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Research Results

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Alaska Railroad Collision Avoidance System (CAS) Project

SUMMARY

The Alaska Railroad (ARRC) is developing a program to design, develop, and implement a communication-based vital positive train control (PTC) system called collision avoidance system (CAS). This system will ensure an environment in which the safety of ARRC passenger and freight train operations in centralized traffic control (CTC) and non-signalized direct traffic control (DTC) will be significantly enhanced as well as providing for efficient train operations. The proposed safety enhancements include:

- Generating and delivering safe mandatory directives,
- Fail-safely enforcing authority limits to prevent train-to-train collisions,
- Fail-safely enforcing speed restrictions to prevent overspeed derailments,
- Protecting roadway workers within their assigned limits from incursions, and
- Protecting train movements from a switch aligned in the wrong position.

The CAS system will be implemented system-wide on the ARRC rail network including 65 miles of CTC and 435 miles of DTC territory; the network is a single main-line rail system that has both freight and passenger traffic concurrently (Figure 1). All controlling locomotives will be equipped with vital onboard computer equipment and two data packet radios for both low (44 MHz) and high (161 MHz) band radio frequencies.

Figure 1. Example Distribution of Stopping Points for Freight Train Stopping from 60 mph.

BACKGROUND

The collision avoidance system (CAS) project architecture comprises the following fail-safe subsystem functions; a computer-aided dispatch (CAD) segment that incorporates a vital office safety server (OSS), a vital onboard computer (OBC) with a location determination system, and a communication segment that includes VHF packet data radios and vital wayside switch and signal monitoring (SSM). In addition, the CAS includes detection of and safe reaction to vital and non-vital wayside detector devices (e.g., track integrity detectors), as well as nonvital authority limit warning devices for on-track equipment (Figure 2). The SSM and wayside detectors are interrogated by approaching locomotives via low-band data radio for status. If needed, the train will be enforced to stop before moving over the specific device.

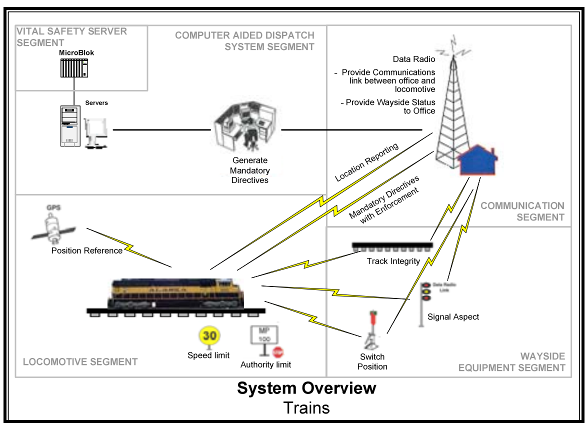

Figure 2. CAS Configuration

CAS is designed to be scalable with minimal operational impact to support railroad system expansion planned for Alaska Railroad (ARRC). Scaling will consist of adding additional hardware components that require only minimal updating of system configuration parameters.

In addition to the safety enhancements listed above, the CAS is designed to provide operational improvements:

- Enabling passenger train speeds up to 65 mph and freight trains speeds up to 60 mph in locations where track integrity is installed,

- Electronically delivering mandatory directives in a vital manner to eliminate the verbal read and repeat cycle, and

- Movement planning that allows operation of dark territory operations in an automatic mode, issuing directional authorities to trains and automatically releasing blocks (based on the OBC confirming the blocks as cleared) behind the train via the OSS, without dispatcher intervention.

Authorities and track bulletins are vitally verified and validated by the OSS using data for defined block system boundaries (enforceable limits of train movement) and track acknowledgements of authority blocks released. All current train and maintenance-of-way employee authorities are maintained in the OSS, ensuring the safety of subsequent commands. Unsafe requests from CAD, which could result in unsafe authorities, are rejected by the OSS.

CAS SSM and wayside detector systems each have a uniquely identified radio transceiver for peer-to-peer communications with the OBC using the low-band locomotive data radio. This allows the OBC and the wayside device to transmit and receive specific wayside device messages. The state of each monitored device is detected and interpreted by OBC on the locomotive where appropriate action is taken, including enforcing a penalty brake application, if required, to ensure safe braking before exceeding the signal or switch location.

