SAND93- 1582
Unlimited Release
Printed 1993

Commercial Vehicle Architecture Systems Study

Volume II: Task Reports

Draft of 10-21-93

(Original draft: 7-14-93)

NOT FOR DISTRIBUTION

R.H. Byrne, B.C. Caskey, J. Cashwell, M.R. Garcia, P.H. Heerman, J.P. Berry, R.J. Peterson, S.C. Roehrig, and S.J. Weissman

Transportation Systems Center 9600
Sandia National Laboratories
Albuquerque, NM 87185

ABSTRACT

This report details progress to date on a set of tasks being performed by Sandia National Laboratories (SNL) for the Department of Transportation (DOT). These tasks identify and examine the feasibility of technologies for the DOT's Commercial Vehicle Operations (CVO) component of the Intelligent Vehicle Highway Systems (IVHS) program. Specifically, these tasks are as follows: Enhancements to Commercial Vehicle Inspections; Commercial Vehicle Brake Study (Project Short Stop); RAMPOST (RadioActive Materials POST notification reports) Database Support; Assessment of Technologies for Hazardous Material Transport; and Technologies for Covert Inspections Monitoring. Reports on progress to date on each of these tasks are presented as attachments to this report. This report also outlines and presents a rationale for an overall Systems Approach to building a Commercial Vehicle Architecture that will best meet CVO needs. This approach is based on a top-down, life-cycle approach to technology development that takes advantage of Sandia's experience in systems engineering, prototype development, and technology transfer.

DOT/FHWA
101879

Contents

Volume II: Task Reports

ATTACHMENT 1

Enhancements to Commercial Vehicle Inspections

Draft of 10-21-93
(Original draft: 7-14-93)
NOT FOR DISTRIBUTION

R. H. Byrne
9616 - Advanced Vehicle Development Department

J. P. Berry
324 - System Safety Engineering Department

Sandia National Laboratories
Albuquerque, NM 87 185

Abstract

This report documents a study sponsored by the Federal Highway Administration (FHWA) on technologies to enhance the commercial vehicle inspection process. The Federal Motor Carrier Safety Regulations, Commercial Vehicle Safety Alliance (CVSA) Out-of-Service Criteria, CVSA North American Standard Inspection, and European inspection procedures are reviewed. Current technologies and research efforts are also summarized. Based on a review of the commercial vehicle inspection process and available technologies, candidate technologies and recommendations for enhancing the commercial vehicle inspection process are identified.

TECHNICAL TASK PLAN

TITLE: Enhancements to Commercial Vehicle Inspections

Sponsor:	Federal Highway Administration (FHWA) 6300 Georgetown Pike McLean, VA 22101	
Technical Program Officer:	Mike Freitas	(703) 2852421 (703) 285-2264 (FAX)
Sandia Proposal Number:	959200309	Date: March 23, 1992
Principal Investigator:	Ray Byrne, Dept. 9616 Sandia National Laboratories Albuquerque, NM 87185-5800	(505) 845-8716 (505) 844-5946 (FAX)
Technical Program Manager:	Steve Roehrig, Dept. 9604 Sandia National Laboratories Albuquerque, NM 871855800	(505) 844-1180 (505) 844-2193 (FAX)

TASK SUMMARY

Many technologies have been proposed to improve commercial vehicle operations (CVO). These include automatic vehicle identification, weigh-in-motion, automatic vehicle classification, and electronic placarding/bill of lading. For commercial vehicle freight operations, the benefits include fewer required stops, reduced paperwork burden for interstate operations, and improved safety performance.

There is considerable interest in improving the process of inspecting commercial vehicles and drivers through the use of advanced technology. The purpose of this task is to identify and assess various concepts to aid in monitoring, selecting, and inspecting large trucks and their drivers. Concepts to be considered include systems that assist in selection of vehicles for inspection by providing such data as a carrier's safety record, etc. while the vehicle is still on the mainline; remote sensors that monitor key vehicle components or driver characteristics and alert inspectors of potential problems; and sensors, meters, and other systems to aid in the actual inspection process. A long term goal would be the development of a fully automated on-board computer inspection system that can alert the driver immediately of any unsafe conditions. This system would also be able to transmit the results of the latest inspection to the inspection station as the truck passes, thereby reducing the need for manual inspections. This system will improve productivity by reducing the time required for manual inspections and improve safety by allowing continuous monitoring of the systems checked during an inspection.

Sandia has extensive experience with battery operated computer systems that have been employed on robotic vehicles, missiles, satellites, and the Department of Energy's tractor trailers used to transport highly valued assets. This expertise, as well as the capability to design custom, miniature sensors, makes Sandia well qualified to perform this task.

STATEMENT OF WORK

The project will be broken into the following sub-tasks:

Phase I. Gather Information - Through a literature review as well as meetings and conversations with key officials, determine the process used to select trucks (and/or drivers) for inspection, the critical items, the inspection process, and the problems and shortcomings associated with these activities. Time - 4 months.

Phase II. Identify and Assess Technologies - Examine proposed or implemented efforts to improve the inspection process through the use of technology. This should include efforts to provide data to aid in the selection of vehicles or drivers, as well as any sensors, meters, or other devices intended to improve the quality or efficiency of inspections. Time - 2 months.

Phase III. Analysis and Summary of Findings - Identify opportunities for improving the commercial vehicle inspection process through the use of technology as well as candidate technologies. Analytically evaluate the potential for the candidate technologies to improve the commercial vehicle inspection process in a cost effective manner. Based on the analysis, develop a recommended course of action for further development of inspection systems. Document analysis and recommendations in a SAND Report. Time - 3 months.

Phase IV. Negotiate Future Work - Based on the analysis and recommendations, mutually agree on a course of action for further development of inspection systems by Sandia.

ESTIMATED COST

YEAR	MANPOWER	EXPENSE	TOTAL
FY93 Phase I-III*	$130K	$50K	$180K

*Includes approximately $20K for support from the Commercial Vehicle Safety Alliance in researching the truck inspection process.

MILESTONES

Deliver SAND Report outlining Phase I-III findings July 1, 1993

RISK

The risk in Phase I-III is negligible since it mainly involves gathering and analyzing information.

APPROVALS

FHWA	[signature] Mike Freitas	10/20/92 Date
Sandia	[signature] Bill Caskey	10/20/92 Date

Contents

Figures

Tables

1. Introduction

1.1 Project Goals

Many technologies have been proposed to improve commercial vehicle operations (CVO). These include automatic vehicle identification (AVI), weigh-in-motion (WIM), automatic vehicle classification (AVC), and electronic placarding/bill of lading. For commercial vehicle fleet operators, the benefits of these technologies include fewer required stops and a reduced paperwork burden for interstate operations. These technologies are currently being demonstrated in several smart corridor projects, including HELP/Crescent and ADVANTAGE I-75 (Cambridge, 1993; Walton, 1993). However, none of these projects are looking at the safety inspection task in great detail.

Vehicle safety inspections are performed to ensure that carriers and drivers are complying with the Federal Motor Carrier Safety Regulations (FMCSR). The Commercial Vehicle Safety Alliance (CVSA) has developed a Standard North American Inspection Procedure as well as uniform Out-of-Service Criteria, which have been adopted by most states with minor variations. CVSA is an alliance of federal and state officials responsible for the administration and enforcement of motor carrier safety and hazardous materials laws; the alliance is working together with government and industry to improve commercial vehicle safety and to standardize inspections. While CVSA has been working to standardize the inspection process, there have been no large-scale efforts to develop technologies to improve this process. Several states are currently conducting tests with pen computers, laptops, and voice recognition systems, but these tests are not part of a larger plan to integrate technologies into the commercial vehicle inspection process. The goal of this report is to gather preliminary data about the inspection process and the technologies being tested, and to make recommendations on how to better use technologies to improve the commercial vehicle inspection process.

1.2 Information Sources and Acknowledgments

Information for this report was gathered from a number of different sources. A literature search of the Society of Automotive Engineers (SAE) database and several other databases was conducted to obtain information about previous and ongoing research projects. Several conferences were attended to keep abreast of the most current research and to meet people in the field. A brake workshop was also conducted at Sandia National Laboratories in Albuquerque, NM, as part of a related project. (See Attachment 2 of this report.) Local contacts that were very helpful include the New Mexico Motor Carrier's Association, the State of New Mexico Motor Transportation Division, and the Albuquerque Federal Highway Administration (FHWA) Office of Motor Carriers. CVSA was an excellent resource, on both the state and national level. Meetings with CVSA and attending the CVSA two-week North American Standard Level I Class were invaluable sources of information. Visits to the University of Michigan Transportation Research Institute (UMTRI) and the Transportation Research Center in Ohio were also conducted. In order to obtain hands-on information about the inspection process, inspection stations were visited in Anthony, NM, St. George, UT, and Helena, MT. In addition, visits to European industry and research centers related to commercial vehicle inspection were conducted. These visits included WABCO/UK (United Kingdom), Lucas (United Kingdom), Mercedes Benz (Germany), and IMechE (United Kingdom). Phone interviews were also conducted to obtain information about some of the technologies discussed in this report. The authors would like to thank all of the people who provided information for this study. Although a complete listing here would be impractical, it is hoped that everyone who contributed has been listed on the distribution page for this report.

1.3 Report Overview

This report attempts to identify and assess ways that advanced technology can improve the commercial vehicle inspection process. It begins with a discussion of the fundamentals of computers, sensors, and communications, all of which are essential components of commercial vehicle inspection systems (Section 2). Then the details of the inspection process are described (Section 3). The report then provides a review of technologies currently being tested in the area of vehicle inspection (Section 4) as well as mature technologies that could easily be implemented. Finally, the report closes with near- and long-term recommendations for enhancing commercial vehicle inspections (Section 5).

Although this report does not contain an executive summary, those already familiar with the truck inspection process can skip to Section 5 to find the report's conclusions.

2. Technology Fundamentals

All of the technologies described in this report involve some combination of computers, sensors, and communications. This section explains the basics of computers, sensors, communications, and smart materials so that the nontechnical reader will have a better understanding of how they might be applied to improve commercial vehicle inspections and safety. This section should also help nontechnical readers better grasp other Intelligent Vehicle Highway System (IVHS) concepts that are being proposed for commercial vehicle operations (CVO). Readers who are already familiar with computers, sensors, and communications might want to skip to the next section of this report.

2.1 Computers

Computers are electronic devices that are capable of storing large amounts of data and very quickly performing operations on that data. An inexpensive computer can perform millions of operations per second. A block diagram of a typical computer system is shown in Figure 2- 1.

The four basic components that make up most computers are the central processing unit (CPU), memory, input/output (I/O) devices, and display. (Often primary memory, I/O capabilities, and the CPU are integrated on a single chip; this single chip is called a microprocessor.) Computers run a program, or a sequence of instructions stored in memory, that determines how the data will be obtained, manipulated, and displayed. These programs are often called software. Software can improve memory, speed, and efficiency without necessitating hardware upgrades. Memory can be broken down into two main types, volatile and nonvolatile. The data stored in volatile memory is lost when the power is turned off. In contrast, information stored in nonvolatile memory is not lost when power is removed. Therefore, programs are usually stored in nonvolatile memory. An example of volatile memory is random access memory (RAM), which is what the computer uses to store temporary data while executing a program. Examples of nonvolatile memory include read-only memory (ROM), electrically programmable read-only memory (EPROM), electrically erasable/programmable read-only memory (EEPROM), diskettes, hard disks, and CD (compact disk) ROM.

Although RAM is considered volatile memory, information can be stored for over 10 years in a low-power RAM device, if it has a battery backup to ensure that power is never lost. This pseudo-nonvolatile memory type is often called Battery-Backed RAM (BRAM). For applications that involve rugged operation, electronic storage devices like EEPROM and BRAM are preferable to hard disks (electromechanical) for storing large amounts of data. The only advantage of hard disks over EEPROM and BRAM is that hard disks are generally less expensive and smaller when large amounts of data must be stored. However, as electronic devices continue to shrink, EEPROM and BRAM will become superior to hard disks in all areas for rugged applications.

I/O devices allow the CPU to communicate by input and output of data. Examples of input devices include keyboards, mouses, parallel ports, serial ports, and other electronic devices. Examples of output devices include parallel ports, serial ports, printers, and plotters. Note that parallel and serial ports are both input and output devices, that is, they are bidirectional. Sometimes a display is considered an output device, but, for this discussion, we will consider displays separately.

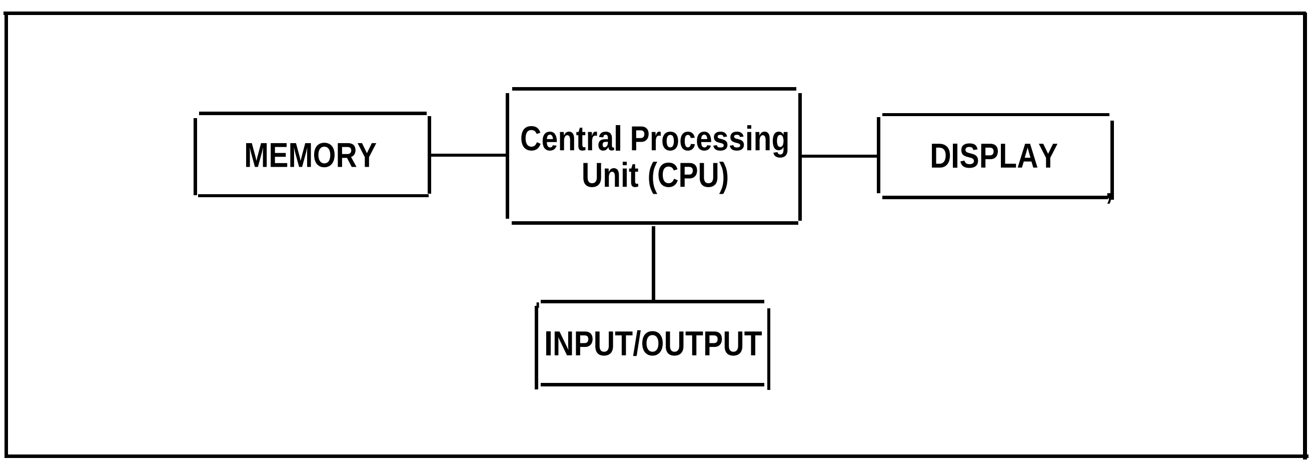


Figure 2- 1. Computer block diagram.

For this application (commercial vehicles), two important I/O devices are analog-to-digital converters (A/Ds) and digital-to-analog converters (D/As). A/DS are used to convert analog, or continuous-time, signals from sensors and other devices into a digital format that the computer can use. D/As are used to convert digital data in the computer into analog signals that are output to the real world. A/Ds are critical for this application because many sensors, as discussed in the next section, output an analog signal.

Displays are used to present data to the operator. The most common type of display is a cathode ray tube (CRT), which displays text and graphics for most personal computers. However, other types of displays include bar graphs, lights, and head-up displays. An important type of display for this application is the liquid crystal display (LCD). LCDs require less power than CRTs and are used in most laptops. Important display parameters for this application include resolution, size, power requirements, ruggedness, and visibility under different lighting conditions. LCDs usually require lighting from the back, or backlighting, to be seen in the dark or under low-light conditions.

Power requirements are an important consideration for embedded computer applications. In an office, power is readily available. But on vehicles, the power available from the battery and alternator is limited. Computing power (operations per second) is also directly proportional to power in general. The faster a computer is, the more power it usually requires.

Almost every IVHS CVO application involves using a computer in one form or another. However, computers need to obtain data about the real world using sensors before they are really useful. Sensors are described in the next section.

2.2 Sensors

Sensors are devices that are used to measure physical quantities (i.e., temperature, speed, displacement, or position) and typically convert these quantities into electrical signals (i.e., voltage, current, or frequency) that can be used by computers and other electronic equipment. Sensors usually have to contact the physical quantity that they are measuring. For example, a temperature sensor must usually be in contact with the medium whose temperature is to be measured. Remote sensing refers to when a sensor does not have to be in physical contact with the medium being measured. An example of remote sensing would be measuring temperature with an infrared sensor (measures the temperature by looking at the infrared energy being emitted from it). Although sensors are usually thought of as complicated devices, a simple switch that detects an open door is also a sensor.

Sensor outputs can be subdivided into two broad categories: analog and digital. Analog sensors output a continuous signal, usually a voltage or current, that is proportional to the quantity being measured. Digital sensors output a digital value that is proportional to the quantity being measured. This digital value may be either on or off, or a digital representation of a number (i.e., in binary or gray code). Most sensors are analog in nature. However, some analog sensors are packaged with electronics built in to convert the analog signal into a digital signal. This is done to make the sensor more compatible with a microprocessor. The concept of an A/D presented in the previous section is important because most sensors require an A/D to interface with a microprocessor.

