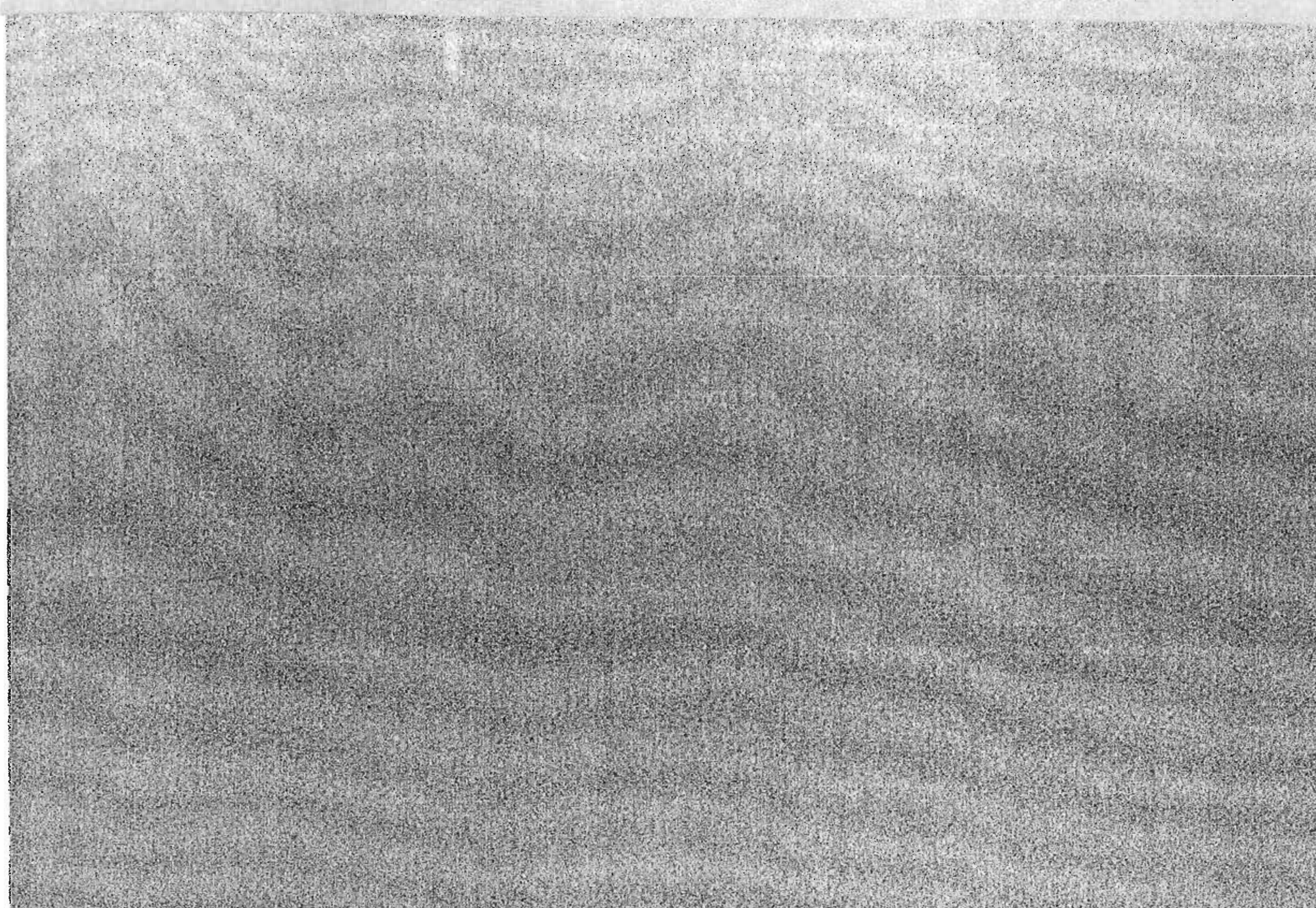
U. S. Department of Transportation
Federal Railroad Administration

Intruder and Obstacle Detection Systems (IODS) for Railroads

1998 Requirements Workshop

**Office of Research and Development
Washington, D.C. 20590**

U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Cambridge, MA 02142



DOT/FRA/ORD-01/13

**Final Report
December 2001**

always expect a train

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13. ABSTRACT (Maximum 200 words)

The Intruder and Obstacle Detection Systems (IODS) for Railroads Requirements Workshop was held June 11 and 12, 1998, at the U.S. Department of Transportation (DOT) John A. Volpe National Transportation Systems Center in Cambridge, Massachusetts. Participants included DOT staff and consultants, state highway and rail representatives, railroads, railroad suppliers, and research and development organizations.

The Workshop aimed to gather practitioner input regarding requirements and constraints for intruder and obstacle detection on rail rights-of-way (ROW) and grade crossings, identify institutional and implementation considerations, and develop a consensus for a high-level functional concept for such a detection system. Objectives were achieved through sessions designed to review the operational, technical, and regulatory issues; hear the concerns, priorities, and ideas of all participants; and formulate a consensus statement to guide the next steps. Workshop input is the first step in gathering and validating IODS requirements.

IODS will integrate systems that sense hazards; detect threats by assessing sensor data; transmit alarms and supporting data to decision/control points; and collect and display event data for analysis and action. The technologies will be applied to meet the varied requirements of rail grade crossings, ROW, and railroad facilities. The technology requirements will be consistent with Intelligent Transportation Systems architecture.

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Preface

The staff of the Federal Railroad Administration, Office of Research and Development, and the John A. Volpe National Transportation Systems Center (Volpe Center), Accident Prevention Division, expresses their appreciation to the Intruder and Obstacle Detection System (IODS) for Railroads Requirements Workshop participants. These volunteers offered their respective points of view and contributed their experience, ideas, priorities, and knowledge of current standard practices to help build a foundation for valid and useful IODS requirements.

In addition, the authors wish to thank the following staff and consultants who contributed to the workshop's success: Ms. Carol Ann Courtney of Camber Corporation, who with her staff in the Volpe Center's conference office, made all the workshop arrangements; Dr. Jeff Everson, Mr. Jonathan Luedeke, and Mr. David Wagner of Battelle Memorial Institute who provided technical material as a starting point for the workshop discussions; and Mr. David Daley and Ms. Donna Woodford of the Volpe Center for facilitating the breakout sessions.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

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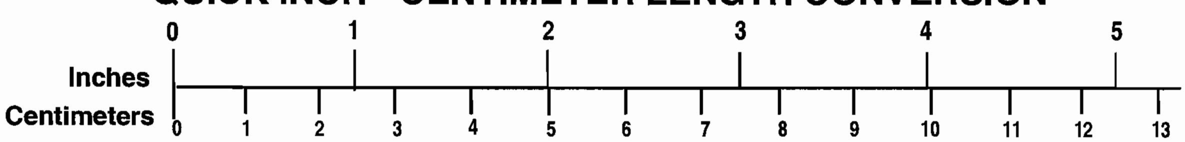
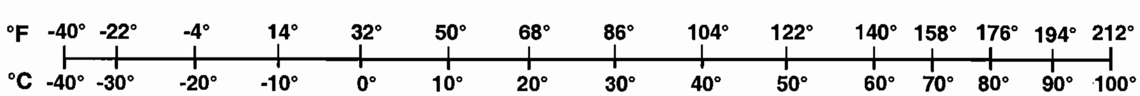
QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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EXECUTIVE SUMMARY

The Intruders and Obstacle Detection System (IODS) for Railroads Requirements Workshop was held June 11 and 12, 1998, at the U.S. Department of Transportation (DOT) John A. Volpe National Transportation Systems Center (Volpe Center) in Cambridge, Massachusetts. Participants included DOT staff and consultants, state highway and rail representatives, and stakeholders representing the railroad industry (see Appendix B). Industry practitioners concerned with rail safety included representatives from several railroads, railroad suppliers, and research and development organizations.

The purpose of the IODS Requirements Workshop was multi-faceted: gather practitioner (i.e., railroad, government, and technology industry) input regarding requirements and constraints for intruder and obstacle detection on rail rights-of-way (ROW) and highway-rail grade crossings; identify institutional and implementation considerations; and develop a consensus for a high-level functional concept for such a detection system.

The workshop allowed the formation of a high-level conceptual framework for gathering and specifying system requirements. Once the operational concept is validated, the detailed outputs from this workshop can be used in specifying requirements for an IODS. When implemented, an IODS will integrate a number of systems that (a) sense hazards (i.e., things, people, and the environment); (b) detect threats from assessment of sensor data; (c) transmit alarms and supporting data to decision/control points; and (d) collect and display data for analysis and action. The various technologies will be applied as needed to meet the varied requirements of highway-rail grade crossings, ROW, and railroad facilities. The technology and data requirements will be consistent with the Intelligent Transportation Systems (ITS) architecture.

The technical sessions reviewed the basic issues and current work in railroad hazard detection, both for highway-rail grade crossings and for ROW, and then suggested some functional concepts. The first session reviewed the types of obstacles that are likely to occur in a highway-rail grade crossing and that are a threat to an approaching train. While the system questions remain the same for both ROW and highway-rail grade crossings, the problem presents different challenges for each. Visible obstructions, such as debris, vehicles, or rocks, still pose a threat to the train in the ROW, but less apparent are trespassers and vandals, who also present the potential to do damage to the ROW and to endanger the train. A train accident is defined as a "safety-related event involving on-track equipment (both standing and moving), causing monetary damage to the rail equipment and track above a prescribed amount." A highway-rail grade crossing incident is defined as "any impact between a rail and a highway user (both motor vehicles and other users of the crossing) at a designated crossing site, including walkways, sidewalks, etc., associated with the crossing.[1] While the discussion focused around vehicles, accident statistics show the most frequent cause of ROW incidents has been vandalism, followed

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[1] Definitions from FRA *Railroad Safety Statistics Annual Report, 1997*. Train accident definition reported on form F 6180.54 "Rail equipment accident/incident report." Highway-rail grade crossing incident definition reported on form FRA F 6180.57, "Highway-rail grade crossing accident/incident report."

by debris on the track. The issues of intentional sabotage and weapons of mass destruction were not addressed.

The second session introduced concepts for introducer and obstacle detection. The concepts discussed in this session included a technology-independent set of top-level functional requirements; a proposed path from identifying general needs and issues; and the construct of "smart" versus "dumb" sensor systems, provided as a stimulus to discussion of how the system might work.

The roundtable discussion changed the direction of the workshop to emphasize highway-rail grade crossing issues. Some discussion continued to apply to ROW requirements; however, much of the discussion addressed the cost-benefit ratio and feasibility of IODS equipment. The group agreed that the mission of IODS is to protect the train from obstacles and sabotage. A side benefit of IODS can be to document (using video and digital data) incidents and to gather evidence to protect the railroad from frivolous lawsuits. Part of the basic requirement of IODS is determining the amount of lead time it takes to stop a train of various configurations at various speeds. IODS installations will have to be configured with special attention to the hazards represented at the site, and to the types of trains that use the rail line.

The two breakout sessions focused on obstacle detection at individual highway-rail grade crossings. The groups agreed that significant thought, analysis, and testing should go into the design of obstacle detection equipment, and that the operational IODS must be highly reliable. Both groups addressed the principle of train control and agreed that the use of standard train control signals and dispatcher involvement are a key to safe operation. At the same time, both groups discussed the possibility of certain specific alarms going directly to the train cab signaling system, and even stopping the train automatically. While all workshop participants did not agree on the need for IODS for all highway-rail grade crossings and ROW for all railroads, principles and constraints were discussed that will meet the near-term needs of high-speed rail corridors. This system of sensors, processing, communication, and decision support may later be applied to other passenger and freight rail routes as needed.

1. INTRODUCTION AND BACKGROUND

This report presents the issues and discussion of the Intruder and Obstacle Detection System (IODS) Requirements Workshop, held at the John A. Volpe National Transportation Systems Center (Volpe Center) in Cambridge, Massachusetts, on June 11 and 12, 1998. It offers an approach to IODS development based on the vision and requirements contributed by workshop participants.

This report is organized into two sections and five appendices. The sections of the report are organized as follows:

1. ***Introduction and Background:*** Provides the rationale, policy background, and logistical process for the workshop.

2. ***Workshop Presentations:*** Describes each of the presentations and summarizes each of the discussion sessions.

The appendices include the workshop participant list; highlights of the presentation visual aids; functional requirements introduction; sensor technologies; and a set of working definitions for IODS-related terms and abbreviations.

1.1 Background

The 1998 IODS Requirements Workshop was one of a series of steps by the Federal Railroad Administration (FRA) and the rail transportation industry to improve highway-rail grade crossing safety, protect high-speed trains from damage, enhance the physical security of rail facilities and rights-of-way (ROW), and protect this segment of the nation's critical transportation infrastructure.

While highway-rail grade crossing injury statistics show an improved safety trend in the past few years, the cost in life and property of each remaining incident suggests further attention is necessary. As high-speed rail is implemented in several rail corridors in the United States, the requirement for protection of passengers on the moving train has gained more importance in the safety equation.

