Migration from Conventional Signaling to Next-Generation Train Control

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Migration from present-day signaling systems to next-generation train control, such as Advanced Train Control Systems (ATCS), will need to be an evolutionary process. Interoperability and compatibility with existing signal systems will be essential if ATCS, integrated with management information systems (MIS), are to provide suitable returns on investment. Some of the benefits of ATCS can be realized now, some later, and probably the "train control" feature will be the last implemented, certainly where signaling is now in service. Some of the benefits sought are already being realized through developments applied to existing, traditional technology.

The introduction of computer-based equipment and high-speed communication links brought to the railroad industry promises of timely transfer of information, which could benefit operations. It promised that not only could nonvital functions be implemented, such as train health monitoring, but also vital control data could be transmitted over the communication links between the central control and the trains. It promised to eliminate the need in many areas for wayside equipment such as track circuits, signals, and line wires. But with these promises come many questions about how to implement a smooth migration path from existing signaling to next-generation train control.

There are several key issues regarding both the ease of migration and the overall total cost/benefit of converting from conventional signaling to next-generation train control. These issues include compatibility with existing signal systems, movement of unequipped trains over controlled territory, ability to implement in a piecemeal fashion, and the possibility of significant training costs for dispatchers, locomotive maintenance personnel, and train crews.

DEFINING ATCS

Definitions are a central problem in the current discussion about next-generation train control systems. Terms need to be carefully defined to avoid any confusion. One definition of an Advanced Train Control Systems (ATCS) is that proposed by the Association of American Railroads (AAR) and the Railway Association of Canada (RAC) and described in specifications generated by ARINC Research Corporation. Frequently "ATCS" in capital letters is also used to describe any next-generation train control and train management system, regardless of its resemblance (or lack thereof) to the AAR/RAC specifications. It is worth noting that, so far as is known, no existing, functioning system fully implements the AAR/RAC specifications.

For clarity's sake, in this paper "ATCS" refers only to the system defined by the AAR/RAC specifications. The term "next-generation train control" refers to other types of advanced train control systems. (Others define these systems using lowercase "atcs.") We will further define "next-generation train control" to refer only to systems that provide *actual control of train movement*, as opposed to management information systems (MIS).

Management information is one of the two principal functions of advanced train control systems: issuing work orders, locomotive health monitoring, crew calling, event recording, and planning dispatching strategy, to mention a few. The second principal function is vital and nonvital train control: throwing switches, moving trains, and stopping trains.

The railroads must weigh the expense of tying both management information and *train control* functions into a single package. Next-generation train control systems can be designed to be compatible with MIS just as existing train control systems are compatible with these systems (e.g., crew calling, event recording, and dispatcher assistance).

BENEFITS OF ADVANCED SYSTEMS

Although not everyone in the railroad industry agrees on the choice of a single advanced system, probably everyone agrees on the desirability of the benefits an advanced system can provide: the ability to move more trains more efficiently on existing tracks, to maintain the existing high standards of safety, and to reduce the costs associated with the signal and control system, especially the costs of wayside equipment. In addition to these an important practical consideration can be added: interoperability/interchangeability with existing signal and control systems, facilities, and personnel. Beyond these, there are additional benefits that can be realized when an MIS is added to a next-generation train control system.

With ATCS, for example, one of the key features will be the integration of MIS. Much of the information needed to provide more efficient train handling (hence reduced fuel consumption and less damage to lading) comes from MIS waybill and car equipment data on the type and contents of each car (Universal Machine Language Equipment Register, or UMLER). In addition, MIS provides the number and identity of cars in the train.

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Traffic Capacity

Some proponents of ATCS assert that the "moving-block" feature could increase traffic capacity by allowing closer headways between trains. Although this may be true for the traffic mix on European railroads, it does not appear to have been demonstrated for the traffic typically encountered on U.S. and Canadian railroads—a large number of long freight trains and a small number of passenger trains. For the U.S./Canadian situation, fixed-block systems with blocks of suitable length can provide comparable traffic capacity. To increase capacity, next generation train control systems will allow shortening block length easily and at a reasonable cost.

Interoperability/Interchangeability

The definition of interoperability/interchangeability needs to be expanded to include interoperability with existing systems. Many of the benefits of interoperability/interchangeability are obvious, especially as they relate to providing a smooth transition from existing systems to advanced ones without the problems of the "D-Day" cut-over required when changing to a completely different type of system. These benefits are discussed in greater detail below.

