetable, speed restrictions derived from Form A and Form B bulletins expire and can be voided. When a bulletin is voided or expires, a configuration option within the Train Sentinel® system determines the enforcement behavior for a train already within the limits of bulletin. The configuration option either immediately ends enforcement, or continues to enforce the restriction until the train clears the limits.

The method to be implemented with OCRS and Train Sentinel® for providing the Form B Work Enforcement protection will be utilized as follows:

- The train will approach the Form B limits, at 2-3 miles prior to the encounter
- The engineer will contact the EIC (Employee-in-Charge) and request movement through the Authority limits
- If the EIC allows the train to operate through the Authority Limits, the EIC will dictate a speed to the train crew
- The engineer will enter the speed into Train Sentinel® and the braking algorithm will be applied based on the speed entered, through the Limits.

Form F bulletins are often used to convey safety information, such as notification of stumbling hazards or other similar information, to the crew. Train Sentinel® will display this information for convenient reference by the crew.

All of the bulletins described above are available for display on-board the locomotive. The crew may view detailed information about specific instructions or bulletins by selecting the Track Bulletin button on the display.

4.9.4.2 Timetable Derived Speed Restrictions

The Quantum – Positive Train Control System enforces various speed restrictions derived from the railroads timetable, including permanent and temporary speed restrictions, restrictions based on the direction of travel, train type, the train's gross weight, and combinations of the above. The Train Sentinel® system can enforce restrictions due to the presence of a specific car in the consist, such as a car containing hazardous material.

4.9.4.3 Speed Enforcement

The Train Sentinel® system initiates penalty enforcement when such the action is required to bring the train into compliance with an upcoming restriction. Enforcement once initiated, continues until the train is completely stopped. In addition, the Train Sentinel® Locomotive Segment will initiate penalty enforcement on a train that has violated the current speed restriction. Speed violations that are minor or of brief duration can be exempted from enforcement by properly configuring the speed tolerance table.

4.9.5 Train Termination

From the perspective of the Quantum – Positive Train Control System, train "termination" refers to the train reaching its ultimate destination. Once the train is terminated, the system provides protection against individual locomotives not assigned to any train from entering the main track.

Similar to train termination, a Quantum – Positive Train Control equipped train can also exit protected track, perhaps to enter an industry. The Quantum – Positive Train Control System will not manage the movements of the train or monitor its movements once a train has exited mapped track. The on-board Train Sentinel® equipment will be in a state waiting for initialization and authority to move upon the train's return to controlled track.

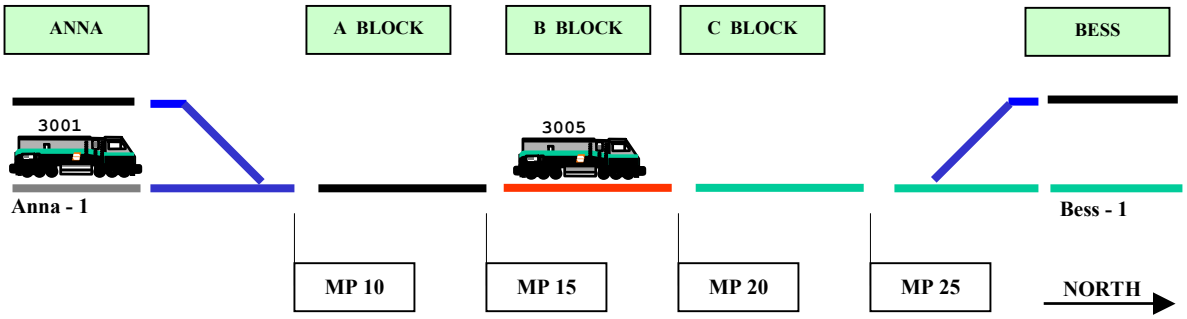
5. Operational Conditions for Movement

There will be situations where all entities on the track are equipped or non-equipped. In order to alleviate safety concerns, the following guidelines will be used for action by two entities. It should be understood that equipped or non-equipped may be either trains or equipment. It should also be understood that non-equipped means that verbal instructions are being relayed to that entity by the train dispatcher. There are basically 4 scenarios that can evolve with the operation:

5.1 Equipped Train ahead of an Equipped Train

When an equipped train (communication link in tact) is following another equipped train, Q – CAD will receive periodic information on the rear position of the train that is ahead. The following train will be allowed to proceed at track speed to the last reported absolute block (B track section) location and then at reduced speed to the last reported position of the train ahead.

In this scenario, Train 3005 North already has a TWC movement authority to travel from the B track section to BESS – 1. The 2nd train, Train 3001 North, also needs to travel to BESS – 1. The dispatcher will "click" with the mouse on the train occupation (ANNA – 1), changing the track section from red to gray.



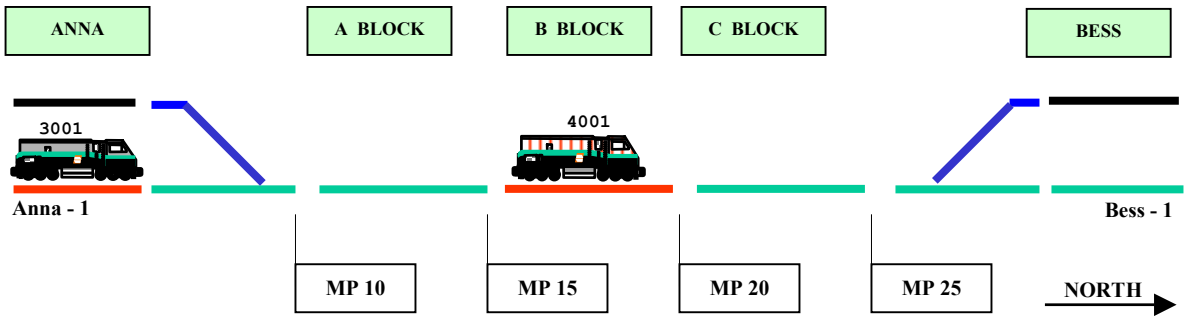
1. Both trains are given authorities, Anna to Bess, Train 3001 is at Anna and Train 3005 is in the B track section, both with Absolute Authority.
2. Both trains in unique track sections (Absolute Authority) operate at track speed. Train Sentinel® will electronically report each train position to both trains.
3. If Train 3005 is still in the B track section and Train 3001 is about to enter the B track section prior to Train 3005 exiting the track section, then the following will apply: 1) Train 3005 is notified that Train 3001 is about to enter the same track section, but can operate at track speed and cannot perform reverse movements; 2) Train 3001 is downgraded to a Restricted Authority and must operate at restricted speed until Train 3005 exits the track section, then operate at track speed; and 3) Train 3001 is only allowed at restricted speed to the last reported location of Train 3005 and then controlled speed looking for the rear of Train 3005.

5.2 Non-Equipped Train ahead of an Equipped Train

A non-equipped train normally has absolute authority for movement. There are several exceptions: a Joint status to help or assist the train or for work or a restricted authority. The restricted authority can only be generated if the train dispatcher emulates the non-equipped train with a position report for the end of the train. If no position report is generated by the train dispatcher, the absolute block authority is enforced.

In the scenario above, both trains are destined to Bess – 1. The non-equipped train ahead (4001) occupies the B track section. By rule, Train 3001 North will be given an authority to occupy the A track section, until Train 4001 clears the B track section. If the train dispatcher manually provides a rear location report for Train 4001 as MP 17, then Train 3001 is given an absolute authority with the A Block and a restricted speed condition from MP 15 to MP 17 looking for the rear of Train 4001. A braking curve will be generated to MP 15, the beginning of B track section. If the dispatcher did not enter a location report, the braking curve will be monitored for Train 3001 to stop at the beginning of B track section, MP 15, thereby providing absolute authority for Train 4001 in the B track section.

For all non-equipped trains, there can be no automatic roll-up of blocks behind a train. The train dispatcher must communicate with the non-equipped train and make manual reports to Q – CAD in order for blocks to be released.



Note that a non-equipped train shall be authorized to proceed at speeds greater than restricted speed only within an Absolute Block. No other train shall be authorized to enter the limits of an Absolute Block.

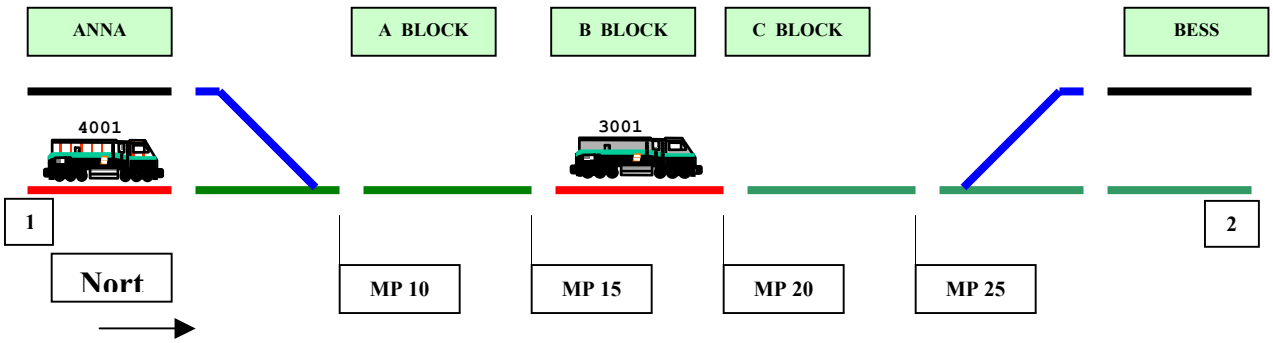
The dispatcher must clear (or void) and then reissue the Absolute Block authority granted the non-equipped trains (4001) as the train releases the track sections as required in OCRS Rule 17.7. Only then should the Q – CAD allow an electronic authority to the following equipped train (3001).

Regardless of the verbal position reports generated by Train 4001 to the train dispatcher, no action will be allowed by Q – CAD or Train Sentinel® for Train 3001 until Train 4001 reports clear of the B track section by the train crew.

5.3 Equipped Train ahead of a Non-Equipped Train

In this scenario, a non-equipped train (4001) is following an equipped Train 3001 North. By rule, the non-equipped train should have absolute authority for movement within the blocks and operate at track speed. Train 3001 can also operate at track speed with no restrictions. Train Sentinel® will provide periodic train position reports denoting the rear of its train. Since Train 4001 has no onboard equipment, track occupancy is absolute and is not allowed into another block, regardless if the occupying train is equipped or non-equipped.

Note: The exception to this rule is if the trains are downgraded from Absolute to Joint with trains or Joint Work Between.



Note that a non-equipped train shall be authorized to proceed at speeds greater than restricted speed only within an Absolute Block. No other train shall be authorized to enter the limits of an Absolute Block.

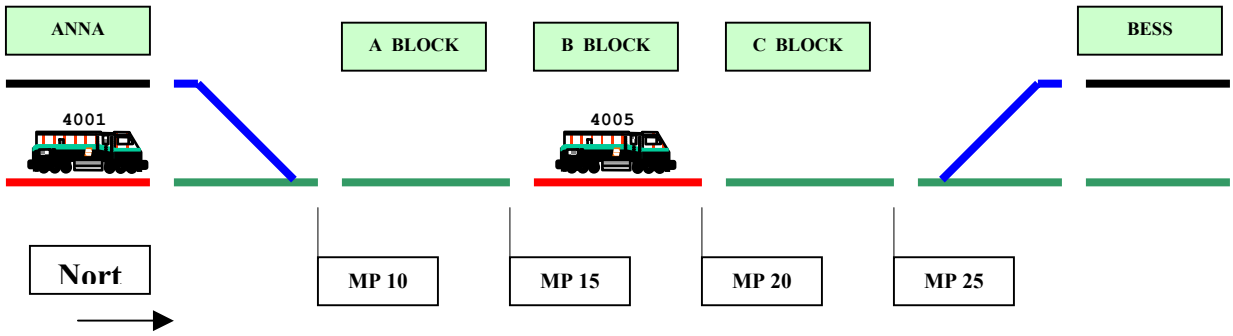
The trailing non-equipped train will continue to be verbally authorized to the last non-occupied block segment by the train dispatcher. Conflict checking rules within Q – CAD will prevent the train dispatcher from issuing a directional authority to the non-equipped (following) train within the block limits of another train (equipped or non-equipped).

For conflict checking and operational scenarios, non-equipped entities require an Absolute Block with any other trains or entities, unless operating under Joint or Work Between.

5.4 Non-Equipped Train ahead of Non-Equipped Train

This section provides the information for issuing a train movement authority for trains and equipment that have no Train Sentinel® equipment or failed equipment. These entities are classified as non-equipped for purposes of operations. By rule, the non-equipped entities have to operate in an absolute condition for separation or under joint for work or assistance.

In this scenario, a non-equipped train (4001) is following another non-equipped Train 4005 North. By rule, every non-equipped train should have absolute authority for movement within the blocks and operate at track speed. Train Sentinel® is not available to either train. The train dispatcher will have to provide manual position reports for each train in order for the trains to have absolute authority in unique blocks.



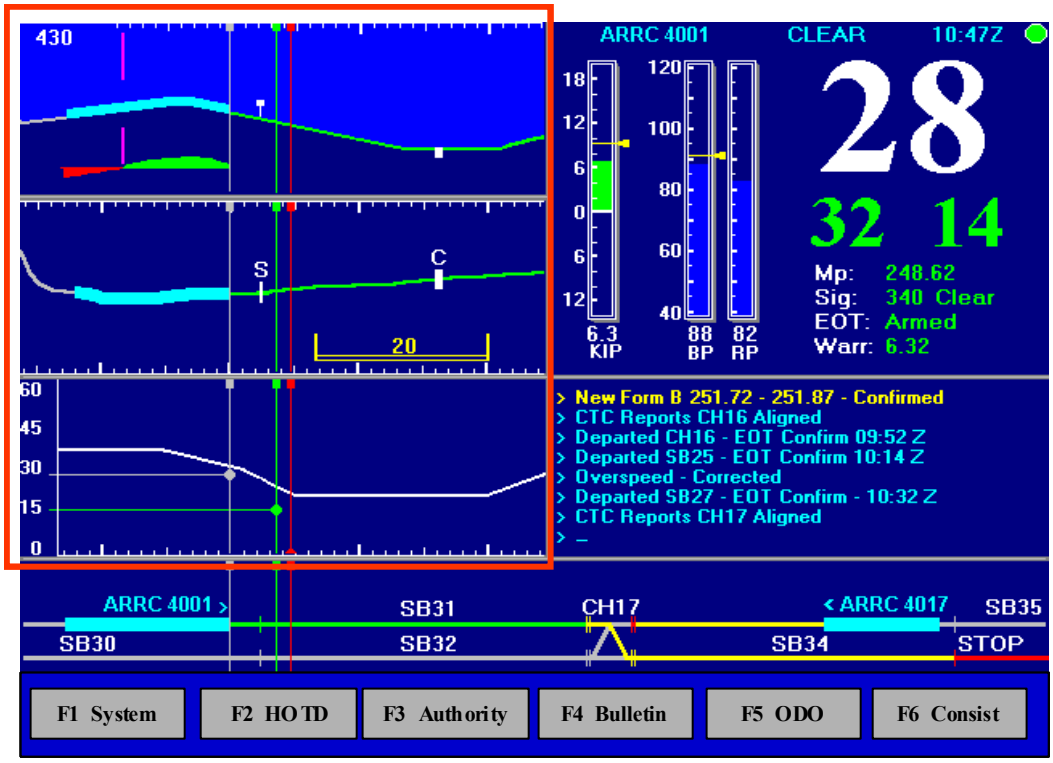
Both trains will continue to be verbally authorized to the last non-occupied track section by the train dispatcher. Conflict checking rules in Q – CAD will prevent the dispatcher from issuing a directional authority to the non-equipped train within the track section limits of another train (equipped or non-equipped). As the lead train releases a Train Movement Authority in accordance with GCOR Rule 16.7, the train dispatcher will enter the information into Q – CAD for the non-equipped train on the trackline overview display. As the "train symbol" is moved to a different track section, the dispatcher may manually issue a verbal authority to the following non-equipped train by transmitting it verbally to the train crew for read-back and acknowledgement.