It is important to define the architecture for a detection and information system that will detect objects and intruders in railroad ROW. The advent of high-speed rail has increased the potential cost and consequence of failing to detect objects and intruders. Technology is providing compact, durable, reliable, and highly sensitive sensor devices. Most railroad communication systems can support the increase in signal load because of recent upgrades to fiber-optic communication media. The information gathered for object and intruder detection can, with minor enhancements, also be used to supplement operations and maintenance data, thereby contributing to more efficient railroad operations. The Intelligent Transportation Systems (ITS) National Architecture provides the underlying communications, data format, and interface standards to integrate IODS data into the wider transportation information network. While the future will continue to bring technical improvements to most components of the proposed IODS, the current situation and technical resources are sufficient to get started.

1.2 Invitation of IODS Workshop Participants

Using conference participant, interest group, and distribution lists, Volpe Center staff and contractors located and invited a wide variety of railroad safety stakeholders to participate in this workshop. The intention was to assemble a cross section of practitioners, who could provide personal experience, expertise, and operational points of view regarding railroad safety. Participants (Appendix B) were sent a read-ahead package and registration information.

1.3 Workshop Objectives and Format

The objectives of this workshop were to gather practitioner (i.e., railroad, government, and technology industry) input regarding rail ROW and highway-rail grade crossing hazards related to intruder and obstacle detection requirements and constraints, to identify institutional and implementation considerations, and to develop a consensus for a high-level functional concept for such a detection system. These objectives were to be achieved through a series of sessions to (a) review the operational, technical, and regulatory issues; (b) hear the concerns, priorities, and ideas of all participants; and (c) formulate a consensus statement to guide the next steps. All discussions were conducted with no attribution in the hope that a more frank and open discussion would occur.

Two breakout sessions were convened in separate rooms concurrently. One of the indicators of the quality of the information from this workshop is the number of issues and requirements that were discussed by both groups. It is suggested that issues discussed by both groups without reference to the other group probably represent general concerns. Also, breakout sessions brought out additional operational points and technical issues. These discussion points then were consolidated in the later workshop sessions.

2. WORKSHOP PRESENTATIONS

This section summarizes workshop presentations and provides notes from each of the breakout sessions. Visual aids for several of these presentations are provided in Appendix C.

2.1 Welcoming Remarks and Introduction

The IODS Requirements Workshop was held on Thursday and Friday, June 11 and 12, 1998, in the Volpe Center's Management Information Center. Mr. Neil Meltzer of the Volpe Center's Accident Prevention Division, serving as the workshop moderator, welcomed the group of more than 30 industry and government stakeholders. Dr. Frank Tung, Deputy Director of the Volpe Center, took the podium to extend an official welcome to the Volpe Center, and to describe some of its history and its role and accomplishments in rail safety and related technology programs.

Mr. Meltzer then introduced Mr. John Hitz and Ms. Anya Carroll of the Volpe Center Accident Prevention Division to present an introduction to the workshop. The introductory presentations were intended to lay the groundwork for pursuing research and development of the IODS, and to involve the workshop participants in identifying primary functional requirements and constraints. Mr. Hitz, Chief of the Accident Prevention Division discussed program sponsorship, federal mandates for intruder and obstacle detection, and the objectives for this workshop. Ms. Carroll, Principal Investigator of the Highway-Rail Grade Crossing Safety Research Program, provided background on federal involvement in rail intruder and obstacle detection and introduced the Volpe IODS Research Team.

Before moving on to the next session, participants were asked to introduce themselves. Participants included U.S. Department of Transportation (DOT) representatives; state highway and rail representatives; and industry representatives from several railroads, railroad equipment suppliers, and research and development organizations. Mr. Meltzer previewed the handouts provided in the conference folder, summarized the agenda, and pointed out logistics considerations for the meeting. Mr. Meltzer then turned the podium over to the Volpe IODS Research Team to introduce the discussions of specific issues and straw-man concepts for intruder and obstacle detection.

2.1.1 Overview

Mr. Hitz reviewed the reasons for the workshop, its sponsorship, and the national initiatives of which this workshop was a part. Especially timely were the initiatives for 10 high-speed rail corridors in the United States, combined with current concerns over security and protection of critical transportation infrastructure.

The policy mandates for IODS development at the time of the workshop came from three directions: concerns about highway-rail grade crossing safety (especially in high-speed rail corridors); attention to ROW hazards, both intentional and environmental; and inclusion of rail as a critical resource by the President's Commission on Critical Infrastructure Protection.

Mr. Hitz pointed out the importance of starting the IODS requirements-gathering process by asking the practitioners, that is, the people who work with railroad safety, operations, and security on a daily basis for their opinions. He introduced the workshop objectives, and commented on the importance of the issues, ideas, and concerns of the workshop participants.

2.1.2 Current Status

Ms. Anya Carroll, Principal Investigator, Accident Prevention Division, provided an overview of the issues and format of the workshop. She reviewed the reasons for this workshop in terms of rail accident statistics and recent initiatives. She reviewed safety measures of European and Japanese high-speed rail projects, and described recent demonstration projects. She then introduced the rest of the technical presentation team.

The structure of the workshop included a series of technical presentations, and brainstorming and discussion sessions, with the goal of developing a practitioner concept for how IODS should work. Ms. Carroll reviewed recent accident/incident statistics related to highway-rail grade crossings and rights-of-way (ROW). Most highway-rail grade crossing incidents with a significant number of deaths involve vehicles in highway-rail grade crossings. Beyond those associated with equipment failure, ROW incidents were associated with obstructions, tampering, and vandalism; and weather or environmental causes. Several safety initiatives are in progress, including implementing the 800 telephone number used to call in hazard reports from highway-rail grade crossings. Hazard elimination, mobile barriers, and obstacle projects also were described, as were detection systems and other safeguards used by high-speed rail systems in Japan and Europe.

Previous studies of railroad ROW security were conducted by Arthur D. Little, Inc., investigating environmental hazard and intruder detection; and by the FRA investigating Maglev sensors and surveillance, occurrences of sabotage and terrorism, physical security, and obstacle detection. Recent demonstration projects include a video sensor prototype on the Empire Corridor conducted in 1995, and the Transportation Research Board (TRB) Innovations Deserving Exploratory Analysis (IDEA) Program. ITS Positive Train Control (PTC) projects include obstacle detection and train control links with Amtrak in Groton, Connecticut, and on the Long Island Rail Road. These projects show that intruder and obstacle detection is feasible and useful. They provide a foundation of experience for this workshop where more general IODS requirements will be explored.

Ms. Carroll then introduced the Volpe Center technical and support staff and consultants, who conducted and supported the workshop sessions.

2.2 Technical Sessions

The technical sessions provided the participants with a summary of current work. These sessions were intended to suggest a framework for later discussion, and to establish a common set of terms, definitions, and basic concepts. From an engineering point of view, the first step in meeting a need is to state the challenge or issue to be addressed in terms of a problem. The facilitators and presenters advised against closing on a technical solution (e.g., selecting specific technology for sensors, processors, communication, etc.) prematurely, suggesting that the IODS requirements should be stated first in terms of functional requirements. Functional requirements describe what the system will do without determining how each function might be performed. This leaves the technical solution (i.e., how the functions can best be performed) to later engineering work. This approach maintains focus on specific sensing, detection, and processing functions of a complete IODS regardless of technology.

2.2.1 Highway-Rail Grade Crossing Issues

Mr. Jonathan Luedeke reviewed intruder and obstacle detection at highway-rail grade crossings. To illustrate the problem that exists at highway-rail grade crossings, he presented photographs of recent highway-rail grade crossing accidents that might have been mitigated or avoided through the implementation of IODS. He defined the problem as the need to detect obstacles, assess the threat of these objects and make a decision about the threat, communicate this information, and implement the decision. For the scope of the problem for this workshop, it is assumed that the object is already in the highway-rail grade crossing and preventing entry is not the primary focus.

He presented questions, relative to highway-rail grade crossing obstacle detection, to initiate brainstorming and suggest discussion topics for the breakout sessions. Current operational examples of highway-rail grade crossing obstacle detection systems in Sweden and Japan were discussed and considered. In Sweden, high-speed train lines have four-quadrant gates with inductive loops buried in the track bed with a localized computer system for assessment. On their lower-speed line, Japan Rail (JR) uses inductive loops and beam interruption for detection. Detection activates a wayside signal (e.g., flashing red lamps mounted in a standard 2-lamp or 5-lamp configuration), mounted on a post trackside, approximately 50 meters from the highway-rail grade crossing. Use of this detection system has significantly reduced highway-rail grade crossing incidents.

2.2.2 Rights-of-Way Issues

Mr. David Wagner reviewed accident statistics, relating them to defining the ROW problem. The immediate task is to detect obstacles on the ROW, and trespassers who might vandalize the track, switches, or equipment. A detection system also would detect disruption of rail integrity, and would gather other data related to maintenance and/or traffic. To protect the investment in IODS, it must be designed to detect as many types of threats as possible, and must work reliably under all weather conditions. Track conditions (i.e., single/multiple rails, curve, switch, tunnel, highway-rail grade crossing, etc.) require a variety of detection equipment and signal processing.

Mr. Wagner offered examples of the precautions being used to protect current high-speed ROW. The French-built TGV (Train à Grande Vitesse) uses continuous fence along the entire ROW perimeter to deter entry of people and animals. TGV also uses vehicle safety barriers at bridge overpasses and "drop detectors" to sense vehicles or debris that might fall from a bridge onto the track. Other detection technologies that high-speed railroads have tested or demonstrated include application of radar, laser, infrared, ultrasonic, millimeter microwave, and video surveillance. The solution to protect the ROW appears to include a combination of physical barriers and intrusion detection technology.

2.2.3 Functional Concepts for Intruder/Obstacle Detection

Dr. Jeff Everson presented his paper "Functional Requirements Leading to Operational Concepts for the IODS Program" (Appendix D). His presentation included some suggested categories (i.e., functional modules) for IODS top-down system definition. Developing and refining functional concepts for IODS would serve the workshop's objectives by:

- Indicating how the system should interact with the user and the environment (e.g., inputs, outputs, operational modes and scenarios, decision points, geometry, response times, reliability, and other performance characteristics);
- Establishing a requirements framework that is consistent with current practices, institutional constraints, and future considerations; and
- Serving as a tool for surfacing and resolving conflicting viewpoints.

To start the process of developing functional concepts within IODS for the workshop, the Volpe research team originated straw-man concepts for use by participants and the breakout groups. Decision logic diagrams further described the concept for highway-rail grade crossing and ROW applications. From these basic modules, three alternative straw-man functional concepts were developed based primarily on varying levels of sensor intelligence: "dumb" sensor, "smart" sensor, and the "partial-smart" sensor. It was felt that these alternatives would help the groups identify and refine the most useful IODS concepts to address each problem area.

Dr. Everson suggested the following functional concepts:

1. ***Components of the detection and notification process:*** The subsystems of an IODS can be identified as detection, incoming communication, decision making, outgoing communication, and decision implementation.

2. ***Steps in the detection and decision process:*** The decision for appropriate action for a specific situation requires information about the threat, the location of approaching trains, and as much additional information as possible.

3. ***Highway-rail grade crossing obstacle decision process:*** For an obstacle in a highway-rail grade crossing, the system must detect whether the object is stuck or moving, whether it is likely to move off the tracks before a train approaches, and whether the object is large enough to be a threat to the train.

4. ***Rights-of-way obstacle decision process:*** Detection of and response to obstacles in rail ROW is less well defined because of the wider variety of hazards represented. Detection of the object, its size and mass, its speed and direction (if any), and duration of time on the track are important to hazard assessment (e.g., do not want to stop a train for a cardboard box or tumbleweed).

5. ***Dumb sensors:*** A "dumb" sensor simply transmits data as received. It is not designed to determine whether the data (e.g., light beam interrupt or induction loop pulse) indicates a hazard. Sensor data is collected at a central point and added to other data (e.g., other sensors, database of characteristics, etc.) to detect a threat.

6. ***Smart sensors:*** A "smart" sensor performs data filtering and logic (combination of events) within the sensor package, and generates an alarm (rather than simply transmitting raw data). A smart sensor may include multiple data acquisition devices, which feed their real-time data

into a processor. The processor is programmed to transmit an alarm when specific combinations of conditions are met.

7. ***Hybrid or partial-smart sensors:*** A "partial-smart" sensor includes some processing and discrimination function at the sensor site, and transmits a combination of raw data and alarms. The raw data will feed into a central data collection system, and might count traffic or detect other conditions, but will also, upon the predetermined combination of conditions, send an alarm signal.

The functional concepts can be used in developing the IODS operational concept. The operational concept represents the users' view of a system to be designed and is, according to established system engineering principles, a central construct in deriving and validating the requirements specification. It is a prescriptive model for the user(s) and his/her environment, system processes, and constraints.

Copies of these visual aids were provided to the breakout groups for comment and expansion. The breakout groups were asked to comment on these concepts. Specific types of comments requested were comparison of the detection process to current practice, verification that the concepts addressed current railroad concerns, and extension of these (or revised) concepts toward a set of IODS requirements.