Training/Facilities

There are also some less visible benefits of interoperability/interchangeability. When a new system closely follows the framework of the existing one, very little retraining is needed for dispatchers and engine operators, and existing centralized traffic control (CTC) offices can still be used.

If the benefits provided by a completely different system were significant enough, a radical change might be justified. However, other advanced systems offer similar benefits to ATCSs, plus interoperability/interchangeability. Indeed, many of the benefits can be obtained by upgrading conventional systems. Many products from signal suppliers are designed for compatibility with train management systems, including the train management functions of ATCS, based on meeting the ATCS specification for communications. (Note that following the ATCS specification may result in some degradation of performance from conventional systems because of factors such as message response time.)

THE TRANSITION TO ATCS

Train operations and control can be classified as follows:

- Dark territory (no signaling) operated by timetable and train orders, direct traffic control, or track warrants;
- Manual block signaling;
- Automatic block signaling with timetable and train orders or track warrant system;
- CTC or other traffic control system; and
- Cab signaling with or without automatic train control or automatic train stop.

To overlay or apply ATCS to any of these situations will require a smooth transition period, not only to install the digital communications network and the computers on the locomotives and at dispatching headquarters, but also for training dispatchers and operating and maintenance personnel.

Probably the easiest transition will be that of installing ATCS in dark territory. Next easiest will probably be in manual block signaling territory. Next would be in automatic block signaling territory, then in CTC territory, and finally in territory with cab signaling, whether with or without automatic train control or train stop.

In all cases a transition path must be determined that will allow a smooth, orderly change with no disruption in operation, including the ability to handle non-ATCS–equipped trains. This is important not only because of the time required to install wayside and motive power equipment, but also because of the time required to train personnel, especially for handling maintenance of motive power units.

Note that the Federal Railroad Administration will probably not allow ATCS to be installed to replace present signal systems without a period of parallel operation, until ATCS can provide proof that they can be as safe as the signal system currently in service.

Also note that although ATCS provide the movement authority to the train, similar to a train order, the train will still be guided by any wayside signals in regard to safety of the movement. Obviously the engineer would stop the train when it encounters a red signal. Full ATCS would also provide a display on the locomotive computer, telling the engineer to stop in approach to a red signal.

Carrying this further, to the overlay of ATCS on CTC, one school of thought is that the safety features of CTC would be retained, though possibly wayside signals could be retired because the ATCS on-board computer would provide signal displays in the cab.

As for interlockings, the local control would probably be turned over to the dispatching center, but again the interlocking's safety features would be retained. The engineer's cab display would allow the train to move through the interlocking only if it were safe to do so. In many instances the interlocking might never be taken under ATCS control because of its complexity.

Due to the tremendous investment in traditional signaling, the ability to address these transition issues will have significant impact on the acceptance and implementation of future train control systems.

TRANSITION TO A NON-ATCS ADVANCED SYSTEM

Past experience in upgrading systems suggests there will be a relatively long period during which the old and new must coexist, with the old system remaining on less-used routes for several years or longer.

The most likely scenario would be that a currently dark section would be added to an existing signaled section, where this had not been cost-effective using traditional technology. This highlights the need for next-generation train control systems that maintain interoperability with conventional systems.

Another scenario that highlights this requirement for compatibility is overlaying a new technology over existing signaled territory. This could occur when portions of the existing systems are in need of major repair or replacement, or when it is desired to keep a major portion of an existing system, such as a large interlocking. The differences in implementation and operation between currently proposed schemes and existing signaling approaches do not allow for the coexistence of the two systems on the same territory; however, there are some very practical reasons why coexistence should be provided for. These include installed investment, cost of change greater than benefit, existing practices, and many other practical considerations. The compatibility issue is critical to the success of any future control system.

One alternative approach to delivering the benefits sought by our industry—one that addresses the compatibility issues—is based more on existing signaling techniques and practices (Figure 1). It includes a nonvital office work station (or panel board) handling the train movement controls. This computer then feeds control information to centrally located vital Boolean expression evaluators. These vital controllers contain all of the same vital field logic that would formerly have been stored in local controllers located in wayside bungalows. These vital controllers communicate by radio links directly with both the car-borne equipment carried in the locomotives, and the wayside units that handle the physical control of the ground equipment.

