Integrating Technology into the Locomotive Cab  
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With technology impacting every aspect of daily life, it is only natural to begin to see a migration of technologies into the rail industry. Cellular phones, two-way pagers, personal data devices, and high-speed internet communications have all had significant impacts on how people go about their daily work and how efficiently they complete their tasks.

Communication and information gathering and display technologies obviously offer many benefits to the operation of North American freight train and other network type equipment. In recognition of this potential, Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), has pursued a demonstration program of these technologies at the Federal Railroad Administration’s Transportation Technology Center, Pueblo, Colorado. This work is sponsored by the AAR as part of a Strategic Research Initiative (SRI) in Signals, Communications, and Train Control and is being conducted at TTC’s Facility for Accelerated Service Testing (FAST). The goal of the program is to demonstrate the benefits of additional information in the locomotive cab. The program will help determine how safety and efficiency can be improved through the integration of infrastructure and train health information.

With FAST being a captive rail operation, it was an obvious choice for this type of demonstration program (Figure 1). The FAST train is made up of four 1970’s vintage 2.2 MW (3,000 HP) diesel-electric locomotives and up to seventy-six 113.5 metric ton of lading (125 short-tons) gondola and tank wagons for a train weight of 10,866 metric tons (11,970 short-tons).
As a test bed, FAST offers limited track length and consistent equipment. FAST operates 10 hours per night, 4 nights per week. Operations cover roughly 9 months of each year with a shutdown in the summer. The shutdown is beneficial in two ways: 1) train operations are limited during the hot time of year when excessive rail temperatures can easily be reached in daytime operation and are possible in night-time operations, and 2) the shutdown gives ample time for the track oval to be reconfigured with new experiments for the next nine months of operation. FAST has been used for numerous tests since 1976 including experiments to identify the benefits of premium bogies with regard to bogie component and rail wear. Currently, FAST wagons are configured with more typical bogies found in service in North America. Prior to shutdown this summer, the train was operated at an average track speed of 53 km/h (33 mph) rather than the normal 64.4 km/h (40 mph) to monitor wear associated with balance and under-balance operation.

**INTEGRATED TECHNOLOGY DISPLAY**
The integration of technologies onto the locomotive culminates in a display of information in the locomotive cab. The cab display is based on the AAR’s Locomotive Systems Integration (LSI) standard screen. The LSI screen displays pertinent information about the locomotive, as well as information about other associated systems.
Pertinent information from the integration of technology is demonstrated in Figure 2. Integration of onboard systems results in the display of information such as brake condition, train speed, and traction motor current from the locomotive in the top third of the screen. Health information from wayside and other onboard systems is displayed in two forms in the display. First, icons representing the condition of each subsystem are shown on the center status bar of the display. Green icons represent conditions allowing the train to operate at normal speeds. Yellow icons represent compromised operating conditions. Red icons represent unacceptable operating conditions. These icons present information regarding both the status of the system (e.g., broken rail) and system health status (working properly) of each detection system.

In addition to the icon color representations, pertinent text messages are displayed in the bottom right hand field in the event of compromised or unacceptable operating conditions. At FAST, this information is helpful to quickly identify where and when problems exist. It should be noted that only exception-based information is passed through to the display. Due to limited track length, equipment, and consistent staffing, problems can be identified and corrected and train operations can be restored in a timely fashion.
COMMUNICATIONS NETWORK

In order to provide information from a variety of locations to the locomotive cab, a key component is a communications network. A wireless IEEE 802.11 Radio Frequency LAN (WLAN) system with a maximum throughput capability of 11 megabits/second, was chosen to meet the communications needs at FAST. The system works in the unlicensed 2.4 GHz spread spectrum Industry Science and Medicine (ISM) band.

Installation of this system offered several benefits at TTC that may or may not be applicable in other environments:

- Approximately 2 miles line-of-site radius coverage per antenna
- Microsoft Windows®/Linux® operating system compatibility
- Low cost
- Ease of integration with existing communications/network systems at FAST

This communications backbone enabled access to all of the wayside detector locations at FAST and to the lead locomotive of the train. Once the capabilities of the system installed at FAST were identified, TTCI expanded the system to include sitewide coverage (134 kilometers\(^2\) or 52 miles\(^2\)).

WAYSIDE SENSOR SYSTEMS

Four wayside sensor systems are included in the list of devices monitored at FAST. These systems include:

- Rail-Break Detection System (an integral part of the FAST operations)
- Hot Bearing/Dragging Equipment Detection System
- Bridge Deflection System
- Truck (bogie) Performance Detection (TPD) System