2.3 Roundtable Discussion on Concepts and IODS Requirements

This session was intended to allow workshop participants to interact with the IODS Research Team to understand the scope of the problems and how functional concepts can address those problems. The group agreed that the mission of IODS is to protect the train from obstacles and sabotage, though they preferred to defer the analysis of sabotage. It was emphasized that IODS cannot be composed of a series of disconnected concepts, but rather must be a single unifying concept of operation that can be broken down to describe increasingly detailed functions. A concept of operation is a standard construct in systems engineering.

Ms. Anya Carroll and Mr. Neil Meltzer led this discussion. Some of the participants wanted to go directly to specific IODS issues. The first major piece of feedback was a move to reject the ROW problem. The railroads and their main regulators do not see intruders and obstacles as a major threat that can be easily averted or mitigated. Instead, they see major problems persisting at highway-rail grade crossings even where active devices have been implemented. Many participants prefer that research efforts be devoted to threats at highway-rail grade crossings, particularly public, active highway-rail grade crossings where the threat of obstacles (i.e., stopped or stalled vehicles) to the railroad, particularly high-speed railroad, is palpable, and might not have been adequately addressed by current highway-rail grade crossing devices. Furthermore, it was argued that solutions at the highway-rail grade crossing could be extrapolated to the ROW problem at a later time.

Given a consensus that the remaining time be devoted to the high-speed highway-rail grade crossing issues, Ms. Carroll facilitated a discussion to define the specific problem scope, and to clarify the functional elements to be addressed in the remaining sessions. Foremost among the concerns of the participants was definition of the operating conditions. After some debate, it was agreed that the minimum criteria to be met are:

- Train speeds greater than 50 mph,
- At least 10 trains per day, and
- The existence of an automated signal control system.
- It also was agreed that notification to stop must be given to the train at least one minute prior to stopping.

Participants made specific points related to the following topic areas:

1. ***Hazard and threat identification:***

   The focus is on the threat to the train, passengers, and crew. Other systems (e.g., signs, fences, and public education programs) warn trespassers of the train. The initial focus is on high-speed rail trains, but it applies to other rail service as well. Spillover benefits then address other areas.

   A spin-off benefit will be the ability to detect trespassers. Detecting all foot traffic across the ROW can establish patterns, so that the behavior of vandals can be highlighted and scarce police resources can be applied where most needed. A statistic is needed for the number of railroad employees injured annually because of trespassers. Statistics also are needed on stress to employees because of trespassers, prowlers, and vandals on railroad property. It was agreed that there are many incidents when crewmembers and clerks are accosted and beaten up.

   A few definitions: An "intruder" is a trespasser on railroad property or ROW. A "threat" is hazard, placed in a position to do harm (risk), in a combination of conditions that will cause loss of life or property (circumstance).[2]

2. ***Minimum and desired detection thresholds:***

   A suggested threshold for considering IODS is 50 to 80 to 110 mph (varied during discussion) on a track with 10 to 30 trains (passenger and/or freight) per day. Urban track requires a different set of sensors for different problems than does open, rural ROW. This combination of criterion will address 80 to 85 percent of problem areas.

   There are three approaches to IODS alarms that detect an object in a highway-rail grade crossing. Should activation of the detection system stop an oncoming train automatically, or should the engineer/operator receive the data and make the decision, or should a control center dispatcher make the decision and issue a control signal?

   Perception of "smart" versus "dumb" sensors generated discussion. How the sensor uses the information: For a passive or "dumb" sensor, the device gives sensor data only. For an active

[2] Private, low-use highway-rail grade crossings can be controlled by a gate on each side with an electronic lock, controlled by the dispatcher. The user calls in, and the dispatcher arranges a time when the train is not approaching. The user reports clear of highway-rail grade crossing, and the dispatcher re-locks the gate. Assumes the user is on the track until reported clear. Use flagman when appropriate.

or "smart" sensor, the sensor filters the input based on programmed rules and/or other data, and gives different signals depending on the situation. "Dumb" sensor means no filtering of data (e.g., induction loop); a "dumb" indicator activates a "smart" system.

Highway-rail grade crossings with multiple tracks require IODS with special logic and safeguards.

3. ***Sensor operating conditions:***

   Video/photo enforcement has policy and legal issues, and varies by state. State vehicle codes need updating. Obligations of drivers at highway-rail grade crossings are not consistent across states. The state legislators need a model law for photo enforcement that states can adopt.

   Some technologies work for specific environments. For example, a closed-circuit television (CCTV) video surveillance system transmitting images of the upcoming highway-rail grade crossing in "dark territory" is about the only technology that can show what is ahead in ROW with poor visibility or severe curvature of the track.

4. ***Rights-of-way, track, and facility environment types:***

   Is it practical to do anything at a 125 mph highway-rail grade crossing other than grade separation? FRA guidelines state that highway-rail grade crossings above 110 mph must have a positive closure to prevent cars from bypassing gates.

5. ***Performance, system response times:***

   There are several issues relating to highway-rail grade crossing barriers and how soon one should be activated as a train approaches. The specific number of seconds depends upon the time/distance required to stop a given train. Variables include type of train control system, passenger versus freight trains, and safe braking distance, with and without signals. How far back (i.e., distance from train to highway-rail grade crossing) should the system detect an obstruction? What if the obstruction clears the track before the train gets there?

6. ***Data analysis and response requirements:***

   IODS equipment could operate in two scenarios: controlled system (alert or high-traffic status) and automated system (routine status).

7. ***Alarms and signals to be generated:***

   Most railroads have installed highway advisory signs at highway-rail grade crossings with 800 telephone numbers (or 911) to report problems to the rail dispatcher. This measure assumes drivers have cellular phones. Call boxes at highway-rail grade crossings are possible, but few are now installed. 800 telephone numbers are good for stuck/stalled vehicles and equipment malfunctions, but not fast enough if a train is coming. The effectiveness of the sign/number program should be measured. No nationwide standard exists for where the data go, or responsibility for responding. To use the call-in system, the driver must have a DOT grade crossing number and the correct 800 telephone number.

8. *General IODS requirements and issues:*

Ninety-five percent of fatalities occur on main lines, 95 percent of crashes are at highway-rail grade crossings, and 99 percent of damage is done to a struck vehicle, not to the train. Liability is a large cost issue. Operation Lifesaver addresses highway-rail grade crossings and driver education. The highway-rail grade crossing problem is a priority over the ROW problem. After closing some highway-rail grade crossings and building grade separations for others, there are still approximately 2,000 highway-rail grade crossings remaining at 10 high speed corridors. IODS equipment is needed at about 1,500 highway-rail grade crossings on these corridors alone.

Private highway-rail grade crossings are not instrumented.

Any system must be economically feasible and not overly prescriptive. The decision to implement IODS instead of other measures will depend upon factors such as cost, dependability, freedom from disruption, and system benefits. Cost decision points: Less cost than a separated highway-rail grade crossing for that site? Less than an accident?

A video system installed at highway-rail grade crossings must be more than an image transmitter. A smart system with video and data recording is needed because of "Monday morning quarterbacking" and liability. Focusing on liability-driven requirements is needed. Gather data that provide evidence of due diligence. Such a video capture system would be like a wayside black box. A business issue for the railroads is how to add instrumentation and protect the train without taking more responsibility and increasing unnecessary liability.

TGV is entirely fenced; emphasis is on preventing access to ROW. Also causes maintenance access problems. The ROW has safety barriers. Bridges and overpasses have drop detectors. The purpose of the detection system is to detect gross breach of ROW integrity.

A highway-rail grade crossing protection system consists of signals and controls, barriers and warnings, interface from controls to communication system, and obstruction detection.

ROW and highway-rail grade crossing IODS require a global system for the entire corridor, not just highway-rail grade crossing-specific warning devices.

Slide fences, dragnets, and similar devices may be a $50 solution to a 5-cent problem; and other systems and programs (e.g., Operation Lifesaver) address warning the driver of the train. High-speed rail shifts the consequences and scale of a crash dramatically. It is necessary to concentrate on protecting the train from the driver and intruder, especially for high-speed rail. Highway-rail grade crossing issues include driver behavior, preemption, and ROW. IODS should be part of highway-rail grade crossing design. Signals and gates should be configured with attention to avoiding lockout.

U.S. railroad standards cannot be compared to European standards because European railroads have national funding; drivers have different attitudes about highway-rail grade crossings; there are fewer lawyers and a different liability structure. When to build elevated/buried highway-rail grade crossings? Sometimes, they cannot be built because of environmental or space limits. Then, mitigation measures are the only choice.

Railroads will only install equipment with good cost/benefit ratio. Railroads have a lot of equipment and do not need help selecting equipment. They do need help with the complex issues, and with the low-frequency situations that cause catastrophes.

National standards should incorporate all available, proven technologies. For each function, create menus of products that meet the standard, then let states and railroads choose equipment that fits a particular highway-rail grade crossing's requirements. Specify standards and interfaces.

2.4 Breakout Sessions

The original intent of the breakout sessions was to give the participants the opportunity to choose between developing a ROW concept or a highway-rail grade crossing concept, depending upon their particular concern. Based on the consensus to eliminate the discussion of ROW issues from this workshop, both groups instead focused their attention on the problems of highway-rail grade crossings. Participants representing the various stakeholder types were divided equally between the two groups. Assignment was made randomly, and then adjusted so that each group included representation from each type of stakeholder.

Mr. Dave Daley and Ms. Donna Woodford of the Volpe Center served as session facilitators for the breakout sessions. Each session drafted a spokesperson. Under the guidance of the facilitator, each group was asked to establish the functional requirements and constraints for an IODS. A spokesperson was designated to summarize the group sessions and present a brief synopsis to the rest of the workshop participants. Worksheets were distributed to provide direction and focus to the discussion and to facilitate note taking.

Using the requirements categories and suggested functional scope from the previous sessions, each group attempted to reach a general agreement on basic scope and functions. Initial discussion in both groups focused on establishing what are the major threats to the safety and operation of the train and, thus, what the system should detect. They then considered who should be the ultimate decision maker for the system and what information about the obstruction they need to make this determination. They explored the "dumb," "smart," and "partial-smart" system straw-man concepts in an effort to more clearly define a system concept. Subsequently, the communication and implementation of the decision to the train or appropriate authorities was examined.

Session A examined threats in terms of costs: derailments, fatalities, injuries, hazardous materials spills, liability, disruption of schedules, etc. These cost risks can be addressed by using sensors that provide basic information such as size, length, and weight to dispatchers, engineers, software, and exit gates. A fail-safe sensor system can be costly, but ensuring equipment vitality reduces the risk of false alarms and false negatives. In addition, the system must facilitate communication with the train using simple, standard controls (stop/slow/proceed). Session A also addressed general system requirements and noted that most of the equipment needed to build the IODS has already been built and are available. They noted that successful implementation of the system requires a commitment from the rail industry.

Similarly, Session B begins by identifying and addressing threats. The most frequent threat to a train is a vehicle in a highway-rail grade crossing, but smaller objects also can cause catastrophes; therefore, image recognition is the most desirable detection method. Sensor operating conditions are outlined and requirements for nationwide standards and legal and policy issues are addressed. The FRA must also examine the current code of Federal regulations to permit the use of new imaging technology and recommend responses to meet IODS needs.

Discussion points for Sessions A and B are presented in greater detail in Appendix E.

2.5 Reports by Breakout Groups

After two sessions of discussion within each breakout group, the representative of each group was asked to present their conclusions. These presentations are summarized below.

2.5.1 Session A Report

In an attempt to establish a detection threshold for the system, Group A proposed a system that would detect only objects that weigh more than 500 lb. and have wheels. This limits detection to cars, trucks, and some motorcycles. People, bicycles, and smaller objects would not be detected. This sensor system then would provide signal output to a microprocessor for assessment. The microprocessor would filter the output to determine the status of the obstruction. The system would assess a vehicle to be stalled upon meeting some obstruction duration criteria, determined at a later date. This would enable discrimination between continuous traffic flow and a highway-rail grade crossing obstruction. The microprocessor then would communicate a "Go" or "No Go" output through current cab signals to the train engineer. When a train is not approaching, the signal is sent to a dispatcher.

As a system requirement, all equipment must be highly reliable and vital. A large probability of detection as well as a low probability of false alarms establishes reliability in their evaluation. The group defined a "vital" system as a system that fails in the safe direction (i.e., sensor system failure results in obstruction signaling to the train).

2.5.2 Session B Report

Upon exhausting the possibilities of grade separation and closure, this group felt that only a small subset of the remaining highway-rail grade crossings might necessitate IODS. For these highway-rail grade crossings, they would require that the detection system detect anything on the highway-rail grade crossing that could disrupt the service of the train or cause loss of life. Examples of detection targets include a vehicle filled with hazardous materials, a pedestrian, or any number of other dangerous hazards. Even the presence of a railroad tie across the track would need to be detected as they have been known to cause derailment of trains. The system should incorporate some sensor redundancy, such as use of magnetic loop detector, which would trigger a video imaging system. Such a system would require information about distance to nearest train and train speed to determine the communication outlet and decision maker. If a train were on the approach and within braking distance, signaling would go directly to the train, but not require the engineer to be the decision maker. If no train were in the vicinity, the nearest dispatcher would be signaled. As the hazards of the ROW are similar to those at the grade highway-rail grade crossing, an IODS meeting the above requirements also might be applicable to detection on the ROW.

