4.0 Advanced Warning for Railroad Delays

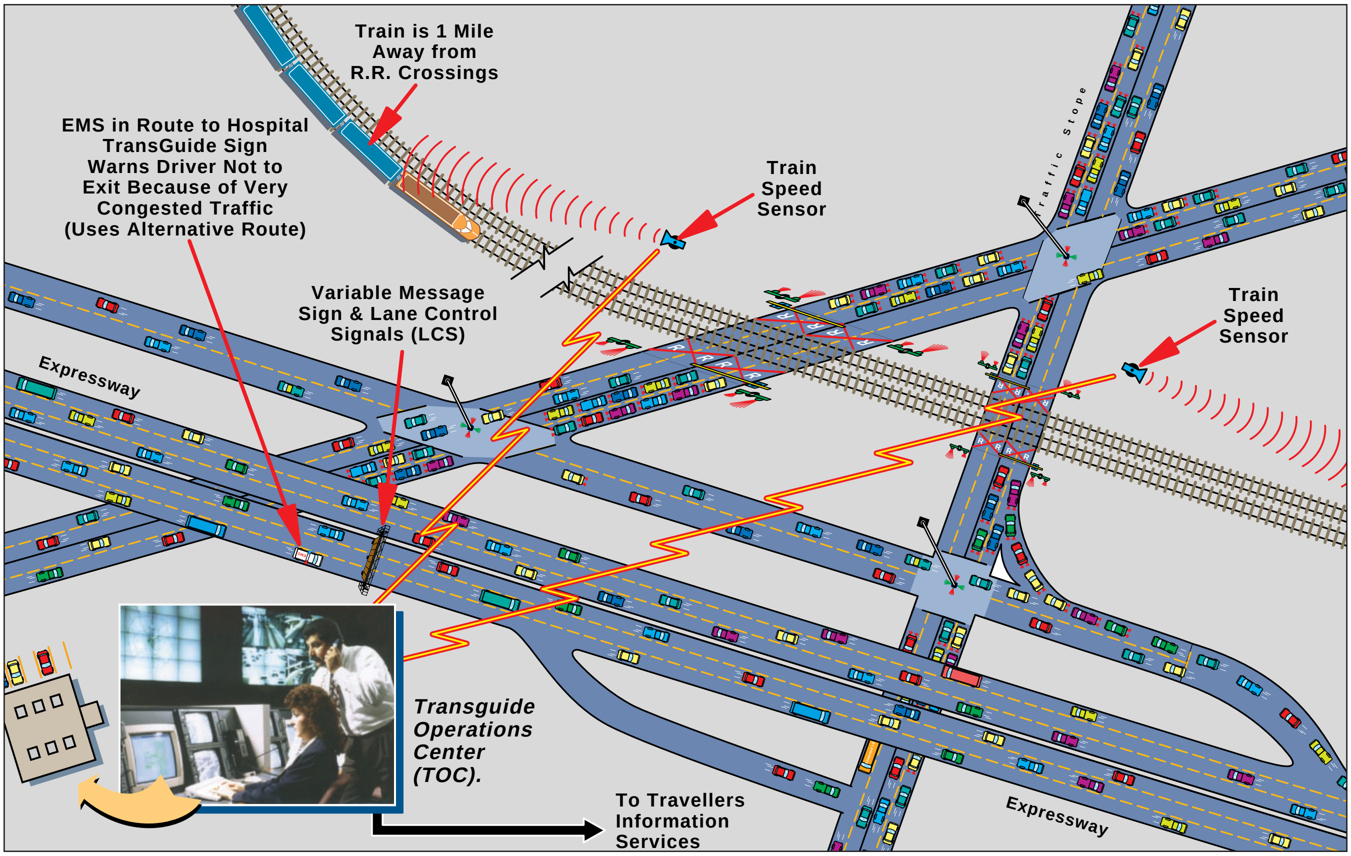

Figure 15. AWARD Conceptual Overview

The Advanced Warning for Railroad Delays (AWARD) System is an ATIS implementation designed to help motorists avoid delays caused by railroad operations that cross freeway access or frontage roads (Figure 15).

This information enables TransGuide operators to control changeable message signs placed at strategic locations along the freeway to alert motorists of potential delays ahead and to allow them to select alternate exits.