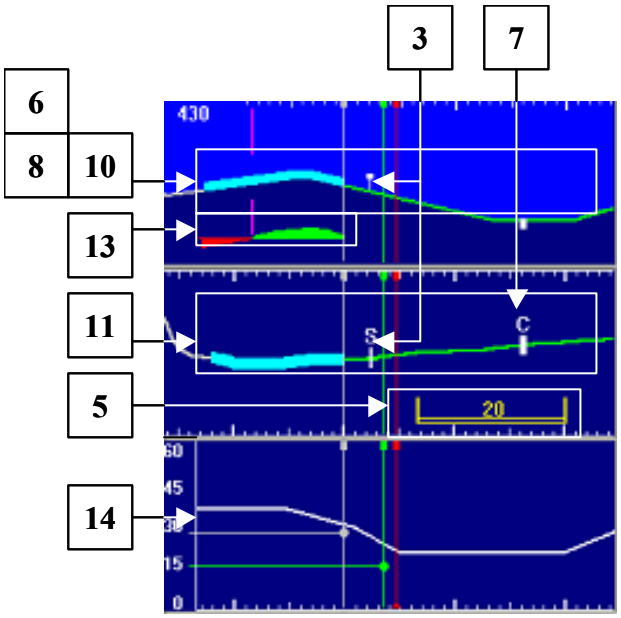
6. Train Sentinel® Human Machine Interface (HMI)

The following section will outline the interface between the Train Sentinel® on-board computer (OBC) systems and the train crews that will operate the system. With the Quantum Positive Train Control System, the human interface requirements will dictate certain criteria that will be used by either the office or the train crews in the form of communications. The ultimate objective is to provide safety scenarios to the train crews. The enforcement criteria for the Quantum Positive Train Control (Q – PTC) System is predominately passive. Information received from the office is displayed on the OBC and the requirements will dictate some type of action by the train crews. If conditions are such that no action is evident through the OBC system, the train will be brought to a safe stop. Q – PTC will only react to non-compliance.

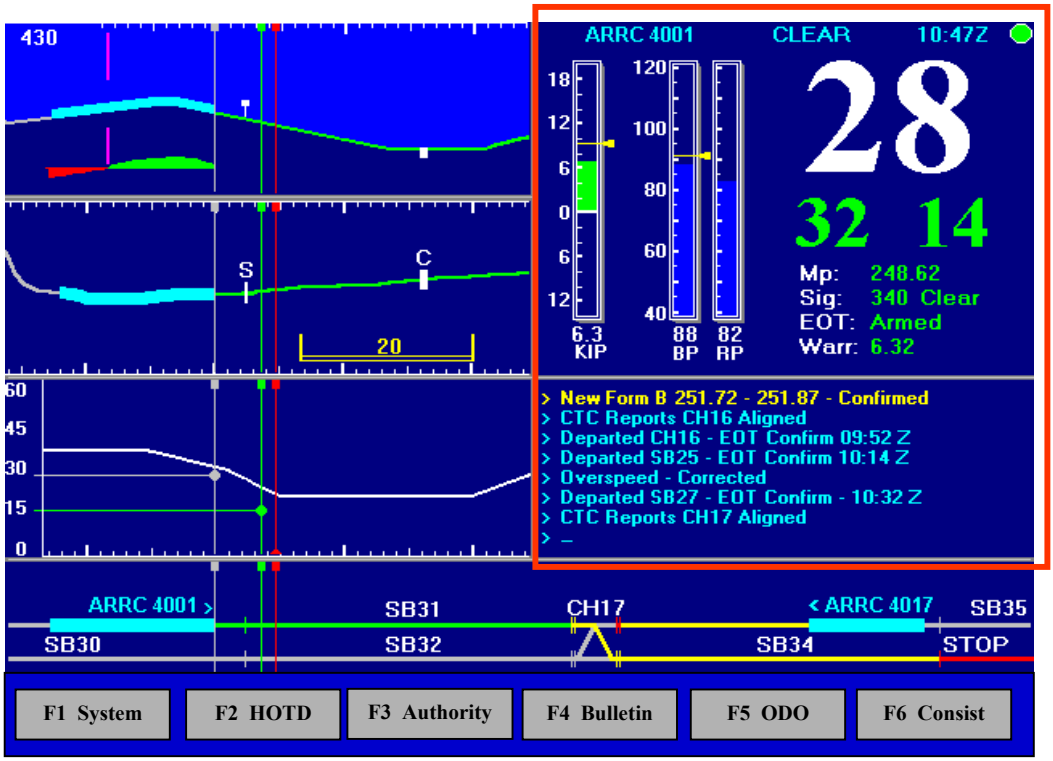
The interface between Q – CAD and Train Sentinel® is electronic for of communications. The primary purpose in ensuring safety for the trains and crews is to digitally display information without the need for verbal communications. This process will ensure proper compliance to movement instructions as well as provide additional information to the train crews while enroute. The various messages for response will be 1) operational, 2) informational, and 3) train crew acknowledgements.

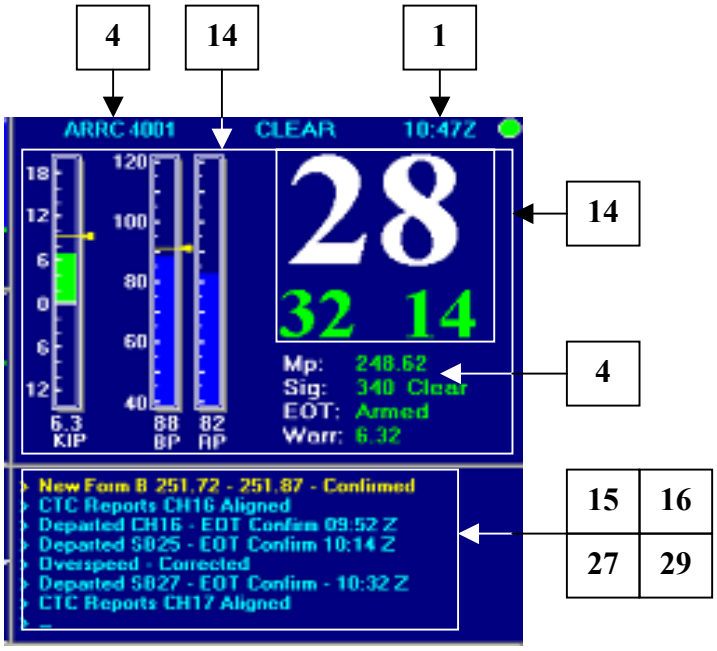
6.1 Train Sentinel® Visual Display



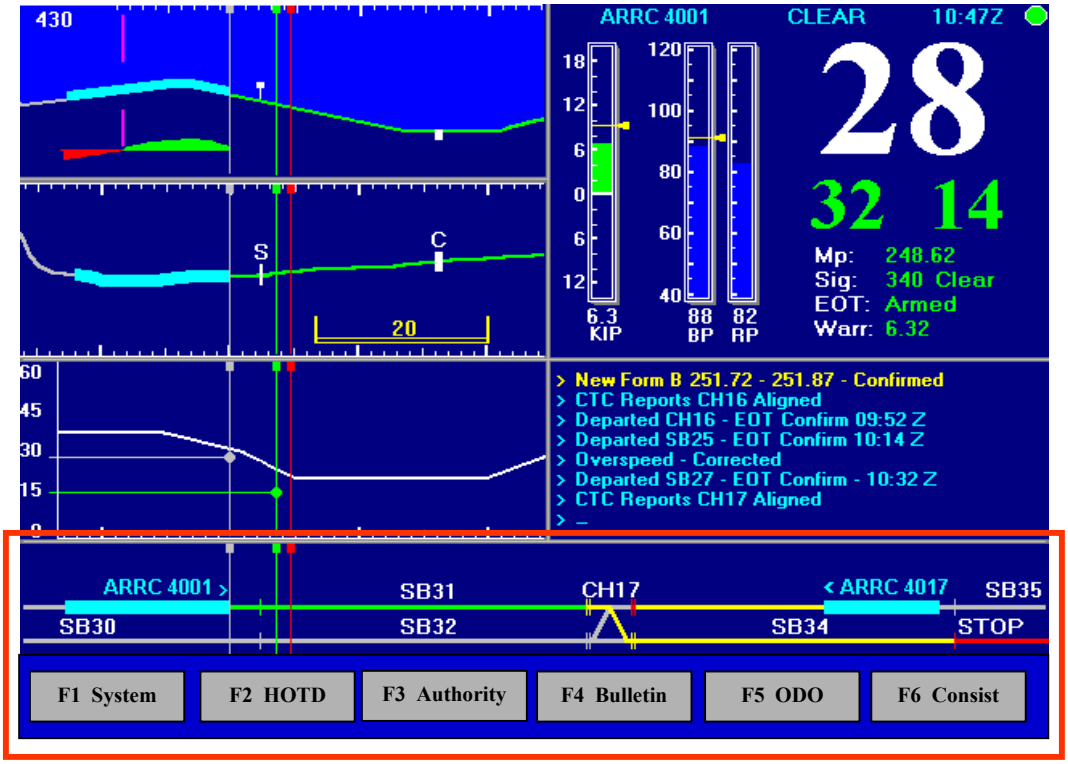


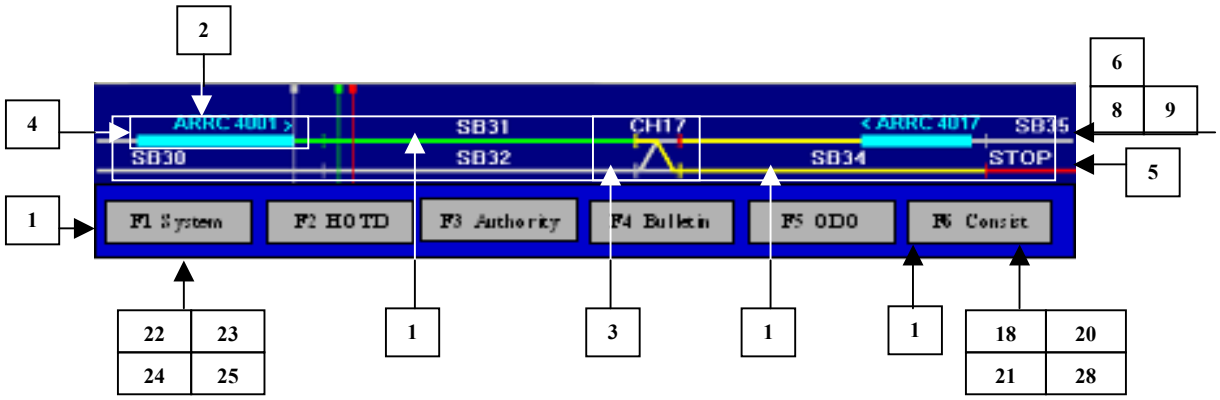
Train Sentinel® Visual Display



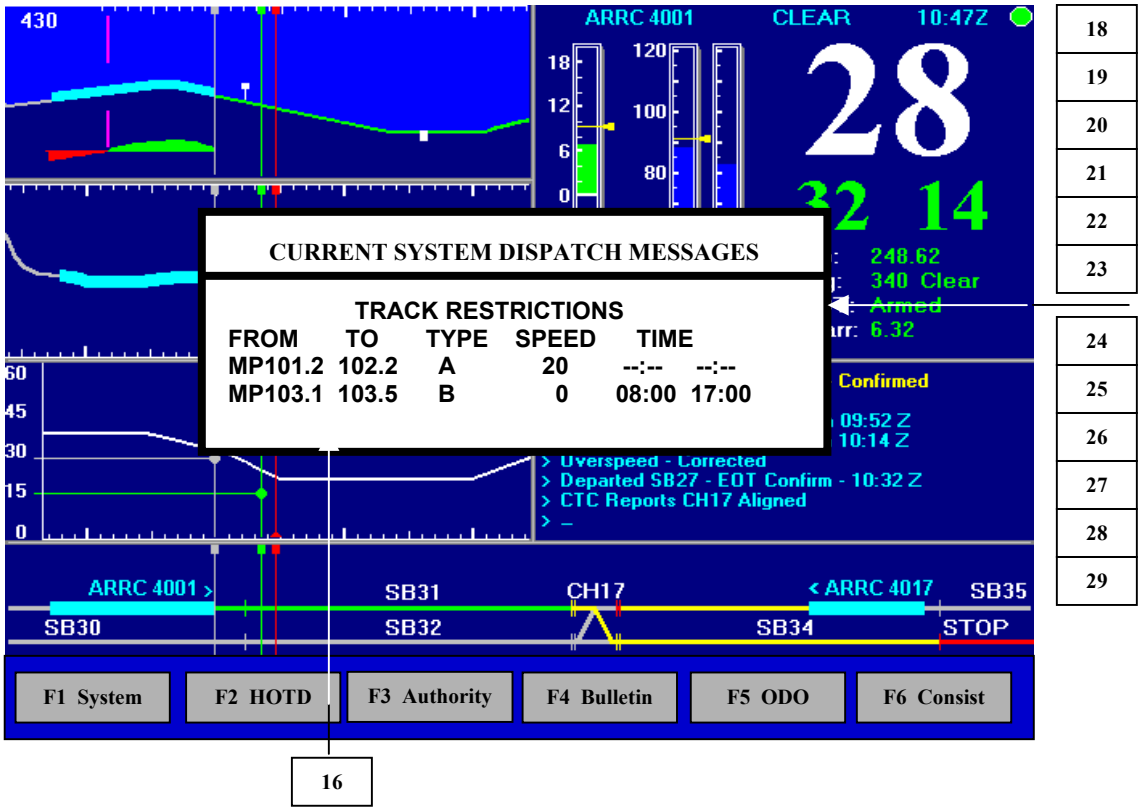


Train Sentinel® Visual Display





Train Sentinel® Visual Display



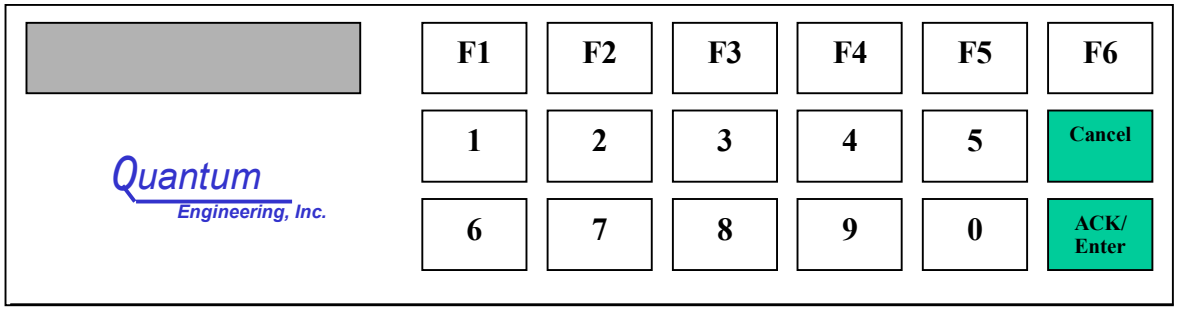
6.2 Train Sentinel® Visual Display Outline

Messages are presented based on Function Key activation as well as inbound messages from Q – CAD. Numbers listed reflect prior pages identification of numeric notations :