Two emerging sensor technologies that have numerous potential applications, including commercial vehicles, are microsensors and smart sensors. Because of their small size, microsensors can obtain information about a system without interfering with system dynamics or size restrictions. Smart sensors combine signal conditioning and self-testing systems on the same chip or in the same package as the sensor. This improves both reliability and performance.

It is possible to embed sensors within a physical structure. An example of this would be tires or brake linings that have temperature or thickness measuring devices built into their structure. Embedded sensors usually take advantage of smart microsensors. One difficulty in designing embedded sensors is the tradeoff between sensor information and reducing the performance of the material by incorporating sensors.

2.3 Communications

Many proposed IVHS technologies require radio communications to be successfully implemented. This includes intra-vehicle communications as well as vehicle-road communications. Two basic methods are used to carry information on a radio signal: frequency modulation (FM) and amplitude modulation (AM).

One important concept for vehicle communications is bandwidth. Bandwidth refers to the amount of data that a channel is capable of handling. The amount of radio spectrum needed is proportional to the bandwidth of the transmitted signal. The Federal Communications Commission (FCC) provides frequency allocations, and obtaining allocations for IVHS systems is a critical issue. In addition, bandwidth is important for drive-by transmissions, where the vehicle has a limited amount of time to transmit data. The higher the bandwidth, the greater the amount of information that can be transmitted in a fixed time period. Therefore, given a short-range radio communications system, the amount of data that can be transmitted from a moving vehicle is limited by the bandwidth of the radio link.

Based on potential communication needs in commercial vehicle operations and IVHS, light-based devices may become an alternative to radio communication systems. Light-based systems combine optical and electrical technologies known as optoelectronics. Advantages of these systems over radio frequency data transmissions would be higher speed, greater precision, and higher density of data transmission. However, one disadvantage of optical systems is their susceptibility to disruptions from dirt, fog, rain, and other obstructions.

For commercial vehicle operations, another critical communication issue is how to communicate with on-board electronics during an inspection. The communication channel (light, radio, or wire) as well as the communication protocol is yet to be determined. As on-board electronics become more commonplace, a standard communication interface will have to be developed to allow inspectors to take advantage of on-board diagnostics.

3. Inspection Process

In order to fully understand the reasoning behind the recommendations presented later in this report, some knowledge of truck inspections is required. Therefore, this section provides an overview of the truck inspection process. This includes an overview of the Federal Regulations (Section 3.1), Out-of-Service Criteria (Section 3.2), the North American Standard Inspection (Section 3.3), and European inspection practices (Section 3.4). Shortcomings noted with the inspection process are also discussed (Section 3.5).

The truck inspection process is based on the Federal Motor Carrier Safety Regulations (FMCSR), found in the Code of Federal Regulations (CFR), Title 49, Subtitle B, Chapter 3, Subchapter B. The truck inspection process is also based on the Commercial Vehicle Safety Alliance's (CVSA) Out-of-Service Criteria for the driver and vehicle (also based on the FMCSR). CVSA includes members from Canada, Mexico, and the United States. The Out-of-Service Criteria outline critical inspection items that can place the vehicle or driver out of service.

Under the CVSA bylaws, inspectors must complete and pass a CVSA-approved 80-hour North American Standard Inspection course. Much of this chapter is based on the material covered in the North American Standard Level I class. This class prepares inspectors for Level I - V inspections. An inspection may be of any of the five types shown below in Table 3-l.

Table 3-1. Summary of Inspection Types

Level	Inspection Type
I	North American Standard Vehicle/Driver
II	Walk-Around
III	Driver Only
IV	Special
V	Terminal

The Level I inspection is a complete inspection of the driver and vehicle. A Level II inspection involves only a quick walk around the vehicle to check for violations visible without going underneath the vehicle. A Level III inspection involves an examination of the driver's principal documents and his compliance with hours-of-service requirements. Level IV inspections are reserved for special inspections, while a Level V inspection involves inspecting vehicles and records of the carrier at the terminal. The MCMIS (Motor Carrier Management Information System) database is used to help prepare for Level V inspections and compliance reviews. This database includes vehicle inspection data that is entered by states into the national database using the SAFETYNET program.

3.1 Federal Regulations

As mentioned earlier, the truck inspection process is based on the FMCSR. An overview of the different regulations that appIy to truck inspections appears below in Table 3-2.

Table 3-2. FMCSR Summary

Part	Description
383	Commercial Driver's License (CDL) Standards; Requirements and Penalties
387	Minimum Levels of Financial Responsibility for Motor Carriers
390	General
391	Qualification of Drivers
392	Driving of Motor Vehicles
393	Parts and Accessories for Safe Operation
394	Notification, Reporting, and Recording of Accidents
395	Hours of Service of Drivers
396	Inspection, Repair, and Maintenance
397	Transportation of Hazardous Materials: Driving and Parking Rules

Sections 3.1.1 to 3.1.8 discuss the highlights of the Federal Regulations. They are reviewed in the order that they are presented in the CVSA 80-hour class. This ordering makes them easier to understand and is a more natural progression than their numerical order.

3.1 .1 Part 390-General

Part 390 of the Federal Regulations covers general applicability, definitions, and general requirements and information. The "general applicability" of the regulations is stated as follows: "The rules...are applicable to all employers, employees, and commercial motor vehicles, which transport property or passengers in interstate commerce" (390.1 (a)). For this chapter (of the FMCSR), a commercial motor vehicle is defined as a vehicle having a gross vehicle weight rating (GVWR) of 10,001 or more pounds, or a vehicle designed to transport more than 15 passengers including the driver, or a vehicle used to transport hazardous materials in a quantity requiring placarding (390.5). (Note: The definition of a commercial motor vehicle in Part 383 (relating to commercial driver's licenses) is different.) Interstate commerce is defined as travel from state to state, or travel between a state and a location outside of the United States. The final destination of the cargo must be taken into account when determining the nature of the shipment. For example, cargo destined for Japan via ship or air would be considered interstate commerce as the cargo traveled through the state of California by truck. Gross Vehicle Weight Rating (GVWR) refers to the value specified by the manufacturer as the loaded weight rating of the vehicle (390.5). GVWR does not refer to the actual load.

The required markings on trucks are also outlined in Part 390. These include the name of the motor carrier, the city and state in which the carrier is located, and the motor carrier identification number.

The following are exempted from the rules in this subchapter: school bus operators; government vehicles (state, federal, and local); transportation of personal property (i.e., U-Haul trailers); fire and rescue trucks involved in emergency operations; and the private transportation of passengers (i.e., a church ski trip).

3.1.2 Part 391--Qualifications of the Driver

Part 391 establishes minimum qualifications for the driver of an interstate commercial vehicle. General exemptions to the driver requirements (but not to the vehicle requirements) are given to farm operators, drivers in the apiarian industry (beekeepers), certain farm vehicle drivers, and certain intracity drivers. A qualified driver must meet the requirements in Table 3-3.

Table 3-3. Summary of Driver Qualifications

1.	Is at least 21 years old.
2.	Can speak and read the English language.
3.	Can safely operate the type of motor vehicle he drives.
4.	Can determine whether the cargo has been properly loaded.
5.	Is familiar with how to secure the cargo.
6.	Is physically qualified.
7.	Has a valid commercial motor vehicle operator's license.
8.	Has furnished his employer with a list of violations.
9.	Is not disqualified from driving a motor vehicle.
10.	Has successfully completed a driver's road test.
11.	Has taken a written examination.
12.	Has completed an application for employment.

Reasons for disqualification include loss of driving privileges (e.g., for too many points from speeding violations in personal car); conviction for driving a commercial vehicle under the influence of alcohol or drugs; conviction for transportation, possession, or unlawful use of drugs while on on-duty time; conviction for leaving the scene of an accident while operating a commercial vehicle (there is a specific definition of accident); and conviction for a felony involving the use of a motor vehicle.

Physical qualifications, which may be circumvented with a waiver, include no missing foot, hand, leg, or arm. Impairment of a hand or finger which interferes with prehension or power grasping or the impairment of an arm, a foot, or a leg which interferes with the ability to perform normal tasks associated with operating a motor vehicle is also a disqualifying condition for which a waiver may be granted. Medical conditions that would disqualify a driver and that are not subject to waivers are listed in Table 3-4.

Table 3-4. Summary of Disqualifying Medical Conditions

1.	Diabetes
2.	Cardiovascular disease
3.	Respiratory dysfunction
4.	High blood pressure
5.	Rheumatic, arthritic, orthopedic, muscular, neuromuscular, or vascular disease which interferes with the ability to control or operate a motor vehicle.
6.	Mental or psychiatric disorders that interfere with the ability to drive a motor vehicle.
7.	Less than 20/40 vision in either eye (corrected), less than 70-degree peripheral vision, inability to discern the colors of traffic signals.
8.	Inability to perceive a forced whispered voice in the better ear at 5 feet (use of a hearing aid permitted).
9.	Drug usage.
10.	Current clinical diagnosis of alcoholism.

Medical examinations are required at least every 24 months, and must be performed by a qualified medical examiner (not necessarily an M.D.--could be a chiropractor, an osteopath, or anyone licensed by the state). Drivers are required to have a copy of the medical examiner's certificate on their person, but a violation of this does not put the driver out of service.

A definition of a commercial motor vehicle different from that in 390.5 is used to determine if controlled substance testing is required or allowed. The definition of commercial motor vehicle in 391.85 used to define the applicability of drug testing is the same definition used to define a commercial vehicle in 383 when describing the commercial driver's license (CDL) requirements. This definition uses a GVWR of 26,001 or more pounds.

3.1.3 Part 383-Commercial Driver's License

The goal of the commercial driver's license (CDL) was to help reduce or prevent truck and bus accidents by requiring drivers to have a single commercial vehicle driver's license. In the past, some drivers had over a dozen different driver's licenses. This allowed them to spread traffic violations over a number of different state licenses, thereby avoiding disqualification in any one state. Part 383 prohibits a commercial motor vehicle driver from having more than one commercial vehicle driver's license (383 (b) (1)). The CDL regulations use a definition of commercial motor vehicle different from that used in Part 390, which outlines the general applicability of the FMCSR.

The definition of a commercial motor vehicle in the CDL regulations is outlined in Table 3-5. If the towed vehicle has a GVWR greater than 10,000 pounds, then the GVWRs of the vehicles are added. The classification of motor vehicles requiring a CDL is broken into three groups, A, B, and C. These groups closely follow the definition in Table 3-5 and are outlined in Table 3-6.

Table 3-5. CDL Definition of Commercial Motor Vehicle (383.5)

(a)	Has a gross combination weight rating of 26,001 pounds or more, inclusive of the towed unit, with a gross vehicle weight rating of more than 10,000 pounds; or
(b)	Has a gross vehicle weight rating of 26,001 pounds or more; or
(c)	Is designed to transport 16 or more passengers, including the driver; or
(d)	Is of any size and is used in the transportation of materials that have been found to be hazardous and that the motor vehicle must be placarded to transport.

Table 3-6. Vehicle Groups as Established by FHWA (383.91)

Group	Description
A	Anv combination of vehicles with a GVWR of 26,001 or more pounds, provided the GVWR of the vehicle(s) being towed is in excess of 10,000 pounds. (Holders of a Group A license may, with the appropriate endorsements, operate all vehicles within groups B and C.)
B	Any single vehicle with a GVWR of 26,001 or more pounds, or any such vehicle towing a vehicle not in excess of 10,000 pounds GVWR.
C	Any single vehicle, or combination of vehicles, that does not meet the definition of Group A or B, but is either designed to transport 16 or more passengers, including the driver, or is placarded for hazardous materials.

In addition to obtaining a CDL for the vehicle group that includes the vehicle the driver will be operating, there are special endorsements that must be obtained to operate special types of vehicles. These include double/triple trailers (T), passenger vehicles (P), tank vehicles (N), and vehicles placarded for hazardous materials (H). There is also a restriction for drivers who are not qualified to operate trucks with air brakes (because they failed the air brake component of the knowledge test, or performed the skills test on a vehicle not equipped with air brakes).

Drivers may be disqualified for driving while under the influence of alcohol or drugs, for leaving the scene of an accident, or for the commission of a felony involving the use of a commercial motor vehicle. These offenses result in a minimum 1- to 3-year suspension. Convictions for multiple serious traffic violations (excessive speeding, reckless driving, improper lane changes, following too closely, or a violation involving a fatality) within a 3-year period will also result in driver disqualification, but for a shorter period of time. These convictions carry 60- to 120-day suspensions.

3.1.4 Part 392-Driving of Motor Vehicles

Part 392 of the FMCSR covers many common-sense rules regarding the operation of a commercial vehicle. This part requires drivers to wear corrective lenses and hearing aids while driving if they are necessary to meet the physical qualifications outlined in 39 1.4 1. This part also requires that the driver wear seat belts if they are installed on the vehicle. Part 391 requires the driver to perform a pre-trip inspection of the vehicle, but this inspection does not have to be documented (as does the post-trip inspection described in a subsequent section).

Requirements relating to the use or possession of drugs or alcohol are outlined in Part 392. A driver is not allowed to be on duty and possess, be under the influence of, or use any drug or substance that renders the driver incapable of operating a motor vehicle safely. The driver is allowed to take prescription drugs provided a doctor has determined that the drug will not impair the driver.

Part 392 also states that a driver must periodically check the securement of the cargo. Should a driver have to park on the side of the road, this part also prescribes the correct placement of reflective devices, which must be in place within 10 minutes of stopping. A summary of prohibited practices outlined in PART 392 appears in Table 3-7.

Table 3-7. Examples of Prohibited Practices in Part 392

1	Carrying unauthorized passengers.
2	Allowing an unauthorized person to drive.
3	Bus driver talking to passengers.
4	Pushing or towing buses with people on board.
5	Riding in the back of a closed truck or trailer.
6	Driving if carbon monoxide is detected in the cab.
7	Driving with an open flame cargo heater going.
8	Driving with the engine disengaged from the wheels.

3.1.5 Part 395-Hours of Service

A driver is required to keep a record of his hours of service, which refers to the amount of time a driver may be on duty and/or driving. A driver keeps a record of duty status, or log book (Figure 3-l), to document his hours of service. There are four status categories that a driver uses to describe how his time is spent: driving, on duty (not driving), off duty, and sleeper berth. There are four regulations which govern how long a driver may drive without rest or time off as well as how many hours a driver may work in a given time period. These four rules are the IO-hour rule, the 15-hour rule, the 60-hour rule, and the 70-hour rule.

The 10-hour rule states that an operator may not drive more than 10 hours following 8 consecutive hours of duty (395.3(a)). The 8 consecutive hours off duty may consist of 8 consecutive hours of off-duty and/or sleeper berth time. The 8 consecutive hours may also consist of 2 periods of sleeper berth time adding up to 8 hours, with no period less than 2 hours. If two periods of sleeper berth time are used to reset the lo-hour rule, the start time is the end of the first sleeper berth period. The 15-hour rule states that a driver may not drive after being on duty 15 hours following 8 consecutive hours off duty (395.3(a)). The same "definition" of 8 consecutive hours used in the lo-hour rule also applies to the 15-hour rule. For both regulations, the driver is only in violation if he is caught driving. For example, if a driver is on duty for 16 hours, but has not been driving the last 2 hours, he is not in violation.

The other two rules that govern the hours of service are the 60-hour rule and 70-hour rule. The 60-hour rule states that a driver may not drive after being on duty 60 hours in 7 consecutive days. The 70-hour rule states that a driver may not drive after being on duty 70 hours in any 8 consecutive days. The 70-hour rule only applies to carriers who operate vehicles 7 days a week. An example of a driver's log appears on the previous page (Figure 3-l).

Drivers are required to keep a record of the last 7 days in their possession. Entries are to be kept current to the time shown for the last duty change (395.8(f)(l)). Exceptions to hours of service regulations include drivers making local deliveries during the Christmas season, driving in adverse conditions, and drivers operating within a loo-air-mile radius of the normal work reporting location (395.1).

The FMCSRs describe in detail the requirements for automatic on-board recording devices (395.15). However, an item missing from the regulations is a standard electronic interface to an automatic recorder which would allow electronic verification of the hours of service regulations by an inspector.

3.1.6 Part 396-Inspection, Repair, and Maintenance

Part 396 of the FMCSR outlines general regulations regarding inspection, repair, and maintenance. This section of the code requires the driver to complete a post-trip inspection every day, and a copy of the post-trip inspection must be carried in the power unit (396.11). The authority to put a vehicle out of service is also granted in part 396 (396.9(c)). Section 396.17 requires the carrier to perform periodic inspections, and 396.19 outlines inspector qualifications. The qualifications of brake inspectors are also outlined in part 396 (396.25).