4.1 Overview

The AWARD System includes acoustic and Doppler radar sensors placed at selected locations along the railroad track to detect the presence, speed, and length of trains before they approach grade crossings. Data from the sensors are transmitted to the TransGuide Control Center where computer programs calculate the predicted time and duration that grade crossings at or near freeway exits will be blocked. This information enables TransGuide operators to control changeable message signs placed at strategic locations along the freeway to alert motorists of potential delays ahead and to allow them to select alternate exits. Information on blocked grade crossings is also placed in the Area Wide Database for use in other MDI components such as Kiosks and IVN.

The AWARD System is part of the TransGuide MDI and operates independently of railroad signals or communications. In fact, a design criteria was that the system had to be nonintrusive in that no equipment could be located on the railroad right of way. System software was implemented with a modular, object-oriented architecture so that additional sensors and crossings can be added easily. This modular design also provides a method for future implementations of the AWARD System in other locations and applications including advance warning of train-related delays on arterial and city streets.

4.2 Design Information

The AWARD System described in this document is the initial implementation and test of a new approach to handling intermodal traffic problems. The system includes a limited number of sensors to predict train activity at three specific grade crossings where blocked intersections affect freeway traffic. The results of this limited implementation are being used to assess the effectiveness and benefits of the concept. The effectiveness of the system will serve as the basis for future expansion of the system and for implementation of advance warning methods at additional intersections. The design of the AWARD System is based on the following goals:

- Provide advance information on train crossings to allow motorists to plan and take alternate routes that avoid blocked intersections. This advance information will reduce congestion at intersections and on freeways and reduce traffic hazards.
- Provide advance information on train crossings to TransGuide operators, allowing them to respond to predicted crossing blockages. This advance information will allow users to include train information in planning VMS messages and in responding to traffic incidents.
- Provide advance information to emergency services to allow route planning that avoids congested intersections. This information will lead to faster response time of emergency vehicles.
- Provide a system architecture that can be expanded to include additional sensor locations and additional grade crossings in the future. This system architecture will allow expansion of the system and implementation at other locations.

4.2.1 System Architecture

As depicted in Figure 16, the AWARD System includes a central master computer at the TOC and multiple field units consisting of an acoustic detector and a radar speed gun connected to a modem. The field units relay train velocity information using a POTS communication link to a second modem attached to the AWARD Master Computer located at the TransGuide facility. Software running