As shown in Figure 3, the FAST train operates for up to 150 laps per night over the 4.3-kilometer (2.7-mile) High Tonnage Loop (HTL) resulting in 3.6 to 4.1 million gross metric tons/week (4 to 4.5 Million Gross short-tons/week) of traffic. This short track length results in a 4-minute interval between locomotive passes (2.9 minutes of no traffic).
Since testing rail weld types and techniques is one of the functions of FAST, nearly 1,000 rail welds within the HTL track compound the importance of the Rail-Break Detection System. The very basic detection system monitors the inner and outer rails separately with low-level direct current circuits. Conventional output through signal masts at two locations around the loop is done with a green light signifying good rail condition and a red light signifying a broken rail condition. To monitor rail-break information remotely, a data acquisition system (DAS) was added with the capability to connect to the WLAN and pass information to the locomotive cab. Thresholds for voltage conditions of certain components are monitored and exception-based messages are passed along to the appropriate personnel. With the new DAS, additional capability to identify compromised (yellow) conditions was added.
The HTL is equipped with a Harmon Cyberscan 2000™ hot bearing/dragging equipment detection system. Conventional output is done through a flashing light and radio output similar to systems in North American revenue service. To pass information directly to the cab, a DAS was attached to the hot bearing system and to the WLAN. As exception information above preset thresholds is measured by the hot bearing/dragging equipment detection system, pertinent information is passed along to the operator.

As part of a bridge deck research program, a two span, 4-girder bridge was installed in the HTL at FAST. As an extension to this research program, one of the girders has fatigue cracks that are monitored. Since the bridge was installed, the girder has been monitored for excessive travel with a limit switch. To enhance the bridge monitoring capability, deflection measurement devices were installed on each girder of the bridge. These deflections are monitored using the same DAS that communicates with the hot bearing detection system. Deflections beyond allowable thresholds are reported through a flashing light and sent through the WLAN to the locomotive cab. Additional sensors with more predictive capabilities such as strain measurements and acoustic measurement systems may be added in the future.

The TPD is the fourth wayside detection device incorporated into the monitoring system. Bogie performance monitoring is accomplished using a DAS system that measures wheel/rail forces at a number of wayside locations. A variety of strain gages attached to the rail measure vertical (V) and lateral (L) wheel forces during each train pass. The lateral and vertical measurements are combined to output the L/V ratio for each wheel. Angle-of-attack (AOA) measurements are also an output of the TPD system. Thresholds for L, V, L/V ratios and AOA are set in the system and alarms are generated appropriately.

The TPD system offers a wide variety of operational benefits to the FAST operation. Since individual wheel, axle, and bogie performance of each wagon are monitored every lap, performance changes over time can be identified. Poor performance due to component failure is identified rapidly and depending on the level of performance, individual wagons can be identified and removed from the train during subsequent laps.

The HTL is equipped with wayside lubrication devices to reduce curving resistance as part of normal operations. If multiple wagons report degraded performance within a short period of time, often the cause is due to lubrication system failures.
Throughout a long history of operation at FAST, the TPD system has been able to identify out-of-round wheels through these same performance measurements.

Conventional output from the TPD system is available in a wide variety of forms including e-mails, pagers, and faxes. Since this system was already incorporated into the WLAN system, integrating the exception-based output into the locomotive cab display was not difficult.

**ONBOARD SYSTEMS**

Onboard data is being captured through an interface with Wabtec Railway Electronics Trailing Locomotive Control (TLC) equipment installed on two of the FAST locomotive as part of the cable-based electronically controlled pneumatic braking system. The TLC system offers distributed power control of multiple locomotive consists at FAST and offers locomotive health feedback information for this program.

Additionally, an onboard monitoring system was installed early in this program on the four FAST locomotives to measure end-of-axle, carrier bearing, and gear-box temperatures. Traction motor current from each locomotive was also monitored. This system will be incorporated into the newly installed cab display this year.

**GPS LOCATION**

Train position through a Global Positioning System (GPS) is monitored as part of the technology integration. A Differential Global Positioning System (DGPS) is in place at TTC from earlier work done for the FRA. As a result, only a few components are required to allow the DGPS train position to be known. This will allow the position of the FAST train to be displayed on board the locomotive relative to facilities and equipment at TTC. It also allows the train location to be monitored by other vehicles and TTC’s Operations Control Center as part of TTCI’s "Mobile Tracking System” (Figure 4).
Other benefits are being realized to FAST operations through this technology integration. Maintenance personnel are able to access systems remotely and diagnose and correct problems as they are identified. In addition, engineers are now able to monitor data, download files, and conduct analyses over the RF WLAN system. Work on system hardening (robustness of software/hardware systems) will continue through this year.

The items discussed in this paper account for only a small portion of technologies and sensor systems that offer potential safety and operational improvements to the North American freight industry. Wide range acceptance and implementation of such devices will come only after system reliability and economic issues are more fully defined. In many cases, communications infrastructure and hardware installation is required over the majority of railroad property to make
the investment economical. Widespread installation of equipment will likely be extremely costly. Issues with older vintage equipment add to the complexity of systems wide integration. Much of the North American locomotive and wagon fleet is approaching 30 years of operation. Retrofit versus replacement of this equipment is always one of the most basic issues to be tackled.

The demonstration program at FAST shows promising results as to the technical capability of such systems to operate over a limited area. Items such as communication networks over areas the size of some North American Railroad properties will have to be considered in order to allow this type of enhanced information system to be possible.