3.1.7 Part 397-Transport of Hazardous Materials: Driving and Parking Rules

Part 397 of the FMCSR covers some common-sense rules regarding the transport of hazardous materials. This includes rules about parking on the side of the road; smoking near a vehicle; fires; traveling through heavily populated areas; and required documents. More specific regulations regarding hazardous materials are located elsewhere in the Federal Code.

3.1.8 Part 393-Parts and Accessories for Safe Operation

Part 393 of the FMCSR includes detailed regulations covering the different parts of a truck. Included are required lighting, wiring specifications, and requirements for battery installation. Detailed brake regulations are contained in this part. Regulations on windshield, fuel systems, coupling devices, and tires are also outlined. Sleeper berth specifications, including occupant restraints, are described. Regulations regarding horns, defrosting devices, rear-view mirrors, speedometers, and other accessories are also covered. General rules for cargo securement are outlined, but CVSA has developed cargo securement guidelines that are used in conjunction with the CVSA Out-of-Service Criteria. The steering system specifications, including those for steering wheel lash, are completely described. The required emergency equipment and rear end protection are described in detail. In summary, almost every component on a truck, with the exception of the electrical system, is described in detail in this section. Most of the electrical specifications are left to SAE standards called out in the FMCSR.

3.2 CVSA Out-of-Service Criteria

The North American Uniform Out-of-Service Criteria developed by the Commercial Vehicle Safety Alliance describe critical inspection items for the driver, vehicle, cargo, and hazardous materials. If an out-of-service condition is met, the driver and/or vehicle will be placed out of service until corrective action is completed. The criteria are updated each year at the an

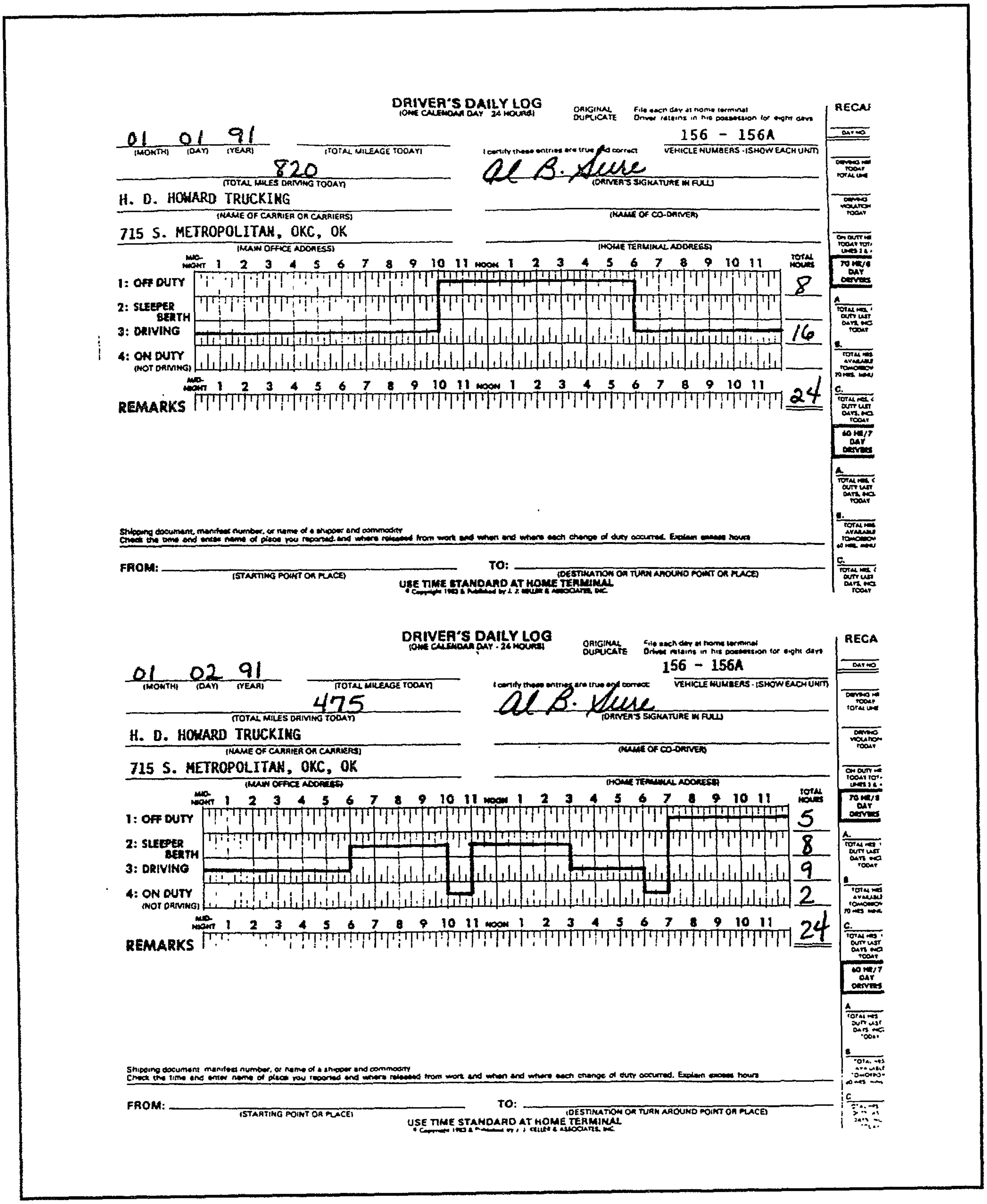


Figure 3-1. Driver's daily log book.

nual CVSA fall meeting. Inspectors are instructed to be no more strict or lenient than the Out-of-Service (O.O.S.) Criteria specify when placing a truck out of service. The inspection items for the driver are summarized in Table 3-8. The critical inspection items for the vehicle are listed in Table 3-9.

Table 3-8. Summary of Critical O.O.S. Items for Driver

1.	Driver's age
2.	Operator's license
3.	CDL
4.	Waiver of physical disqualification
5.	Sickness or fatigue
6.	Driver disqualification
7.	Use of drugs or other substances
8.	Use of intoxicating beverages
9.	Driver's record of duty status

Table 3-9. Summary of Critical O.O.S. Items for Vehicle

1.	Brake system
2.	Coupling devices
3.	Exhaust system
4.	Frame
5.	Fuel system
6.	Lighting devices
7.	Safe loading
8.	Steering mechanism
9.	Suspension
10.	Tires
11.	Van and open-top trailer bodies
12.	Wheels and rims
13.	Windshield wipers
14.	Windshields
15.	Emergency exits (buses)

A driver or vehicle may be in violation of the Federal Code and ineligible to drive a commercial motor vehicle, but the driver and/or vehicle may not be placed out of service unless one of the Out-of-Service Criteria is met. For example, a one-eyed, deaf driver who does not speak English, but who does possess a CDL and a medical certificate, cannot be placed out of service even though he is not qualified to operate a motor vehicle.

3.3 North American Standard Inspection

During the CVSA 2-week class, a recommended North American Standard Inspection Procedure is outlined. The basic flow of the inspection process starts with meeting the driver and inspecting the front of the vehicle. The inspector then moves around the vehicle starting with the front left and finishing with the front right, going under the vehicle several times to inspect different areas. If a pit is available, the undercarriage of the vehicle can be inspected easily all at once. The inspection process concludes with finishing the paperwork, explaining the violations to the driver, and then taking the appropriate enforcement action (if any) and applying the appropriate CVSA decals. Sometimes inspections are done in teams of two inspectors, with one person taking notes while the other person is inspecting the vehicle. The complete Level I inspection can take between 30 minutes and 1 hour (average time is 39 minutes), depending on the size and condition of the tractor-trailer rig. For more details on the North American Standard Inspection Procedure, refer to Table 3-10.

Table 3-10. Recommended North American Standard Inspection Procedure.

STEP 1 CHOOSE THE INSPECTION SITE

- SELECT A SAFE LOCATION

  If possible, find a paved, level surface away from traffic. Avoid hills, curves, and construction sites.

  As you approach the vehicle for the first time, look for placards or other signs of hazardous materials. If such cargo is present, always look for leaks or spills.

STEP 2 GREET THE DRIVER

Make initial contact with the driver.

Check for seat belt usage and condition.

Check for possible illegal presence of alcohol or drugs.

Explain the inspection procedure to the driver.

Table 3-10. Recommended North American Standard Inspection Procedure (continued)

STEP 3 PREPARE THE VEHICLE AND DRIVER

Instruct the driver to remain at the controls.

Have the driver turn the engine off. (Make sure you allow for a cool-down period for turbocharged engines.)

Place chock blocks in position beginning on the driver's side, one in front and one behind the drive axle tires or between the axles.

Advise the driver that the wheels have been chocked.

Have the driver place the transmission in neutral and release all brakes.

Advise the driver in the use of hand signals (lamps and brakes).

An inspection form or note pad can be used to record violations during the inspection.

STEP 4 CHECK DRIVER'S DOCUMENTS

- COLLECT DOCUMENTS BEFORE INSPECTIONS
  All documents should be collected from the driver BEFORE beginning the vehicle inspection. This will prevent the driver from altering the log book while you are under the vehicle, and discourage him/her from leaving the inspection scene until you are finished.
- DRIVER'S LICENSE
  Appropriate license for the vehicle being driven.
  Expiration date, birth date, status check.
- MEDICAL EXAMINER'S CERTIFICATE
  Expiration date, corrective lenses, hearing aid, signature, waiver.
  If Canadian driver has a valid license, he has passed a physical exam.
- RECORD OF DUTY STATUS
  Updated to last change of duty status, legible handwriting, today's date, past 7 days recorded, mileage, driving time, on-duty time, signature, vehicle numbers, remarks.

  Check for written authorization if using an on-board electronic recording device.
- DRIVER VEHICLE INSPECTION REPORT
  Vehicle I.D., defects, signatures.
- Documentation of a periodic (annual) inspection.

STEP 5 CHECK FOR PRESENCE OF HAZARDOUS MATERIALS/DANGEROUS GOODS

- SHIPPING PAPERS/BILL OF LADING
  Check for listings of hazardous materials indicated by the first entry, an "X" in the H.M. column, or a contrasting color. Papers must be within arm's reach and visible.
- PLACARDS
  As mentioned above, check for the presence or placards, but use caution even if none are posted.
- LEAKS, SPILLS, NONSECURE CARGO
  When hazardous materials are present, be ESPECIALLY careful with leaks, spills, or nonsecure cargo.
- MARKINGS
  Cargo tanks and portable tanks will display markings on an orange panel or placard. They indicate the I.D. number of the hazardous materials. There are exceptions to this rule.
- LABELS
  When containers are visible, labels will identify the hazardous materials. There are exceptions to this rule.
- If poisons and edible materials are loaded on the same vehicle, immediately notify the nearest office of the Food and Drug Administration.

Table 3-10. Recommended North American Standard Inspection Procedure (continued)

STEP 6 INSIDE CAB

- STEERING LASH
  Turn the steering wheel in one direction until the tires just begin to pivot.

  Vehicles with power steering may require the engine running to turn the wheel.

  Place a mark on the steering wheel, then hold the marker at that point. Turn to wheel in the other direction until the tires again start to move.

  Measure the distance between the two points. The amount of allowable lash varies with the diameter of the steering wheel.

  Compare that measurement to the regulations and to the current Out-of-Service Criteria.

  Check steering column for nonsecure attachment.

STEP 7 FRONT OF TRACTOR

- HEAD LAMPS, TURN SIGNALS, EMERGENCY FLASHERS
  Check for improper color and operation.

- WINDSHIELD WIPERS
  Check for improper operation.

  Two wipers are required unless one can clean the driver's field of vision.

- WINDSHIELD
  Check for cracks or other damage.

  Check for decals or stickers in field of vision.

STEP 8 STEERING AXLE

INFORM THE DRIVER THAT YOU ARE GOING UNDER THE VEHICLE, AND TO LISTEN FOR YOUR INSTRUCTIONS.

- STEERING SYSTEM (BOTH SIDES)
  Check for loose, worn, bent, damaged, or missing parts.

  Instruct the driver to rock the steering wheel, and check key components: front axle beam, gear box, pitman arm, drag link, tie rod, tie rod ends.

- FRONT SUSPENSION (BOTH SIDES)
  Check for indications of misaligned, shifted, or cracked springs, loosened shackles, missing bolts, spring hangers nonsecure at frame, and cracked or loose U-bolts.

  Any nonsecure axle positioning parts, and signs of axle misalignment.

- FRONT BRAKES (BOTH SIDES)
  Check for missing, nonfunctioning, loose, contaminated, or cracked parts on the brake system, such as brake drum, shoes, rotors, pads, linings, brake chamber, chamber mounting, push rods, or slack adjusters.

  Check for "s" cam flip-over.

  Be alert for audible air leaks around brake components and lines.

  With the brakes released, mark the brake chamber push rod at a point where the push rod exits the brake chamber. Identify or measure brake chamber size. Mark the push rods on both sides at this time; all push rods will be measured in Step 21.

Table 3-10. Recommended North American Standard Inspection Procedure (continued)

- FRONT AXLE
  Check for cracks, welds, and obvious misalignment.

- FRAME and FRAME ASSEMBLY
  Check for cracks, or any defect that may lead to the collapse of the frame.

STEP 9 LEFT FRONT SIDE OF TRACTOR

- LEFT FRONT WHEEL AND RIM
  Check for cracks, unseated locking rings, broken or missing lugs, studs or clamps. Bent or cracked rims, Check for “bleeding” rust stains.

  Check for loose or damaged lug nuts and elongated stud holes.

- LEFT FRONT TIRE
  Check for improper inflation, serious cuts, bulges.

  Check tread wear and measure major tread groove depth.

  Inspect sidewall for defects.

  Check for exposed fabric or cord.

  Radial and bias tires should not be mixed on the steering axle.

STEP 10 LEFT SADDLE TANK AREA

- LEFT FUEL TANK(S)
  Check for nonsecure mounting, leaks, or other damage. Verify that the fuel crossover line is secure. Check for nonsecure cap(s).

  Check ground below tank for signs of leaking fuel.

- TRACTOR FRAME
  Check frame rails and crossmembers on the tractor just behind the cab, looking for cracks, bends, or excessive corrosion.

- EXHAUST SYSTEM
  Check for nonsecure mounting, leaks (under the cab), exhaust contacted by fuel or air lines or electrical wires.

  Check for carbon deposits around seams and clamps.

STEP 11 TRAILER FRONT

- AIR AND ELECTRICAL LINES
  Lines between tractor and trailer should be suspended and free or tangles or crimps.

  They should have sufficient slack to allow the vehicle to turn.

  Inspect line connections for proper seating.

  Listen for audible air leaks.

- FRONT END PROTECTION
  Check for height requirements.

  There are many exceptions to the front end protection regulations; be able to recognize these.

Table 3-10. Recommended North American Standard Inspection Procedure (continued)

STEP 12 LEFT REAR TRACTOR AREA

- WHEELS, RIMS, AND TIRES
  Inspect as described in Step 9.

  Check inside tire of dual for inflation and general condition.

  Tires should be evenly matched (same circumference) on dual wheels.

  Without placing yourself between the tires on tandem axles, check for debris between the tires.

  Check for duals touching one another.

- LOWER FIFTH WHEEL
  Check for nonsecure mounting to the frame or any missing or damaged parts.

  Check for any visible space between the upper and lower fifth wheel plates.

  Verify that the locking jaws are around the shank and not the head of the kingpin,

  Verify that the release lever is seated properly, and that the safety latch is engaged.

- UPPER FIFTH WHEEL
  Check for any damage to the weight-bearing plate (and its supports) on the trailer.

  Check kingpin condition.

- SLIDING FIFTH WHEEL
  Check for proper engagement of locking mechanism (teeth fully engaged on rail).

  Check for worn or missing parts, making sure that the position does not allow the tractor frame rails to contact the landing gear during turns.

  INFORM THE DRIVER THAT YOU ARE GOING UNDER THE VEHICLE. ENTER THE UNDERCARRIAGE IN VIEW OF THE DRIVER.

- SUSPENSION (BOTH SIDES)
  Inspect as described in Step 8.

  Check for deflated or leaking air suspension systems.

- BRAKES (BOTH SIDES)
  Inspect brakes as described in Step 8.

  With brakes released, mark the push rods.

STEP 13 LEFT SIDE OF TRAILER

- FRAME AND BODY
  Check for corrosion fatigue, missing crossmembers, cracks, missing or defective body parts.

- CARGO SECUREMENT
  Check for improper blocking or bracing, and unsecure chains or straps. Verify end gates are secured in stake pockets. Check tarp or canvas. Verify number, size, and condition of tie-downs. Check Out-of-Service Criteria.

Table 3-10. Recommended North American Standard Inspection Procedure (continued)

STEP 14 LEFT REAR TRAILER WHEELS

- WHEELS, RIMS, AND TIRES
  Inspect as described in Step 9.