2.6 Workshop Summary Discussion

Participants' comments at the wrap-up session included the following:

Because of the increased risk of high-speed rail, the focus of IODS should be on protection of the train, crew, and passengers. Other programs such as Operation Lifesaver address keeping vehicles and pedestrians off the track.

Prevention of all incursions and trespassing is not likely, so detection and threat determination will be an ongoing objective. IODS must detect vehicles, other objects, and people who end up on the track despite warning and preventive measures. It should then communicate the hazard, and support quick and appropriate decisions and actions. In addition to the potential damage to the train, the other significant threat is disruption of schedule. Although collision with a pedestrian would pose little threat to the safety of the train, crew, and passengers, it would disrupt train service and present train liability concerns.

At this point, the industry's primary concern is with highway-rail grade crossing safety versus ROW safety. Most workshop participants agreed that intruders and obstacles in ROW exist, but they did not feel they were a threat that could be easily avoided or alleviated at this time. Ideally, the system design could be applicable to both cases.

For high-speed rail corridors, there can be no passive highway-rail grade crossings. First, as many highway-rail grade crossings as possible should be converted to grade separations or should be closed. When highway-rail grade crossings are unavoidable, each must be protected and instrumented.

Each highway-rail grade crossing is different because of highway-rail grade crossing geometry, traffic volume, number of trains per day, number of tracks, pedestrians, and types of vehicles and other hazards. The preferred resolution is comprised of heuristics, engineering guidelines, and interface standards. A designer should be guided through a directory of specific technology that can be adapted for standard train-cab electronics and applied to meet the highway-rail grade crossing's specific detection and safety needs. A single specification for all highway-rail grade crossings would be wasteful and ineffective.

The requirements of accurate detection, timely communication, and reliability are a much higher priority than is a specific system architecture. However, from this discussion it appears that the most desirable system uses multiple sensor technologies, filters and interprets the sensor data locally (near the sensors), then communicates decision support information to a central control point.

Detection should not be limited to the time just before the train approaches. At that point, it might be too late to stop the train. Early detection of a stalled vehicle or debris on the track can generate other responses (e.g., maintenance, police, fire, or utilities) or prompt the slowing or rerouting of trains before the train enters the approach.

Interpretation of data and the decision to take action (i.e., stop the train, dispatch a maintenance crew, or call local police) must be made at a central control point such as a dispatcher or railroad police, not in the train cab. The train operator should receive explicit instructions (slow/stop/proceed) through the current signal control system (wayside and cab signaling). The one addition in the train cab might be an alarm, indicating the need for an immediate stop. Video screens and data indicators in the train cab will not produce the desired result, and might be a dangerous distraction to the train engineer.

The detection, signal processing, and communication equipment used in any IODS should comply with a national standard for electronic and signal interface. The subsystems must be defined to provide for standard, vendor-independent modules. The data (as gathered, processed, and communicated) must meet a standard (to be defined) for signal characteristics, data format, and data element definition. Such a modular, standard system can be upgraded over time as additional technology becomes available. Standard components will be generally available and cost less, making IODS feasible and meeting a higher set of requirements. In addition to technology, an IODS must include a validated set of operating procedures, good connection to current procedures and training, working agreements with all local police and fire organizations, and effective use of the gathered data.

Cost is another significant constraint. While adequate instrumentation at a highway-rail grade crossing should never cost more than building a grade separation, the cost of the entire system must not drive up the cost of railroad operation to make passenger rail less attractive.

An IODS must be highly reliable (a "vital" system)—no false alarms, always indicate when a problem exists, and self-monitoring for errors and subsystem failures. Each system must operate in all weather and through power failures. Surviving elements or subsystems should continue to operate when specific elements fail or are vandalized.

Additional, local storage of a highway-rail grade crossing's data for a limited time (hours, days) can provide a low-cost "black box" function, available for retrieval after a crash to document the conditions leading up to the event. Selected data (e.g., traffic rates, times, or problem situations that did not result in a crash) can be forwarded for statistical analysis. With little additional cost, IODS data has additional applications for maintenance and planning. While the initial focus of IODS is toward high-speed rail corridors, the technology can be applied to other rail lines, passenger and freight, as needed.

2.7 Future Considerations—IODS Functional Criteria

The 1998 requirements workshop reviewed basic issues and current work, and facilitated discussion on IODS feasibility and integration. Sessions focused on principles and constraints for IODS and ROW to meet the near-term needs of high-speed rail corridors.

The intent of the IODS program is to extend the ITS architecture to a set of modular specifications, by which sensors, local concentrators, communications, data analysis tools, and dispatcher displays and annunciators can be built by various vendors and integrated as needed to meet each railroad's and each site's security information needs. The highly modular, vendor-independent components would permit field service, replacement, and upgrade without disrupting the rest of the system.

From this overall concept, the next step is to develop a requirements framework that is consistent with current practices, institutional constraints, and future considerations. From the comments provided by workshop participants, a railroad's IODS operations would include the following general functional categories:

- **Sensing** subsystems using a wide range of technologies, deployed primarily at highway-rail grade crossings to detect changes that might indicate the presence of a hazard.

- **Assessment** subsystems to compare the signals from the sensors to the patterns for known hazards, normal traffic, and error conditions. Assessment processing integrates the signals from several sensors and applies logic/rules and data patterns to improve reliability and to reduce the number of false alarms.

- **Messaging/Reporting** selects the appropriate signals, displays, and messages to represent the detected condition. This segment will include intuitive and rapid interfaces to implement decisions, through current train control and emergency communication channels.

- **Event Capture** collects selected sensor data, messages, user actions, and other data. The collected data then can be used for event reconstruction, traffic and hazard analysis, and for other purposes such as maintenance monitoring.

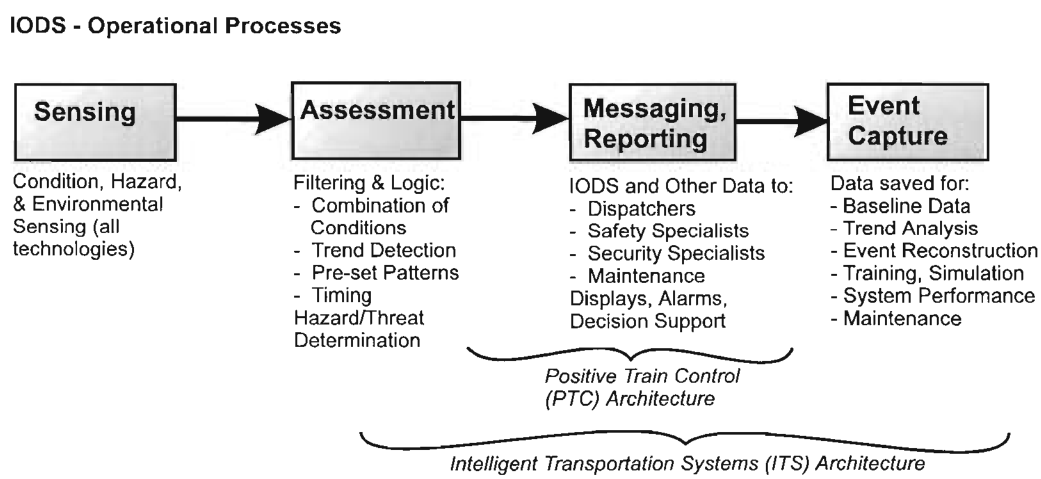

Figure 1. IODS Data Flow

Appendix A. Agenda for IODS Requirements Workshop

Agenda for IODS Requirements Workshop, June 11-12, 1998 Volpe Center Management Information Center	
Thursday, June 11, 1998	
Welcoming Remarks and Introduction **Dr. Frank F. Tung** – *Deputy Director, Volpe Center* **Mr. John Hitz** – *Chief, Accident Prevention Division, Volpe Center* **Ms. Anya Carroll** – *Principal Investigator, Volpe Center* *Highway-Rail Grade Crossing Safety Research Program*	9:00 – 9:30
Railroad Intruder/Obstacle Detection – Problem Discussion	
• Highway-Rail Grade Crossing Issues **Mr. Jon Luedeke** – *(Battelle)*	9:30 – 10:15
Break	10:15 – 10:30
• Rights-of-Way Issues **Mr. Dave Wagner** – *(Battelle)*	10:30 – 11:15
Introducing Functional Concepts for Intruder/Obstacle Detection **Dr. Jeff Everson** – *(Battelle)*	
• Highway-Rail Grade Crossing Concept **Dr. Jeff Everson, Mr. Jon Luedeke** – *(Battelle)*	11:15 – 12:00
Lunch (on your own)	12:00 – 1:00
• Rights-of-Way Concept **Dr. Jeff Everson, Mr. Dave Wagner** – *(Battelle)*	1:00 – 1:30
Roundtable Discussion on Concepts and IODS Requirements **Ms. Anya Carroll, Mr. Neil Meltzer** – *(Volpe Center)*	1:30 – 2:30
Instructions for Breakout Sessions **Facilitators: Mr. Dave Daley, Ms. Donna Woodford** – *(Volpe Center)*	2:30 – 2:45
Break	2:45 - 3:00
Breakout Sessions on Separate Concepts **Facilitators: Mr. Dave Daley, Ms. Donna Woodford** – *(Volpe Center)*	3:00 – 4:45
Wrap-up **Moderator: Mr. Neil Meltzer** – *(Volpe Center)*	4:45 – 5:15
Friday, June 12, 1998	
Review Group Progress on Concepts **Moderator: Mr. Neil Meltzer** – *(Volpe Center)*	8:00 – 8:30
Conclude Breakout Group Sessions **Facilitators: Mr. Dave Daley, Ms. Donna Woodford** – *(Volpe Center)*	8:30 – 10:00
Break	10:00 – 10:15
Informal Reports by Breakout Groups **Breakout Groups**	10:15 – 11:30
Workshop Review and Follow-up **Group**	11:30 – 12:00

Appendix B. List of Workshop Participants

Name	Organization	Address	Phone
Forrest Ballinger	Harmon Industries Senior Signal Specialist	PO Box 600 Grain Valley, MO 64029	800-990-6245
Beth Boardman	EOTC Deputy Director of Policy & Property	10 Park Plaza, Rm. 3170 Boston, MA 02116	617-973-7013
Anne Brewer	Florida DOT Administrator, Rail Operations	605 Suwannee Street Tallahassee, FL	850-414-4541
Bill Browder	Association of America Railroads Director of Operations	50 F Street, NW Washington, DC 20001	202-639-2474
Vince Burget	Rail Progress Institute Chairman of RPI Committee on Grade Crossing Safety		
Rick Cantwell	Conrail Assistant Chief Engineer	2001 Market Street Philadelphia, PA 19101	215-209-2927
John Carpenter	Camber Corporation Chief, Information Management Section, IISS Contract	114 Hanscom Avenue Reading, MA 01867	781-944-6216
Anya Carroll	US DOT Volpe Center Principal Investigator, Accident Prevention Division	55 Broadway Cambridge, MA 02142	617-494-3122
Mike Coltman	US DOT Volpe Center	55 Broadway Cambridge, MA 02142	617-494-2591
Joe Denny	General Railway Signal Engineering Manager	150 Sawgrass Drive Rochester, NY 14620	716-783-2064
Bill Dufer	Union Switch & Signal	1000 Technology Drive Pittsburgh, PA 15219	412-688-2008
Jeff Everson	Battelle Memorial Institute	505 King Avenue Columbus, OH 43201	
Pamela Foggin	Federal Railroad Administration Highway-Rail Crossing & Trespassing Prevention	1120 Vermont Avenue, NW, Stop-25 Washington, DC 20590	202-493-6291

Jeff Gordon	US DOT Volpe Center	55 Broadway Cambridge, MA 02142	617-494-2303
William Gordon	Federal Transit Administration	55 Broadway Cambridge, MA 02142	617-494-3514
John Hitz	US DOT Volpe Center Chief, Accident Prevention Division	55 Broadway Cambridge, MA 02142	617-494-2400
Haji Jameel	CA Public Utilities Commission	505 Van Ness Avenue San Francisco, CA 94102	415-703-2701
Norman Knable	Volpe Center Engineer Emeritus	243 Mason Terrace Brookline, MA 02146	617-731-2096
Kannan Krishnaswami	Aspen Systems Optical Engineer	184 Cedar Hill Street Marlborough, MA 01752	508-481-5058
Jon Luedeke	Battelle Memorial Institute	505 King Avenue Columbus, OH 43201	
Richard McDonough	NYS DOT 305-7A	1220 Washington Avenue Albany, NY 12232	518-457-1046
Neil Meltzer	US DOT Volpe Center	55 Broadway Cambridge, MA 02142	617-494-2594
Lorraine Pacocha	MBTA Senior Project Coordinator	10 Park Plaza Boston, MA 02116	617-222-1668
Martin Paget	Safetran Systems Manager Product Development	10655 7th Street Rancho Cucamonga, CA 91730	909-987-4673
Craig Reiley	Oregon DOT Rail Crossing Safety Manager	55 13th Street, NE Salem, OR 97310	503-986-4273
Cliff Shoemaker	Union Pacific Railroad Director of Industry & Public Projects	1416 Dodge Street, Rm. 1000 Omaha, NB 68179	402-271-4357

James Smailes	Federal Railroad Administration General Engineer	1120 Vermont Avenue, NW (MS-20) Washington, DC 20590	202-493-6360
Robert Smith	Amtrak Police for NE Corridor	2 Frontage Road Boston, MA 02118	617-345-7802
James Sottile	Federal Railroad Administration, Region 1	55 Broadway Cambridge, MA 02142	617-494-2215
Stephen Szegedy	Connecticut DOT Office of Rail	2800 Berlin Turnpike Newington, CT 06131	860-594-2897
David Wagner	Battelle Memorial Institute	505 King Avenue Columbus, OH 43201	
Bill Watson	Amtrak Field Engineer	100 Gaspee Street Providence, RI 02903	617-345-7518

Appendix C. Visual Aids from Workshop Presentations

Presentation by Chief, Accident Prevention Division, Volpe Center

Mr. John Hitz, Chief of the Accident Prevention Division (DTS-73) reviewed the reasons for the workshop, its sponsorship, and the national initiatives of which this workshop is part. Especially timely are the initiatives for potentially five high-speed rail corridors in the United States, combined with the current concern over security and protection of critical transportation infrastructure.