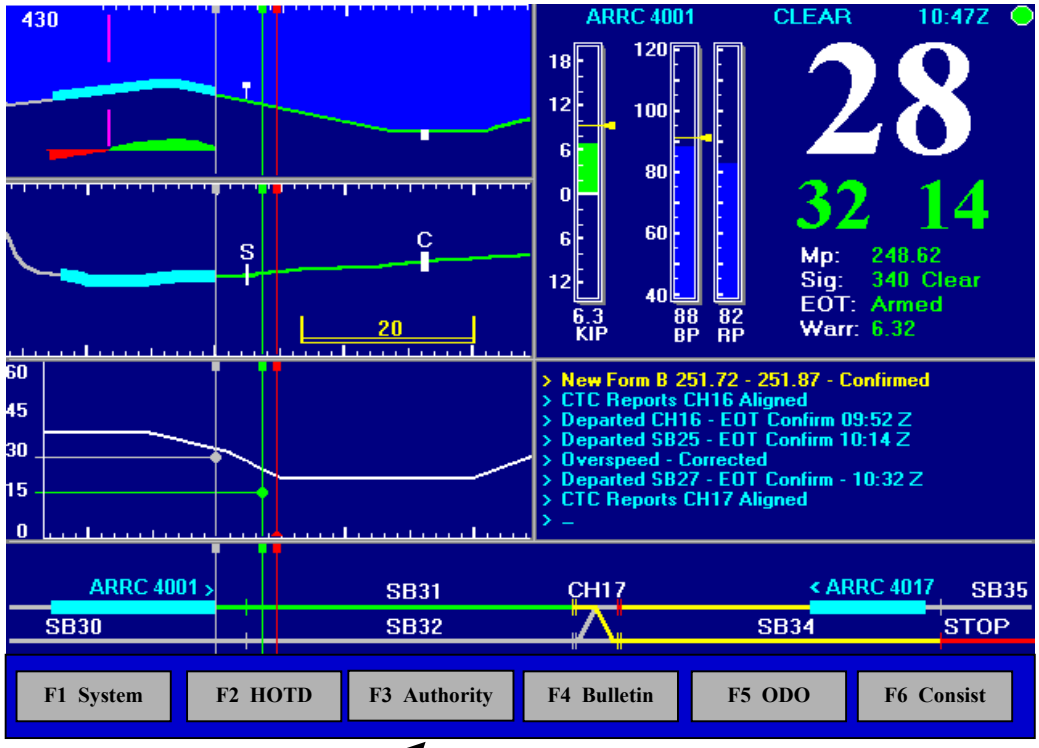
1 – Graphical representation of the HMI Train Sentinel® device for the train crews
2 – Trackline Overview panel or strip map of the territory in front of the train
3 – Visual indication of the position of signal devices ahead of the train. Shown in 2 places: the grade view and the curvature view.
4 – There is a vertical line that is stationary in the middle of the left-hand portion of the screen. The map under the view moves to the left to denote train movement. The train is located normally on the left-hand side of the screen with the remaining territory on the right-hand side of the screen.
5 – On the view, there is a 20 MPH speed restriction. For any workers there is also a "Stop" field on SB36.
6 – Track workers will be noted by a red or blue "Stop" indication on the track that the work is being performed.
7 – Road crossings are noted on the screen by a "C" on the curvature screen and a small white box on the grade screen.
8 – If tunnels were evident on the territory, those devices would be noted on the grade, curvature and synoptic panels for the train crews.
9 – Station names, block names, or identified milepost will be noted on the synoptic panel.
10 – Grade outline for the train
11 – Curvature outline for the train
12 – Use of the F6 Consist soft-key will provide consist information.
13 – The buff and draft for the train
14 – Dynamic train information
15 – Speed conditions are noted for the train crews, example "Overspeed corrected."
16 – When a message is necessary as additional information, the message is overlaid on the HMI screen for easy reference to the train crew for compliance.
17 – Button for secondary screen – Soft-Key panel
18 – Button for secondary screen – additional locomotive units
19 – Button for secondary screen – future activities for maintenance
20 – Button for secondary screen – train consist information
21 – Button for secondary screen – train consist for locomotive information
22 – Button for secondary screen – Train Crew Logon/Logoff
23 – Button for secondary screen – to ATP
24 – Button for secondary screen – to SAI (Locomotive Optimization)
25 – Button for secondary screen – to Wheel Slip
26 – A field vehicle will utilize the same screen format as a train. The field device will be housed in an attaché case to provide ease of transferring between vehicles
27 – Dynamic information for the train crew
28 – Soft-keys for additional information
29 – Dynamic information for the train crew

6.3 Train Sentinel® Keypad

17 **Keypad for Train Crew input or response**

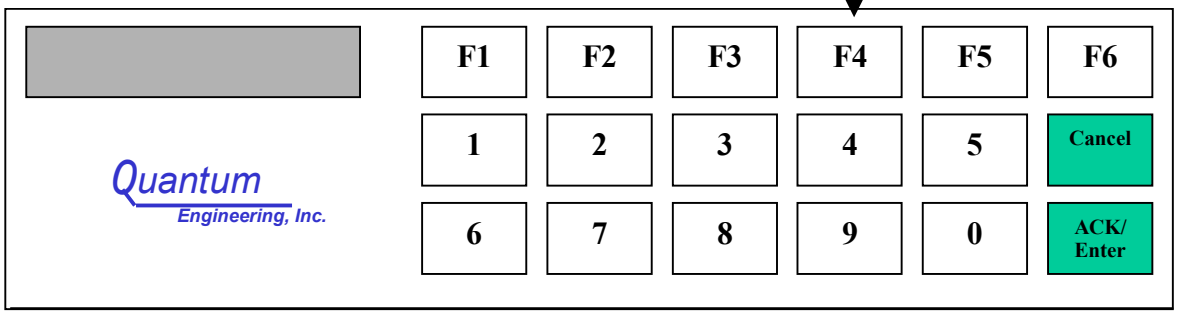


6.4 Train Sentinel® HMI



Information Keys

Soft Keys



Crewmember Keypad

6.5 Train Sentinel® Soft Key Migration

F1 System

- **1.1 Test**
  - **1.1.1 Outputs**
    - 1.1.1.1 Horn — Test the horn output (run sequence)
    - 1.1.1.2 Bell — Test the bell output (toggle)
    - 1.1.1.3 Penalty — Test the P2A valve
    - 1.1.1.4 –
    - 1.1.1.5 –
    - 1.1.1.6 Back
  - **1.1.2 Comms**
    - 1.1.2.1 HOTD
      - 1.1.2.1.1 — 1200 — Transmit 1200 Hz tone
      - 1.1.2.1.2 — 1800 — Transmit 1800 Hz tone.
      - 1.1.2.1.3 — Emergency — Send emergency dump command
      - 1.1.2.1.4 — Off — Turn off all tests.
      - 1.1.2.1.5 — –
      - 1.1.2.1.6 — Back
    - 1.1.2.2 Disp — Q – CAD dispatch RF test.
    - 1.1.2.3 –
    - 1.1.2.4 –
    - 1.1.2.5 –
    - 1.1.2.6 Back
  - **1.1.3 GPS** — View the GPS status.
  - **1.1.4 –**
  - **1.1.5 –**
  - **1.1.6 Back**
- **1.2 LCD**
  - **1.2.1 Backlight** — Adjust the backlight level
  - **1.2.2 Contrast** — Adjust the contrast
  - **1.2.3 Scale** — Set the display scale
  - **1.2.4 –**
  - **1.2.5 –**
  - **1.2.6 Back**
- **1.3 Setup**
  - **1.3.1 Time** — Adjust the time units of display
  - **1.3.2 Zone** — Set the current time zone.
  - **1.3.3 –**
  - **1.3.4 –**
  - **1.3.5 –**
  - **1.3.6 Back**
- **1.4 –**
- **1.5 –**
- **1.6 Back**

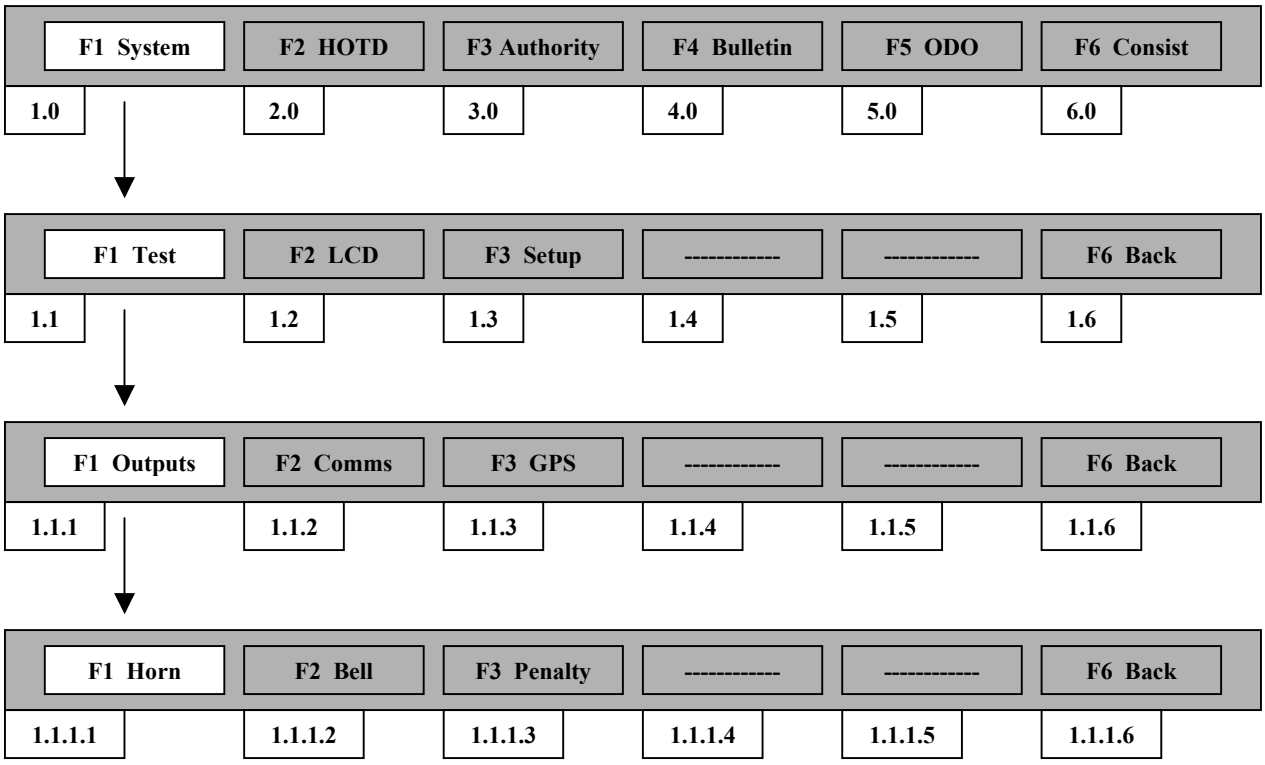
F2.	**HOTD**	
2.1	**Arm**	Arm the HOTD
2.2	**Disarm**	Disarm the HOTD
2.3	**Set Code**	Set the EOTD ID Code
2.4	**EOT Position**	Check the EOT position, if available
2.5	**Test**	Run a communications test
2.6	**Back**	
F3.	**Authority**	
3.1	**Current**	Show the Q – CAD messages
3.1.1	**First**	Go to the first
3.1.2	**Previous**	Go to the previous
3.1.3	**Next**	Go to the next
3.1.4	**Last**	Go to the last (default)
3.1.5	**–**	
3.1.6	**Back**	
3.2	**Request**	
3.2.1	**Enter**	Request to enter controlled track
3.2.2	**Exit**	Request to operate manually (exit)
3.2.3	**W&T**	Request Work and Time
3.2.4	**Lead**	Request Lead Loco Change
3.2.5	**–**	
3.2.6	**Back**	
3.3	**–**	
3.4	**Select**	
3.4.1	**Head**	Set the head-end occupancy
3.4.2	**EOT Blk**	Set the EOT occupancy
3.4.3	**EOT Pos**	Set the EOT position
3.4.4	**–**	
3.4.5	**–**	
3.4.6	**Back**	
3.5	**Report EOT / Last Car**	Report the ID of a passing EOT/Car
3.6	**Back**	
F4.	**Bulletin**	
4.1	**Form B**	Permission to enter Form B received
4.2	**Cancel**	Cancel (last car clear)
4.3	**List**	List all in advance
4.4	**–**	
4.5	**–**	
4.6	**Back**	

F5. Odo
- **5.1 Count up**
- **5.2 Count down**
- **5.3 Stop**
- **5.4 –**
- **5.5 –**
- **5.6 Back**

F6. Consist

6.1	**Setup**	Set the initial consist completely
6.2	**Pickup**	Picked up cars (locos)
6.3	**Drop**	Set aside cars (locos)
6.4	**–**	
6.5	**–**	
6.6	**Back**	

Example of Soft-key execution with cascading menus -



6.6 Interfaces between Q – CAD and Train Sentinel®

The following section will detail the interface between the office and field or Q – CAD to Train Sentinel®. With any Positive Train Control System, the interface requirements will dictate certain criteria that will be used by either end of the transactions to provide safety scenarios to the train crews.

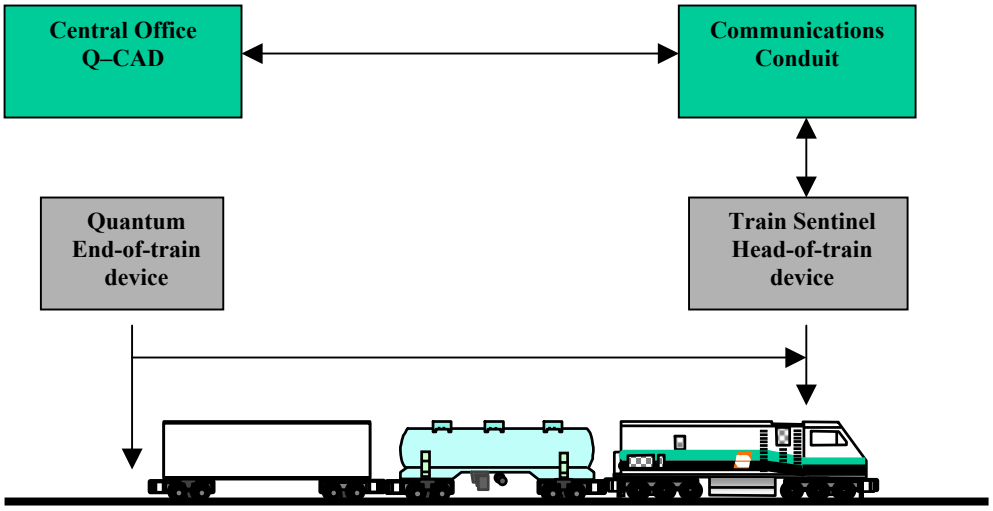
The interface between Q – CAD and Train Sentinel® is composed of various messages that are 1) operational, 2) informational, and 3) acknowledgements.

6.7 Primary Components — Engesis and Train Sentinel®

In order to qualify as a true Positive Train Control system on an equipped locomotive, the following conditions must apply:

- There must be an Q – CAD Central Office component used by the train dispatcher to conduct movement authorities through a trackline overview display;
- There must be a communications conduit to electronically move messages between the office and train (VHF, UHF, Cellular, Satellite, Fiber Optics cable, etc.);
- There must be a Train Sentinel® onboard locomotive computer to handle messaging between the rear of the train and the communications conduit, and;

There must be a Quantum end-of-train device located on the rear car, equipped with GPS and able to communicate with the head end of the train.