- SLIDING TANDEM
  Check for misalignment and position. Look for damaged, worn, or missing parts. Check locking mechanism; teeth of locking mechanism must fully mesh with those of the rail secured to the frame.

  INFORM THE DRIVER THAT YOU ARE GOING UNDER THE VEHICLE. ENTER THE UNDERCARRIAGE IN VIEW OF THE DRIVER.

- SUSPENSION (BOTH SIDES)
  inspect as described in Step 8.

- BRAKES (BOTH SIDES)
  Inspect as described in Step 8.

  With brakes released, mark push rod.

STEP 15 REAR OF TRAILER

- TAIL, STOP, AND TURN LAMPS, AND EMERGENCY FLASHERS
  Check for improper color and operation. This will require the use of the hang signals explained to the driver earlier.

- CARGO SECUREMENT
  Inspect as described in Step 13.

  Also check tailboard security. Verify end gates are secured in stake pockets.

  Check both sides of trailer to ensure protection of cargo from shifting and failing.

  Verify that rear doors are securely closed.

  Check for and inspect rear end protection.

STEP 16 RIGHT REAR TRAILER WHEELS

- WHEELS, RIMS, AND TIRES
  Inspect as described in Step'9.

- SLIDING TANDEM
  Inspect as described in Step 14.

STEP 17 RIGHT SIDE OF TRAILER

- FRAME AND BODY
  Inspect as described in Step 13.

- CARGO SECUREMENT
  Inspect as described in Step 13.

- SPARE TIRES
  Check for nonsecure mounting.

Table 3-10. Recommended North American Standard Inspection Procedure (continued)

STEP 18 RIGHT REAR TRACTOR AREA

- WHEELS, RIMS, AND TIRES
  Inspect as described in Step 9.

- UPPER, LOWER, SLIDING FIFTH WHEEL
  Inspect as described in Step 12.

STEP 19 RIGHT SADDLE TANK AREA

- RIGHT FUEL TANK(S)
  Inspect as described in Step 10.

- TRACTOR FRAME
  Inspect as described in Step 10.

- EXHAUST SYSTEM
  Inspect as described in Step 10.

STEP 20 RIGHT FRONT SIDE OF TRACTOR

- WHEELS, RIMS, AND TIRES
  Inspect as described in Step 9.

STEP 21 BRAKE ADJUSTMENT CHECK

- INSTRUCT THE DRIVER
  Proceed to the driver's door, and have driver make a full brake application and hold in the applied position with the reservoir air pressure at approximately 90 p.s.i.

  INFORM THE DRIVER THAT YOU ARE GOING UNDER THE VEHICLE. ENTER THE UNDERCARRIAGE IN VIEW OF THE DRIVER.

- MEASURE PUSH ROD TRAVEL (ALL BRAKES)
  While the brakes are applied, move around the vehicle and measure the distance of push rod travel at each chamber.

  Again, listen for leaks as you move around the vehicle.

  Write down each push rod measurement, and compare them to the regulations and Out-of-Service Criteria for the appropriate size and type of brake chamber.

STEP 22 FIFTH WHEEL MOVEMENT CHECK

- USE CAUTION
  If conducted improperly, this method of checking for fifth wheel movement can result in serious damage to the vehicle. Use caution and instruct the driver carefully.
- PREPARE THE VEHICLE AND DRIVER
  Have the driver put the vehicle in gear, release the service brakes, and apply the trailer brakes.

  Remove the wheel chocks and have the driver start the vehicle.

  Carefully explain the procedure to the driver. Tell him/her to GENTLY rock the tractor as you watch the fifth wheel.

- CONDUCT THE PROCEDURE
  As the tractor rocks, watch for movement between the mounting components and frame, pivot pin, and bracket, and the upper and lower fifth wheel halves.

Table 3-10. Recommended North American Standard Inspection Procedure (continued)

STEP 23 AIR LOSS RATE

- WHEN TO CONDUCT THE TEST
  If you heard an air leak at any point in the inspection, you should now check the vehicle's air loss rate.

- CONDUCT THE PROCEDURE
  Have the driver run the engine at idle, then apply and hold the service brake.

  Observe the air reservoir pressure gauge on the dash. Have the driver pump the pressure down to 80 p.s.i. Compressors do not activate until system pressure drops below a certain level. At about 80 p.s.i., most compressors should be operating.

  Air pressure should be maintained or increased. A drop in pressure indicates a serious air leak in the brake system, and the vehicle should be placed out of service.

STEP 24 LOW AIR PRESSURE WARNING DEVICE

- TEST THE WARNING DEVICE
  The ignition must be in the "on" position for this test.

  Instruct the driver to deplete the air supply by pumping the foot valve until the low air pressure warning device activates.

  Observe the gauges on the dash. The low air pressure warning must activate at a minimum of 1/2 the compressor governor cutout pressure, i.e., normally 55 p.s.i. or above.

STEP 25 TRACTOR PROTECTION VALVE

- BE SURE THAT WHEELS ARE PROPERLY CHOCKED

- CONDUCT THE TEST
  Instruct the driver to release all brakes. Make sure air pressure is at the normal operating level.

  Instruct the driver to get out of the vehicle and give him the following instructions:

  - DISCONNECT BOTH AIR LINES AT THE GLAD HANDS AND LAY THEM DOWN ON THE FRAME. (Be sure to tell the driver to be careful, as high-pressure air and possibly water and oil may come out of the air lines.) After the lines are disconnected, the air coming out of the supply emergency line may shut off almost immediately, or may still bleed out. Either is acceptable.

  - RETURN TO THE TRUCK CAB AND MAKE A FULL BRAKE APPLICATION. While the driver does this, check the service glad hand to make sure no air is coming out of the service line. If air comes out of the service line and air is still coming out of the supply emergency line, ask the driver to maintain the brake application until the air stops. Most of the time, the air will stop when the air gauge reads about 60 p.s.i.

  - AFTER THE AIR STOPS, MAKE A SECOND FULL BRAKE APPLICATION. No air should come out of either line. <u>If air is still escaping the tractor protection valve is malfunctioning</u>

STEP 26 TRAILER EMERGENCY BRAKES

- While the air lines are detached from the trailer at the glad hands, check the glad hand connection on the trailer to make sure that air is not bleeding back from the trailer. Air escaping from the trailer air lines at the glad hand connection indicates a malfunctioning of the trailer emergency braking system.

Table 3-10. Recommended North American Standard Inspection Procedure (concluded)

STEP 27 COMPLETE THE INSPECTION

- COMPLETE PAPER WORK
  Complete inspection form and other paperwork, as required. Make sure to list all violations. Then refer to the Out-of-Service Criteria to determine if these violations should cause the driver or vehicle to be placed out of service.

- CONCLUDE WITH THE DRIVER
  Explain any violations to the driver. Take appropriate enforcement action, if necessary.

- OUT-OF-SERVICE PROCEDURES
  Follow the appropriate procedure when placing a driver or vehicle out of service.

- APPLY C.V.S.A. DECAL
  If the vehicle(s) passed the inspection, remove or cover any old C.V.S.A. decals and apply the correct C.V.S.A. decal(s).

3.4 European Inspection

European inspection practices are similar to those in North America in terms of the inspection items, but inspections differ from country to country. In the United Kingdom (UK), commercial vehicles are referred to as goods vehicles. A list of inspections for the UK published in the 1984 edition of the ***Goods Vehicle Tester's*** Manual, by the Department of Transport, is included as Table 3-l 1. Inspections in the UK follow an annual inspection procedure (Shilton and Noon, 1993). Goods vehicles are prepared for annual inspection by an operator or carrier. The preparation usually involves taking the vehicle out of service for at least an entire day. Official Testing Stations are at fixed site locations where all inspections are conducted. Though European inspection procedures vary from country to country, member nations of the European Economic Community (EEC) accept certification of inspection from other member countries.

Random roadside inspections are not performed in the UK as they are in North America. Random inspections in the UK would probably be equivalent to a Level III inspection. A goods vehicle is stopped by an enforcement officer, papers are examined, and, if applicable, tachograph operation is examined. A tachograph is an electromechanical device on goods vehicles that records hours of operation, speed, and engine RPM onto a circular paper using a stylus. A tachograph card from Germany appears in Figure 3-2. Proper operation of the tachograph is inspected, including proper paper supply. Significant differences between North American and EEC inspections include the use of brake dynamometers and the use and checking of tachographs.

3.5 Shortcomings

The following are shortcomings noted in the inspection process that were gathered as data for this report:

- It is very difficult and unsafe to conduct a thorough Level I inspection in bad weather or at night. For this reason, states tend to waive Level I inspections under these conditions. Some states do have enclosed inspection stations, but the typical inspection station does not have any protection from weather or a pit to facilitate inspecting the undercarriage of a vehicle. A critical issue for night inspection is lighting.

- The inspection process itself, although oriented toward increasing truck safety, is really an enforcement task. Inspectors are enforcing the FMCSR and using the Out-of-Service Criteria to determine when trucks and/or drivers are to be placed out of service. CVSA is working to standardize the truck inspection with the North American Standard Inspection Procedure and the Out-of-Service Criteria, but the policy of giving warnings vs. violations carrying fines is left up to the individual states. Therefore, some states use violations as a source of revenue, while other states give out mostly warnings to let the driver know he needs to make repairs. CVSA is working for standard fines, but the current system does not provide uniform incentives (fines) for becoming compliant, even though the inspection itself is becoming standard.

- There exists a problem with inspection capacity regarding staff and space. Staff and space limitations determine the number of trucks that can be inspected in a reasonable manner. When inspections crews are occupied, all vehicles except those having visibly gross violations or incorrect paperwork are allowed to pass through.

Table 3-11. List of Inspections for Goods Vehicles (UK Department of Transport, 1984)

No.	Title	No.	Title
1	Ministry Plate Position	38	Service Brake Operation
2	Ministry Plate Details	39	Hand Operated Brake Control Valves
3	Seat Belts	40	*Not allocated*
4	*Not allocated*	41	Condition of Chassis
5	Smoke Emission	42	Electrical Wiring and Equipment
6	Road Wheels and Hubs	43	Engine and Transmission Mounting
7	Size and Type of Tyres	44	Oil Leaks
8	Condition of Tyres	45	Fuel Tank and System
9	Side Guards, Rear Under-Run Device and Bumper Bars	46	Exhaust System
10	Spare Wheel Carrier	47	Not *allocated*
11	Trailer Coupling	48	Suspension Pins and Bushes
12	Coupling on Trailer	49	Suspension Spring Units and Linkages
13	Trailer Landing Legs	50	Attachment of Spring Units, Linkages and Sub-Frames
14	Condition of Wings	51	Shock Absorbers (Dampers)
15	Cab Security	52	*Not allocated*
16	Cab Doors	53	Stub Axles/Wheel Bearings
17	Cab Floor and Steps	54	Steering Linkage
18	Driving Seat	55	Steering Gear
19	Security of Body	56	Power Steering
20	Condition of Body	57	Transmission
21	*Not allocated*	58	*Not allocated*
22	Mirrors	59	Mechanical Brake Components
23	View of Front	60	Brake Actuators
24	Condition of Glass or Other Transparent material	61	Braking Systems and Components
25	Windscreen Wipers and Washers	62	Rear Markings
26	Speedometer	63	Front Positional Lamps
27	Audible Warning (Horn)	64	Rear Positional Lamps and Rear Fog Lamps
28	Driving Controls	65	Reflectors
29	Tachograph	66	Direction Indicators
30	Play at Steering Wheel	67	Aim of Headlamps
31	Steering Wheel	68	Headlamps .
32	Steering Column	69	Stop Lamps
33	*Not allocated*	70	Trailer Parking Brake
34	Pressure/Vacuum Warning	71	Service Brake Performance
35	Buildup of Pressure/Vacuum	72	Secondary Brake Performance
36	Hand Lever Operating Mechanical Braking Systems (Except Trailers)	73	Parking Brake Performance
		74	*Not allocated*
37	Service Brake Pedal	75	*Not allocated*

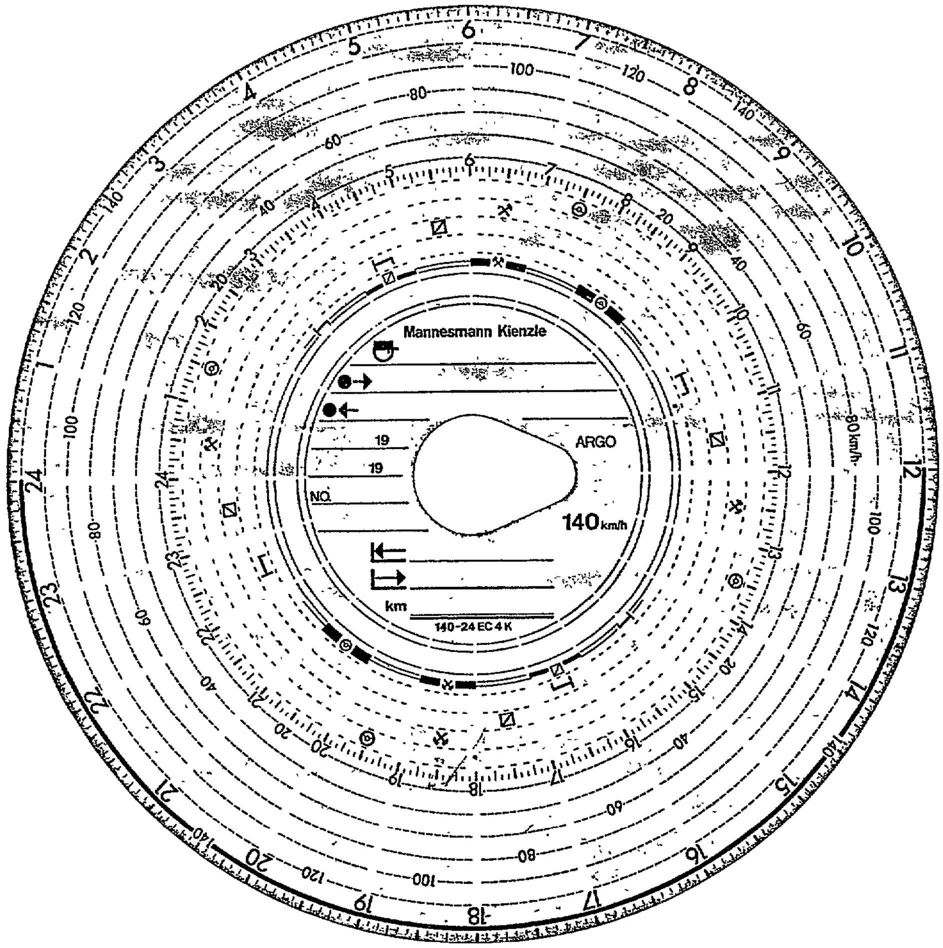


Figure 3-2. Tachograph card.

4. Review of Current Technologies

This section reviews current technologies being tested to improve the inspection process as well as mature technologies that could be implemented easily using system integration techniques. Section 4.1 discusses automated brake inspection technologies, including dynamometers and infrared systems. Section 4.2 discusses computer systems being used to reduce paperwork. This includes pen-based computers and laptops. Section 4.3 discusses a novel voice recognition system being tested by the state of Nebraska. Section 4.4 describes special paints being developed to visually detect thermal cracks. Section 4.5 discusses "smart cards" and PCMCIA (Personal Computer Memory Card International Association) cards. Section 4.6 reviews the capabilities of current transponder systems, while section 4.7 summarizes related IVHS corridor programs.

4.1 Brake Inspection and Testing

Current brake tests in North American standard inspections rely on visual inspection of the brake components and measurement of push-rod travel (also called air stroke measurement). Air stroke measurement consists of marking a push rod, applying the brake at a specified pressure (generally 90 to 100 psi) and measuring the resulting push-rod travel.

In North American commercial vehicle inspections, four types of brake testers are emerging as available brake assessment technologies that can potentially replace or complement air-stroke measurement. These devices are roller dynamometers, skid plates, decelerometers, and infrared systems. These technologies, whose basic characteristics are comparatively evaluated with each other and conventional techniques in Table 4-1, are discussed in detail below.

4.1.1 Roller Dynamometer Testing

Roller brake dynamometers (also called "roller testers") are used to measure brake torque. Roller testing involves rotating a wheel and evaluating brake axle effectiveness. Brake effectiveness is measured by a vehicle's ability to brake the rotating wheels.

A schematic diagram of dynamometer testing is provided in Figure 4-l. A vehicle drives into the testing position and brakes are tested by contact rollers driving the wheel. Stopping performance is based on a brake response to the roller driving force.