Mr. Hitz pointed out the importance of starting the Intruder and Obstacle Detection System (IODS) requirements-gathering process by asking the "practitioners," the people who work with railroad safety, operations, and security on a daily basis. He introduced the workshop objectives, and commented on the importance of the issues, ideas, and concerns that will be contributed by the workshop participants.

Intruder/Obstacle Detection System (IODS)
Requirements Workshop

- *Sponsored by*
  - FRA Office of Research and Development,
    Steven R. Ditmeyer, RDV-30
  - High Speed Rail Program,
    Claire L. Orth

Mandates for IODS Development

- Grade Crossing Safety
  - General Applications, e.g. stuck truck
  - High Speed Rail Corridors, (obstacle detection)
- Right-of-Way Safety
  - Obstructions (debris)
  - Intruders (vandals, trespassers)
  - Environmental Calamities (avalanche)
- President's Commission on Critical Infrastructure Protection

Workshop Objectives

- Gather practitioner input on IODS requirements and constraints
- Identify institutional and implementation considerations
- Develop consensus on IODS functional concepts

Presentation by Principal Investigator, Accident Prevention Division, Volpe Center

Ms. Anya Carroll, Principal Investigator, Accident Prevention Division, Volpe Center

IODS Requirements Workshop

INTRODUCTION

Anya A. Carroll, Principal Investigator
Highway-Rail Crossing Safety Research
US DOT/RSPA/Volpe Center

FRAMEWORK of WORKSHOP

- Presentations
- Brainstorming
- Review Volpe Battelle Concepts
- Develop Practitioner Concept

Highway-Railroad Grade Crossing Accident Statistics Summary – 1996

- Vehicle-related incidents at public crossings:
  - 313 cases involved "stalled on crossing,"
  - 683 "stopped on crossing",
  - 2,616 "moving over the crossing."
- Of 3,788 accidents/incidents at public crossings:
  - 60% involved automobiles
  - 25% involved trucks, and
  - 9.5% involved tractor-trailers
- These accidents accounted for approximately 83% of all fatalities and 95% of all injuries.

Rail Equipment Accident Incident Reports (Jan 1996 – Sep 1997)

- Out of 5,377 Total Rail Equipment Accident Incident Reports:
  - 148 were attributed to obstructions on ROWs
  - 116 derailments were attributed to tampering with safety devices, vandalism, and other miscellaneous causes.
  - 70 derailments were attributed to extreme environment causes such as washouts and other damage to the ROW.

Recent History

- DOT Action Plan and Swift Rail Development Act, 1994
  - Call for FRA to conduct pilot programs on the 1-800 call-in system at grade crossings
- Grade Crossing Research Needs Workshop, 1995
  - CIP #7 - Intelligent Highway-rail Intersection
  - CIP #18 - Video Monitoring/Detection System

High Speed Rail (HSR) Crossing Safety Initiatives

- Intermodal Surface Transportation Efficiency Act of 1991
  - Funding for Technology Demonstrations, Crossing Improvements and Closures
- Hazard Elimination - ISTEA, Section 1010
  - Dragnet System - Illinois
- Friendly Mobile Barrier System - Prototype
- Volpe/Battelle Obstacle Detection System Survey Report (In progress)

Japan Railway (JR) East Experience MIT Study

- Between 1987 and 1993 JR East experienced 927 crossing accidents
- Average accident rate dropped from 0.43 to 0.12 per million trains following the installation of detectors at the crossings

Railroad Right-of-Way Security

- Arthur D. Little (ADL), Inc. Study - ROW, 1990
  - Rock Slide Detector Fencing
  - High Wind Detector
  - Transit System Intrusion Barriers
- MAGLEV Initiative, 1992
  - Multiple Sensor/surveillance
- Occurrences of Sabotage/Terrorism, 1995
- FRA (In progress) Technology Survey, 1996
- FRA Small Business Innovative Research (SBIR)
  - Aspen Systems, Inc - ROW Obstacle Detection

Recent Demonstration Projects

- RTL Turboliner - Empire Corridor, 1995
  - Cameras Mounted at Crossings
  - Transmit back to Train Operator
  - ~ Four Mile successful transmission of video data
- Transportation Research Board(TRB), Innovations Deserving Exploratory Analysis (IDEA) Program
  - Monitoring Crossings - Nestor, Inc

Recent ITS/PTC Projects

- Long Island RR, FHWA
  - Field Demonstration
  - Intermodal Control System
  - Intelligent Grade Crossing System
- School St Crossing, Groton, CT
  - Four-quad with obstacle detection
  - PTC initiative
  - Video Monitoring of Driver Behavior at Crossing

INTRODUCTIONS

- Volpe Staff
- Battelle Memorial Institute Staff
- Camber IISS Staff

Technical Session 1: Highway-Rail Grade Crossing Issues

Mr. Jonathan F. Luedeke, Battelle Memorial Institute

IODS Grade Crossing Issues

IODS Requirements Workshop
Volpe Center
June 11 - 12, 1998

Jonathan F. Luedeke

BATTELLE

IODS Grade Crossing Topics

- What is the problem?
- What are the issues?
- What is the solution?

BATTELLE

Problem Definition/Scope

- Detect obstacles
- Assess threat and make decision
- Communicate information
- Implement decision
- Assume object already in crossing

BATTELLE

Typical Obstacles

- Automobiles
- Trucks/tractor-trailers
- Buses/vans
- Bicycles/pedestrians
- Other objects

BATTELLE

Reasons for Obstacle Presence

- Stalled
- Stuck
- Blocked
- Stopped
- Moving through

BATTELLE

Accident Statistics

- In 1996, 488 killed and 1,610 injured in 4,257 accidents/incidents
- Motor vehicles at public crossings:
  - 75% involved "motor vehicle struck by train"
    - 327 killed and 1,048 injured
  - 313 "stalled," 683 "stopped," 2,616 "moving over crossing"
  - Vehicles involved--automobiles (60%), trucks (25%) and tractor-trailers (9.5%)
  - Account for 83% of all fatalities and 95% of all injuries

BATTELLE

Operational Considerations

- What needs to be/can be detected?
- What information is needed?
- Who needs to know?
- When do they need to know?
- Where is information needed?
- How is it communicated?
- Who/what makes the decision?
- What is the decision?
- How is it implemented?

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Decision Process and Issues

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FRA Action Plan

- Public crossings, 110 - 125 mph
  - Fail-safe vehicle detection between barriers
  - Notify approaching trains
  - Train to stop without emergency brake
- Private crossings, 110 - 125 mph
  - Fail-safe vehicle detection or video monitor
  - Direct link telephone to RR dispatcher

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Operational Examples

- Sweden - high-speed train
  - Inductive loops in trackbed between barriers
  - Local computer system
  - Interlocked with barriers
  - Train braking enforced
- Japan - lower train speeds
  - Inductive loops and beam interruption
  - Special signals for train operator
  - Motorist "Emergency Buttons"

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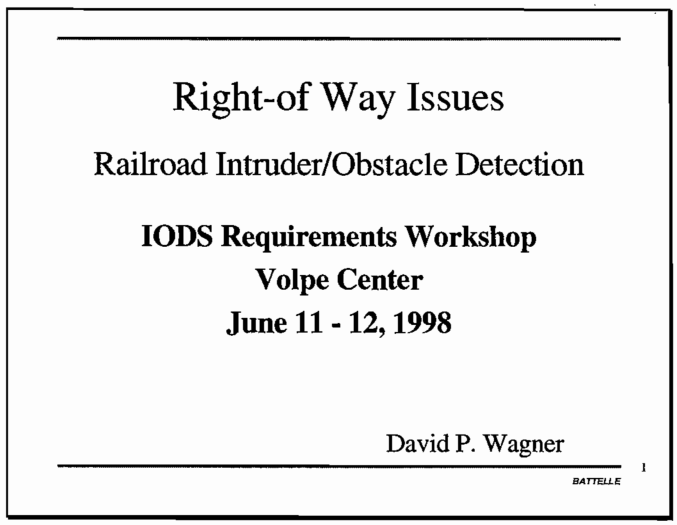
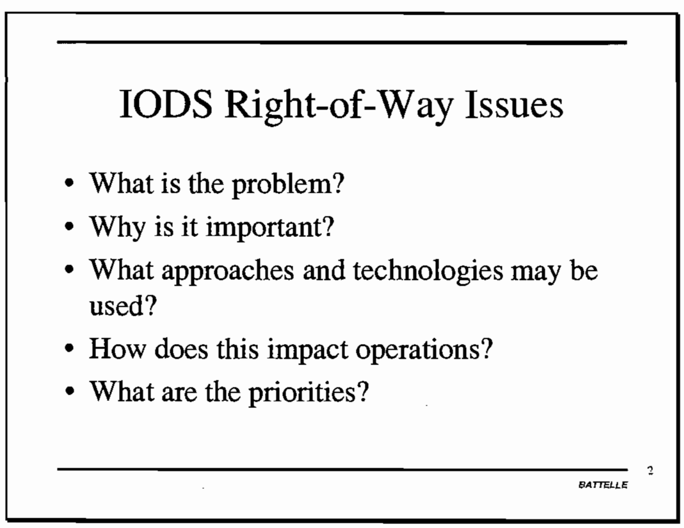
Technical Session 2: Rights-of-Way Issues

Mr. David P. Wagner, Battelle Memorial Institute





IODS ROW Problem

- Defined principally as
  - (1) visible obstructions along the ROW
  - (2) intruders/trespassers with the potential or intent to do damage to the ROW.
- Ancillary definition (but not a principal focus) is
  - (3) a catastrophic disruption of ROW integrity (e.g., missing sections of rail).

3

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Obstruction/Vandalism Accidents

Accident Cause	1995	1996
Total Accidents	2,619	2,584
Snow, ice mud, gravel on track	7	27
Object/equipment (vehicle)	7	10
Object/equipment (debris/other)	19	21
Vandals, on-track equipment	14	17
Vandals, track	44	36

Source: 1995 &1996 USDOT/FRA Accident Incident Bulletins, Table 23.

4

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Types of ROW Obstructions

- Construction/maintenance equipment
- Fallen trees
- Abandoned vehicles
- Rockslides, mudslides
- General debris

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What is being done now?

- TGV
  - continuous fencing
  - vehicle safety barriers on bridges over TGV
  - road vehicle drop detectors
- Literature references include radar, laser, infrared, ultrasonic, and video surveillance, and a remote-controlled vehicle with image processing technology.

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What Problems need to be Addressed?

- Obstructions?
- Vandals?
- Saboteurs?
- Trespassers?
- Gross breach of ROW integrity?

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Operational Considerations?

- What can be done?
- Who needs to know?
- When do they need to know?
- Where is IODS needed or most valuable?
- How should this be accomplished?

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Are ROW Characteristics Important?

- Bridges, trestles, tunnels?
- Terrain?
- Track curvature?
- Grade?
- Track appliances?
- Proximity to populated areas?

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Functional Concepts for Intruder/Obstacle Detection

Dr. Jeff Everson, Battelle Memorial Institute

Copies of these visual aids were provided to the breakout groups, for comment and expansion.