Position locating is achieved through the use of wayside transponders that mark block boundaries. These blocks can be short, train-length blocks. The equipment required is very inexpensive. For overlaying on existing systems, the transponders are located at existing block boundaries (i.e., where signals are now located.) Equivalent logic will be provided in the office to allow wayside signals and cab signals to be in

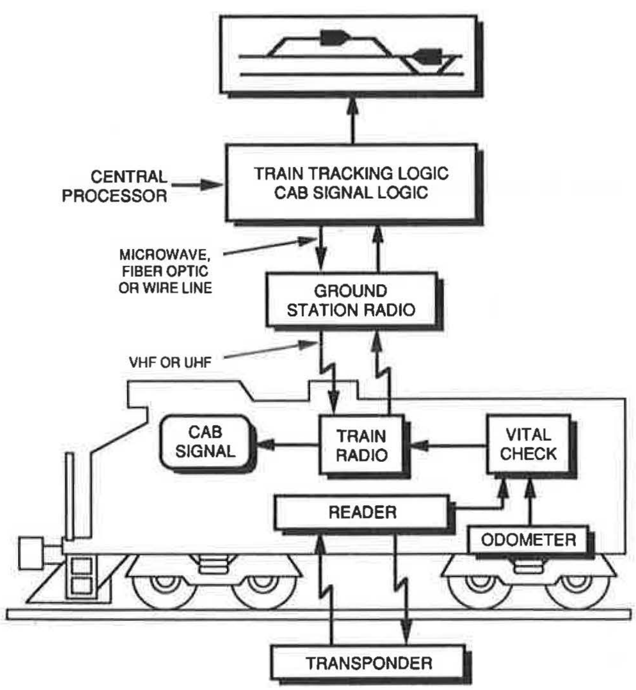

FIGURE 1 Alternative approach.

agreement. Eventually, wayside signals could be removed or block lengths redesigned very economically.

This approach makes use of existing, proven practices and technologies. The office controller is a traditional CTC device, the vital controllers perform the same functions as existing microprocessor-based interlocking controllers, and the fixed-block approach provides a very economical element of compatibility with existing systems.

Because the office computer is the same as today's, and a fixed-block design is used, this system can easily be added to an existing signal system. It would require adding a separate code line (or radio-based code transmission) to the office computer, its implementation technique transparent to the rest of the system.

This approach to next-generation train control offers many practical advantages, particularly in the area of compatibility. In this system, an existing office computer, or any CTC computer (readily available from a number of suppliers) could be used. Because the existing basic principles of office control are used, and every component of the system is based on proven, safe technological and operational practices, the confidence curve in demonstrating the safety of the system will be much shorter than if new approaches are used. This evolutionary approach to next-generation train control provides benefits comparable to revolutionary approaches, but far fewer risks.

Operational compatibility with existing systems is another benefit with practical implications. The block approach presents the same operational information to the engineer regardless of whether this information is presented on the cab display or on wayside signals. This compatibility allows for smooth travel of trains over territory controlled under existing technology or under new technology. It also allows the simultaneous operation of both systems during the interim phase when cab and wayside signals are to be used in tandem. And it minimizes the extent of training required when installing the new system. Signal aspects or speed limits, displayed in the cab with meanings similar to existing wayside signal aspects, are an efficient way to convey information to the operator and do not require extensive training to learn how to understand new, more complex material.

This coexistence of existing and next-generation train control provides a practical scenario for migrating from an existing system to a next-generation system. This allows for piecemeal migration over time as opposed to the alternative, which calls for the instant abandonment of existing systems and cut-in of new systems. Thus, initial installation of next-generation systems can be made in those segments of a territory where it is most cost-effective. And such train control technology is compatible with developing management information technologies, whatever form they may eventually take.

CONCLUSION

The transition to a next-generation system must be evolutionary. Many benefits can be obtained before the last piece is installed—actual train control.

There are three requirements for a smooth transition to a next-generation system:

1. Compatibility between new and existing equipment and systems during the transition period, which may take several years;
2. Extensive training of dispatchers, operating personnel, and maintenance personnel; and
3. Investment and benefits realized incrementally.

A fourth point might be added: educating and working with governmental regulatory agencies to foster cooperation with the railroad industry and suppliers in making the transition to the new systems.

In closing, it should not be overlooked that many of the benefits promised by ATCS are being realized today. Through the application of vital electronic interlocking controls, vital electronic track circuits, vital electronic cab signals, radio transmission of control data, desktop central offices, and remote diagnostic systems, traditional technology is being upgraded economically. Maintenance requirements are being reduced, training simplified, line wires are coming down, and information is being exchanged electronically, making railroads more competitive, more profitable, and safer than ever.