Table 4-1. Principal Approaches to Brake Testing (Vaughn, 1993)

Type	Identify Faults?	Repeat-ability?	Mobile?	Capital Cost	Quick?
Road Test	Poor	Poor	Yes	Low-Moderate	No
Air-Stroke	Good	Very Good	Yes	Low	No
Skid Plates	Poor-Good	Poor	No	Moderate-High	Yes
Dynamometer (fixed)	Very Good	Very Good	No	Moderate-High	Yes
Dynamometer (port.)	Very Good	Very Good	Yes	High-Very High	Yes

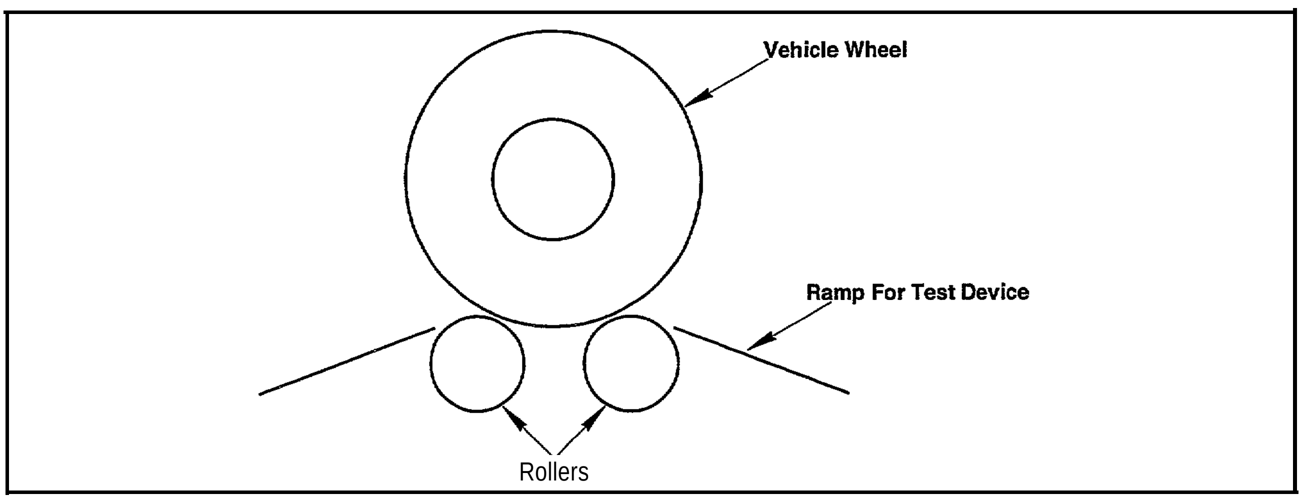


Figure 4-1. Dynamometer tester schematic.

Both fixed and portable roller dynamometers are available. Fixed systems are already used in European inspections (UK Department of Transport, 1984). A variation on this system uses the in-ground fixed roller brake test with tie-down straps for unladen vehicle testing. These tests allow brake system performance to be measured including load simulation capabilities for unladen vehicles.

Portable roller brake dynamometers were originally designed in Australia, where they are currently being used (Vaughn, 1993). An enhanced version of these portable systems is being evaluated in North America by the National Highway Traffic Safety Administration (NHTSA) (Radlinski, 1992). Other designs of the portable roller brake tester now exist (e.g., the Hicklin engineering model) and are being evaluated. These roller blade dynamometer variations emphasize a portable design, making them better suited for North American Commercial Vehicle Operations.

Portable brake dynamometers have several advantages as a testing tool. One basic advantage is that a driver's cooperation is not required in systems that use a computer to conduct the test. This eliminates variations in the data as well as deceptive techniques to pass the test. Because the device is portable, it can be easily deployed, allowing random inspections. Both NHTSA and Hicklin versions of the portable roller brake tester use microcomputers but differ in their portable design.

4.1.2 Skid Plate Testing

Skid plate testers evaluate the brake force exerted on in-ground plates. To perform a test, the vehicle must travel at a designated speed and the brakes must be applied as the wheels travel over in-ground skid plates. Forces created between vehicle and plate surfaces are a function of vehicle dynamics and brake effectiveness. These forces can be used to evaluate braking ability. Figure 4-2 is a schematic of the skid plate test process. One basic advantage of skid plates over air stroke measurement or infrared techniques is that skid plates provide performance assessments.

Skid plate testing requires the assistance of a skilled driver. Test results are not repeatable. In-ground skid plates are usually not portable and therefore would be difficult to deploy randomly. Skid plate tests, because they are dynamic, are more dangerous than static roller brake dynamometer tests or air stroke measurement (Vaughn, 1993).

Currently, versions of skid plate testers are being evaluated by NHTSA at the Transportation Research Center (Radlinski, 1993). One of the designs is by Hunter engineering. These systems were developed in the U.S., but to the knowledge of the Sandia investigators, these systems are not being used as a part of any inspection process.

4.1.3 Deceleration Testing

Deceleration testers are simply attached to a vehicle and measure deceleration as the vehicle stops. This information is processed and used to assess a vehicle's braking ability. The advantages to these tests are that they could be relatively inexpensive, and they do not require extensive hardware test fixtures. However, safety risks associated with dynamic vehicle testing would be involved.

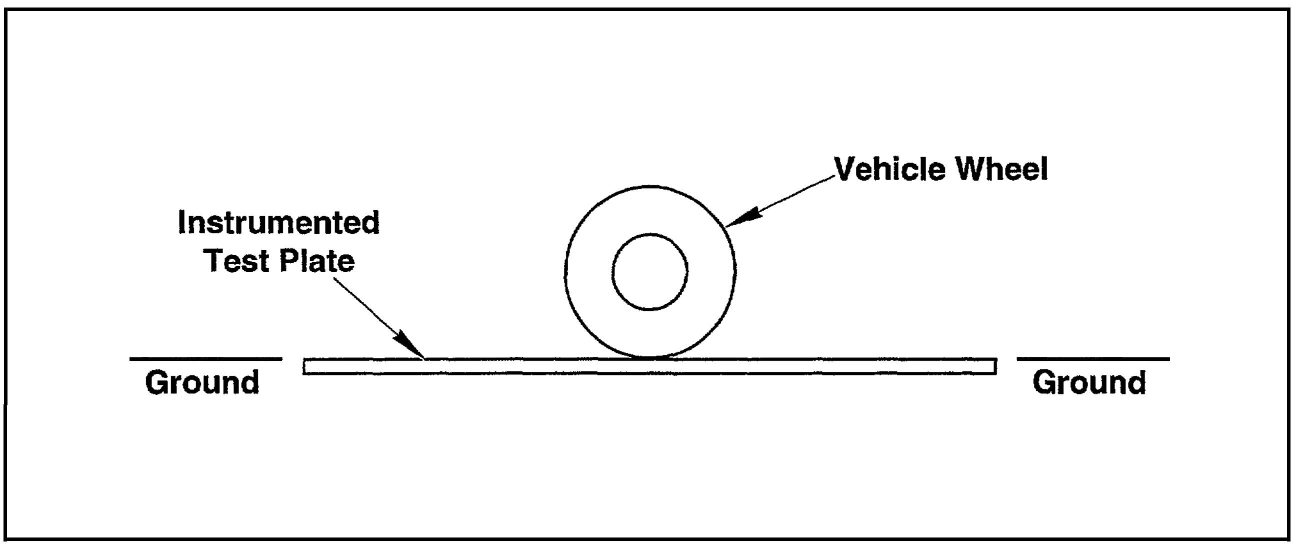


Figure 4-2. Skid plate tester schema tic.

Decelerometers are used in European inspections when a vehicle cannot be tested using a roller brake device tester. Deceleration testing is used in Europe (UK Department of Transportation, 1984) but is not used in North America.

4.1.4 Infrared Testing

Infrared test designs are being considered for brake system assessment. Infrared tests are based on the relationship between heat and kinetic energy. Test sensor devices are stimulated by heat sources and could detect out-of-adjustment brake systems by identifying heat variations. The amount of kinetic energy being removed from a vehicle system by a braking device is directly related to increased heat associated with that device. By comparing a vehicle's individual brake temperatures or heat variations, brake performance can be analyzed. Figure 4-3 shows how an infrared test would work. In this case, an out-of-adjustment brake that does not perform properly would be relatively cool, while a correctly adjusted brake would be hotter because it is performing more work.

The advantage of infrared test systems is that they can be randomly deployed and designed for various testing scenarios. These systems, however, do not provide a direct measure of braking capability like roller brake testers or skid plates. Infrared techniques, like conventional air stroke measurements, provide only an indirect assessment of brake performance. The major benefit from infrared testing is that these tests may be able to provide brake system assessments without requiring that the vehicle stop.

In 1980, an infrared system was developed for automatically testing brakes on railcars (Spaulding et al., 1980). The system consisted of a reaction rail, infrared detectors, a car counter, and support electronics and hardware. The test results were promising, but the single reaction rail was inadequate and the study recommended using two rails in further studies. There were also problems with the infrared sensor detecting unwanted thermal effects. The study did conclude that the technique of measuring rail forces along with brake temperature was a plausible method for determining railcar brake performance.

Infrared systems previously used in other applications such as assessment of road conditions are currently being considered for brake assessment (Henry, 1993). Small hand-held camera-like devices are available for infrared assessments. The applicability of infrared technology to commercial vehicle inspection is still under evaluation. Table 4-2 shows the Sandia investigators' assessment of infrared testing. This assessment can be compared with the assessment of other brake testing technologies provided by Vaughn (1993) (Table 4-1).

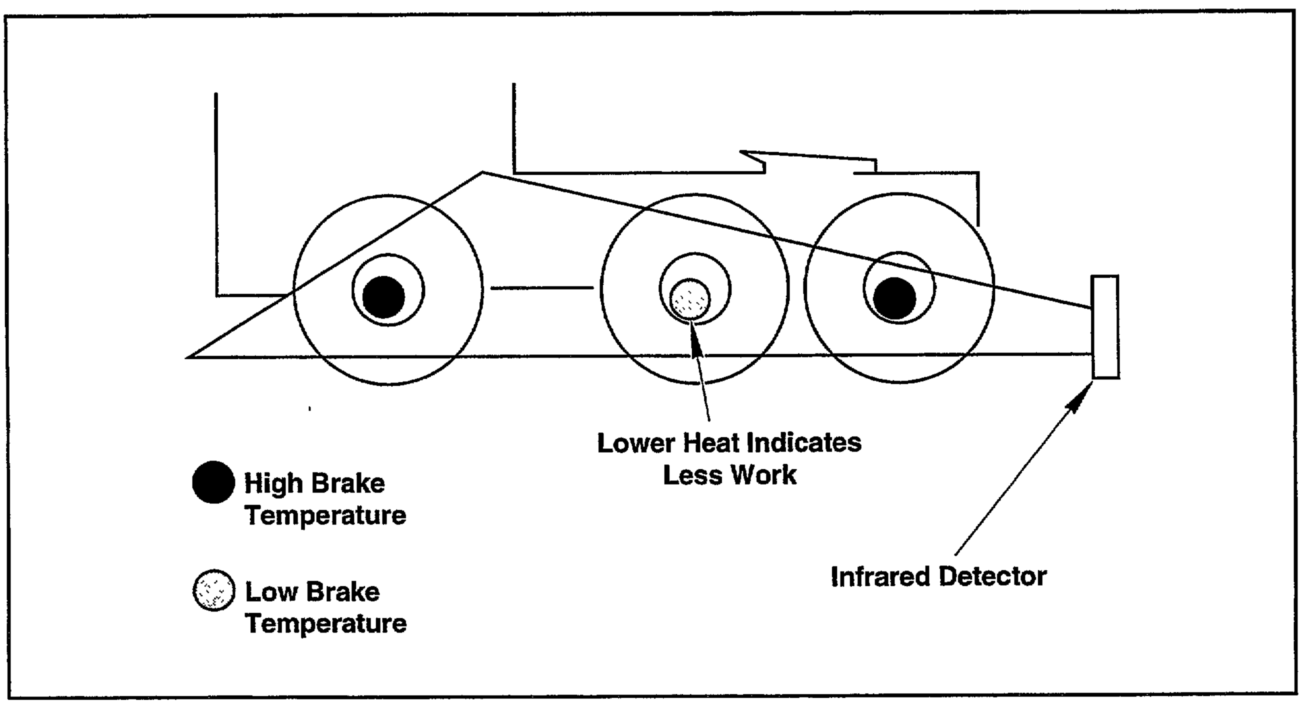


Figure 4-3. Infrared test schematic.

Table 4-2. Infrared Brake Testing

Identify Faults?	Repeatability?	Mobile?	Capital Cost	Quick?
Good	Very Good	Yes	Not Available	Yes

4.1.5 Evaluation of Commercially Available Technologies

Several types of brake testers are now commercially available technologies. The Motor Carrier Safety Assistance Program (MCSAP) is funding evaluation of innovative brake testing devices (Hagan, 1993). Commercial devices are tested and evaluated at the East Liberty, OH Transportation Research Center; recommendations are then made to the manufacturer regarding desired improvements. After the company has a satisfactory device, field testing is conducted. Products, technologies, and the companies developing them are listed in Table 4-3.

Table 4-3. Summary of MCSAP-Funded Brake Tester Research

Company	Technology	Test Site
Australian Government	Portable Dyno	OH, WV
Control Devices	Infrared	OR
Hicklin Engineering	Portable Dyno	IA, CO
Hunter Engineering	Skid Plate	MN

The Australian portable dyno is probably the furthest along in testing, along with Control Device's Renstar system. If the devices pass field testing for about one year and become certified, MCSAP will pick up 80 percent of the cost if states wish to purchase one (Hagan, 1993).

4.2 Notepad and Pen Computers

The Idaho State Police are field testing a GridPad pen computer in early July (1993) to help inspectors prepare inspection reports (Sammons, 1993; DOT, 1993). The screen on the computer will look very similar to an Idaho Inspection Form. The special pen that is sensed by the screen has two modes of operation: character identification and keypad operation. In the character identification mode, the computer recognizes printed handwritten characters on the screen and converts them to typewritten symbols. This mode has some problems discerning messy writing, so it will not be used for the field testing. The other method allows data entry by typing on a keypad with the special pen. This method of data entry will be used to enter the carrier and driver information. Other information, like violations and the inspection location, are stored in the computer and can be selected from a menu. The officer's/driver's signatures will be stored as signatures. A printer in the car will be used to print out a copy of the inspection form for the driver. The results of the inspections can be sent electronically via a modem to a central database. There the inspection results are reviewed before being entered in SAFETYNET.

There are two places for the officer to record comments: a space after each violation and a space for an officer to record comments that do not go on the form but are stored in a database on the hard disk of the computer. These notes are meant mostly to aid in court cases. After two months of field testing the Grid computer, Idaho plans to test five other models to get an idea of the relative performance of different brands. The software for the pen computer was developed at Boise State University in Idaho.

Alabama is also testing the GridPad computer to aid inspectors (DOT, 1993; Holt, 1993; Marzano, 1993). The software for the Alabama project is being developed by Technology Solutions, Inc., and should be ready for field testing in late July 1993. The Alabama program is attempting to use the handwriting recognition capability of the computer, in addition to the keypad capability, to enter information. The initial phase of testing will last six months. Alabama opted not to use modems to transfer data from the GridPads. Instead, solid-state memory cards are mailed in to enter the SAFETYNET data, a form of "sneakernet." Alabama is also using printers in cars to print out the inspection form for the driver. Alabama currently does not plan to test computers from other vendors in the near future.

California has a similar pen-based initiative, and is the farthest along in testing (Khoygani, 1993). The California system is also based on a GridPad computer. The field testing, which has been going on since early June, involves the use of four units at an inspection station in Cordellia, CA. The inspectors use the pen-based system, capable of print recognition, to record inspection results. The information entered into the GridPad is transferred to the office computer electronically via a modem. In the office, the inspector can review the information, make changes or additions, and then print out the inspection form for the driver's signature. The database constructed by the program on the PC is directly compatible with and easily transferred to the SAFETYNET database. The California system can also be used by inspectors conducting roadside inspections and operating out of cars. After the field testing in Idaho, California, and Alabama has been completed, some of the advantages and disadvantages of using pen-based computing for inspections will have been identified.

The state of New Hampshire has been using laptops for truck inspections for the last 3 years [Peaseley, 1993]. Originally, they were using a PC version of the SAFETYNET program. For the last 9 months, they have been using a program developed by Wayne Peaseley using the Paradox Application Program to enter truck inspection results. After completing an inspection, the inspector enters the same data that would normally be handwritten on an inspection form. A database of CDL numbers and Carrier Numbers (ICC) automatically enters the appropriate information if the number is in the database. This database is updated once a month. Every 2 weeks the inspectors use modems to download the inspections to a central database. Sometimes the data is transferred using floppy disks. The inspectors also have access to the FMCSR on the laptop. A WordPerfectTM-compatible version of the FMCSR is available, and the ZyindexTM program can be used to search for key words and phrases. This capability is rarely used because the electronic version of the FMCSR is always out-of-date and using ZyindexTM is not an effective way to search the code. For example, if the keyword is "brakes," the program would look for every mention of the word "brakes." This word is mentioned throughout the FMCSR, but only the section in PART 393 would be of interest. A keyword search would therefore yield many useless results.