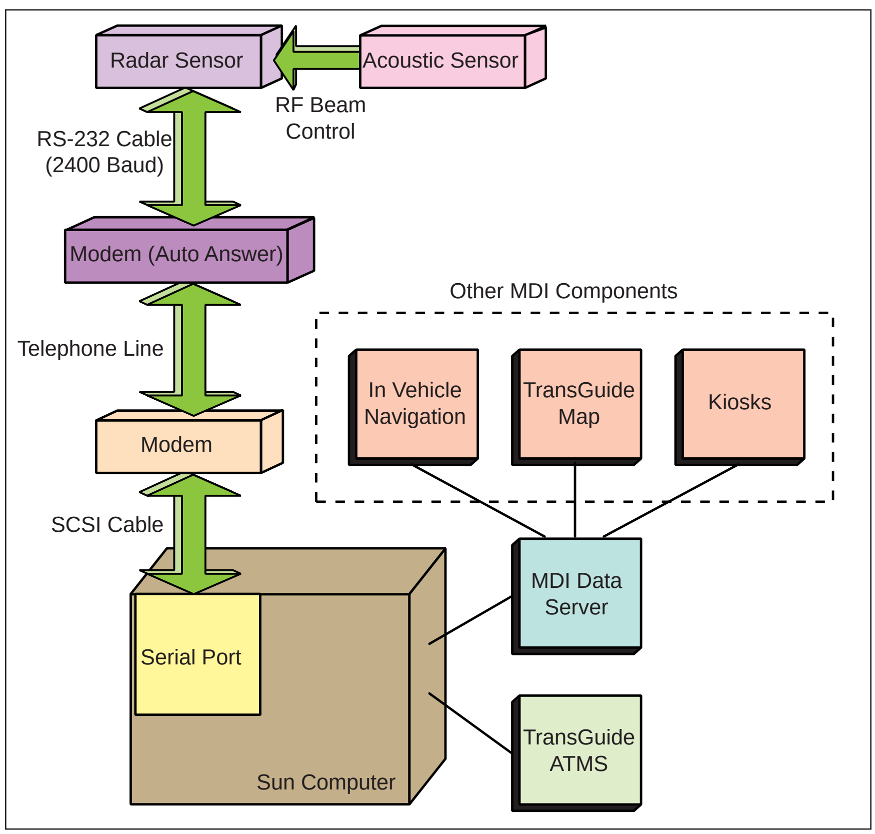

Figure 16. AWARD System Block Diagram

on the AWARD Master Computer monitors the remote radar units to determine train location and speed. After calculating the time and duration of grade crossing closures, the data are relayed to the TransGuide ATMS and the Area Wide Database. From the Area Wide Database, the data are available for use by other elements of the MDI.

The flow of information related to grade crossing closures is illustrated in Figure 17. Train speed measurements are transmitted to the AWARD Master Computer Subsystem, where estimated time and duration of crossing blockages are calculated. If any blockages are predicted to occur within specified time intervals, a railroad incident event is generated. This information is provided to the Scenario Management Subsystem, which communicates with TransGuide operations personnel through GUIs.

4.2.2 System Geographic Layout

One important consideration in the design of the AWARD System was the selection of grade crossings to be monitored and the location of sites

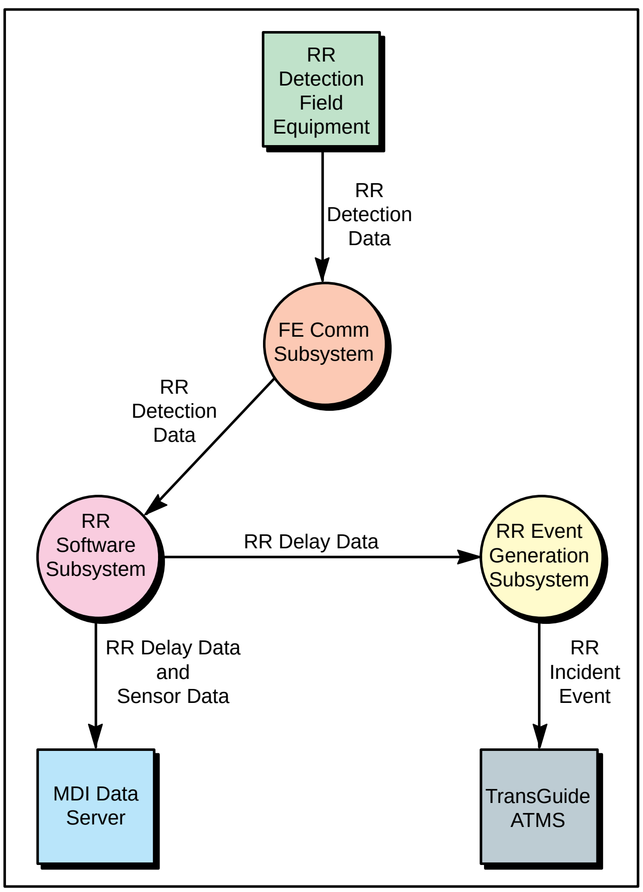

Figure 17. AWARD Process Flow

for train speed sensors. In the specific case of freeway-railroad interaction considered for AWARD, the Kerrville line of the Union Pacific Railroad runs nearly parallel to IH 10 from south of Culebra Road to near Basse Road, where IH 10 turns westerly. The railroad line continues northward, crossing under IH 410 at Jackson-Keller Road. In this interval of slightly over five miles, the railroad track crosses three major roads where crossing blockages can affect freeway traffic.

This track is used primarily to haul gravel and rock from a quarry north of town. Due to the congestion of the area and the condition of the track, trains operating on this section of track are limited to speeds of ten miles per hour. Delays of up to ten minutes have been reported by residents and motorists in the area as they waited for the train to clear a grade crossing. The trains do not maintain a fixed schedule, but five or more trains may move across the track on some days. Because of these factors, train operations in this section have an appreciable effect on freeway traffic and on the travel time of motorists, including emergency vehicles.