6.8 Interface Messages

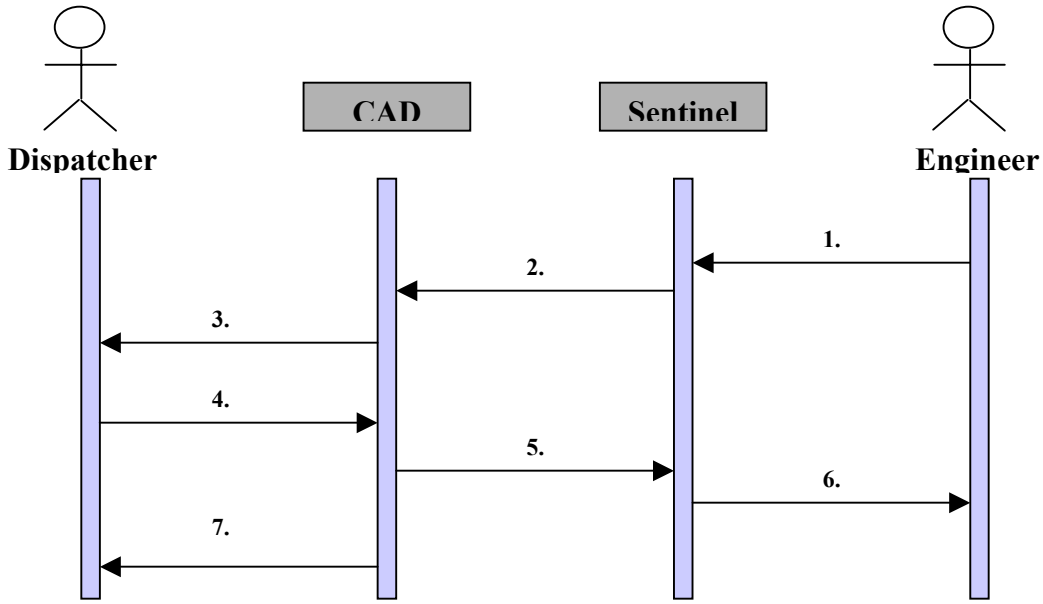
RX – Central Control Operations (Dispatcher) to Train (Field)

Message 31	Authority to Enter the Track
Message 32	Movement Authority
Message 33	Request to Cancel Movement Authority
Message 34	Modify Movement Authority
Message 35	Restricted Movement Authority
Message 36	Joint Movement Authority
Message 37	Authority to Work on Track/Switch
Message 38	Stop
Message 39	Denial of Request to Entering Controlled Track
Message 40	Track & Time Authority (CTC)
Message 42	Work & Time Authority (DTC)
Message 43	Work & Time Joint Warning
Message 48	Add a Single Speed Restriction
Message 51	Confirmation Error
Message 52	Waiting CCO confirmation message from train
Message 53	Advise train in lead that new train is coming behind the lead train
Message 54	Delete Restricted Authority (back to absolute authority)
Message 55	Improper Train Location
Message 56	Not Used
Message 57	Request for Train Position
Message 58	Error in Confirmation of Cancel
Message 59	Waiting for Confirmation
Message 60	Turn Off OBC
Message 61	Not Used
Message 62	Correct (Final) Validation for Movement (“Have a Safe Trip”)
Message 64	Advise the Restricted Train of the EOT of Front Train
Message 69	Consist Information - Stats
Message yy	Consist Information - Acknowledgement

TX – Train (Field) to Central Control Operations (Dispatcher)

Message 01	Request Authorization Get on Track (Manual)	
Message 02	Confirm Movement Authority (automatic)	
Message 03	Confirm Cancel (Manual – Y/N)	M-33
Message 04	Confirm Alteration of Movement Authority	M-34
Message 05	Train Departure (Anyplace with 0 speed)	
Message 06	Actual Position (Automatic)	
Message 07	End-of-Train, Last car	
Message 08	Line Occupied, train cars left in place	
Message 09	Stop, not scheduled	
Message 10	Leaving Controlled Track	
Message 11	Changing the Control Locomotive	
Message 12	Adding Cars	
Message 13	Deleting Cars	
Message 14	Lead Train Position Message for Restricted Authority	
Message 15	System Message Command from the Wayside	
Message 16 through Message 22	Not Used	
Message 23	Proposed (Request to get an equipped Hi-Rail vehicle on the track)	
Message 24	Proposed (Request to get an equipped Hi-Rail vehicle off the track)	
Message 25	Confirmation of Receipt of Advisement of Restricted Authority	
Message 26	Not Used	
Message 27	Not Used	
Message 29	Alteration of Train Consist	
Message 30	Work & Time Joint Authorization	
Message xx	Consist Information - Stats	
Message yy	Consist Information - Acknowledgement	

6.9 Train Movement Authority— Train Requests Authorization Get on Track

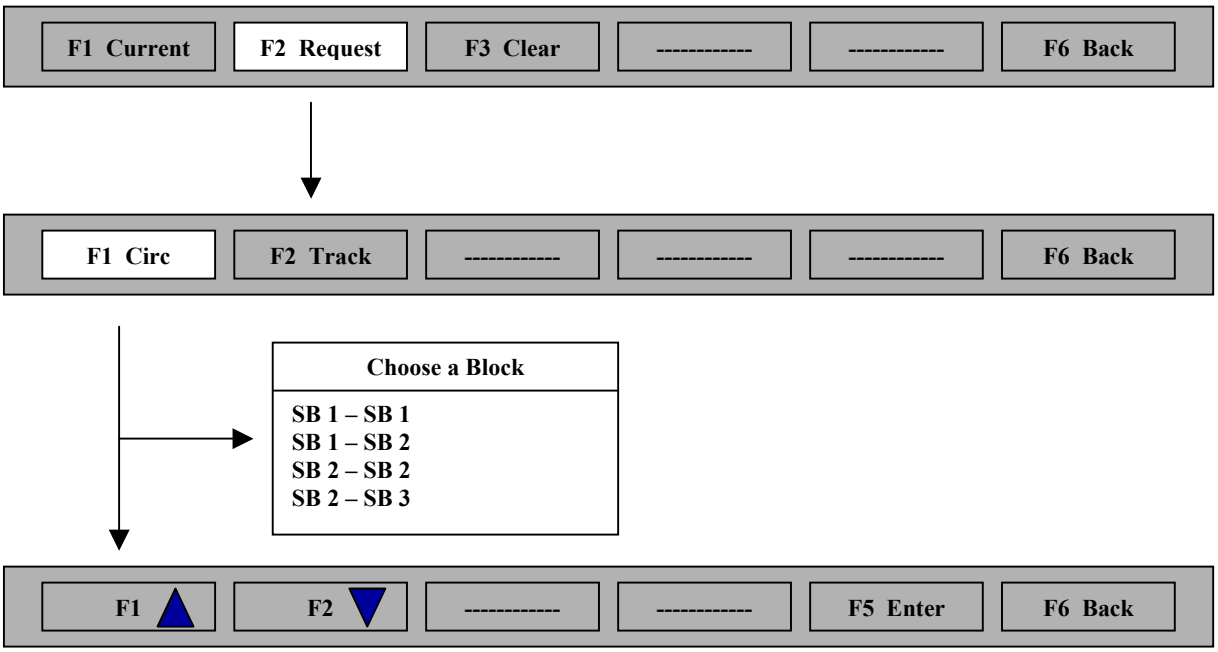


The authorization to enter the track must occur in the following way:

1. The Engineer/Conductor requests authorization to enter controlled track through Train Sentinel®;
2. Train Sentinel® sends Q – CAD a message (01) requesting authorization to enter the track;
3. Q – CAD displays on the trackline overview to the Dispatcher the request to enter the track (Note: small yellow arrow under the station symbol);
4. Dispatcher authorizes the entrance of the train on the controlled track through Q – CAD;
5. Q – CAD responds to Train Sentinel® and authorizes the entrance into the track with a Message 31;
6. Train Sentinel® passes the single section movement authority to the Engineer/Conductor that he has authorization to enter the track and passes a confirmation to Q – CAD;
7. Q – CAD shows the Dispatcher the representation of the entrance of the train on the controlled track.

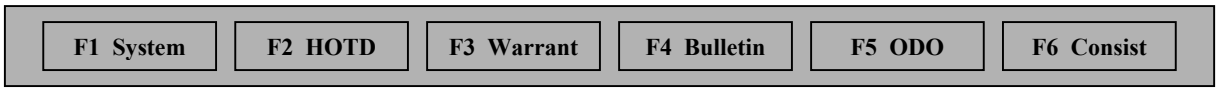
TX – Train (Field) to Central Control Operations (Dispatcher)

Message 01 **Train Requests Authorization Get on Track**



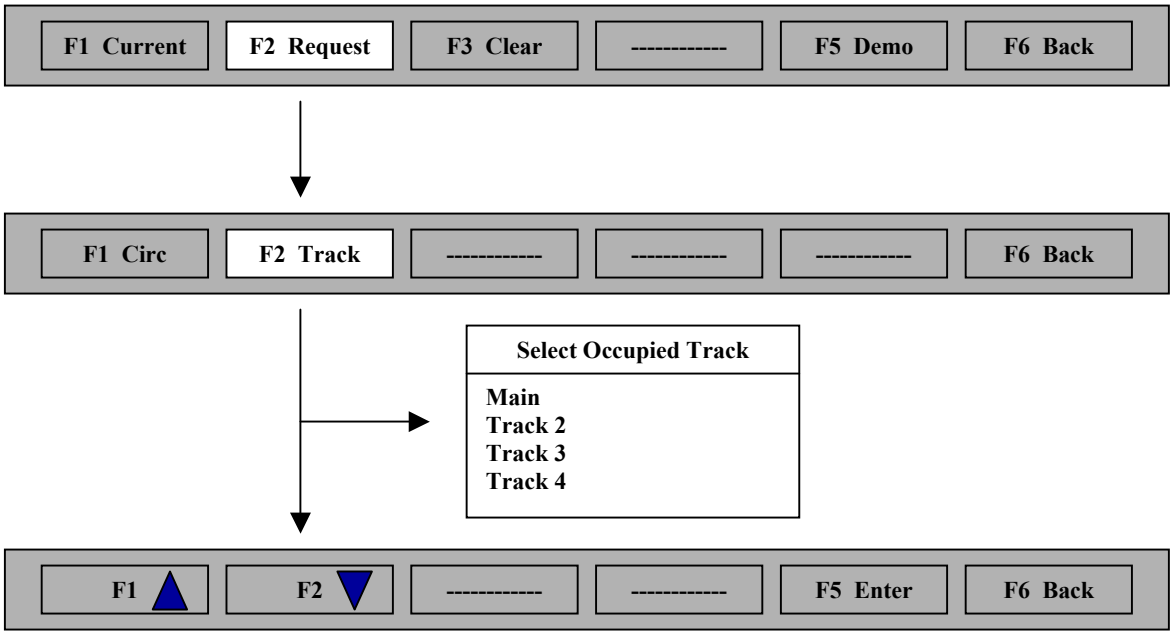
The train is requesting authorization to enter the track:

1. The Engineer/Conductor initiate the process by pressing the F# Warrant" key;
2. On the Train Sentinel® keypad, the Engineer/Conductor will then depress the "F2" and when the next menu line appears, press the F1 to designate the block in which the train will enter the track;
3. The Engineer/Conductor will "pan" through the blocks using the "up" and "down" keys to designate the entry block;
4. When the correct block is identified the Engineer/Conductor will press the "F5" key to enter the block;
5. The Engineer/Conductor will then press the "F3 Warrant" key and then the "F2 Track" key to designate the track that it will enter;
6. The menu will now go back to the normal line sequence, for the next command.



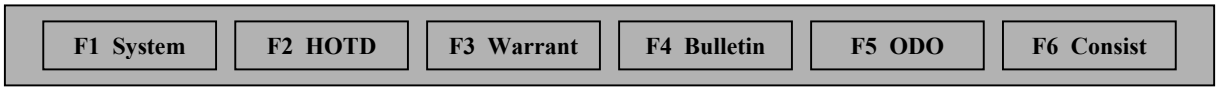
TX – Train (Field) to Central Control Operations (Dispatcher)

Message 01 **Request Authorization Get on Track**

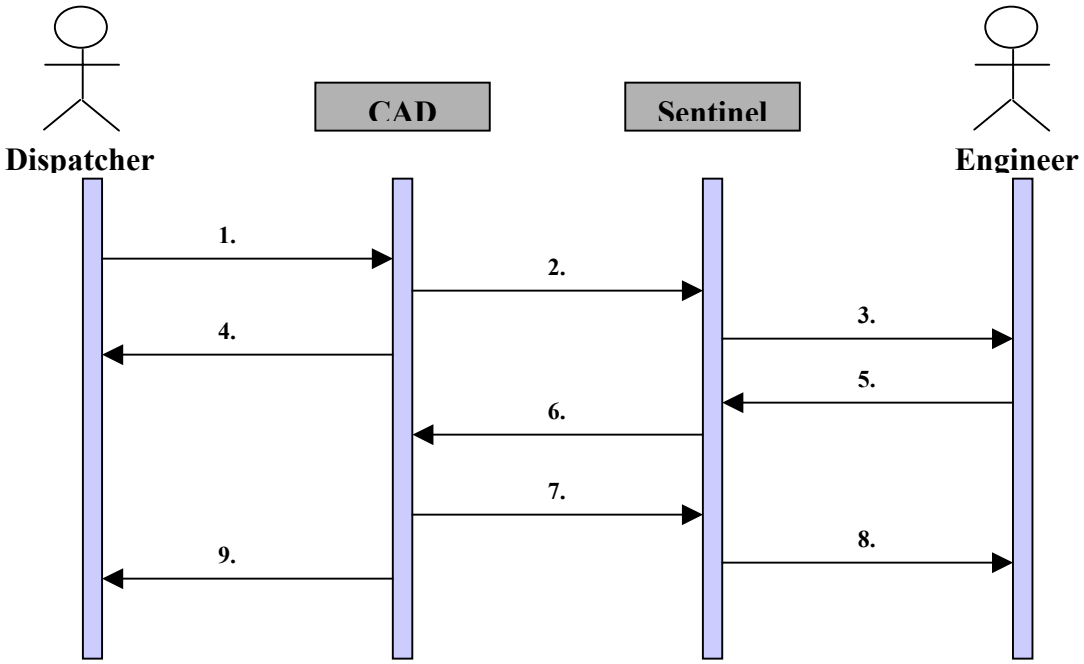


The train is requesting authorization to enter the track:

1. The Engineer/Conductor will then press the "F3 Warrant" key and then the "F2 Track" key to designate the track that it will enter;
2. The Engineer/Conductor will "pan" through the blocks using the "up" and "down" keys to designate the entry track;
3. When the correct block is identified the Engineer/Conductor will press the "F5" key to enter the track.
4. The menu will now go back to the normal line sequence, for the next command.



6.10 Train Movement Authority (Absolute)

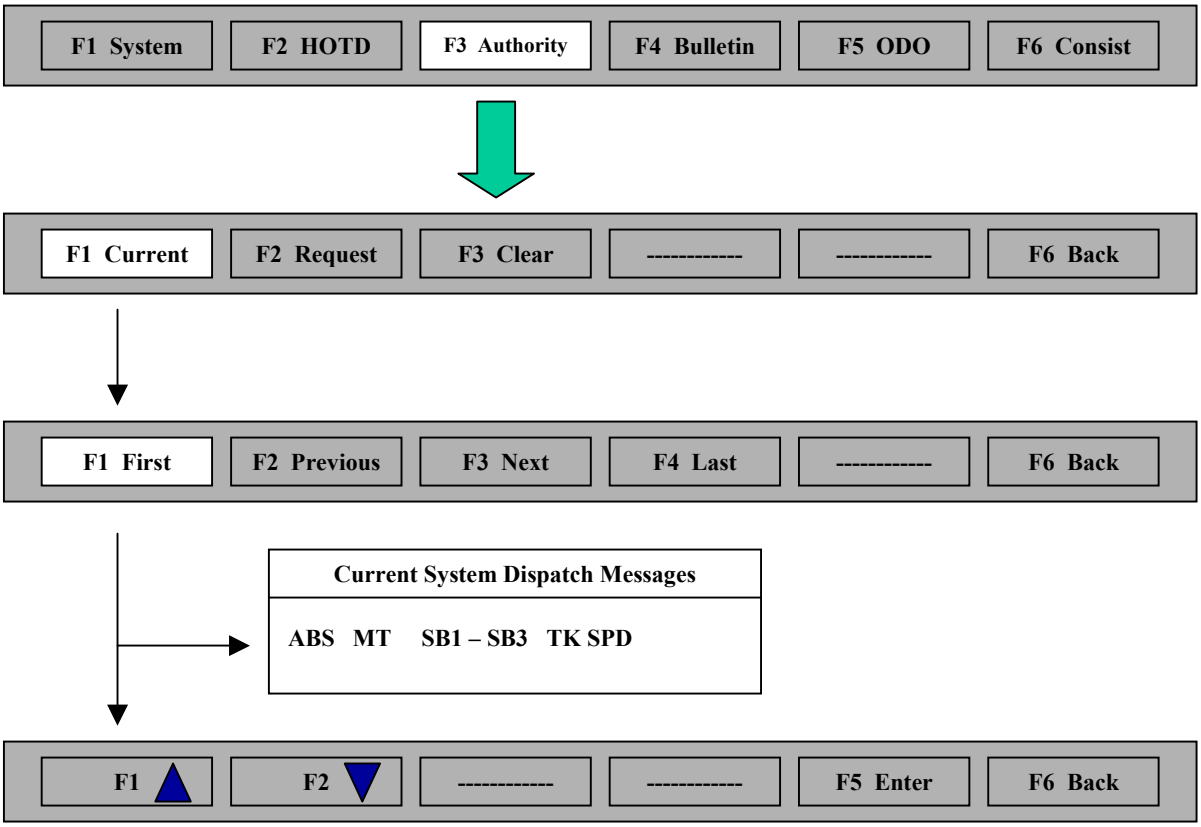


The Train Movement Authority procedure must occur as follows:

1. The dispatcher generates a Train Movement Authority (Message 32);
2. Q – CAD checks if the warrant can be granted, and then sends a Train Movement Authority message to Train Sentinel®;
3. Train Sentinel® displays to the Engineer/Conductor the train movement authority received (Message 32) and waits for the Engineer or Conductor confirmation;
4. Q – CAD shows the Dispatcher the indication of the Train Movement Authority sent and waiting to be confirmed.
5. The Engineer/Conductor confirms the Train Movement Authority received (Message 02);
6. Train Sentinel® replies to Q – CAD, confirming the acknowledgment of the movement authority;
7. Q – CAD analyzes the movement confirmation and responds to Train Sentinel® with a “that is correct” message (Message 32);
8. Train Sentinel® shows the Engineer/Conductor the received message (Message 32);
9. Q – CAD shows the Dispatcher the indication that the movement authority was confirmed;

RX – Central Control Operations (Dispatcher) to Train (Field)

Message 32 **Train Movement Authority**

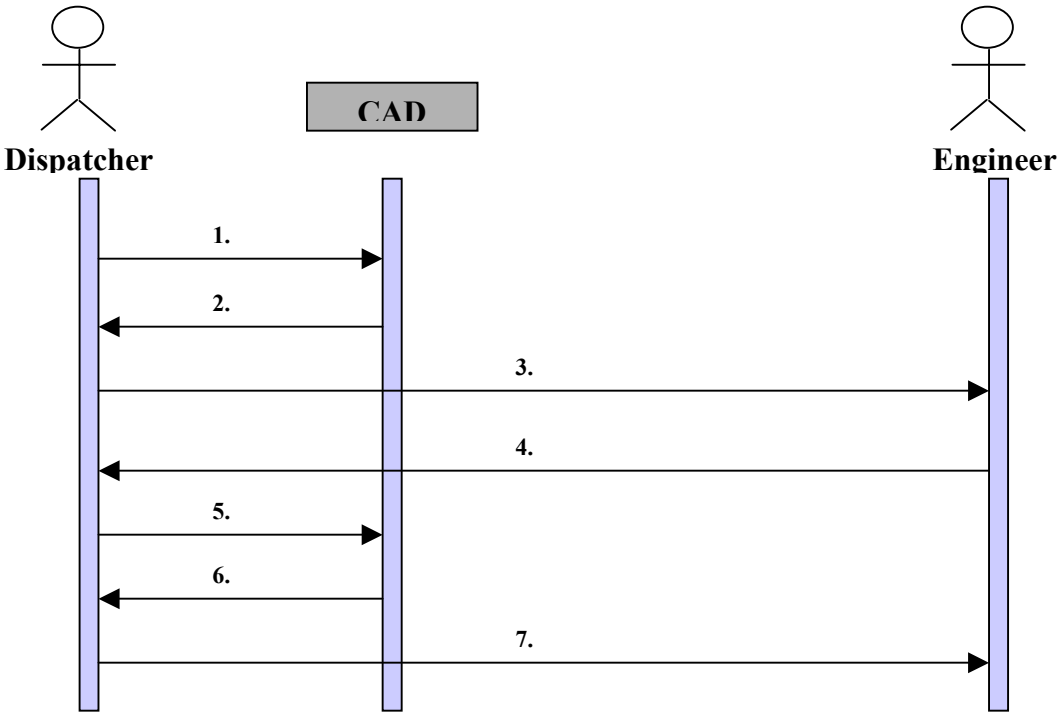


The Dispatcher will generate a movement authority to the train:

1. The Dispatcher performs an entrance/exit command through Q – CAD to move the train, the system sends a Message 32 to the train;
2. The Engineer/Conductor will then press the Warrant key (F3) then "F1", then "F1" to "pan" through any unconfirmed authorities, using the "up" and "down" keys to designate the appropriate movement authority;
3. When the correct movement authority is identified the Engineer/Conductor will press the "F5" key to enter the confirmation of the receipt of the movement authority.

The menu will now go back to the normal line sequence, for the next command.

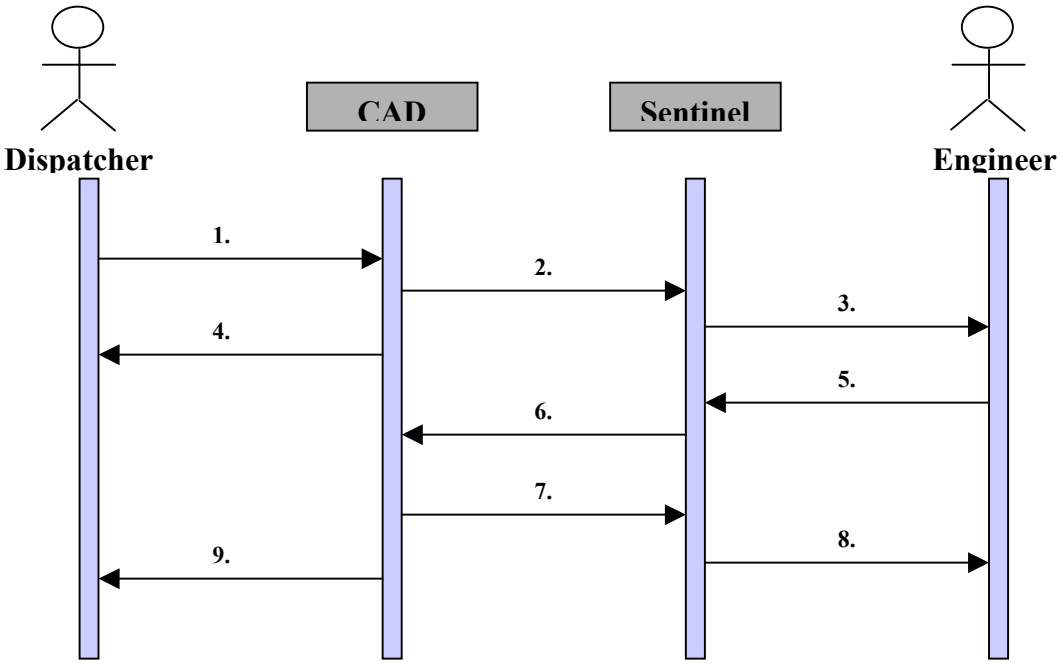
6.11 Train Movement Authority (to trains operating without Train Sentinel®)



The process to grant a Train Movement Authority to trains operating without Train Sentinel® must occur as follows:

1. Dispatcher creates a Train Movement Authority ;
2. Q – CAD checks if the movement authority can be granted and indicates to the dispatcher that the movement authority is waiting to be confirmed;
3. Dispatcher reads the Train Movement Authority to the Engineer/Conductor;
4. Engineer/Conductor confirms the Train Movement Authority to the Dispatcher;
5. Dispatcher provides a movement authority confirmation to Q – CAD;
6. Q – CAD shows to the Dispatcher the indication of the confirmed movement authority;
7. Dispatcher reads to the Engineer/Conductor a “That is correct” message.

6.12 Joint Track Movement Authority

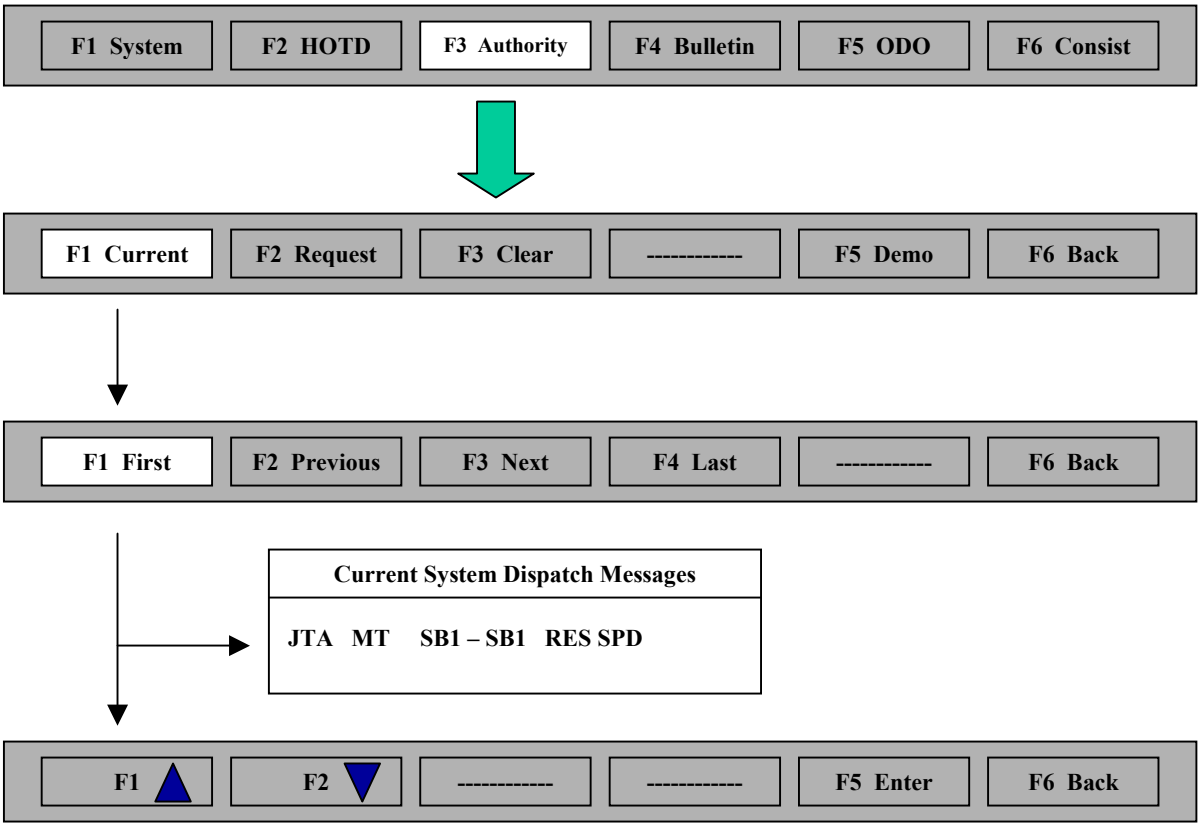


The Joint Track Movement Authority procedure must occur as follows:

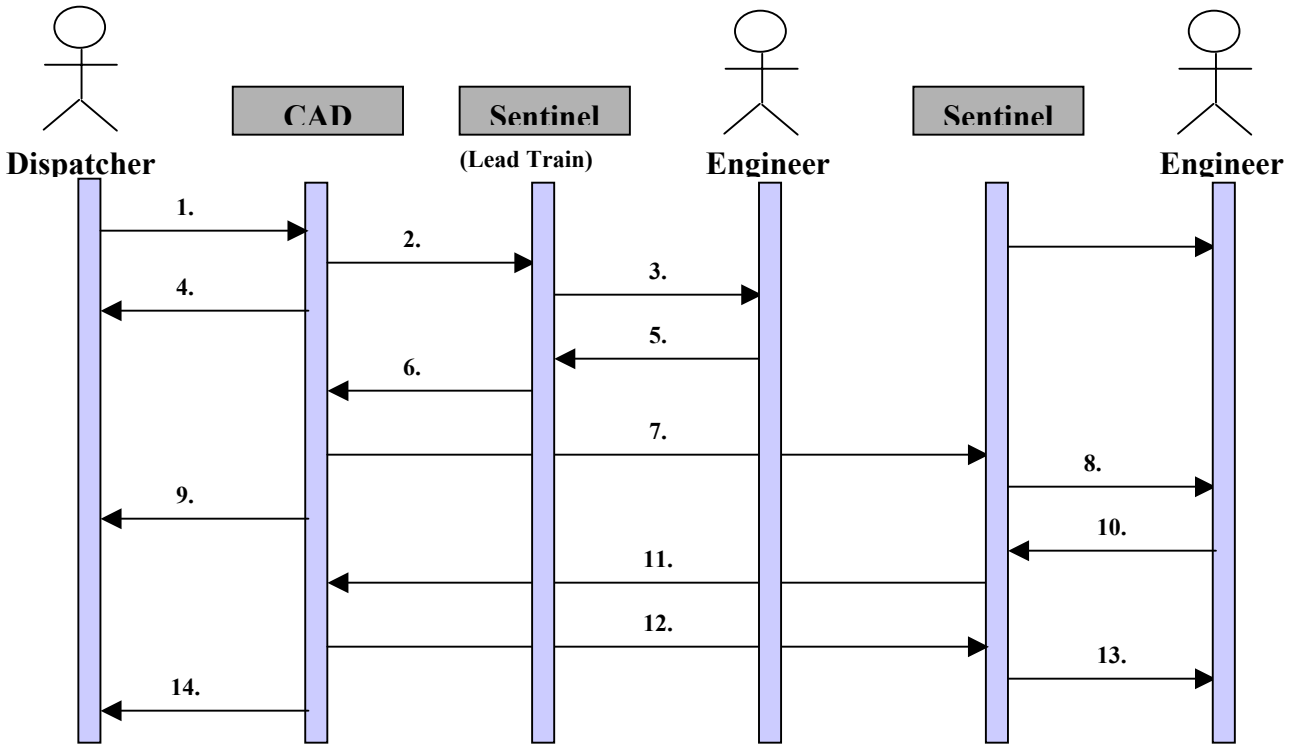
1. Dispatcher will generate a Joint Track Movement Authority;
2. Q – CAD checks if the authority can be granted, and then sends a Joint Track Movement Authority (Message 36) to Train Sentinel®;
3. Train Sentinel® displays to the Engineer/Conductor the received Joint Track Movement Authority and waits for its confirmation;
4. Q – CAD shows to the Dispatcher the indication of the Joint Track Movement Authority send and waiting to be confirmed;
5. The Engineer/Conductor confirms the Joint Track Movement Authority that was received;
6. Train Sentinel® responds to Q – CAD (Message 02), confirming the acknowledgment of the Joint Track Movement Authority;
7. Q – CAD checks the authority confirmation and responds to Train Sentinel® with a "that is correct" message (Message 62);
8. Train Sentinel® displays to the Engineer/Conductor the received message;
9. Q – CAD shows to the Dispatcher the indication that the authority was confirmed.