The St. George, Utah port of entry also uses computers to print inspection reports (Kendall, 1993). However, instead of entering information into a pen computer, the inspector takes notes on a small pad of paper. Then, the inspector uses a PC in his office to write up the inspection form. The software constructs a database of all carriers and drivers who are inspected. When the carrier number or driver's license number is entered, the other relevant information is automatically entered if it is in the database. Otherwise, the inspector enters the driver and carrier information with the keyboard and it is added to the database. This is a local database, and it only stores information regarding drivers and carriers who have inspections performed at the St. George port. The FMCSRs are easily brought up with a menu, and the inspector can select the correct violation from a menu. An experienced operator can skip the various menus and enter information quickly using keyboard commands. The software was developed by an inspector, Lane Elmer. The software currently does not output SAFETYNET-compatible data, but an upgrade is under way to allow electronic transfers of data to SAFETYNET.

West Virginia is currently using a portable computer system developed by the Radix Corporation to generate truck inspection reports in the field (Radix, 1992; Horracks, 1993). The FW60 portable computer and FP40 thermal printer are used to log violations and generate inspection reports in the field. Inspectors transmit data to a central location via a modem, where the data is manipulated into a form compatible with SAFETYNET. A sample of the inspection form given to the driver appears on the following page. The software is menu-driven to help the inspector easily locate the proper section of the West Virginia code. The corresponding Federal Code is automatically entered on the inspection form (Figure 4-4). The system is capable of reading magnetic strips, but this capability is not being used.

Many states put a magnetic strip on commercial driver's licenses, which would allow automatic entry of the driver information. The GridPad supports this capability, but no one is currently using it. The main difference between the pen-based technology and the Radix system is that the Radix system relies on an alphanumeric keypad to enter data and select menus while pen-based systems use a special pen. Pen-based systems tend to have larger displays than the Radix system, which allows the display of more information.

4.3 Voice Recognition

The Nebraska State Patrol will conduct field testing of a voice recognition system that should allow inspectors to conduct "hands free" inspections. The inspector will talk into a headset, which will send his commands over a radio link to a computer. The computer will interpret his commands, record inspection results, and interact verbally with the officer if it detects a mistake. The voice recognition system, developed by the Artisan Group in Baltimore, MD, is user-dependent. Each officer who uses the system must make a training tape which is recorded on a floppy disk. The system was supposed to be fielded in January of 1993 (DOT, 1993), but the system has not been tested because the software is not yet functional (Danahy, 1993; Gembicki, 1993). An operational version of the software should be ready in the next several months.

4.4 Visual Inspection of Thermal Wheel Damage

Researchers have developed a "thermo-paint" for wheels which shows when wheels have been exposed to excessive heat from braking (Kigawa and Kirimura, 1988). Thermal cracks and fracture of the wheel rim are easily caused by overheating. The thermal paint developed shows distinct discoloration when exposed

WEST VIRGINIA
FORM 58
DRIVER/VEHICLE REPORT

REPORT NO: WV00000002 PSC NO: 000001

CARRIER: MILLER TRANSPORT
ADDRESS: 12 MAIN
CITY: SLC
STATE: UT ZIP: 84115

ICC NO: 000002
DOT.MC.NO: 9999999
STATE NO: 0000004

INSPECTION LOCATION: CHARLESTON, WV
LOCATION CODE: I-64 COUNTY: BRAXTON

MCSAP LEVEL: 1 INSPEC DATE: 05/17/93 FACILITY: ROADSIDE

SPECIAL STUDY NO: 44 MAGISTRATE COURT VIOL:
LADING THIS TRIP: INTERSTATE START TIME: 07:03

DRIVER IDENTIFICATION: MIKE . SMITH
LIC: 437776, UT
VEH. IS: OWN
TYPE CARRIER: PRIVATE
COMMODITY TRANSPORTED: LUMBER
ORIGIN: ATLANTA, GA
DESTINATION: CHARLESTON, WV
SHIPPING PAPER NO: 47
WHOSE DOCUMENT?

MC SPEC. OR 'NON': HAZ/MAT EXCEP NO:
HAZARDOUS MATERIALS? N HAZARDOUS WASTE? N PLACARDS REQUIRED:
MATERIAL: REPORTABLE QUANTITY: N
WASTE: REPORTABLE QUANTITY: N

VEHICLE IDENTIFICATION

	UNIT CODE	MAKE	CO. NUMBER	V.I.N.	LICENSE & STATE
1.	12	WHIT	10	10	10 GA
2.	02	FLNR	14007	13467	400077 GA
3.	05	FRHF	20077	1344	0047 GA
4.					
5.					
6.					

A MEMBER OF THE WVPSC REMOVED A SEAL IN ORDER TO INSPECT THE CARGO BEING TRANSPORTED THE SEAL WAS REPLACED WITH A WVPSC SEAL.

SEAL # REMOVED:
WVPSC SEAL #:

BRAKE ADJUSTMENT (FRONT)

	AXLE 1	AXLE 2	AXLE 3	AXLE 4	AXLE 5	AXLE 6
	0.25	0.25	0.25	0.25		
	0.25	0.25	0.25	0.25		

CODE OF FEDERAL REGULATIONS

	UNIT NO	ST. CODE	FED CODE	UNIT TYPE	O.O.S.	VER CODE
1.	1	01	395.3a1	DRIVER		N
2.	2	1A4	396.3a1	TRUCK-TRACTOR		N
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						

COMMENTS ON ABOVE VIOLATIONS:

1. Driving more that ten hours
2. Audible air leak at brake chamber
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.

Pursuant to authority contained in Title 49 Code of Federal Regulations, Section 396.9 [illegible] by an "X" in the Out of Service column [illegible] the out of service stickers applied to these vehicles or operate such vehicles until the out of service [illegible] the vehicles have been restored to safe operat[illegible] [illegible]

Pursuant to authority contained in Title 49 Code of Federal Regulations Section [illegible] Virginia, I hereby notify and declare [illegible] to drive or operate any motor vehicle [illegible]

DATE [illegible]

UNIT NO. 11111 TIME COMPLETED: 07:09
COPY RECEIVED BY:

OUT OF SERVICE STICKER NO:
1.
2.
3.

CVSA DECAL NO:
1. 401
2.
3.

ACCIDENT: N
REQUESTED BY:
STATE:
COUNTY:
CITY:
FATALITY:
INJURY:

SIGNATURE OF PERSON MAKING REPAIRS

DATE OF REPAIRS

NOTE TO DRIVER This report must be furnished to the motor carrier whose name appears at the top of this report
NOTE TO MOTOR CARRIER Please SEE BACK OF THIS FORM

wv-983a

Figure 4-4. West Virginia inspection form.

to temperatures between 200” to 300°C. This technology was primarily developed for passenger cars, but might have some application in the trucking industry for visually detecting exposure to damaging temperatures .

4.5 Smart Cards

A “smart card” is defined as an integrated-circuit-based, credit-card-sized portable data carrier (Komanecky and Claus, 1991). Many people mistakenly refer to credit cards with bar codes or magnetic stripes as smart cards. These type of cards, although programmable in a limited sense, do not meet the true definition of a smart card, which usually includes a microprocessor and memory (EEPROM). Other components in a smart card include an analog IC for power conditioning, a communications interface, and a method of transferring power to the card. Smart cards are currently used in Electronic Toll and Traffic Management (ETTM) systems with Automatic Vehicle Identification (AVI). Although smart cards are not currently being used in any CVO demonstrations, they have many possible applications. A driver’s credentials (CDL, medical certificate, violations, etc.), along with the carrier and cargo information, could easily be stored on a smart card, possibly all integrated into a CDL with a picture of the driver. Applications for smart cards in the inspection process are discussed in more detail in Section 5.

Another device related to a smart card is the PCMCIA (Personal Computer Memory Card International Association) Standard. This standard defines the physical requirements, electrical specifications, and software for these “PC cards” (Gyorki, 1993). Currently these cards measure 85.6 x 54 mm and come in three thicknesses (3.3 mm, 5 mm, and 10.5 mm). These devices usually are used as memory devices, holding battery backed SRAM or EEPROM. These devices are very rugged storage devices compared to hard disks, and also have much faster access times. However, the maximum capacity currently available is 40 megabytes. In addition to memory, these devices can also contain other electronics. Applications for vehicles include rugged data storage devices that are easily removed and analyzed by a personal computer. Black box storage devices on trucks could use PCMCIAs or other solid-state memory devices.

4.6 Transponder Systems

Transponders are used to identify vehicles in Automatic Vehicle Identification (AVI) systems. AVI systems are composed of three functional elements: the vehicle-mounted transponder or tag; the roadside reader unit; and a computer system for processing and storing the data (Case, 1990). This is shown in Figure 4-5.

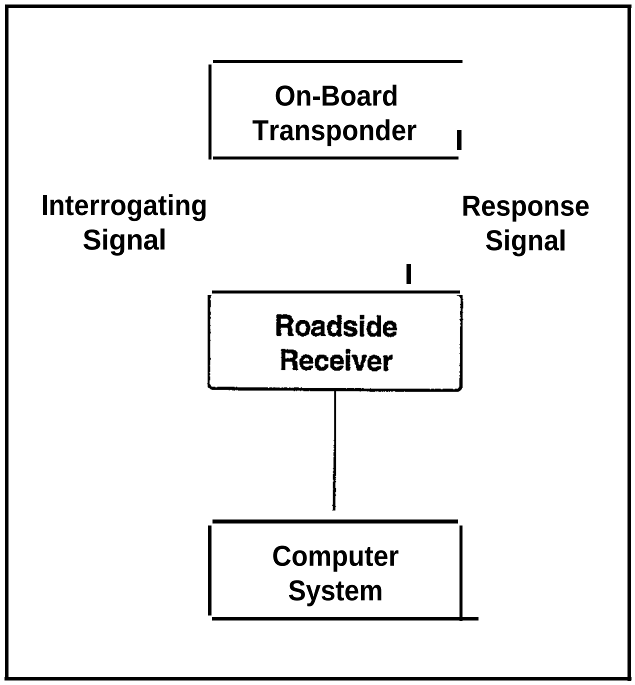


Figure 4-5.AVI block diagram.

Automatic vehicle identification systems allow a vehicle to send information to the roadside as the vehicle drives by at highway speeds. Technologies are available that allow sending a fixed message (vehicle identification) as well as changeable messages about vehicle status. The largest application for vehicle transponders is currently automatic toll collection (Car-render, 1993). Transponders are also being used for Automatic Vehicle Identification of commercial vehicles by several demonstration projects.

The earliest AVI systems relied on optical and infrared technologies (Case, 1990). These systems required clear visibility and were seriously affected by snow, rain, ice, fog, and dirt. Therefore, optical and infrared technologies have been largely abandoned by AVI manufacturers (Case, 1990). Current technologies being used for AVI include inductive loops, microwave signals, and Surface Acoustic Wave Systems (SAW) (Case, 1990). A listing of AVI vendors appears in Case (1990).

Amtech has developed many types of sensors that have been used for AVI (both vehicle and rail) and toll collection. The specifications of an Amtech system are described to give the reader an idea of the capabilities of AVI systems. The Amtech system uses passive tags that remodulate the backscatter of a roadside radar to transfer information from the vehicle to the roadside. The information on the vehicle tag can be either fixed or variable, and the maximum message length is 4096 bits of data. Passive tags, which are powered from the

RF beam, have a maximum range of about 25 ft. Battery-powered active tags have a longer range, about 100 yards. The Amtech systems transmit at 915 Mhz, and higher frequency systems are under development (Carrender, 1993). All transponders operate on the same frequency, and the closest transponder to the roadside detector is the strongest signal. Therefore, even though all transponders are “talking at once,” the roadside sensor is able to determine the strongest signal and read the data correctly. The Amtech system works at speeds of up to 200 mph.

Although vehicle transponders are currently being used mainly for AVI and toll collection, these types of systems could easily be adapted to transmit vehicle safety information to the roadside inspection station. Because these systems can only transmit a limited amount of data, the day will probably come when more on-board vehicle data is available than can be transmitted to the roadside. Therefore, some research will probably have to be performed to determine what vehicle data provide the most information about the overall safety of the tractor trailer system.

4.7 IVHS Corridor Programs

There are two IVHS CVO demonstration corridor programs that are currently in progress, the HELP/ Crescent and ADVANTAGE I-75 programs (Walton, 1993; Grayson, 1993). Both projects are focused on improving CVO efficiency using electronic technologies. The HELP (Heavy Vehicle Electronic License Plate) program was initiated in 1983 by representatives of the Arizona and Oregon Departments of Transportation. The first phase was a feasibility assessment and was completed in 1985. Phase II consisted of a number of technical studies of different technologies. It included a core group of Western states and was completed in 1989 (on-board computing and refinement of certain technologies continue to be studied). Phase III consists of the Crescent Demonstration, which is testing and evaluating the integration of technologies in a real-world environment. The states participating in the Crescent Demonstration are shown in Figure 4-6.

The HELP/Crescent Demonstration integrates automatic vehicle identification (AVI), automatic vehicle classification (AVC), weigh-in-motion, and communication linkages (Walton, 1993). These technologies are more closely associated with the taxation and revenue process than the truck safety inspection process. The current stage of the demonstration is not applying any technologies to improve the truck safety inspection process. However, plans for the next stage include remote brake testing as the truck drives at slow speeds. Details of this technology are unavailable because of a nondisclosure agreement (Gentner, 1993). Other plans for improving truck safety include using MCMIS (Motor Carrier Management Information System) carrier safety data to determine which trucks should be inspected (Gentner, 1993). The MCMIS database would also have the results of the previous inspections for a particular truck. The HELP/Crescent Demonstration is also hoping that as on-board diagnostic equipment becomes more prevalent, trucks will be able to transmit these results as part of the automatic vehicle identification message to give inspectors another metric of the truck’s safety (Gentner, 1993) .

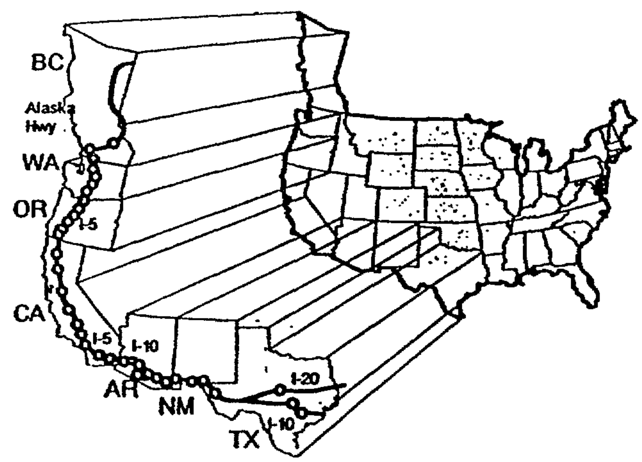


Figure 4-6. Crescent Demonstration Project (Walton, 1991).

The ADVANTAGE I-75 program is also not currently applying any technologies to improve truck safety inspections. They plan to have trucks participating in the demonstration provide self-certification (Grayson, 1993). This will put the burden on the carriers of ensuring that the trucks meet the FMCSRs. Random safety inspections will be conducted to determine how well the self-certification works.

Other demonstration projects include the proposed I-80 Corridor demonstration project (Cambridge, 1993). This project will also focus on reducing the number of stops trucks are required to make for licenses, permits, registrations, fuel tax reporting, and other credentials. This will involve AVI, WIM, and AVC. The highway safety functions are envisioned to include remote driver and vehicle inspections at mainline speeds, but the appropriate technologies have not yet been identified. As in the I-75 project, all operational trucks will have pre-clearance (self-certification) for safety and credential checks. The Port of Entry Advanced Sorting System (PASS) in Oregon will also be performing operational testing of AVI, WIM, AVC, on-board computers (OBC), and two-way communications to pre-clear trucks on the mainline. The main thrust of these and other IVHS demonstration projects has been to reduce the amount of time trucks spend stopping for documentation and permits.

5. Recommendations

Commercial vehicle inspections depend on the interaction of three components: the inspector, the inspection facility, and the vehicle and driver being inspected [Figure 5-l). This section outlines how promising technologies could be evaluated in the near term and how they could be further developed and integrated in the long term to improve interactions between the three main components of commercial vehicle inspection.