Sites for sensors must be located far enough from the three grade crossings to provide advance warning to allow motorists to decide on an alternate route, possibly change freeway lanes, or take an earlier or later exit from the freeway. On the other hand, the sensors must be close enough to the crossings so that train speed is relatively constant, and crossing closure can be accurately predicted. For this section of freeway, an advance warning time of four to eight minutes was selected to provide motorists with several miles of driving in which to make and execute alternate route plans. Based on the nominal train speed of 10 miles per hour, a distance of one mile from sensor to grade crossing was selected to provide a six-minute advance warning to drivers.

Based on this distance requirement, six sensors (one on each side of each crossing) are used to provide accurate time and duration estimates. Regions of the track approximately one mile on each side of the three grade crossings were investigated to determine the availability of sites for mounting train sensors. In addition to being the correct distance from grade crossings, acceptable sites must provide opportunities for mounting the sensor, an unobstructed view of the railroad track, and the availability of power and communications. Sites were identified at each required location that possessed the required characteristics.

Each remote site includes an acoustic sensor to detect a train and a speed sensor to measure the speed of trains approaching a crossing. A typical site installation is shown in Figure 18.

4.2.3 Sensor Details

The acoustic train sensor is a SmartSonic Traffic Surveillance System (TSS-1), a noncontact sensor designed for highway use. The TSS-1 can detect the acoustic emissions of a vehicle and provide vehicle presence signals to a traffic controller or other system. Each SmartSonic sensor is composed of a microphone array, which listens continuously to sound energy from sources within its detection zone. The signals from the microphones are processed to provide sensor directivity, creating an effective detection beam of only a few degrees. For the typical installation along the Union Pacific railroad track, the detection zone is approximately a 12-foot by 12-foot area. When a train enters the detection zone, an increase in sound energy is detected, and a train presence signal is generated. This signal closes a relay, providing power to the transmitter of the radar unit. When the train leaves the detection zone, the sound energy level drops below the detection threshold, the train presence signal becomes inactive, and the radar beam is turned off. During tests, it was noted that the sound level may drop below the detection level for short periods of time as long cars pass through the detection zone. To prevent the radar power from being turned on and off intermittently as a train passes, a time-delay relay was used to hold the radar on for the short quiet intervals as a train passes.

The selected Doppler radar sensor is from MPH Industries, Inc., manufactured by O'Conner Engineering and distributed by MPH Industries. The radar operates with five milliwatts at 24.125 GHz with a four-inch sealed horn antenna, and it provides target speed and direction over an RS-232 port.

The radar, modem, signal-conditioning circuits, and power supply are mounted in a custom enclosure designed for utility pole mounting. The enclosure is based on current enclosure designs selected and used for traffic control installations in the city