RX – Central Control Operations (Dispatcher) to Train (Field)

Message 36 **Joint Track Movement Authority**



6.13 Restricted Train Movement Authority (Joint Also)



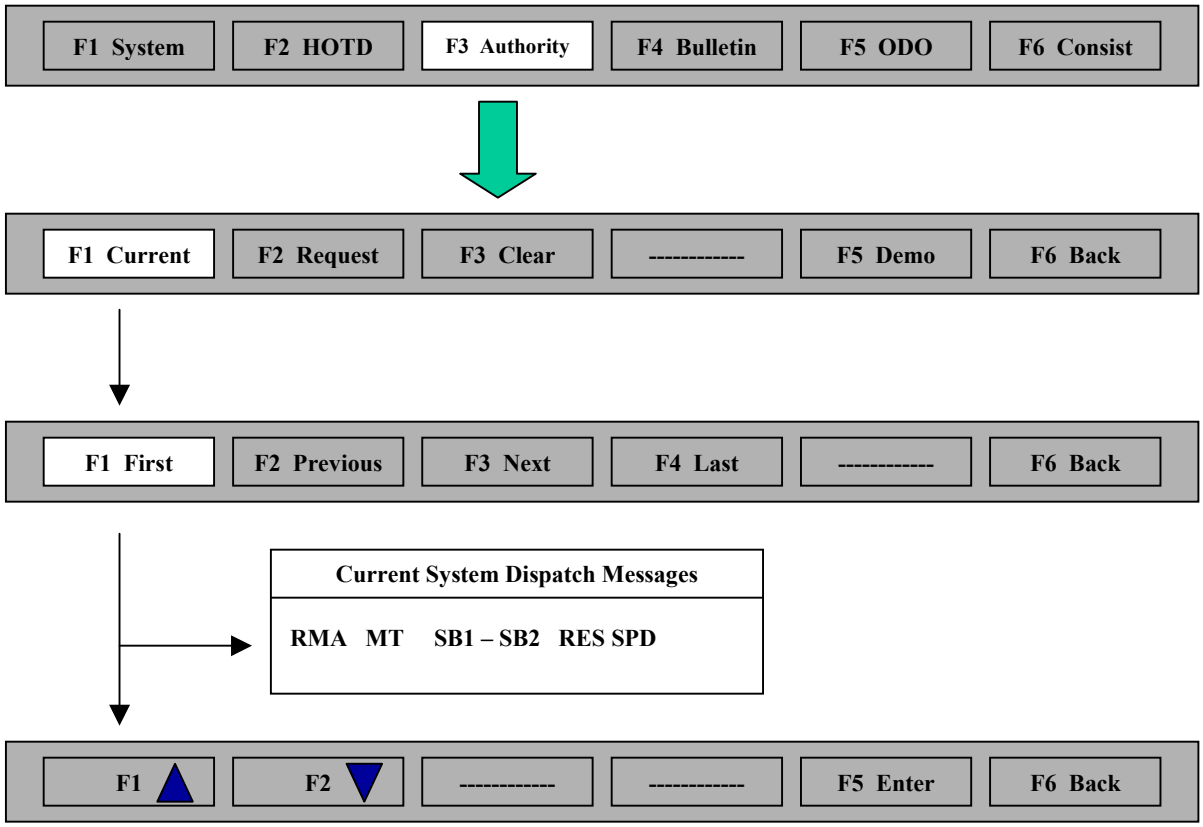
The Restricted Movement Authority (RMA) must occur as follows:

1. Dispatcher creates an RMA;
2. Q – CAD sends to Train Sentinel® (to the train that is currently occupying the selected TS) a message requested confirmation of another train to occupy the same TS;
3. Train Sentinel® shows to the Engineer/Conductor the RMA "request" and waits for its acceptance;
4. Q – CAD shows the Dispatcher the indication of the RMA sent and waiting to be accepted;
5. The Engineer/Conductor of the front train (which is currently occupying the TS) accepts the RMA;
6. Train Sentinel® sends to Q – CAD the acceptance of the RMA;
7. Q – CAD sends to Train Sentinel® (of the train that will enter the TS that is already occupied) the RMA;
8. Train Sentinel® displays to the Engineer/Conductor the RMA and waits for its confirmation;
9. Q – CAD shows the Dispatcher the indication of the RMA sent and waiting to be confirmed;

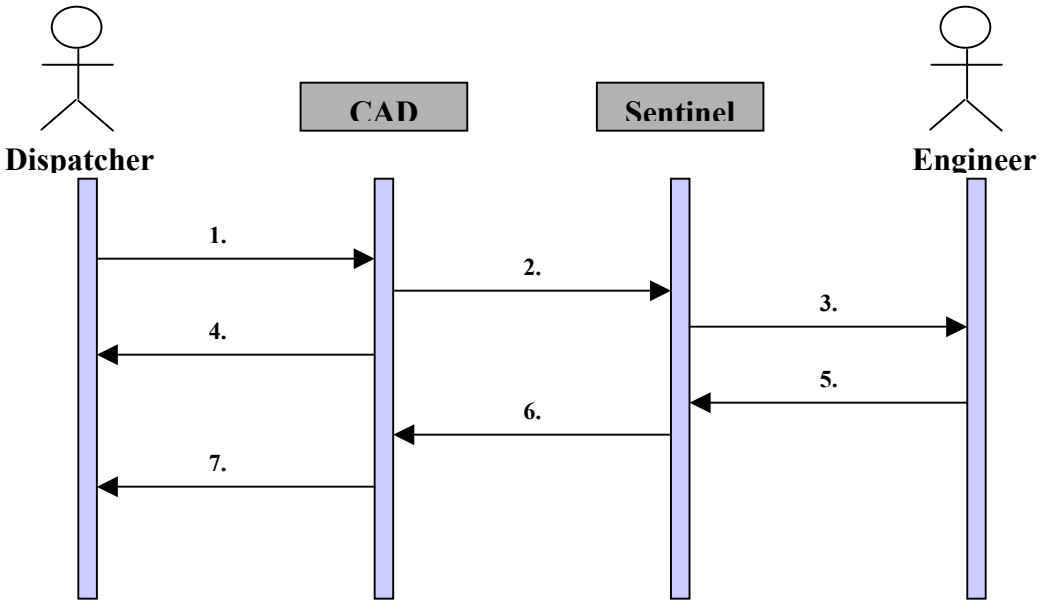
10. Engineer/Conductor confirms the received RMA;
11. Train Sentinel® responds to Q – CAD, confirming the acknowledgment of the RMA;
12. Q – CAD analyzes the confirmation and responds to Sentinel with a "That is correct" message;
13. Train Sentinel® displays to the Engineer/Conductor the received message;
14. Q – CAD shows the Dispatcher the indication that the RMA was confirmed.

RX – Central Control Operations (Dispatcher) to Train (Field)

Message 35 **Restricted Train Movement Authority**



6.14 Train Movement Authority Cancellation



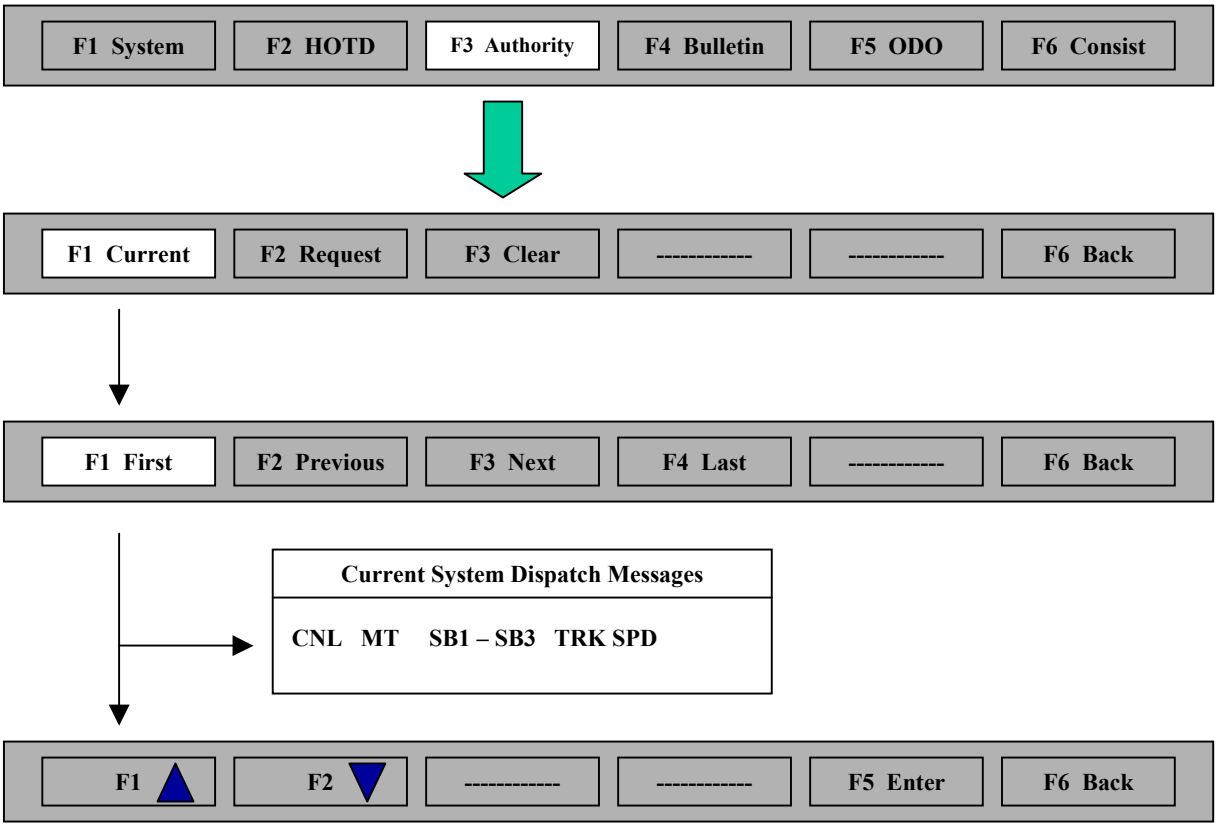
The cancellation of a Movement Authority will indicate a invalidation of a previously executed and confirmed movement authority. The authority that was granted cannot be used, in whole or part, making the train remained stopped at the TS of origin of the Movement Authority .

The Movement Authority cancellation procedure must occur as follows:

1. Dispatcher generates a Movement Authority cancellation;
2. Q – CAD sends Train Sentinel® a message of Movement Authority cancellation;
3. Train Sentinel® displays to the Engineer/Conductor the Movement Authority cancellation and waits for it confirmation;
4. Q – CAD shows to the Dispatcher the indication that the selected Movement Authority is in a cancellation process;
5. Engineer/Conductor confirms the Movement Authority cancellation;
6. Train Sentinel® answers to Q – CAD, confirming the Movement Authority cancellation.
7. Q – CAD shows to the Dispatcher the indication that the Movement Authority was cancelled.

RX – Central Control Operations (Dispatcher) to Train (Field)

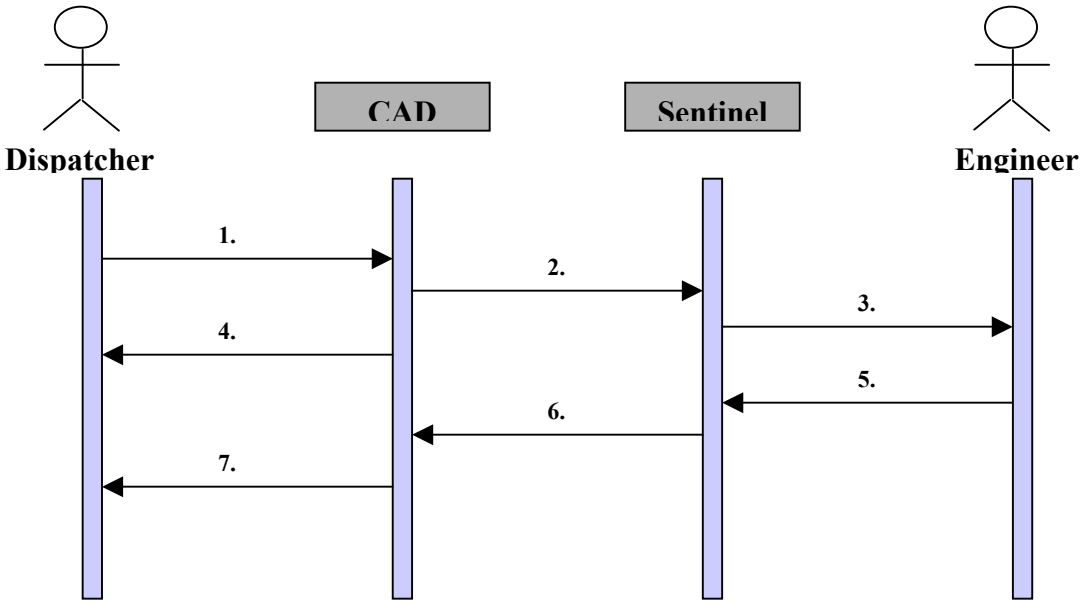
Message 33 **Request to Cancel a Train Movement Authority**



The Movement Authority cancellation procedure must occur as follows for a previously confirmed Movement Authority:

1. Dispatcher will generate a Movement Authority cancellation (Message 33);
2. Q – CAD sends Train Sentinel® a message of Movement Authority cancellation;
3. Train Sentinel® displays to the Engineer/Conductor the Movement Authority cancellation and waits for it confirmation;
4. Q – CAD shows to the Dispatcher the indication that the selected Movement Authority is in a cancellation process;
5. Engineer/Conductor confirms the Movement Authority cancellation;
6. Train Sentinel® responds back to Q – CAD (Message 03), confirming the Movement Authority cancellation.
7. Q – CAD shows to the Dispatcher the indication that the Movement Authority was cancelled.

6.15 Modification of a Train Movement Authority



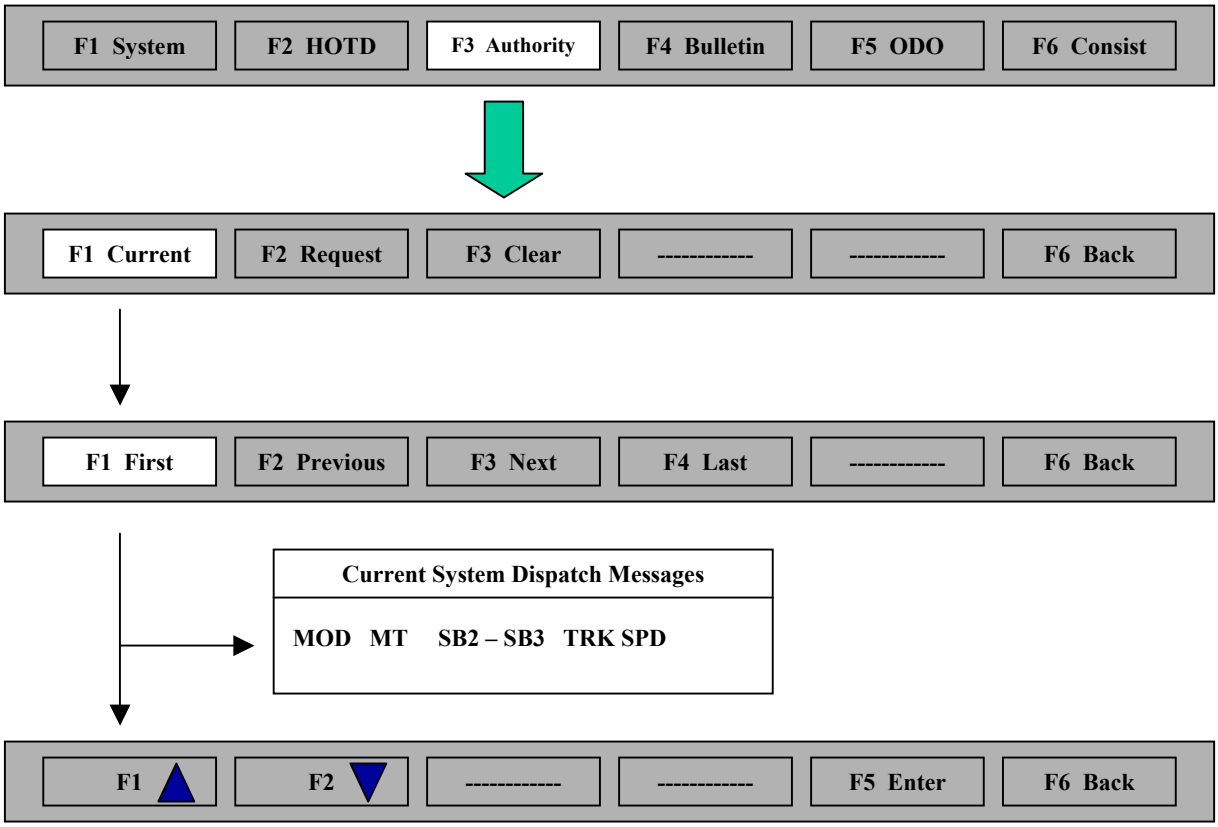
A Train Movement Authority modification may occur under two conditions. The Movement Authority must be active and the "from location" may be shortened, but not the "to location".

The Train Movement Authority modification must occurs as follows:

1. Dispatcher recalls an active Movement Authority for modification;
2. Q – CAD sends Train Sentinel® a Train Movement Authority modification message (Message 34);
3. Train Sentinel® displays to the Engineer/Conductor the Movement Authority modification and waits for the confirmation;
4. Q – CAD displays to the Dispatcher on the trackline overview display the indication that the Movement Authority request is pending for modification;
5. Engineer/Conductor confirms the requested modification;
6. Train Sentinel® responds to Q – CAD (Message 04), confirming the requested modification;
7. Q – CAD displays on the trackline overview to the Dispatcher the indication that the movement authority was modified.

RX – Central Control Operations (Dispatcher) to Train (Field)

Message 34 **Request to Modify a Train Movement Authority**



6.16 Operational Restrictions

Operational restrictions are used to inform trains of the places within its route where the train must move at restricted speed in relation to their current speed. In some cases the train will even be required to come to a complete stop before proceeding. This second condition is usually caused by maintenance-of-way or malfunctions at highway-rail grade crossings.