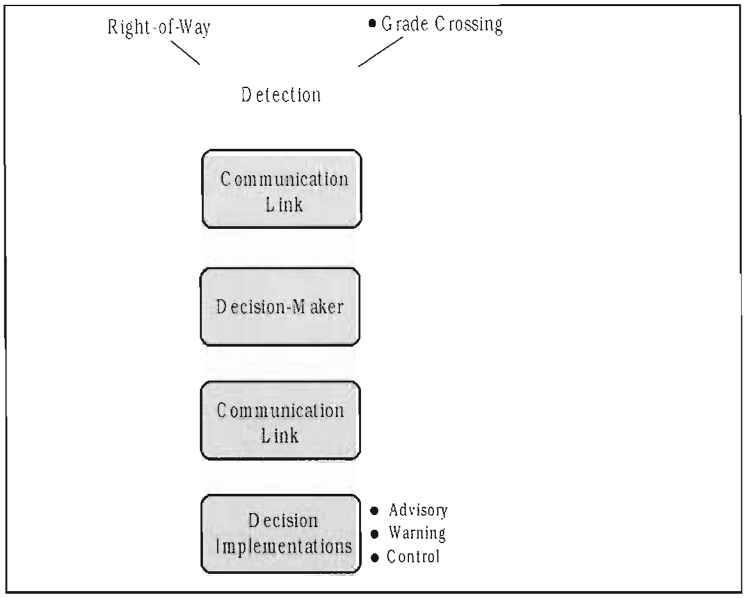

Figure C1. IODS Basic Architecture

Components of the detection and notification process: The subsystems of an IODS can be identified as detection, incoming communication, decision making, outgoing communication, and decision implementation.

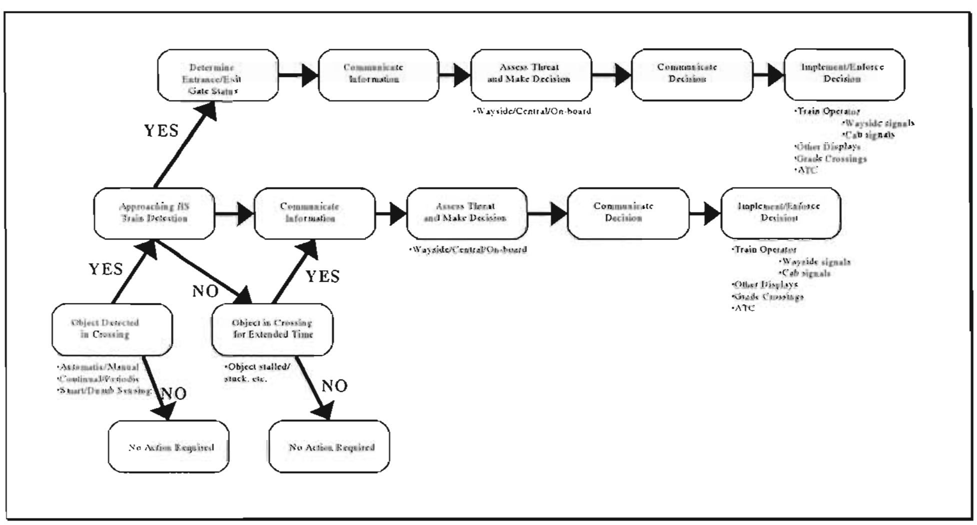

Figure C2. Decision Tree Logic for Implementing IODS

Steps in the detection and decision process: The decision for appropriate action for a specific situation requires information about the threat, the location of approaching trains, and as much additional information as possible.

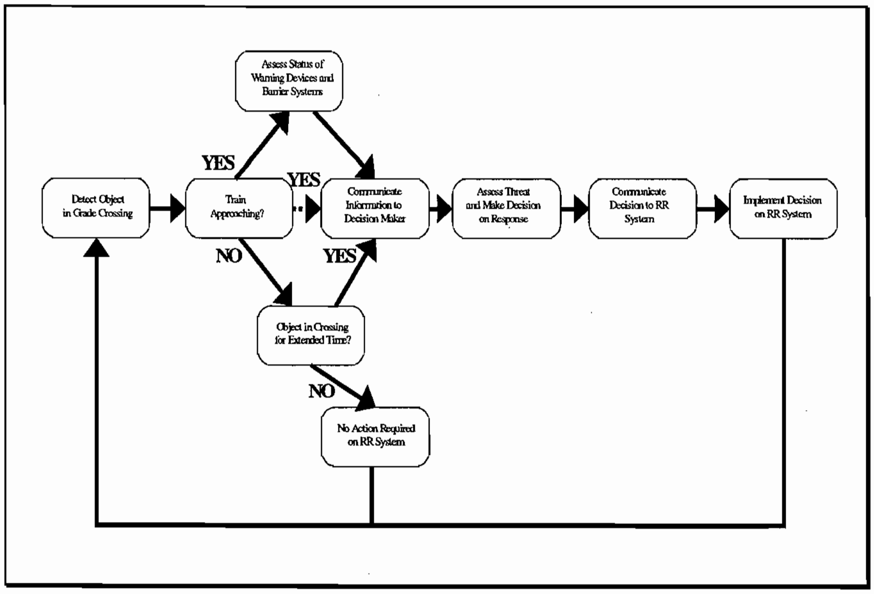

Figure C3. Decision Tree Logic for Grade Crossing

Highway-rail grade crossing obstacle decision process: For an obstacle in a highway-rail grade crossing, the system must detect whether the object is stuck or moving, whether it is likely to move off the tracks before a train approaches, and whether the object is large enough to be a threat to the train.

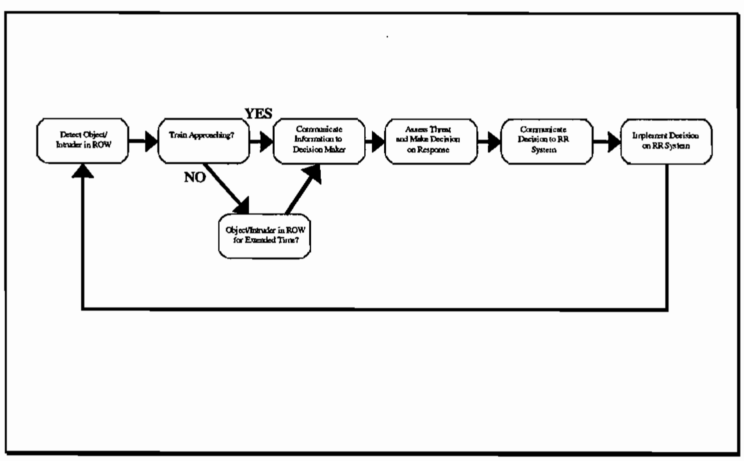

Figure C4. Decision Tree for ROW Aspects of IODS

Rights-of-way obstacle decision process: Detection of and response to obstacles in rail rights-of-way (ROW) is less well defined due to the wider variety of hazards represented. Detection of the object, its size and mass, its speed and direction (if any), and duration of time on the track are important to hazard assessment (e.g., do not want to stop a train for a cardboard box or tumbleweed).

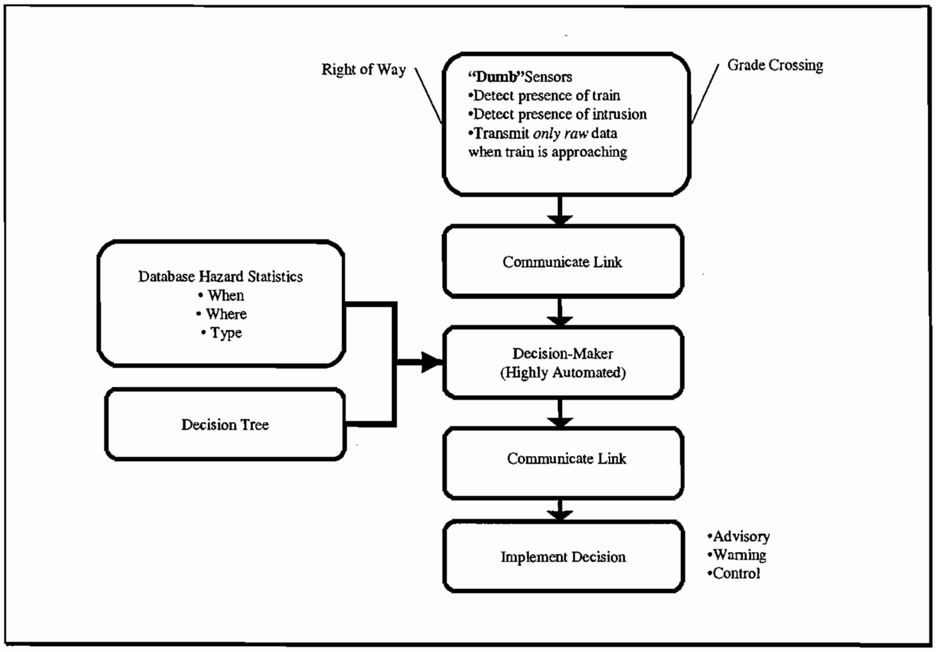

Figure C5. Possible IODS Architecture for "Dumb" Sensors

Dumb sensors: A "dumb" sensor simply transmits data as received. It is not designed to determine whether the data (e.g., light beam interrupt or induction loop pulse) indicates a hazard. Sensor data is collected at a central point, and added to other data (i.e., other sensors, database of characteristics, etc.) to detect a threat.

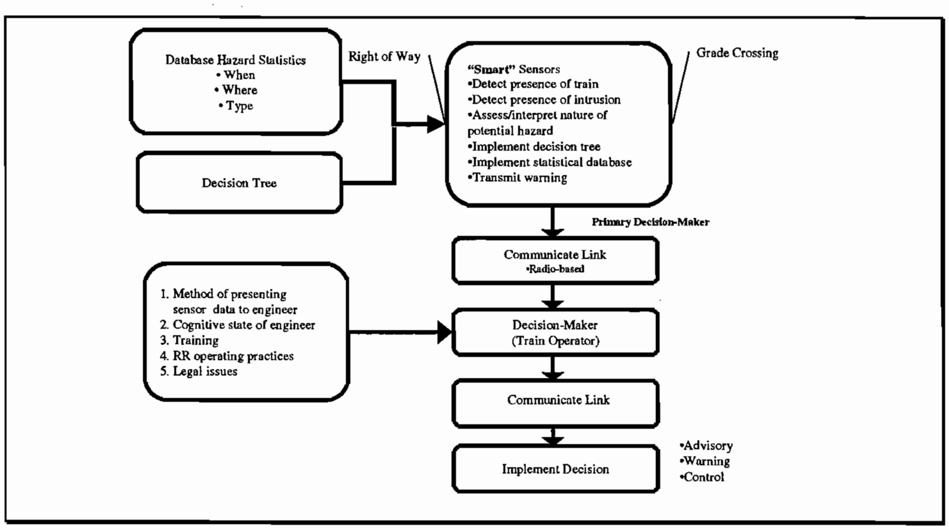

Figure C6. Possible IODS Architecture for "Smart" Sensors

Smart sensors: A "smart" sensor (which may be a group of sensors) includes local processing capability, and sufficient data and logic to determine when a hazard condition exists (e.g., highway-rail grade crossing gates down; large magnetic object on track between gates; train approaching). The transmitted signal may contain data, but is an alarm.

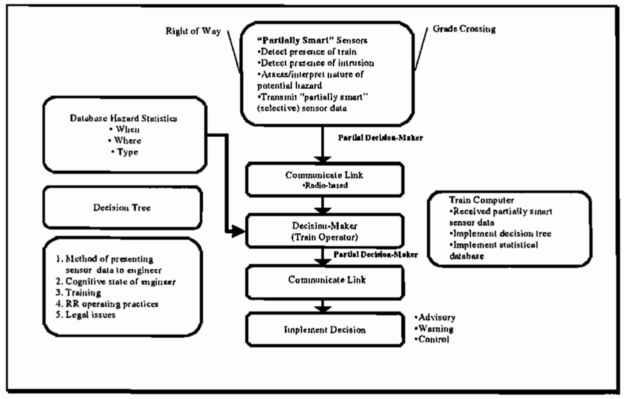

Figure C7. Possible IODS Architecture for "Partial Smart" Sensors

Hybrid or partial-smart sensors: A "partial-smart" sensor includes some processing and discrimination function at the sensor site, and transmits a combination of raw data and alarms. The raw data will feed into a central data collection system, and may count traffic or detect other conditions, but will also, upon the predetermined combination of conditions, send an alarm signal.

Appendix D. Functional Requirements Introduction

Functional Requirements Leading to Operational Concepts for the Intruder and Obstacle Detection System (IODS) Program

Prepared for

The IODS Workshop
Volpe National Transportation Systems Center
Cambridge, Massachusetts

By
Jeff Everson, Ph. D.
Battelle Memorial Institute
Columbus, Ohio
June 1998

Introduction: The purpose of this memo is to suggest a set of functional goals to address the detection of intruders and/or obstacles at both highway-rail grade crossings and along rights-of-way (ROW). Since the highway-rail grade crossing and ROW applications are sufficiently different, two sets of functional goals may be required beyond a certain level of detail. Certainly at a high level of detail, both applications are similar (i.e., the detection of obstacles/intruders and conveying that information to the railroad authority). Once a set of functional goals has been defined, then block diagrams illustrating various operational concepts can be created (Figures are presented at the end of this text.).

Once the functional requirements have been delineated, several related issues will be presented in this paper. These issues focus on the railroad decision maker, his/her requirements, as well as operational, legal, and cost constraints that may be relevant. A major purpose of this workshop is to determine the nature of these non-technical constraints in order to define the IODS sensor problem. This paper will set the stage for the breakout sessions of this workshop.