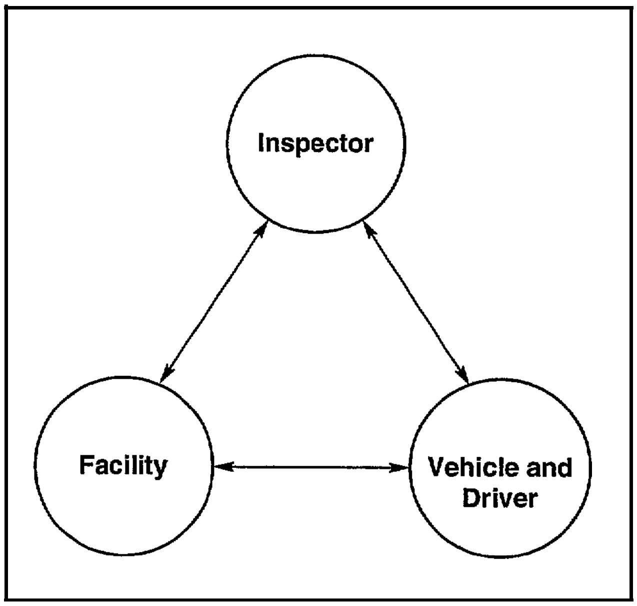


Figure 5-1. Three components of the inspection process. Ultimately, the success of any commercial vehicle inspection technology will depend on how well it enhances interactions between the inspector, the inspection facility, and the vehicle,

As Section 4 explains, there are several field tests currently in progress to evaluate laptops, pen-based computers, portable brake testing systems, and voice recognition systems. Field testing is just beginning, but over the course of the next year the opportunity will exist to compare these systems side by side. The laptop, pen-based, and voice recognition tests will provide valuable information about the direction inspection-related computing technology should take. Technologies that are being field tested or could soon be field tested are identified and examined in the near-term recommendations presented in Section 5.1.

In order to determine how the inspection process can be modified to improve safety, further research will have to be conducted to determine from a systems perspective what the goals and requirements are and how these technologies enhance the interactions between the inspector, inspection facility, and vehicle. As explained in the main portion of the overall report, *Commercial Vehicle Architecture Systems Study* (to which this task report is an attachment), a systems approach will provide a systematic way to identify, assess, and plan the development of the most appropriate commercial vehicle inspection technologies. As these candidate technologies are developed, the systems approach will help identify important interactions between candidate technologies, meaningful criteria for comparing candidate technologies, and the best approaches for developing them. These developing technologies are examined in the long-term recommendations presented in Section 5.2.

5.1 Near-Term Recommendations

This section discusses near-term candidate technologies for improving the truck inspection process. As Figure 5-2 shows, the truck inspection process in the U.S. is primarily an enforcement process. The overall goal of the inspection process is to improve safety. CVSA works to refine the Federal Regulations and the Out-of-Service Criteria. In the real world, inspectors enforce the Federal Regulations and the Out-of-Service Criteria.

Because improved truck safety is sought through inspections that enforce existing regulations, we examined the inspection process in detail and used it as a starting point for identifying near-term solutions. A step-by-step analysis of the recommended North American Standard Inspection Procedure presented in Section 3 revealed deficiencies, and existing technologies that could address those deficiencies were identified. The report on this study is presented in Appendix A; the study's outcome is summarized in Table 5-1.

The most promising of the candidate technologies identified in Table 5-l are discussed in more detail below in Section 5.1.1. These technologies involve mostly devices to help the inspector with the current system. If the assumption is made that on-board computing capabilities of trucks will increase significantly in the future, then the capability for on-board safety monitoring will become practical. Section 5.1.2 outlines technology areas that show promise for on-board inspection capabilities. Section 5.1.3 recommends how these candidate technologies could be developed to enhance commercial vehicle inspections.

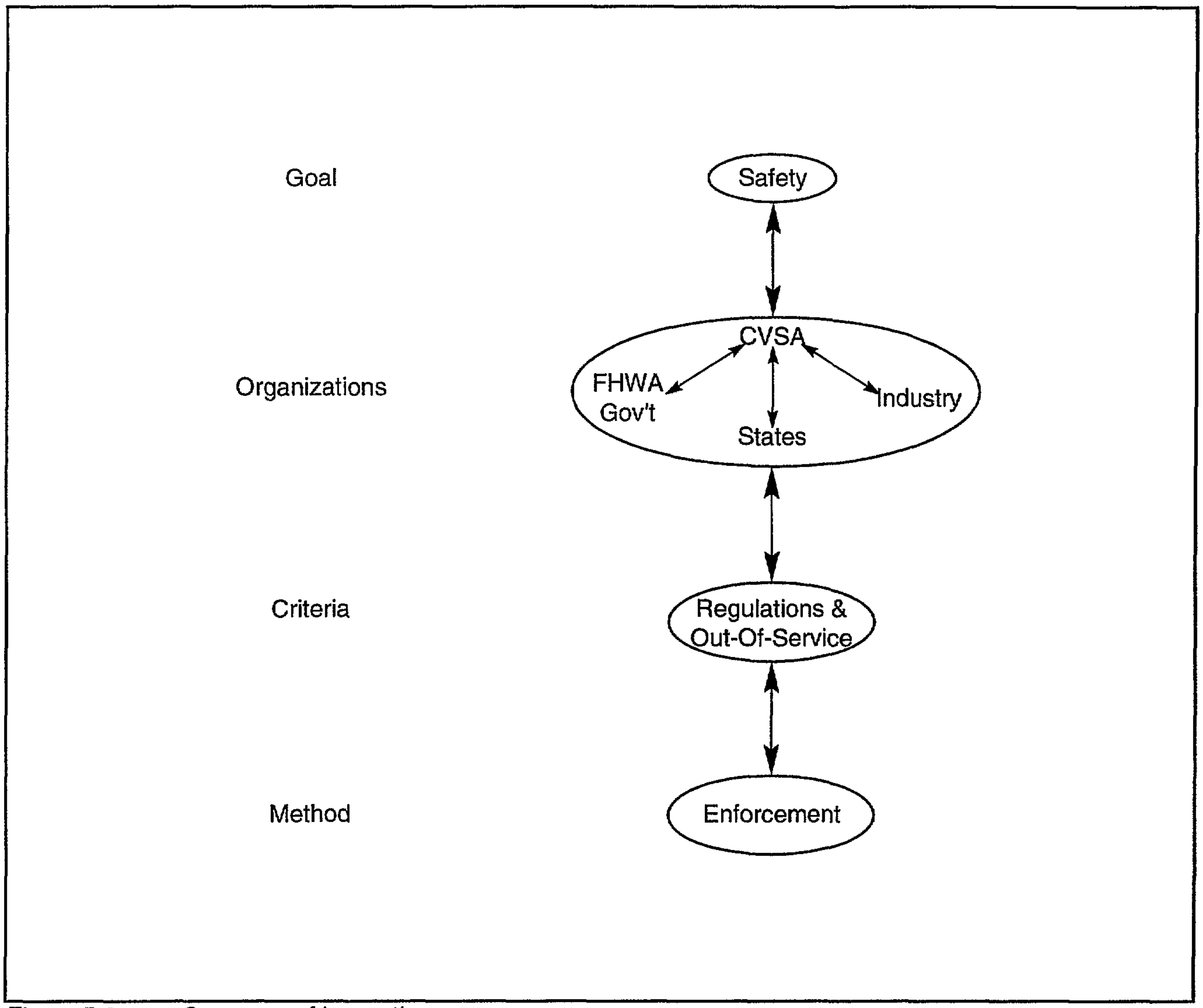


Figure 5-2. Summary of inspection process.

5.1.1 Inspection Process

Inspector Aids

As mentioned in Section 4, different types of pen-based and laptop systems are currently undergoing field testing in several states. Because all of these systems have basically been developed independently, there will be an opportunity to compare the systems side-by-side over the next year. The goal of some pen-based systems is to allow the inspector to take notes while he is doing the inspection, even underneath the vehicle. After the field testing of the different devices has progressed, it will be interesting to compare the advantages of using a pen-based computer versus taking notes on a pad of paper and then entering the results in a PC or laptop.

As electronic aids are being developed for inspectors, one area which has not received much attention is cleaning up the interpretations and listing them with the regulations in an easy-to-access database. This database could be incorporated into the existing pen-based systems being developed, or a custom electronic "reference" could be developed with easy-to-use menus and touch screens. Comments on this concept have been positive, but one person noted that the trucking industry might oppose such a device. If inspectors had the capability to quickly access the regulations and interpretations electronically, they might do so during inspections, adding several minutes to the length of an inspection. This would hold up trucks a few minutes longer. This device could also be used during accident reconstructions and carrier reviews where time is not as critical. As the regulations and interpretations are changed, the electronic reference could easily be updated. However, there are apparently problems keeping the current electronic version of the FMCSR up to date.

Table 5-1. Technology Study of the Recommended North American Standard Inspection Procedure*

Step	Deficiencies	Candidate Technologies
0. Select truck for inspection	• limited inspection frequency • no intelligent screening of inspections	Improve method of screening trucks for inspection using the following technologies: • on-board storage of driver and vehicle information • Automatic Vehicle Identification (AVI) • vehicle-roadside communications • smart cards • national databases and communications networks • data encryption • portable interrogations systems • portable brake testers • portable interrogation systems
1. Choose the inspection site	• alternate routes bypass fixed inspection sites • inspector safety • driver leaving during inspection	Remote monitoring of alternate routes using: • video systems • weigh-in-motion systems • AVI
2. Greet/assess the driver	• presence/use of illegal substances hard to detect • driver's condition during inspection not necessarily same as while driving	• noninvasive drug/alcohol testing during inspection • on-board noninvasive drug/alcohol testing • on-board monitoring of driver performance
3. Prepare the vehicle and driver	• paper inspection form makes information archiving/retrieval difficult	• notepad/pen computers • voice recognition system
4. Check driver's documents	• paperwork extensive and therefore subject to error and fraud	• smart card • voice recognition system
5. Check for presence of hazardous materials/ dangerous goods	• labels and documents do not necessarily indicate true nature of hazardous materials	• infrared spectroscopy to independently identify/classify hazardous material
3. Check steering lash inside cab	• inspection does not detect steering lash problem when it first occurs on the road	• on-board monitoring • transmission of problems to nearest inspection station
7. Inspect front of tractor	• lighting/wiper problems not detected when they first occur on the road	• on-board monitoring • transmission of problems to nearest inspection station
8. Inspect steering axle	• functioning steering axle problem not detected when it first occurs on the road • push-rod travel brake inspection time consuming, dangerous, and not exact	• on-board monitoring of steering axle • transmission of problems to nearest inspection station • dynamometer testing • skid plate testing • infrared testing of brakes (temperature measurement) • on-board sensing of brake performance
9. Inspect left front side of tractor	• problems not detected when they first occur on the road • thermal cracks hard to detect	• on-board monitoring • transmission of problems to nearest inspection station • thermal paint

* See Appendix A for a more complete report on this technology study.

Table 5-1. Technology Study of the Recommended North American Standard Inspection Procedure (continued)

Step	Deficiencies	Candidate Technologies
10. Inspect left saddle tank area	• problems not detected when they first occur on the road • some problems hard to detect	• on-board monitoring • infrared spectroscopy to identify leaking fuel • thermal paint
11. Inspect trailer front	• tangled lines not detected when they get tangled on the road	• on-board monitoring • transmission of problems to nearest inspection station
12. Inspect left rear tractor area	• problems not detected when they first occur on the road • thermal cracks hard to detect • push-rod travel brake inspection time consuming, dangerous, and not exact	• on-board monitoring • transmission of problems to nearest inspection station • thermal paint • dynamometer testing • skid plate testing • infrared testing of brakes (temperature measurement) • on-board sensing of brake performance
13. Inspect left side of trailer	• problems such as unsecured cargo not detected when they first occur on the road	• on-board monitoring of cargo • transmission of problems to nearest inspection station
14. Inspect left rear trailer wheels	• problems not detected when they first occur on the road • thermal cracks hard to detect • push-rod travel brake inspection time consuming	• on-board monitoring • transmission of problems to nearest inspection station • thermal paint • dynamometer testing • skid plate testing • infrared testing of brakes (temperature measurement) • on-board sensing of brake performance
15. Inspect rear of tractor	• lighting problems not detected when they occur • problems such as unsecured cargo not detected when they first occur on the road	• on-board monitoring of cargo and lighting • transmission of problems to nearest inspection station
16. Inspect right rear trailer wheels	• problems not detected when they first occur on the road • thermal cracks hard to detect	• on-board monitoring • transmission of problems to nearest inspection station • thermal paint
17. Inspect right side of trailer	• problems such as unsecured cargo not detected when they first occur on the road	• on-board monitoring of cargo • transmission of problems to nearest inspection station
18. Inspect right rear tractor area	• lighting problems not detected when they occur • problems such as unsecured cargo not detected when they first occur on the road	• on-board monitoring of cargo and lighting • transmission of problems to nearest inspection station
19. Inspect right saddle tank area	• problems not detected when they first occur on the road • some problems hard to detect	• on-board monitoring • infrared spectroscopy to identify leaking fuel • thermal paint
20. Inspect right front side of tractor	• problems not detected when they first occur on the road • thermal cracks hard to detect	• on-board monitoring • transmission of problems to nearest inspection station • thermal paint

Table 5-1. Technology Study of the Recommended North American Standard Inspection Procedure (concluded)

Step	Deficiencies	Candidate Technologies
21. Inspect brake adjustment	• push-rod travel brake inspection time consuming, dangerous, and not exact	• dynamometer testing • skid plate testing • infrared testing of brakes (temperature measurement) • on-board sensing of brake performance
22. Check fifth wheel movement	• serious damage to vehicle can occur during inspection	Various types of sensors: • optical sensors • magnetic sensors • LVDTs
23. Check air loss rate	• influenced by inspector's hearing and background noise	• pressure sensor
24. Check operation of low air pressure warning device	• no major deficiencies	• on-board monitoring • transmission of problems to nearest inspection station
25. Check operation of tractor protection valve	• safety problems related to high-pressure air, water, and oil	• automate tractor protection valve inspection using on-board diagnostics
26. Check emergency brakes	• escaping air must be detected audibly, which is very subjective	• pressure and flow sensors
27. Complete the inspection	• paperwork time consuming • handwritten forms hard to read • verifying correction of out-of-service condition difficult	• notepad/pen computers • computer printouts * covert monitoring of out-of-service trucks
28. Enter inspection data into MCMIS database	• erroneous data entered because of typographical data entry errors and unreadable inspection reports	• use of computers to generate inspection reports

Although this report is supposed to recommend "technologies" to improve the truck inspection process, some of the best aids for inspectors might be improvements in truck inspection station design. Pits, like the one located at St. George, UT, allow the inspector to easily and more thoroughly inspect the undercarriage of a vehicle. It is also easier to show the driver what is wrong if the driver can accompany the inspector into the pit. Although safety considerations must be taken into account, pits are becoming relatively commonplace in fast-service lubrication stores. Having some protection from the elements would also make the safety inspections easier and safer. Improving the truck inspection process should probably involve a combination of using technology as well as improving the inspection facility. This systems approach is discussed in more detail in Section 5.2.

Smart Driver's License

A truck driver is currently required to carry numerous documents in the cab. Whenever a truck inspection is performed, the documents listed in Table 5-2 are requested from the driver.

Table 5-2. Documents Requested in Typical Level I Inspection

1.	Commercial Driver's License
2.	Medical Card
3.	Bingo Card
4.	Registration - Tractor & Trailer
5.	Bill of Lading

The state of Arizona is currently testing a Commercial Driver's License (CDL) that combines the license and medical card into one card. By using a "smart card," all of the required information could be accessed quickly and electronically. Often, the inspector has a difficult time determining who the actual carrier is (the truck may be owned by the driver but leased to a carrier for the current cargo). If this information were available quickly on a "smart card," the information could be automatically entered on the inspection form.

Current WIM and AVI demonstrations are requiring the inspection station to keep a database of trucks and carriers. If this information were recorded on a smart card coupled with a transponder system, some of the burden of maintaining a database would be removed from the ports of entry.

Electronic Log Reader

Electronic logs are currently available to record the driver's hours of duty, thereby replacing the handwritten log. Because there are not many in use, inspectors are often unfamiliar with them and have a difficult time verifying the hours of service. Also, the inspector must get into the cab to view the screen that displays the hours of service (inspectors don't like getting into the cab). The FMCSRs currently define the requirements of an electronic log. These include a display capable of showing the previous 7 days. If an additional requirement were made for a standard communications interface, the log could be inspected electronically instead of manually. This could be accomplished by defining a standard communications interface (protocol, electrical, and hardware). The inspection process would then consist of hooking a cable from a laptop (or dedicated computer in a box) to the electronic log. The log verifier would then check for 10-hour, 15-hour and 60- or 70-hour violations. This process could be taken a step further if the wire interconnection were replaced with a radio link; then the hours of service could be verified as the truck drove by the inspection station.