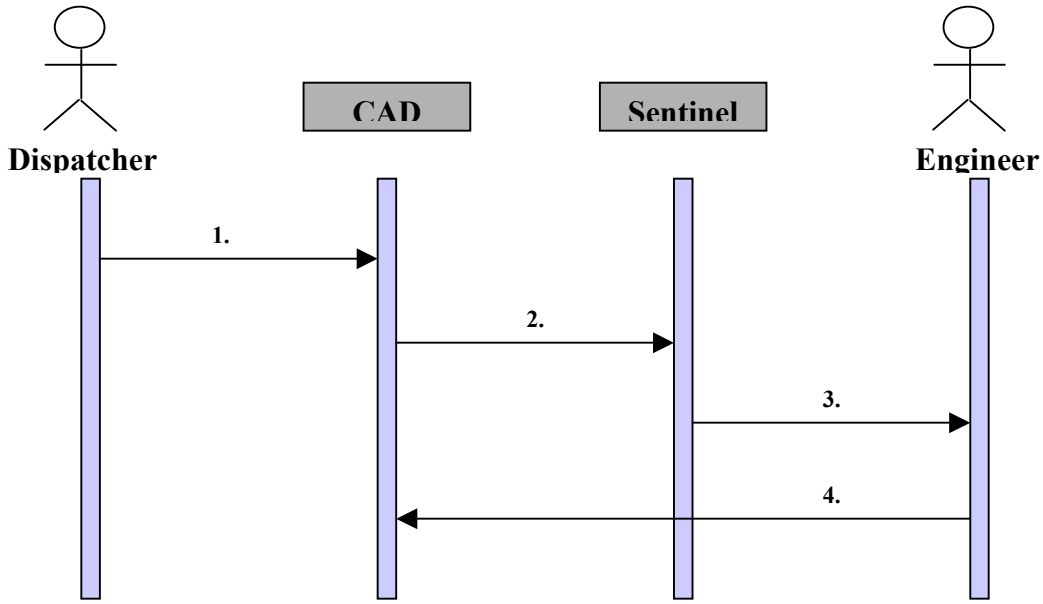
There are currently three defined types of restrictions:

- Form A Track Bulletins— these bulletins consist of a starting and ending milepost location of the restriction. It will also designate the speed for the train, either full train or head-end.
- Form B Track Bulletins— these bulletins are used to inform the train crews of work being performed by maintenance-of-way employees. The bulletin will contain the beginning and ending mileposts as well as the time of the restrictions and the foreman in charge of the working authority.
- Form F Track Bulletins— these bulletins are used to notify train crews of other conditions that need attention, outside of the Form A and Form B bulletins.
- Form G Bulletins— these bulletins will pertain to the notification of a highway-rail grade crossing that has been reported as being either out-of-service or malfunctioning. The enforcement for this restriction will be the train must stop and proceed. Train crews are instructed to flag the crossing for the locomotives to clear the crossing. (Future)

The execution of these restrictions are normally sent with the movement authority for the designated route. The restrictions will be assigned within a particular track section for notification.

If a restriction becomes active after a movement authority has been issued to a train over the particular track section, the restriction is immediately sent to the train crew for acknowledgement.

Operational Restrictions



The process for handling the restrictions will be as follows:

1. The dispatcher enters into Q – CAD the restriction;
2. Q – CAD identifies any active movement authorities or occupations of the track segment for the restriction and will send the restriction to Train Sentinel®.
3. Train Sentinel® displays to the train crew the operational restriction
4. The train crew must acknowledge the received information to complete the safety requirements of the message. Q – CAD is updated with the confirmation.

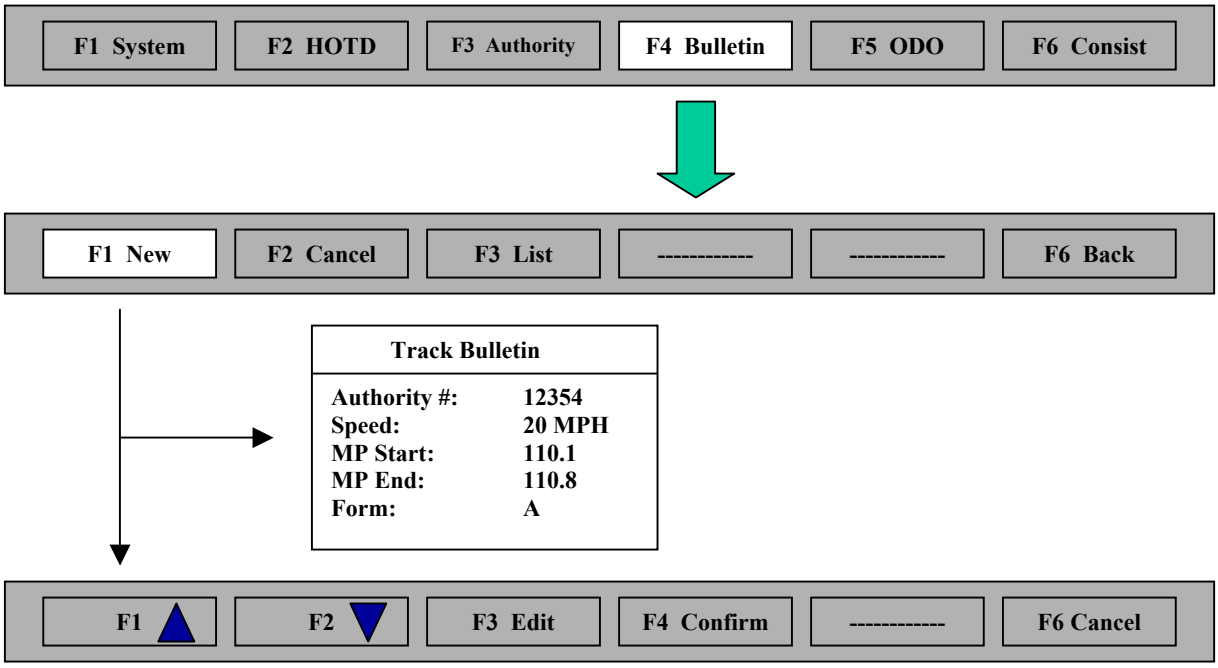
Only active track restrictions are sent to the trains. Once a bulletin restriction has been voided (deleted), the system will mark that restriction as a non-active restriction and not transmit the message in the future.

There is no limit to the number of restrictions that a track segment can have, but there is a limit to the number of restrictions that can be sent with a movement authority. If a unique track segment has more than ten (10) restrictions associated with track, the system will not be able to send the movement authority through that track segment.

The restriction cannot extend beyond the limits of the track segment. Each track segment is consider unique and must contain all the information pertinent to that segment. If for any reason a restriction goes beyond a track segment limit, the restriction will have to be divided into two or more parts. Each being inserted into a track bulletin as a unique restriction.

RX – Central Control Operations (Dispatcher) to Train (Field)

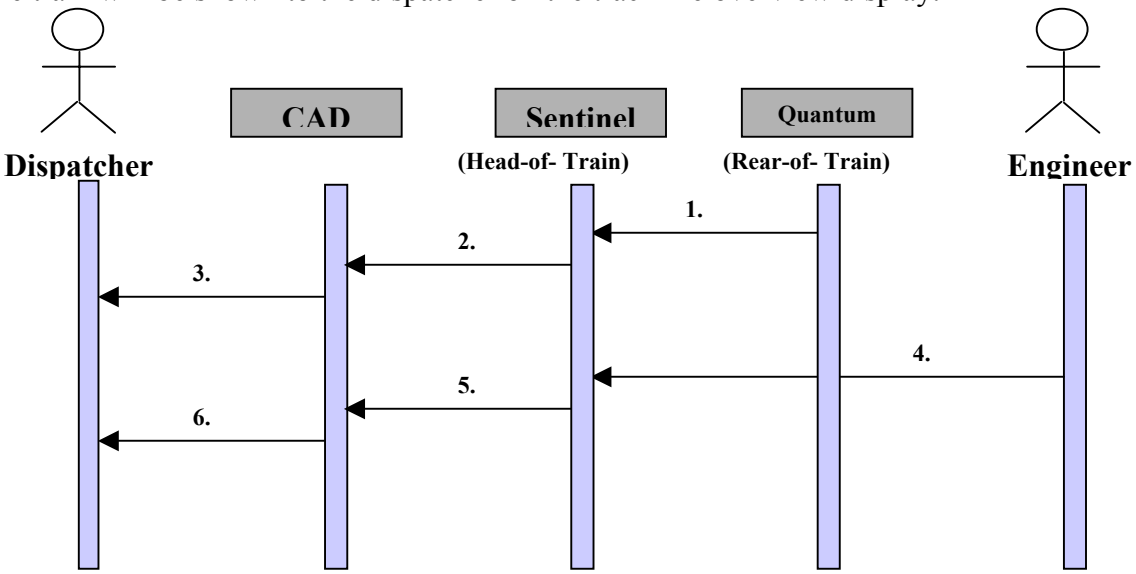
Message 34 **Request to Modify a Train Movement Authority**



6.17 Train Position

With the train position process, the train will send to Q – CAD the current position of the rear of the train (Rear-equipped) on the track. This process allows Q – CAD or Office to monitor train activity by accurate locations of all trains within the system.

A train with an active movement authority, will send its position within a track segment to Q – CAD. When received, Q – CAD will create an occupation of the train within the track section. When a message is received by Q – CAD that the rear-of-train has passed a unique location, Q – CAD will clear (or roll-up) any valid track sections behind that train. When this occurs, the last position will be the last reported position of the train. If the end-of-train has not reported the actual position, the roll-up will not occur and the last position of the train will be shown to the dispatcher on the trackline overview display.



The Train Position procedure will occur as follows:

1. Quantum GPS end-of-train device communicates with the head end Train Sentinel® equipment to relay actual location of the rear of the train;

2. Train Sentinel® sends a message to Q – CAD of the rear of train position report;

3. Q – CAD will clear or roll-up the track segments behind the train to note the actual location of the train at the report time;

4. If the rear end of the train is known and the Quantum GPS end-of-train device is not functioning, the train crew may indicate to Train Sentinel® the actual position;

5. Train Sentinel® sends a message to Q – CAD of the rear of train position report;

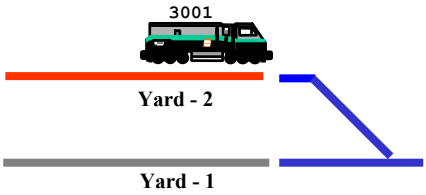
6. Q – CAD will clear or roll-up the track segments behind the train to note the actual location of the train at the report time and as reported by the train crew and dispatcher.

Note: There is no automatic clearing of track segments or roll-up if the end-of-train device is not functioning or is not a Quantum GPS end-of-train device.

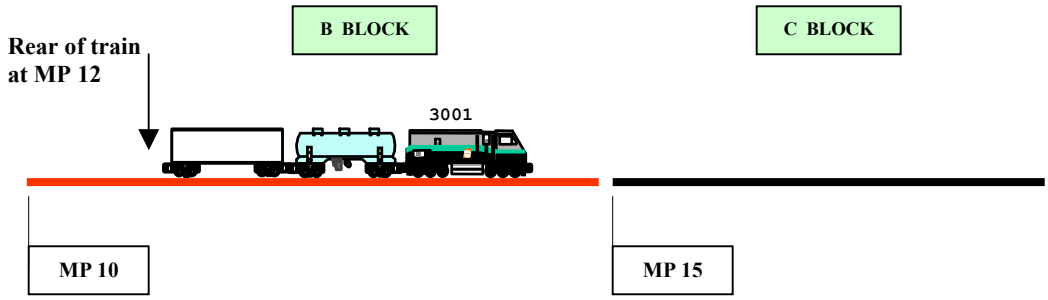
TX – Train (Field) to Central Control Operations (Dispatcher)

Message 06 **Train Position**

No action for train crew for this process — performed electronically



When a train leaves the yard on the initial trip, with a movement authority in place, Train Sentinel® will transmit to Q – CAD a notification of departure with a Message 05.



When a train is operating on main track with a movement authority, the Quantum end-of-train device, with GPS, will make a position report to the head-of-train device as to the position of the rear of the train. Train Sentinel® will transmit to Q – CAD, a notification of position with a Message 06. In the example, the rear of the train is noted at MP 12.

7. Definition of Terms

Absolute Signal

A block or interlocking signal without a number plate, or designated by an "A" marker.

Acknowledgment, Machine-to-Machine

Computer-generated message, sent from a Train Sentinel® -equippeequipped locomotive to the Q – CAD System, confirming that a digital message has been received on board.

Authority

Authority to occupy a main track or other controlled track, generated by a dispatch system or by the dispatcher using a dispatch system, conveyed through signal indications in CTC and, track warrant, track and time, or other means, and supplied to the Train Sentinel® system as the basis for an enforceable authority.

Authority Enforcement

Quantum – Positive Train Control system capability of preventing a violation of movement authority through an automatic full service application of train brakes to stop the train before a violation occurs; under certain conditions, capability of stopping a train following detection of an authority violation.

Authority Limits

Segment of controlled track defined by mileposts or station names, over which a train has authority to occupy and move on a main track.

Automatic Interlocking

An interlocking through which train movements are governed by means of the track circuitry without human intervention.

Automatic Train Control

A system to enforce compliance with cab and wayside signal indications. If the train exceeds a predetermined speed for a given signal indication and speed is not reduced at a sufficient rate, brakes are automatically applied.

Bi-directional Authority

Authority for a train or maintenance vehicle to occupy a specified main track or controlled siding and move in either direction within designated limits.

Block

A length of track between consecutive block signals or between a block signal and the end of block system limits. Designated by timetable of a block in non-signaled territory.

Block Signal

A fixed signal at the entrance of a block that governs trains entering and using that block.

Brake Pipe Pressure

The amount of air pressure supplied to the brake pipe from the locomotive air compressor, expressed in pounds per square inch.

Braking Curve

Dynamic calculation of the point at which full-service braking must be applied for a train to be stopped within its movement limits or for its speed to be reduced short of a speed restriction limit. This may be portrayed graphically as a curve plotting train speed against distance remaining to the enforcement reference point; used in triggering braking for predictive enforcement.

Braking Distance

Distance required to stop a train, measured from the point at which a full-service (P2A) application of braking begins; projected by the onboard computer through a calculation based on train speed, weight, and length, consist detail, brake pipe pressure, track gradient, and other possible inputs.

Cleared Route

One or more consecutive blocks in CTC territory over which a train is authorized to move, as by signal indication.

Quantum – Positive Train Control (Q–PTC)

Dispatcher office, on-board, wayside and data radio network segments integrated to provide safety and efficiency gains in railroad operations.

Communications Infrastructure

Basic installations and facilities, such a railroad's communication radio base stations, on-board communication devices, required to support data communications for the Quantum – Positive Train Control System.

Communications Outage

Loss of data communications over a limited geographic area, as through a failed radio base station, or on-board communication device.

Configuration Information Module (CIM)

A module in the data radio that stores the radio script and the node unique information such as ID, Site Name, etc. The CIM is used in configuration management control.

Controlled Track

Track on which occupancy and movement by a train engine or on track equipment require authority issued through some method of train control.

Crossing

Point of intersection at grade between two tracks belonging to the same or different railroads.

Crossing Move

Movement of a train through a railroad crossing at grade or gauntlet track.

Centralized Traffic Control (CTC)

A block system that uses block signal indications to authorize train movements.

Dark Territory

Railroad tracks not equipped with signals; also known as *Non-ABS, DTC or TWC*.

Non-signaled Territory

Track without signals, over which train movements are governed by timetable, track warrants, or operating rules (aka: Dark Territory).

Database Speed Restriction

Enforceable speed limit defined in a database and associated with train attributes, with track location, or with a combination of train attributes and track location.

DTC

Direct Train Control, an alternative to Track Warrant Control in dark territory.

Effective Date

Date on which a track bulletin restriction takes effect, designated in a track bulletin line item or heading.

Effective Time

Time at which a track bulletin restriction takes effect, designated in a track bulletin line item.

Engineering Change Notice (ECN)

Document that identifies all modifications made to hardware and software documentation and drawings.

End-of-Train Interface

Electromechanical means of monitoring end-of-train brake pipe pressure and train integrity through systems installed in the locomotive cab.

Enforceable Authority

Computer-readable authority defining limits of train movements that are subject to Collision Avoidance System enforcement.

Enforceable Speed Limit

At any given location, the nominal maximum speed at which a train can move before invoking a response from the onboard enforcement function; may differ from the actual speed limit, as in the case of an enforceable speed limit dictated by signal aspect, and from the actual speed at which enforcement braking is triggered, which may reflect a margin of overspeed tolerance.

Enforcement Braking

Automatic application of full service to stop a train either before it violates its authority limits or an upcoming speed limit (*predictive enforcement)* or in response to a detected violation of authority limits or a current speed limit (*reactive* enforcement).