Functional Requirements: At a top level, an IODS performs the following functions:

(1) Detect intruders and obstacles

(2) Assess the nature of the intruder/obstacle

(3) Communicate information to the railroad authority for decision making purposes

(4) Implement the decision on the railroad system

These four functions apply to the ROW and highway-rail grade crossings to indicate that there is danger to the train. The information conveyed to the railroad authority is intended to minimize danger to the train and its passengers by stopping and/or slowing the train.

A problem along the ROW is defined principally as:

(1) Visible obstructions on the ROW

(2) Intruders or trespassers with the potential to do damage to the ROW

An ancillary consideration of the ROW problem is the catastrophic disruption of the ROW integrity in terms of damaged or missing sections of rail. A problem at a highway-rail grade crossing is defined to be blockage of the highway-rail grade crossing when a train is approaching. Blockage could be due to:

(1) Vehicles

(2) Other objects

The primary focus of the IODS is the safety/protection of the train crew and passengers in high-speed rail operation, although low-speed scenarios are not excluded.

Issues Concerning Functional Requirements: The purpose of the IODS is to detect the presence of a potential problem at a highway-rail grade crossing or along the ROW, convey that information to the railroad authority, and then formulate a course of action with respect to the detected problem. Discussed below are certain fundamental issues that effect functional requirements. For example, there are basic issues concerning the identity of the decision maker (issue #1). There are concerns regarding the amount of intelligence that the sensor needs to convey to the decision making body (issue #2), its reliability (issue #3), and timing (issue #4). An architectural question is: "How should the sensor intelligence be distributed (issue #5)? Should it be all located at the sensor, or all at a central control facility miles away from the sensor, or should some fraction be resident at both the sensor and at the control facility or should some sensor processing intelligence be accomplished on the train itself?"

These issues can be envisioned in the form of a practical example. In the case of the ROW application, the train engineer (decision maker in this case) needs to know the difference between a cardboard box and a boulder that might be in the middle of the tracks (level on intelligence). The engineer needs to know this level of intelligence within 95 percent accuracy (data reliability, which is impacted by legal/cost/railroad operational practice considerations) and must have this information with x-number of minutes (timing) to avoid hitting the boulder, if it is, in fact, a boulder. The efficiency/effectiveness by which this information is conveyed to the engineer may depend on whether "smart" or "dumb" sensors were utilized (system architecture). These issues are discussed below.

<u>Issue # 1: The Decision Maker</u>

A very basic issue concerns the identity of the decision maker and the railroad operational practices, legal, and cost considerations that constrain his/her resolution of potential hazards in terms of saving of human life and the mitigation of injury.

Issue #2: Level of Intelligence Required by the Decision Maker for Hazard Assessment

In the case of sensors for both highway-rail grade crossings and the ROW, there is a certain amount of signal or image processing required to extract a degree of recognition regarding the object/person under surveillance from the raw data. In the military parlance, this degree is given by terms, such as "detection," "recognition," and "identification." In other words, "there's something there," "it's a tank," or "it's one of their tanks," respectively. This degree of recognition will be a concern for the IODS application. In the case of a "dumb" sensor, there may only be "detection" level information (i.e., there's something there).

The railroad authority may want to augment "dumb" level information by fusing it with data from other sources. These other sources could be statistical databases that indicate the likelihood of a hazard, the type of hazard, as well as the time of day and season when it has occurred. For example, vehicles are a major concern at highway-rail grade crossings and considerably less so along the ROW. Pedestrians and trespassers represent a similar problem (i.e., size and speed) as far as the sensor detection process is concerned. Pedestrians are not a major problem for the highway-rail grade crossing scenario (in terms of threat to a train), but trespassers could, in principle, be anywhere along the ROW. Thus, there is a sensor range issue for the highway-rail grade crossing versus the ROW application.

There may be a fundamental engineering trade-off to be considered. For example, it may be enough to know that there is an obstruction at a highway-rail grade crossing, given the accident history of highway-rail grade crossings. In this case, "detection" level information may be sufficient and will be, most likely, acquired over a short range. On the other hand, higher level, identification information may be needed over a longer range for the ROW scenario. Statistical database information may be helpful in knowing when and where to look for potential hazards in order to make the ROW problem more tractable. Obviously, cost considerations will limit the number of sensors that can be deployed for ROW applications.

Issue # 3: Data Reliability Needed by the Decision Maker

How reliable does the sensor data need to be? What is the tolerance for false alarms? What is the required level of detection probability?

Issue #4: Data Timing to Support the Decision Maker

An important concern is the timing of that information (i.e., How quickly is it needed by the decision maker?).

Issue # 5: System Architecture, "Smart" versus "Dumb" Sensors

The architectural issue is of fundamental importance, since it guides the technical approach, will impact subsequent engineering trade studies, and may have a decisive influence on the overall effectiveness of the IODS. The architectural question concerns the degree of intelligence to be invested in a sensor for both the highway-rail grade crossing and the ROW applications. Given below are functional requirements for two distinct approaches, one for "dumb" sensors and the other for "smart" sensors. Other possibilities include a distribution of intelligence between the local level (i.e., at the wayside) and at a central control facility, as well as possibly on the train itself.

"Dumb" sensors:

1. At the sensor level

   - detect the presence of potential obstructions or intruders

   - perform low-level decision making (transmit data only when train approaching)

   - transmit only raw data with no assessment of hazard at the sensor level

2. At the assessment level

   - human or automated interpretation of hazard

   - decision on railroad system response

3. At the communication level: communicate to

   - wayside/central control

   - train control (engineer or ATC [automatic train control])

4. At the implementation level

   - train operator

   - train operator enforcement

"Smart" Sensors

1. At the sensor level

   - detect presence of obstruction or intruder

   - assess/interpret nature of hazard condition

   - transmit hazard warning (i.e., may or may not be considered as a railroad control decision

2. At the communication level: communicate to

   - railroad dispatch or control center

   - wayside control

   - train control (engineer or ATC system)

3. At the implementation level

Appendix E. Breakout Sessions Discussion Points – Sessions A and B

Discussion Points - Session A

The discussion points related to the following topic areas were noted from the breakout session:

1. ***Hazard and threat identification:***

   Look at the threat in different ways: derailments, fatalities, injuries, hazardous materials spills, liability, disruption of schedule, etc. One could demonstrate the value of IODS by converting probability of various hazards into cost risk (i.e., potential dollars lost per highway-rail grade crossing, per 100 miles of ROW, etc.). Representing risk as cost to be avoided would be more persuasive to industry.

   From a sensor-engineering point of view, the basic task of IODS is to detect the objects that represent the threats. Vehicles at highway-rail grade crossings are the major threat, but other equipment or debris on the track can derail or damage a train.

   Situations to sense: Highway-rail grade crossing gate up/down, vehicle stopped/stuck on track, vehicle trapped inside four-quadrant gates, obstruction on track. Once highway-rail grade crossing gates are activated, sensor system is activated.

   Information sensors should provide: Is object metallic? What is its size? Length? Weight? Time object is in highway-rail grade crossing. Is it moving and at what speed (to know how long object will take to clear the track)? Speed of approaching train? Is highway-rail grade crossing clear? Are gates operating?

2. ***System reliability, availability, and serviceability:***

   System must be fail safe/vital—no false alarms, no false negatives. Real cost is in ensuring the vitality of the equipment. Stopping a train for a false alarm has a cost (fuel, schedule). Not stopping a train when a hazard exists has a much greater cost.

   When applied beyond high-speed rail, there are 162,000 highway-rail grade crossings nationwide. Cost per highway-rail grade crossing (i.e., equipment, communication, processing, maintenance, and operation) must be low or IODS will never be installed.

   Constraints include system cost/benefit, train speed, local politics, traffic flow, vital communication, local/wayside detection equipment, timeliness of warning, multiple tracks, and location of stations (within detection area).

3. ***Communications requirements:***

   Communication issues: Communication with the train should be simple, standard controls: stop/slow/proceed. Red alert signal to train cab, alarm to engineer, or automatic brake through PTC? Every second the engineer does not react, the train is moving. Detection system or central decision maker must make the decision for the engineer.

   Must establish communication with the train in time to stop the train. At high-speed rail speeds, are we prepared to close highway-rail grade crossing gates for three minutes? But public will tolerate only a 20 to 30 second wait. Need 90 seconds for a passenger train going 50 mph. IODS detection gear must detect a vehicle that is heavier than 500 lb.

Signal to train cab must be simple: stop/slow/proceed. Must use same control path as other signals (via dispatcher and control system).

4. ***Data analysis and response requirements:***

   Where should sensor information go? Multiple destinations: dispatcher (for decision), exit gate (raise exit gate in four-quadrant system), highway-rail grade crossing analysis software, train cab. Acceptable time delay from first sensing to action is three seconds because of the distance the train travels toward the hazard.

   Important for the dispatcher to know about the problem, even if no train is approaching the highway-rail grade crossing. Dispatcher can take other actions (e.g., dispatch railroad police, maintenance, local emergency crews, etc.).

   Emergency braking should not be part of normal procedures. Emergency brakes applied only if engineer's life or train is in grave danger. Application of emergency braking can cause derailment, other equipment problems with major implications.

5. ***Deployment—Application to specific sites:***

   Potential ROW technologies include radar, infrared, video, millimeter microwave, seismic, laser, and ultrasound.

6. ***General IODS requirements and issues:***

   Most of the equipment items (e.g., sensors, rugged processors, and communications) needed for IODS have been built and are available. Implementation requires a commitment from the rail industry and must justify investments in equipment, training, and maintenance. No demonstrated saving is a reason for not doing it.

   Issue: What do we want to do about PTC? The PTC standards are in development. IODS is not part of PTC, but might provide data/control input to PTC. Suggested division of mission would be to allocate hazard sensing, data aggregation, analysis, and decision to IODS. Then either by preprogrammed alarms or by dispatcher decision, the command for one or more trains to stop/slow/proceed is passed to PTC.

Discussion Points - Session B

The discussion points related to the following topic areas were noted from Session B:

1. ***Hazard and threat identification:***

   The major (most frequent) safety threat to trains is a vehicle in a highway-rail grade crossing.

   Vehicles that present the greatest threat include non-magnetic vehicles (such as a fiberglass boat on a light trailer) and vehicles hauling hazardous materials. Part of the assessment should be the size, mass, and content of the vehicle.

Threat assessment: Loss of life and loss of property should be used to determine the threshold of a threat from the perspective of the train.

Small objects, such as a railroad tie or boulder, also can cause derailment. Size of the obstruction does not equate to a catastrophic event.

Image recognition is the most desirable object detection method. Magnetometers and induction loops are not as reliable. Cannot do much with the data. Should video system be activated only when a train is approaching or also when a vehicle or other object is detected?

2. ***Minimum and desired detection thresholds:***

Loop (induction) detectors would sense presence of (metal) vehicle. Examples of vehicles that are not detected include fiberglass boats on light trailers, horse-drawn wooden wagons, and small wood-frame trailers. More vehicle parts are being made of plastic and composites.

3. ***Sensor operating conditions:***

Photo-enforcement has legal and policy issues. Need a model law for photo enforcement that states can adopt.

Requirement for video varies with level of exposure/risk. Greatest priority for high-speed corridors, highway-rail grade crossings with high vehicle volumes or frequent hazardous cargoes, and highway-rail grade crossings where school buses cross routinely.

No nationwide standards exist. There are 180,000 highway-rail grade crossings so there are 180,000 different situations. Minimum standard is a way to detect an approaching train and an object. What threat conditions dictate the use of "smart" versus "dumb" sensors?

Last resort is a detection system (after trying to close the highway-rail grade crossing or to build a grade separation). There are approximately 200 highway-rail grade crossings in each of the six high-speed corridors.

Recommendation: specify all proven technologies, and permit states and railroads to choose.

Obstacle detection logic: IODS must detect the size and mass of the object, whether it is moving, and how long it has been there. A large cardboard box or tumbleweed is a false positive. The dispatcher will need to know if the object moves away from the tracks before a train arrives (so the dispatcher can direct the train to proceed and/or send someone to investigate).

Railroads have a lot of equipment now. Help is needed on complex issues, such as inexpensive ROW detection and communications technology.

The four-quadrant gate problem started because the highway-rail grade crossings originally were manually controlled. Then when the gates were automated, no flagman was there to anticipate the problem (vehicle trapped inside the gates) and raise the exit gate.

Implementing IODS in high-speed corridors is a good test bed for wider implementation. About 1,500 highway-rail grade crossings meet worst-case conditions and "really need" IODS.

Operating constraint: federal law does not permit enforcement by use of emergency brake. Only full service brake or split-reduction application is permitted.

Re: engineer making the decision to stop the train. Some situations are clear-cut, while others are not. Must not distract operator from current responsibilities. Must simplify indicators in the train cab. Best to use wayside signals. The highway-rail grade crossing information does not have to go to the engineer.

Re: highway-rail grade crossing barriers. Issue is how much effort and money should be spent to protect scofflaws and signal runners. Even a substantial barrier can be a problem. For example, if a truck hits the barrier at 40 mph, it could launch its cargo over the barrier and into the train.