Train location, speed, and direction data are determined by the onboard location determination segment (LDS), using tachometer inputs and vitally encoded topographical maps of the infrastructure in conjunction with the global positioning system (GPS). The GPS satellite constellation is used to assist in determining the location of CAS-equipped locomotives. In addition, wide-area augmentation system GPS corrections are used to increase the accuracy and reduce uncertainty. The GPS position is used with a track mapping algorithm and other locomotive inputs such as the wheel tachometer and onboard accelerometers to provide vital location of the ends of the train. Additionally, the GPS readings will indicate train speed and direction of travel for reporting to the CAD office systems.

The CAS project has tackled many challenging issues in the development and testing of the PTC system, including:

- How CAS will perform a large array of safety functions in its role of providing safe train operation by mitigating hazards endemic to CAD-only operation,
- How to predict enforcement braking distance accurately enough so that a train will not go passed the target but not impact the train operators ability to efficiently operate the train,
- How to manage and maintain the critical feature track database efficiently, and
- How to ensure adequate communications performance to ensure that system performance requirements are met.

METHODS

Because of the complexity, challenges, and costs of the entire CAS, ARRC will implement this project in a multiyear and multiphased approach, with the goal that the completion of each phase would provide benefits to safety and train operation.

Phase I

The first phase, the communications segment, is currently installed and consists of mobile and base station Meteor Communications Corp. (MCC) VHF RF packet data radios and GPS receivers on locomotives that provide for wide-area augmented corrections. Additionally, 33 base station sites with dual MCC data radios have been installed along the railroad to provide office-to-locomotive and locomotive-to-wayside transmissions. The system is operational today and provides for situational awareness of train location in the dispatch office (Figure 3).

Phase II

The CAD system was implemented in May 2006 to support the fixed-block, nonsignaled dark territory control method called direct traffic control and provides for centralized traffic control (CTC) and auto-routing in signal territory.

Phase III

Currently underway is the installation, implementation, and testing of the OSS and Locomotive Segment. All 53 controlling locomotives have been equipped with dual MCC data radios, onboard computer and display units. Some locomotives have been outfitted with New York Air Brake CCB I and II braking subsystems that facilitate penalty brake application. Other locomotives with the 26L brake equipment have been outfitted with magnet valves to provide penalty brake application when needed.

Plans are being developed to add a second display for the conductor to view all data provided to the engineer. Additionally, this display will allow the conductor to enter the Form B personal identification number from the maintenance way employee, update train consist information, and switch position when required. The illustration shows the CAS locomotive display unit in the middle of the Electro-motive Division SD70MAC control displays for easy access to buttons and increased visibility for the train engineer.

Figure 3. Engineer Work Station

Site integration testing began in the second quarter of 2008. Field acceptance testing is expected to be completed in March 2011.

Phase IV

Dark territory monitoring of manual switches, track integrity, and detectors will be implemented in Phase IV. Currently, seven locations are part of the current test plan with the full rollout to 142 switch locations to be completed by December 2015.

DESIGN CHALLENGES AND SOLUTIONS

The first challenge has been to develop a system that would comply with the then FRA Notice for Proposed Rule Making (NPRM) Title 49 Code of Federal Regulations (CFR) Part 236 Subpart H and now FRA NPRM 49 CFR Part 236 Subpart I without major modifications. The decision was made early that CAS would be designed on the basis of well-established and comprehensive safety assurance principles, and the system architecture would take maximum advantage of the specifications developed for existing programs and technologies. As a result, the system is designed to be fail-safe; this means pursuing a design philosophy in which the result of a hardware failure or the effect of a software error either prohibits the system from assuming or maintaining an unsafe state, or causes the system to assume a state known to be safe. In addition, the system design would adhere to the closed-loop principle requiring all conditions necessary for the existence of any permissive state or the action be verified to be present before the permissive state or action can be initiated. Likewise, the requisite conditions shall be verified to be continuously present for the permissive state or action to be maintained. Finally, as a result of the interactions between the safety-related features, detailed analysis is required and planned to ensure all hazards remain mitigated across all the combinations of operational scenarios and failure modes.

The second challenge was to ensure that the data radio network would provide enough capacity to support the performance requirements without impact to ARRC operations. It was determined that dual radios would allow wayside traffic to communicate via a peer-to-peer protocol on the low-band data radio while office communications for bulletins and authorities could use high-band communications. In the case of a locomotive radio failure, a degraded mode would allow the train to operate on one radio, swapping frequencies; until the radio is repaired in the next locomotive repair station is encountered without cutting out the protection of the OBC.

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