Equipped Train

Train equipped with the onboard communications, computing, and location-tracking systems required for Quantum – Positive Train Control System functions; required equipment includes data radio, onboard computer, location-tracking device (such as GPS receiver), and a computer interface with the braking and throttle systems.

Flag Protection

A method of manually protecting the rear end or head end of a train to prevent collision, in accordance with GCOR Rule 6.19.

Field Service Bulletin (FSB)

Document update containing information pertaining to hardware modification.

Following Move

Authorized movement by a train constrained by another train ahead moving on the same track in the same direction.

Form A

Track bulletin item establishing a temporary speed limit over a specified track segment.

Form B

Track bulletin item establishing protection for men or machines on track within specified limits and limiting train movement within the limits to restricted speed or another speed negotiated with the maintenance foreman.

Form F

Track bulletins that advise the train crews of other conditions outside of the Form A or a Form B.

Form G

Track bulletins that advise the train crews of malfunctioning highway-rail grade crossings. The system will treat these locations as a stop and proceed.

Forward Move

Authorized movement to a specified limit ahead of a train, conferred by signal indication in CTC territory, or by track warrant item 2 or 3, or track and time, or other means.

Global Positioning System

A satellite-based radio navigation system deployed and operated by the Department of Defense, providing highly accurate three-dimensional position, velocity, and time data; input to Train Sentinel® train location tracking.

Head-End-Only Speed Restriction

Timetable speed restriction in effect for a train until the train's leading engine moves past the far limit of the restriction.

Human Machine Interface (HMI)

Interface between human operator and Q–PTC equipment that identifies necessary operations information.

Interlocking

An arrangement of signals and signal appliances, either manually or automatically controlled, that are interconnected so that their movements occur in a proper and safe sequence. Interlocking may be operated manually or automatically.

Joint Authority

Movement authorities issued to multiple trains, to a combination of trains and track forces or multiple maintenance crews with the same or overlapping limits.

Limit, Speed

Maximum speed in force for a train at a given track location.

Limits, Authority

Segment of track, defined by mileposts or location names, over which a train has authority for occupancy and movement.

Limits, Speed Restriction

Segment of track, defined by mileposts or station names, over which a train is subject to a specified speed restriction.

Location Tracking

Quantum – Positive Train Control System through which an equipped train's location is determined for train control and enforcement purposes; also known as *positioning*.

Main Track

A track extending through yards and between stations that must not be occupied without authority or protection.

Main Track Permission

Method of train control, closely resembling track warrant control, authorizing track occupancy within designated yard limits subject to Main Track Permission rules.

Management Information System (MIS)

A railroad's computer system providing data on resources and operations.

Manual Input Function

On-board Train Sentinel® function requiring a manual input by a train crew member in order to initiate a data request or transaction, acknowledge a digital message, or provide information on train movement to the Quantum – Positive Train Control System.

Manual Interlocking

An interlocking, through which train movements are controlled by a human operator, such as a dispatcher, who must manually request the desired route for each movement.

Meet

Opposing trains authorized to move past one another at a designated location, where one train clears the main track onto a siding while the other holds to the main.

Non-ABS

Railroad tracks not equipped with signals; also known as *dark territory*.

Non-controlled Territory

Tracks on which trains are free to move with Timetable Special Instructions authorization. Their movement may be governed by signals.

Non-equipped Train

Train not equipped with the onboard communications, computing, and location-tracking systems required for Collision Avoidance System functions.

Normal Switch Position

Position of a switch such that a train moving on the main track through the switch remains on the main track.

On-board Computer (OBC)

Computer installed on an equipped train and used for running on-board Train Sentinel® functions, including location tracking, authority and speed limit enforcement, and various display and input functions.

Opposing Train

Train authorized to move toward a given train on the same track but in the opposite direction, requiring a meet.

Overlapping Authorities

Movement authorities issued to multiple trains, multiple maintenance crews, or a combination of trains and maintenance crews having the same or overlapping limits.

Pass

One train passing another train moving in the same direction at a designated location, where one train clears the main track onto a parallel track, while the other holds to the main.

Passing Train

Train authorized to move past a given train, which is required to wait on a parallel track.

Position, Rear-End

Location of a train's rear end, calculated by subtracting the train length from the head-end position, or obtained from a GPS device on the rear of train.

Position, Head-End

Location of a train's lead locomotive as determined by a wheel tachometer or a GPS device.

Position Report

Message sent from an on-board computer to the dispatcher office indicating the current train location, speed, and direction.

Positioning

Positive Train Control System function by which an equipped train's location is determined for train control purposes; also known as *location tracking.*

Power Braking System (PBS)

Train Sentinel® subsystem used to stop Train Sentinel® εθυιππεδ λοχομοτιωε υσινγ a full brake application.

Predictive Enforcement

Application of enforcement braking to prevent violation of authority limits or violation of an upcoming speed limit.

Pre-enforcement Alert

Textual message, accompanied by an audible alert, warning the train crew of an impending application of enforcement braking unless the engineer acts to take control of the train.

Protection

Prevention of train collisions through various measures, such as block signals, flagging, or the intervention by the Quantum – Positive Train Control System.

PTC Movement Authority

A Track Warrant Control Movement Authority issued to an equipped train through digital means to the onboard conmputer system, Train Sentinel®.

PTC Territory

Track Warrant Control territory that has been digitally mapped through GPS processes to provide the Railroad with the capability of operating equipped trains electronically with PTC Movement Authorities..

Q–CAD System

Quantum Computer-Assisted Dispatching system, a computer hardware and software system that automates some dispatching functions and provides information support for dispatching.

Reactive Enforcement

Application of enforcement braking to stop a train that has violated a current speed limit or authority limits.

Release of Limits

Relinquishment by a train crew of all or a portion of their authority limits.

Restricted Speed

Speed that allows stopping within half the range of vision short of a train, engine, railroad car, men or equipment fouling the track, a stop signal, a derail, or an improperly lined switch, not in excess of 15 mph, in accordance with GCOR Rule 6.27; enforced as a 20 mph speed limit in Quantum – Positive Train Control System operations.

Revocation of Authority

Action by the Train Sentinel® system to shorten a train's authority in response to a new constraint, such as a signal changing to *Stop.*

Reverse Movement

Train movement in the direction opposite of the authorized direction.

Reverse Switch Position

Position of a switch such that a train moving on the main track through the switch leaves the main track.

Rollup

Manual or automatic process whereby a train's authority is released behind the train after the train passes, making the track available for other traffic.

Rollup Location

Location to which a train's authority has been rolled up.

Rule 6.4.1

Rule governing reverse movements, requiring the dispatcher's permission for a reverse movement except for movements within the same block in CTC or signaled TWC territory.

Rule 9.12.1

Rule governing *Stop* indications in CTC territory, providing for verbal authority to pass a signal displaying *Stop.*

Rule 10.1

Rule governing entrance into CTC limits, providing for verbal authority to enter limits at a location between block signals.

Siding

A track connected to the main track and used for meeting or passing trains.

Speed Enforcement

Quantum – Positive Train Control System capability of preventing violations of speed limits through an automatic application of braking either in anticipation of or in response to over speeding.

Spur Track

A short track connected to a main track, often serving an industry location.

Stacked Route

CTC route requested but not yet cleared because of one or more previously requested overlapping routes having precedence; having been requested, the route will line automatically once traffic permits.

System Problem Report (SPR)

Reports used to document and trace a problem or change requirement initiated by either the vendor or the railroad.

TBD

To Be Determined.

TBS

To Be Specified.

Threat Alert

Textual message accompanied by an audible signal alerting the train crew to a threatening condition, such as an absolute signal ahead that has changed to *Stop,* or a train in the vicinity in violation of its authority.

Track and Time

Authority granted verbally in CTC territory for a train or track forces to occupy designated limits and move in either direction within those limits. The Quantum – Positive Train Control System enforces a speed of 15 mph or less within the limits.

Track Bulletin

A notice of conditions affecting train movement, including speed restrictions for designated limits, authority for a maintenance crew to work on or about the track.

Track Database

Database containing locations and attributes of track over which trains are subject to location tracking and enforcement.

Track Forces Terminal

Device installed on-board a maintenance vehicle, such as a hi-rail, and used for running collision avoidance or proximity warning functions requiring the input or attention of track maintenance forces.

Track Warrant

Standardized form used to authorize the movement of trains or track forces on a main track within specified limits in a territory subject to Track Warrant Control (TWC), as designated in the timetable.

Train Control Speed Restriction

Enforceable speed limit derived from temporary movement instructions generated through the dispatcher system, as through a track warrant or track bulletin, or from timetable train handling instructions and the train consist.

Train Movement Authority

Authority for movement given to a train in a specified manner. Primarily pertains to non-signaled territory.

Train Sentinel® System

Refers to the locomotive on-board railroad safety system developed by Quantum Engineering, Inc.

TWC

Track Warrant Control, a method of authorizing train movements or protecting track forces on a main track within specified limits in a territory so designated in the timetable.

Unconditional Authority

Movement authority effective immediately upon issuance, not contingent on fulfillment of any condition.

Undefined Track

Track not represented in the track database and, therefore, not subject to location tracking or enforcement functions.

Visible Authority

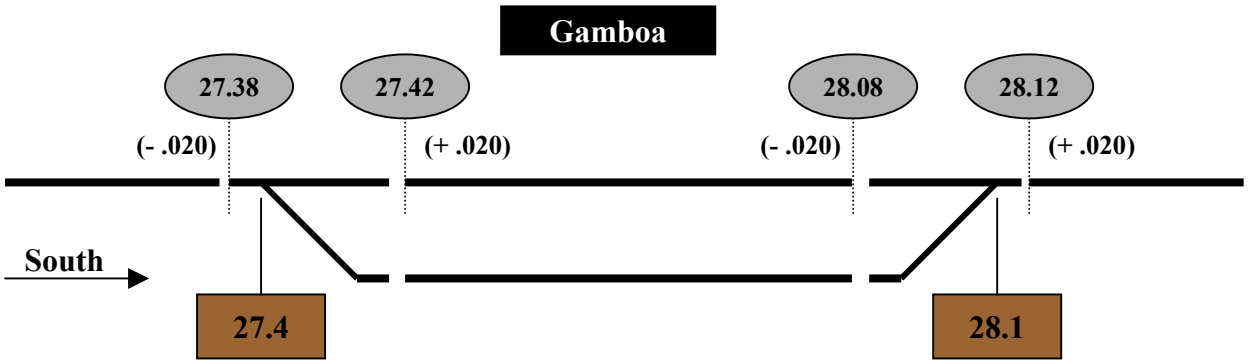
Movement authority issued to the human operators of a train, by means of signals, track warrant, or other visible instrument, as distinct from the computer-readable enforceable authority, which is not displayed to the human and may differ in extent from the visible authority.

Attachment 7 – PCRC Track Warrant Control Messages

With the implementation of Train Sentinel® on the Panama Canal Railroad (PCRC), there was an extensive effort to validate the message exchange between the office and the controlling locomotive. This process involved a tremendous workload for the train dispatchers as well as the train crews. The process involved the train dispatcher to verbally execute a track warrant to the train crew, which would write down the instructions. Then the dispatcher would go to the computer (CAD) and enter the identical information into the system to be delivered to Train Sentinel®, which the train crew would electronically acknowledge. The test were conducted from 2/8/2006 until 4/25/2006. During this time period, the number of active units on the locomotives grew from 4 units to 10 units. The main track on PCRC is 39.0 miles long. The track is rated at 60 MPH by timetable.

A total of 1271 consecutive test were run to validate the message exchange between the office and the onboard Train Sentinel® equipment. There was a 100% compliance to all of the tests. The basis for Ohio Central Railroad is the same as the PCRC onboard computer system. The only variable will be the communication infrastructure at OCRS to accommodate the message exchange. The messages from office to locomotive and return are the same as PCRC. While PCRC has some back holes in their radio network, due to tunnels and the jungle, there have been no interruptions in the message exchanges. The office and Train Sentinel® can be altered to allow for message to be sent on a delayed basis if the train last reported near the area of black holes so that the message will be retained until a communication link is reestablished with the locomotive. Jay Wallace of PCRC has all of the tests for review.

Attachment 7– PCRC Track Warrant Control Messages



The example above is the actual passing siding on PCRC, Gamboa. The square box represents the switch point of the siding.

The oval box represents the foul point of the siding switches.

As explained in the Conops document, Attachment 2 section 5.3, Train Sentinel® is designed to navigate to the safest point closest to the end of limits, a switch or milepost. While a milepost sign board may not have a "switch or fouling point" the system will still provide a buffer to the sign board. The nose of the locomotive will never be on top of a switch or against the actual sign board.

Attachment 7– PCRC Track Warrant Control Messages

In the analysis of the data from PCRC, the first line in this example, E04 is the electronic Track Warrant sent to the locomotive, Train Sentinel® unit. The second line, S04, is the acknowledgement of the message received, acknowledged and transmitted back to the office.

Date	Nbr	Time	Lead	TMA	AT		YD	Line 1	Line 2			
4/25/2006	E04	1116	1858 North	106	MP	43.50			MP	43.50	MP	34.00
	S04	1117			MP	44.22	Y		MP	43.50	MP	34.00
4/25/2006	E05	1133	1856 South	107	MP	4.50			MP	4.50	MP	27.40
	S05	1131			MP	4.05	Y		MP	4.50	MP	27.38

The header is defined as:

- Date
- Number (E=electronic delivery, S=Train Sentinel® acknowledged)
- Lead Locomotive
- Movement Authority Number
- At = location of the message delivered
- Yard = was the train in the yard at the time of the authority
- Line 2 is the Movement Authority limits

Attachment 7– PCRC Track Warrant Control Messages

Taking the first example of 1858 North on 4/25/2006, we see that the train was in the Yard at MP 44.22 (generated by GPS on the locomotive), the yard limit sign is at MP 43.5.

Date	Nbr	Time	Lead	TMA	AT		YD	Line 1	Line 2			
4/25/2006	E04	1116	1858 North	106	MP	43.50			MP	43.50	MP	34.00
	S04	1117			MP	44.22	Y		MP	43.50	MP	34.00
4/25/2006	E05	1133	1856 South	107	MP	4.50			MP	4.50	MP	27.40 ←
	S05	1131			MP	4.05	Y		MP	4.50	MP	27.38 ←

The 1858 North has been given a Track Warrant to move from MP 43.5 to MP 34.0 (a milepost sign board). This is very straightforward and is easy to see. Train Sentinel® acknowledged the identical information. This relates to a match for data comparisons. The system is prohibited from generating milepost combinations in the movement authority for yard track, it always uses the yard sign (MP 43.5 or MP 4.5)

In the 2nd example (E05-S05), the train 1865 South is in the Yard at the other side of the railroad and is given an authority to move from the yard to the switch at Gamboa. At this time the dispatcher is analyzing the movements to make the meet at Gamboa. Notice that the Track Warrant is to the switch, by rule, but Train Sentinel®, S05, has built in the foul point as a stopping location, not the switch point.

Attachment 7– PCRC Track Warrant Control Messages

In this example example of 1865 South there is a variation of the milepost. In the beginning, it was stated that the train dispatcher had to execute a manual or verbal authority to the train and then place the train into tracking on the computer. In this case the dispatcher was busy and there was a time lag in the execution. The Track Warrant was from the yard, MP 4.5 to MP 17.0, E15. When Train Sentinel® received the message the train had already departed the yard and was at MP 10.14. Train Sentinel® does an automatic roll-up of territory behind the train, based on the length of the train and the distance from the prior milepost signboard, MP 11.0.

4/25/2006	E15	1741	1865 South	118	MP	4.50		117	MP	4.50	MP	17.00
	S15	1742			MP	10.14			MP	11.00	MP	17.00
4/25/2006	E16	1750	1865 South	119	MP	11.00		118	MP	11.00	MP	27.40
	S16	1748			MP	15.59			MP	15.00	MP	27.38

The major test for compliance is that the end of the authority remained the same regardless of the position of the train at the time of movement authority execution. This is a match. In many cases the train will not be where the movement authority is executed from, because the train crews may be late in rolling up behind the train, but Train Sentinel® has already performed the task for them.

The 2nd example, E16-S16, shows the same thing with a reporting milepost, but the train is routed to the switch by the movement authority but to the fouling point by Train Sentinel®. This is termination point of the braking algorithm.