A "smart" system that collects data can preclude "Monday morning quarterbacking" and unnecessary lawsuits. Can also capture information for safety improvement and traffic statistics. Showing extreme driver behavior before the crash (by video or sensor data) will place liability properly.

4. ***System reliability, availability, and serviceability:***

   Activation failure (of highway-rail grade crossing lights and barriers) indicates that it is safe to cross the tracks when it is not (false negative). Eighty percent of failures are battery backup failures and are not tied to signal equipment failures.

5. ***General IODS requirements and issues:***

   Current Code of Federal Regulations (CFR) provisions inhibit progress. The FRA should examine rules to permit use of new technology. The FRA is gathering data (including this conference) to improve rules via better information.

   Cannot make the precautions so expensive that the cost drives passenger costs up. Then people will not use rail.

   Because each highway-rail grade crossing represents a different combination of geometry, traffic, vehicle types, hazards, number of pedestrians, etc., a cookie cutter approach to IODS would not be effective. The FRA should recommend a range of responses that meet the range of needs. Set performance standards, but not prescriptive operating parameters. IODS will be implemented differently by different railroads. It is hard to get by the regulatory requirements.

   Re: stalled versus stuck vehicles. Difference is more than time. Need to know about stuck vehicles long before train approaches (in order to dispatch help to clear the track). Very few vehicles actually get hung up on the track. Most stuck vehicles get free and move on before train approaches. Video would help to identify the type of object and to determine the hazard. So video should record when an object is detected, not just when a train is approaching.

"Dumb" sensors (induction loops) are already in use. When "smart" sensor architecture is available, link it to central control and to wayside signals, not to the train cab. Simple obstacle detection would not have helped in most recent crashes.

Appendix F. Sensor Technologies

The following is an inventory of technologies currently available for application as sensors in an Intruder and Obstacle Detection System (IODS) installation.

Radar Detectors

Radar detectors can be used to detect both intruders and objects of various sizes and materials. A radio frequency (RF) transmitter radiates electromagnetic energy in the direction of the detection zone. RF energy is reflected from the intruder or object back to the receiver. The reflected RF energy indicates the presence of an intruder or obstacle. More robust radar detectors not only can determine if an intruder or obstacle is detected, but also can provide data on the size and material makeup of the hazard.

Laser Detectors

A laser beam is a high-energy light beam. Simple laser detectors work by detecting when an object passes through the light beam, interrupting its path to the receiving sensor. Laser beams are line-of-sight and do not work through smoke or fog.

Infrared (IR) Detectors

Passive IR detectors produce an alarm signal when they sense a quick change in incidence IR radiation within its field of view. The unit is utilized for remote detection of vehicles, people, and objects. Easily concealed, it is ideal for perimeter protection, border observation, tactical surveillance systems, and airport security. IR detectors are available with various detection ranges and capabilities.

IR sensors are designed to detect a target when the pulsed IR beam that transmits across the detection zone is interrupted. Multiple beams can be arrayed vertically to provide a line of detection to the height desired. The beams are infrared and not visible to the eye. Their vertical spacing defines the detection pattern. The configuration can be designed to suit the application by balancing the cost of additional beams with the severity or skill of the likely threat.

Ultrasonic Detectors

Ultrasonic detectors are designed to detect changes in the frequency of sound waves. These alarm systems generate ultrasonic sound waves that have frequencies above those detectable by the human ear. The systems "listen" to the waves as they bounce, or echo, off objects in the protected area. The frequency of these waves changes slightly when the waves bounce off a moving object such as an intruder. An ultrasonic alarm is designed to trigger an alarm when it detects such frequency changes.

Millimeter Microwave

These beam devices use microwaves to detect the presence of a foreign body crossing its arc-shaped field. Since the beam passes readily through barriers, movement beyond the intended area may cause a false alarm, therefore, microwave detectors are often used in combination with other detection technologies.

Magnetic

The buried or concealed magnetometer detects disturbances in the earth's magnetic field caused by movement of ferrous or magnetically sensitive material moving through the sensored area. Stationary objects do not affect the detectors. The magnetic detectors may be deployed as single units to detect personnel movement and vehicles, or in pairs to determine direction of travel.

Buried Coaxial

Buried coaxial cable detectors are used for providing intrusion detection at perimeter boundaries. They can be installed below the ground surface in soil, asphalt, and concrete pavements to form an envelope of detection around the area to be secured. The buried coaxial cable sensor system consists of two parallel coaxial cables that transmit and receive RF signals through small "ports" or openings in the outer shield of the cables. As RF energy is transmitted along the transmit cable, some of the energy leaks out and couples onto the parallel receive cable. The resultant electromagnetic field at the receive cable is continuously analyzed to determine the presence of intruders. Intruders in the vicinity of the cables alter the RF coupling between the transmit-and-receive cables, thus producing a discernible change in the signal received. Analyzing the time and signal relationship between the transmit pulse and the received signals, the system is able to locate the position of the intruder on the boundary.

Although the buried coaxial cable system is very reliable, initial siting and installation requirements are critical and must be fully observed to ensure successful system operation. Particularly important is the requirement to conduct soil sample tests for the area of installation to ensure the electrical properties of the soil do not exceed established thresholds for conductivity. When the soil conductivity exceeds the allowable threshold, it is necessary to remove the native soil and replace it with a specified level of sand.

Video Motion Detection (VMD) Closed-Circuit Television (CCTV)

VMD combines CCTV with an internal software system designed to protect a specified interior or exterior area by monitoring light pattern disruptions. Available in a variety of proficiencies, VMD allows the user to select a software package that will provide the necessary intensity to meet specific protection needs.

With the rapid advance of video technology, there are a wide variety of products and features from which to choose for any given application (e.g., low light level cameras, slow-scan and time-lapse models, video motion detectors, sophisticated switching hardware, cable-less laser video transmitters, and even pop-up buried cameras).

Seismic

This hardware monitors for the types of vibration created by footsteps, vehicles, etc. Sensors may be imbedded in paving, in the ground, or in roofing materials.

Fiber Optic Intrusion Detection System (FOIDS)

The fiber optic sensor can be used on fences directly (if the fence is well constructed) or in conduit if high winds are a potential problem. The fiber optic sensor can be installed in gravel for people and vehicle detection or, if only vehicles need to be detected, under other media such as soil or paved roads. The fiber optic sensor also can be installed on roofs, in walls, or in the ceilings of buildings.

When an optical fiber is disturbed, the disturbance changes the way the fiber conducts light. Although the change is very small, with the right light source and detection method, this change can be amplified to create a useful signal similar to the voltage generated by a microphone in contact with a moving or vibrating object.

On the simplest level, a laser injects coherent light (light for which all of its components consistently rise and fall together) into the fiber. This light transverses the fiber to a detector, where it is converted to an electrical signal. The signal from the detector is processed to decide whether there is a disturbance of the right quality to generate an alarm. This signal processing is based on parameters set by the user to control the type of signal that will cause an alarm.

Perimeter fence

Perimeter fencing is the most basic protection for corporate grounds, parking facilities, exterior storage areas, or other outdoor spaces that need access control. Fencing provides a simple physical barrier, or can be wired or laced in a number of ways to actively detect intrusion.

Fence protection sensors are designed to detect attempted penetrations of a chain link security fence. It consists of a strain-sensitive cable sensor consisting of a coaxial cable mounted on the fence and a sensor processor. A mechanical disturbance of the fence causes a small strain on the sensor cable that is converted to an electrical signal. The sensor processor provides an alarm output signal when a disturbance is detected.

Photoelectric Beam

This electric eye type monitor senses any objects that break its photoelectric beam. It can be applied along property lines, rooflines, parking lot perimeters, and other exterior areas that need monitoring.

Appendix G. Definitions

Part of the challenge in setting Intruder and Obstacle Detection System (IODS) requirements is to detect, communicate, and respond in time to all threats. The level of available technology, resources, public interest, and multiple uses of information will drive the number of hazards that can be detected and managed by the same system at the same time.

Architecture is the combination of shape and function. For an electronic system like IODS, the architecture consists of the major functional elements, the rationale for each major function, a vision of how the system will be deployed, and the interaction of the major elements to perform the system's mission. The architecture description should be in sufficient detail to show how each of the functional requirements and constraints has been met, and why the proposed architecture is the best possible solution.

The ***Code of Federal Regulations*** (CFR) contains the implementation of federal legislation and supporting rules. CFR Title 49 includes most of the transportation-related provisions. References in the discussion to "regulation" refer to provisions of the CFR.

Critical infrastructure, as identified by the President's Commission on Critical Infrastructure Protection, includes a list of transportation, communication, information, and commerce resources that are essential to the national economy and subject to sabotage. The national rail system and information systems such as IODS are identified as critical resources and are part of the planning for infrastructure protection.

The ***dispatcher*** is the individual or function in railroad operations that is responsible for controlling the movement of trains, along with other communications and control duties.

A ***"dumb" sensor*** is a sensor that transmits data indiscriminately, that is, it sends all data it senses without filtering. Examples include video cameras and induction loops.

A ***highway-rail grade crossing*** is an intersection of a railroad track and a road, where the vehicle must drive over the railroad tracks to cross (i.e., the road is "at grade" relative to the track, not an overpass or underpass). Highway-rail grade crossings are of special safety concern because most train/vehicle crashes occur at highway-rail grade crossings.

A ***hazard*** is a condition that may, if left uncorrected, result in damage, injury, or delay. Hazards may include adverse weather conditions, unprotected highway-rail grade crossings, deteriorating road bed, or debris in the right of way.

High-speed rail (HSR) is a set of rail transportation technologies that includes 150 to 200 mph train sets, specially engineered rails and road beds, communications, rights-of-way (ROW) protection, and other elements that enable a new generation of competitive passenger rail service. Ten HSR corridors are currently in development in the United States.

A ***highway-rail grade crossing incident*** is any impact between a rail and a highway user (both motor vehicles and other users of the crossing) at a designated crossing site, including walkways, sidewalks, etc., associated with the crossing[3]

An ***incident*** is an occurrence of damage or injury, or another event that causes train controllers to slow or halt one or more trains.

An ***intruder*** is a trespasser on railroad property or ROW. Intruders are of rail safety concern due to the potential for injury to the individual, the potential injury the intruder may inflict on others, and the potential for vandalism or sabotage to railroad equipment.

The ***Intruder and Obstacle Detection System*** (IODS) is a proposed system of sensors, processors, communications, and annunciators to permit consistent detection of people and objects on tracks, rail facilities, and highway-rail grade crossings. It is a safety and security improvement initiative, with technology in compliance with Intelligent Transportation Systems (ITS) architecture.

An ***object,*** as used in this report, refers to a thing that is large enough and heavy enough to cause damage if a train strikes it. When an object is located on a railroad track, it is an ***obstacle***. Objects might include vehicles, boulders, or debris.

Operation Lifesaver, *Inc.* (OLI) is a private, nonprofit organization dedicated to reducing highway-rail crossing incidents and casualties through a program organized under the three concepts of education, engineering, and enforcement. Founded through a grass-roots movement in 1972 and incorporated in 1986, OL's operations and programs are funded by grants mandated by Congress through the FRA and the FHWA, in addition to private and public donations. For the first time in 2001, the Federal Transit Administration will be providing a grant to OLI.

Positive Train Control (PTC), is a Federal Railroad Administration (FRA) and industry initiative to improve en route control of trains, to prevent collisions, and to permit safe movement of a greater number of trains. Proposed PTC technology is a suggested route for IODS to issue automated alarms. Several railroads have adopted some form of train control technology into their electronics suite, such as BNSF's Advanced Railroad Electronic System (ARES).

Railroad ***rights-of-way*** (ROW) include railroad tracks and the strips of land on both sides of the track that is used for maintenance, communication lines, etc. Railroads retain special legal rights to their ROW.

A ***"smart" sensor*** consists of one or more sensors that transmit only when specified conditions are met, that is, processing of raw data occurs within the sensor set. The signal coming out of a properly programmed "smart" sensor is not a data stream, but an alarm.

A ***state change*** is when a sensor detects an occurrence that exceeds the defined threshold, and so perhaps indicates a hazard.

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[3] Definition from FRA *Railroad Safety Statistics Annual Report, 1997* reported on form FRA F 6180.57, "Highway-rail grade crossing accident/incident report."

A ***threat*** is immediate and will result in probable damage, injury, or delay. A threat is a hazard in a position of risk or in a circumstance that makes harm likely. For example, a loose boulder at the top of an embankment is a hazard, but when it rolls down, strikes the rails, and comes to rest on the track or jams a switch, it becomes a threat.

A ***train accident*** is a safety-related event involving on-track equipment (both standing and moving), causing monetary damage to the rail equipment and track above a prescribed amount.[4]

A ***"vital" system*** is a highly reliable and self-diagnosing, mission critical system. A "vital" system is designed to send no false alarms, to always indicate when a problem exists, and is self-monitoring for errors and subsystem failures. Each system must operate in all weather and through power failures. Surviving elements or subsystems should continue to operate when specific elements fail or are vandalized. To fulfill its mission and justify its investment, IODS must be a "vital" system.

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[4] Definition from FRA *Railroad Safety Statistics Annual Report, 1997* reported on form F 6180.54 "Rail equipment accident/incident report."