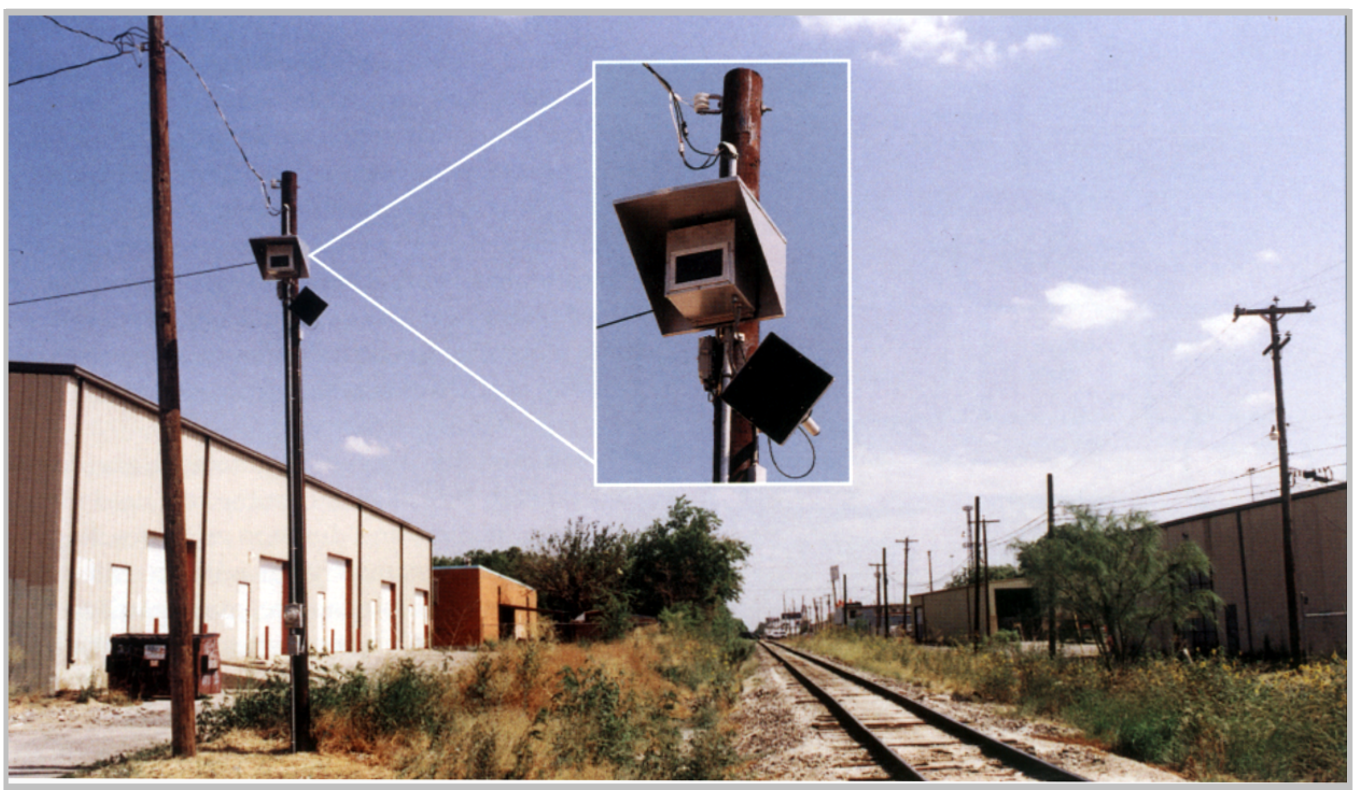

Figure 18. AWARD Site Installation

of San Antonio. The dimensions of the enclosure are 12 by 12 by 12 inches. These dimensions permit ready access to components and ample room for additional components if needed. The enclosure is equipped with a sun shield and designed for operation in typical San Antonio conditions of 10° to 120°F.

The radar window is Lexan. The thickness and clarity are designed to prevent thermal loading and damage due to elements or vandalism. A two degree-of-freedom mount permits sensor alignment. This mount allows for rotation about the pitch and yaw axis of the enclosure. All components are designed for rigid mounting within the enclosure.

Each remote train speed sensor installation is connected to 115 VAC single-phase power. A terminal strip provides a circuit breaker and surge protection. The terminal strip provides 120 VAC power to the modem and a power supply. The power supply provides 15 VDC power for the acoustic detector and the Doppler radar sensor.

4.2.4 System Software

The AWARD System software is written in C++ and treats trains passing through the system as objects. Configuration information, provided in text files, enumerates sensors, crossings, and connections between sensors and crossings. Equations of motion are used to calculate train length and arrival times at different crossings from the measured train speeds. Train acceleration is derived from speed changes, and there are provisions for additional rules to accommodate regular train speed patterns for different days or times if any patterns are identified. The system polls the train sensors on a regular schedule and updates predicted blockage times and durations at each polling cycle. Modifications to the system, such as changing the location of sensors, including additional grade crossings, or adding sensor sites, can be accomplished by changes in the configuration files that describe the system geography.

4.3 Tradeoff Decisions

Each AWARD remote site includes sensors to detect the presence of trains and a sensor to measure the speed of trains approaching a crossing.

4.3.1 Sensor Tradeoffs

A number of sensing approaches were considered for detecting trains and measuring their velocity and acceleration. Table 6 lists the techniques considered for measuring train speed and the major advantages and disadvantages identified for each.

Given the significant difficulties associated with the use of the other techniques, Doppler radar technology was selected. Although radar gun technology was chosen as the most appropriate, it has some limitations. No commercial off-the-shelf (COTS) radar unit was found that was specifically designed to monitor slow vehicles, to provide a direction indication, and to communicate with a remote computer. Therefore, a vendor was found who was willing to quote and provide such a system.

Normal frequency bands of the radar units are X, K, and Ka. The frequency band least affected by rainfall is the X band. However, the vendor had no X band radar that could determine vehicle direction. Therefore a K band radar was chosen. Radar gun technology is based on measuring frequency shift of a returned signal (i.e., Doppler shift) and small, inexpensive units are not sensitive to small frequency shifts indicative of slow speeds. The filter circuits of radar units, however, may be adjusted so that they are more sensitive to slower speeds than the nominal 60 miles per hour. An additional limitation of using radar gun technology is that the Federal Communications Commission (FCC) regulations discourage operations that require unattended radar units to transmit continuously.

Due to the need to control radar transmit power and to eliminate false signals due to blowing rain, a separate train presence sensor was also included at each site. A number of sensing technologies were considered, including:

- Seismometers to detect the vibration of passing trains
- Passive infrared sensors to detect the heat of engines and wheels
- Magnetometers to sense the mass of locomotives and cars
- Acoustic sensors to detect the sound of locomotives and cars

Acoustic sensors were selected for train presence since they could be installed off the railroad right of way and still provide reliable detection of engines.

Table 6. AWARD Sensor Comparisons
(Selected sensors are highlighted in yellow.)

Technique	Advantages	Disadvantages
RF Tags Readers Train cars in the U.S. have electronic tags detailing at least the length of the car. Tag readers placed beside the track could read this tag and calculate the speed and length of the train.	Tag readers are supplied by several manufacturers. Available commercial systems are suitable for use in outdoor environments. Determining the time intervals and length of railroad cars would allow accurate calculation of train speed and length.	The sensing range of tag readers is low so that the readers would have to be placed on railroad right-of-way. The cost of tag readers is higher than other systems.
Acoustic Vehicle Detectors Trains entering the sensitive "footprint" of the sensor would be detected by acoustic emission. Two sensors located a known distance apart could determine train speed.	Acoustic detectors are in use as loop detectors. Commercially available systems are suitable for outdoor use.	Velocity detection requires two detectors a distance apart at each location. Speed can only be measured at the front and rear of the train. Acceleration can only be derived from the two velocity measurements. Since variations in speed and acceleration cannot be measured, calculations of length and crossing arrival times will be inaccurate. Field box installation requires significant on-site calibration.
Laser Radar (LIDAR) Distance to an object is measured by a reflected beam of light. Speed is calculated by the change in distance measurements.	Laser radar guns are readily available due to the law enforcement industry. The laser radar instrument provides range and speed data.	Laser radar must track a single point on an object to acquire an accurate speed measurement. A rigid-mounted unit can measure only the locomotive but cannot track points on the side of moving train cars.
Doppler radar Speed is measured by frequency shift of the reflected radio frequency beam.	Laser radar guns are readily available due to the law enforcement industry. No FCC license is required for low-power (short-range) use. The Doppler technique provides direct speed measurement. Speed can be measured from the sides of moving train cars.	Radar guns have some sensitivity problems with low-speed objects but this sensitivity can be overcome with modifications to the standard designs.

4.3.2 Communications Subsystem Tradeoffs

The communications subsystem transmits train speed measurements from the train sensor to the workstation located in the TOC. Several alternative communication techniques were considered as a part of the system design with the design goals of:

- Reliability
- Economical installation and operation
- Adaptability to installation in multiple locations
- Expandability to allow use of many sensors for many grade crossings

The communication tradeoffs were the same as the AVI program. The AWARD System utilized dial-up telephone communications due to its cost effectiveness.

4.4 Summary

The AWARD System shows the feasibility and benefit of providing advance warning of grade crossing closures. The combination of acoustic train detection and Doppler radar provides accurate speed measurement and effectively eliminates false signals. Experience shows that even slow-moving trains can be monitored, and the time and duration of crossing closure reported to ATMS operators. Some variations in arrival time because of manual speed control by locomotive operators was observed, but the variations are not enough to affect the overall operation of the system. Advance knowledge of crossing closures has been used by motorists and emergency equipment to select freeway exits to avoid congested conditions and reduce driving delays. The use of very general, object-oriented software to express the geometry of the railroad track, sensor and crossings provides a flexible system. Coupled with the use of commercially available sensors and components, this AWARD system can be easily and economically expanded or replicated at other locations.