5.1.2 On-Board Monitoring Systems

As on-board computing technologies become more prevalent, the opportunity to take advantage of on-board sensing becomes available. The following sections discuss some specific truck systems that could be monitored using sensors.

Brake System

Various components of the brake system may be measured or monitored using sensors. Brake lining characteristics, including temperature and thickness, could easily be monitored using sensors. Brake effectiveness could be measured by looking at slack adjuster displacement, brake temperature, brake pressure, tire pressure, and torque applied during braking. Brake systems could include self-diagnostics of expected brake performance in addition to having anti-lock braking systems (ABS).

Road Surface Conditions

Variations in road surface conditions can result in accidents for vehicles with or without mechanical deficiencies. These variations can be detected using infrared and ultrasonic sensors. Infrared sensory devices detect heat changes and have been used for this purpose at airports and for efficient road sanding/salting. Information on the road surface could help in calculating real-time braking ability.

Driver Alertness

Different technologies could potentially measure driver alertness. These include fuzzy logic or neural network systems that analyze the driver's performance in real time. Some work has also been done using voice to determine alertness (Hayre, 1993). Although these technologies have great potential, further research is required.

Lghts and Other Electrical Systems

Testing systems could easily be designed to sense failure in lights and other vehicle electrical systems. Properly functioning lights can be verified with optical sensors or current sensors. Continuity sensing can be used to determine the integrity of a lighting system without turning on the lights.

Structural Integrity

Embedded sensors could be used to detect cracks and other structural deficiencies. However, it will probably be more practical and economical to rely on visual inspections for most cracks, except in very critical areas. Vibration analysis, a technology widely used in the electric power industry, could also be applied to structural monitoring.

Tachograph - Black Box Recorders

Electronic tachographs, with greatly expanded capabilities compared to the electromechanical European versions, could easily be developed. These electronic tachographs would resemble current airplane "black box" recorders. A number of critical vehicle parameters could be recorded to improve maintenance as well as accident reconstruction. This type of device will probably become commonplace as on-board computing technologies mature.

Sensors

With the exception of infrared cameras, sensors for commercial vehicle operations that would enhance the inspection process are all related to on-board monitoring. Given present commercial vehicle technology, no sensors or combination of devices can provide remote inspection capability. In order for this type of system to be realized, technologies must be applied to commercial vehicles, inspection facilities, and inspectors. These changes would require new enforcement guidelines, standards, and regulations. For this study case, as previously mentioned, the Sandia investigators attempted to identify technologies that not only have application in commercial vehicle operations, but also require no changes to the current inspection process structure.

5.1.3 Proposed Near-Term Activities

Based on the discussion of available technologies and information found in Table 5-1, this section recommends some near-term activities to improve the current inspection process. These tasks are aimed at improving the current system, rather than radically changing it. The recommendations in Section 5.2 deal with long-term, fundamental changes to improve truck safety.

- **Hold an inspection computer conference at St. George, UT.** This conference would provide a forum for evaluating all pen-based, palm-top, laptop, and voice recognition systems that could be used for commercial vehicle inspections. Sandia electrical engineers, computer scientists, and human factors specialists could provide unbiased evaluations of these systems. Also, feedback could be elicited from inspectors who would actually be using the systems in the field. St. George's inspection pit could be used to evaluate whether pen-based systems are truly superior to paper/personal computer systems in a fixed-station/pit environment. The conference would last five days and would heavily involve CVSA.

- **Develop an electronic "regulation/interpretation" reference with CVSA.** This electronic document could replace the books currently used and would provide a means of easily searching for and retrieving desired regulations and interpretations. The device could utilize pen or touch-screen technologies. Revisions could be easily entered with PCMCIA cards.

- **Develop and demonstrate an inexpensive brake out-of-adjustment sensor.** An inexpensive switch-type sensor could be used to determine out-of-service brake adjustments. This sensor could also work with an automatic slack adjuster system.

- **Develop a standard interface to electronic logs.** Such a standard would help electronic log manufacturers make products that would be compatible with the needs of all commercial vehicle inspectors in North America.

- **Develop and demonstrate a smart driver's license system for commercial vehicles.** This system would integrate a smart card with on-board electronics: a communication link and programming devices for the carrier.

- **Develop a modular, standard inspection station design for the twenty-first century.** This project, which would rely heavily on input and guidance from the CVSA, should combine pit and facility design with computer systems identified in the proposed inspection computer conference described above. This design would use an open architecture so new technologies could easily be integrated.

5.2 Long-Term Recommendations

Although there is some room for technology to improve the current inspection process in the near term, other issues will play an equally important role in the long term. Facility design and the interaction between the vehicle electronics and the inspection station will ultimately determine the quality of truck inspections and the extent to which time required to complete inspections can be reduced. This will require the integration of on-board technologies with electronic systems at the port of entry and inspection facilities, combined with an efficient facility design. Only incremental improvements in the truck inspection process will be obtained by applying technologies to the current system.

5.2.1 Fully Automated Inspection

Looking at the deficiencies and candidate technologies listed in Table 5-1, many require on-board monitoring in order to be checked automatically or remotely. With the exception of infrared brake temperature measurements, there is no device that an inspector can point at a truck to determine the truck's state of health, without the truck "talking back." Therefore, long-term improvements in the truck inspection process will include facility design as well as integration of on-board technologies with electronic systems controlled by the inspector.

An example of a fully integrated truck inspection system would have trucks with on-board diagnostics transmit critical information to the port of entry several miles out. Based on the on-board status, as well as the carrier safety record (from AVI), a decision could be made whether or not to inspect the truck. As the truck approaches the station, it could be told to come in for an inspection with a special message sign. The inspection would be performed in a well-designed facility with a pit and protection from the elements. The driver would carry a smart card that would have all of the typical information required by an inspector, possibly including an electronic log. The inspector could interrogate the on-board computer system using special diagnostic equipment. Using the most appropriate computer technology (pen, voice, or laptop) developed during the current field testing, the inspector would write up the inspection report. The inspection report would automatically be entered into SAFETYNET or a similar database. The results of the inspection could be recorded in the truck's black box electronically so a CVSA (electronic) decal would no longer be necessary. Even if a truck was not stopped based on the on-board sensor data, a larger number of trucks would be inspected because of the on-board inspection capability.

Although roadside inspections could not take advantage of a well-designed facility, the same technologies could be used to interrogate a truck's on-board diagnostic system to determine which trucks to inspect. Portable diagnostic equipment as well as pen-based or laptop computers could also be used. Modifying the data in the truck's black box could also be accomplished in the field.

5.2.2 Proposed Long-Term Activities

Based on the above discussion, this section recommends some activities to improve the inspection process in the long term:

- **Conduct safety risk/cost analysis of different truck components to determine which items should be monitored by on-board sensors to improve safety.** The results of this research would also help CVSA determine which items merit inclusion in the Out-of-Service Criteria. Once critical items have been identified, further research can be conducted to identify appropriate sensor technologies or sensors that need to be developed.

- **Further investigate the communications requirements needed to implement remote truck inspections.** Work with CVSA, the FCC, and other agencies to determine the frequency allocations, standards, protocols, and regulations required to implement an automated truck inspection system on the national level.

- **Initiate research to determine the feasibility of driver performance evaluation by monitoring steering, brake, and throttle commands as well as other vehicles states (velocity, acceleration, etc.).** Non-invasive evaluation of driver performance is critical if on-board monitoring is implemented. The feasibility of this technology has not yet been determined.

Bibliography
(Papers reviewed but not referenced)

Mark A. Flick, "The Effect of Brake Adjustment on Braking Performance", Report Number DOT HS 807 287, NHTSA, Vehicle Research and Test Center, P.O. Box 37, East Liberty, OH 43319.

J. G. Pigman and J. A. Deacon, "Integrated Truck Monitoring System", Report Number KTC-89-60, Kentucky Transportation Center, University of Kentucky, Lexington, KY 40506-0043.

H. S. Stein and I. S. Jones, "Crash Involvement of Large Trucks by Configuration: A Case Control Study", American Journal of Public Health, Vol. 78, No. 5, May 1988.

"Automatic Slack Adjusters", SP-574, Society of Automotive Engineers Truck & Bus Meeting & Exposition, Indianapolis, Indiana, November 8-l 1, 1982.

"Safety Study - Heavy Vehicle Airbrake Performance", National Transportation Safety Board, Washington, DC, April 1992.

J. Winsor, "More Brake Regs, NTSB Report Urges", Heavy Duty Trucking, May 1992.

I. M. Jacobs, et. al., "The Application of a Novel Two-way Mobile Satellite Communications and Vehicle Tracking System to the Transportation Industry", IEEE Transactions on Vehicular Technology, Vol. 40, NO. 1, February, 1991.

T. L. McDole, "Inspection, Defect Detection, and Accident Causation in Commercial Vehicles", Society of Automotive Engineers International Automotive Engineering Congress and Exposistion, Detroit, MI, February 28-March 4, 1977.

T. M. Batz, "The Utilization of Real-Time Traffic Information by the Trucking Industry", IEEE Transactions on Vehicular Technology", Vol. 40, No. 1, February 1991.

W. B. Powell, "Optimization Models and Algorithms: An Emerging Technology for the Motor Carrier Industry", IEEE Transactions on Vehicular Technology, Vol. 40, No. 1, February 1991.

A. B. Boghani, "Use of Advanced Technologies for Improving Hazmat Transporatation Safety", Proceedings of the National Conference on Hazardous Materials Transportation, p. 14-16, May 1990, St. Louis, MO.

R. B. Heusser, "Air Brake Inspections on Five-Axle Combinations", Proceedings of the International Truck & Bus Meeting & Exposistion, Toledo, OH, November 16-19, 1992.

E. Milana, L. Strobbia, "The Automatic Inspection of Car Disk Brake Rotors by Using Optolectronic Means", Proceedings of the International Symposium on Automotive Technology and Automation, Vol. 2, Milan, Italy, 24-28 Sept, 1984.

Abkowitz, M. (1990). Availability and quality of data for assessing heavy truck safety. Transportation Quarterly 44(2), 203-230.

Dingell, Motor Vehicle Safety Authorization Act of 1986 Report, committee on Energy and Commerce/House of Representatives, Report No. 99-833 part 1, September 17, 1986.

Eck, W. R. & Lechok S. A. Truckd drivers' perceptions of mountain driving problems. Transportation Research Record, 753, 14-21.

Fiste, W. R. (1989). Highway hunt bags lame trucks. Traffic Safety, Sept./Oct., 16-19.

Goslin, J. (1989). Truck safety regulations. Transportation Builder, Third Quarter, 22-23.

Gosselin, M. E. H., Richardson, A. J., & Taylor, G. Truck accident involvement with and without front-axle brakes: Application for case-control methodology. Transportation Research Record, 1270, 46-56.

Grandel, J. (1985). Investigation of the technical defects causing motor vehicle accidents. SAE Transactions, 94(3), 360-379.

Hollings. Motor Carrier Safety Act of 1989, Report, Committee on Commerce, Science, and Transportation/ Senate Committee on Commerce, Science, and Transportation, Report No., 101-9 1, U.S. Government Printing Office, Washington, July 27, 1989.

Holm, J. Gary C. E., Branch, K. M., Coburn, N. L., & Hauth, J. T. (1991). The CVSA pilot study of highway vehicle inspection procedures for the transportation of radioactive materials. High Level Radioactive Waste Management, 2, 1035-1041.

Jones, I. S. & Stein, H. S. (1989). Defective equipment and tractor-trailer crash involvement. Accid. Anal. & Prev., 21(5), 469-481.

Kirkpatrick, M. (1988). The role of critical incidence and prevalence studies in truck safety research. SAE Transactions, 96(2), 445-455.

Klausmeier, R. (1984). Assessment of emission reduction strategies for heavy duty gasoline powered trucks. SAE. Transactions, 92(3), 709-720.

Knowledge-based vision software for car industry. Sensor Review, 1984, 163-166.

Robin, H. P. (1991). Hours of service violations among tractor-trailer drivers. Accid. Anal. & Prev., 23(l), 29-36.

Roning, J. & Hall, E. L. (1986). Shape, form, and texture recognition for automotive brake pad inspection. Automated Inspection and Measurement, 730, 82-90.

Rotheberg, P. F. (1988). The effectiveness and integrity of MCSAP. Transportation Quarterly, 42(4), 529-552.

Ryan, M. J. (1990). A look at what some states are doing... AASHTO Quarterly, October, 12-24.

Schulz, J. D. (1990). FHWA lax in follow-up checks of truck inspections, GAO says. Traffic World, October, 17.

Stoke, C. B. & Clinton S. H. (1984). Truck safety, regulation, inspection, and enforcement in Virginia. Transportation Research Record, 847, 16-23. Truck Safety. Hearing before the Committee on Commerce, Science, and Transportation United States Senate, Serial No. 98-58, February 15, 1984.

References

Cambridge. 1993. Draft Interim Report: "Systems Planning For Automated Commercial Vehicle Licensing and Permitting Systems," Cambridge Systematics, Inc., May 14, 1993.

Cat-render. 1993. Personal communication o 6/28/93 with Kurt Carrender, Amtech Systems Technologies, (505) 856-8000.

Case. 1990. "An Overview of Available and Developing Highway Vehicle Electronic Technologies", Ministry of Transportation, Ontario Canada, Report No. TP10472E, October 1990.

Danahy. 1993. Personal communication o 6/24/93 with Shirley Danahy, MCSAP Adminstrative Assistant, Nebraska State Patrol, (402) 471-0105.

DOT. 1993. "FY 1993 MCSAP Report on New Enforcement Technologies and Strategies," U.S. Department of Transportation Federal Highway Administration Publication No. FHWA-MC-93-009.

Gembicki. 1993. Personal communication o 6/24/93 with Mark Gembicki, The Artisan Group, (410) 437-1106.

Gentner. 1993. Personal communication o 6/23/93 with Jim Gentner, Deputy Executive Director, HELP Inc., Phoenix, AZ, (602) 255-7041.

Giles. 1993. Personal communication o 5/31/93 with Bill Giles of Hicklin Engineering.

Grayson 1993. Personal communication o 6/23/93 with Calvin G Grayson Director, University of Kentucky Transportation Center, College of Engineering, 106 Transportation Research Bldg., Lexington, KY 40506-0043, (606) 257-4513.

Gyorki. 1993. "New Deal for Smart Cards", Machine Design, June 11, 1993.

Hagan. 1993. Personal communication with Robert Hagan, Officer-in Charge, Nevada Division, Office of Motor Carriers, (703) 687-5335.

Hayre. 1993. Personal communication with Dr. Harb Hayre o 4/10/93.

Henry. 1993. Personal communication with Paul Henry o CVSA/Oregon.

Holt. 1993. Personal communication on 6/24/93 with Mary Holt, Alabama Department of Public Safety, (205) 242-4423.

Horrocks. 1993. Personal communication o 6/24/93 with Steven G. Horrocks, Marketing Manager, Radix Corporation, (801) 537-1717, Ext. 311.

Kendall. 1993. Personal communication o 6/19/93 with Kerry Kendall, Inspector, St. George port of entry, St. George, UT.

Khoygani. 1993. Personal communication o 6/24/94 with Abe Khoygani, Associate Programmer Analyst, California Highway Patrol, (916) 323-0246.

Kigawa and Kirimura. 1988. "Development of a Thermo-Paint for Inspecting Thermal Damage in Wheels," QR of RTRI, Vol. 29, No. 2, May 1988.

M. R. Komanecky and D. M. Claus. 1991. "IVHS Applications of Smart Cards," Proceedings of the 1991 Vehicle Navigatio & Information Systems Conference, Vol. 2, Dearborn, MI, October 20-23, 1991.

Marzano. 1993. Personal communication o 6/24/93 with Angie Marzano, Alabama Dept. of Public Safety, Motor Carrier Safety Unit, (205) 242-4395.

Peasely 1993. Personal communication o 6/28/93 with Wayne Peasely, N.H. Dept. of Safety, (603) 271-3349.

Radix. 1992. "Automated MCSAP Inspection System," Radix Corporation, 4855 Wiley Post Way, P.O. Box 16400-0400, Salt Lake City, UT, 84116.

Radlinski, R., M. Flick, and G. Clark. 1992. Enhancing the Roller Brake Tester. SAE Technical Paper Series, Report 922444.

Radlisnki. 1993. Personal communication on 2/26/93 with Richard Radlinski of NHTSA.

Sammons. 1993. Personal communication o 6/24/93 with Duane Sammons, Deputy MCSAP Commander, Idaho State Police, (208) 327-7180.

Shilton and Noon. 1993. Personal communication in April 1993 with Brian Shilton and Richard Noon of the Westinghouse Air Brake Company (WABCO), U.K.

D. B. Spaulding et al. 1980. "Design, Fabrication and Evaluation of Prototype Wayside Brake Inspection Sensors, " Report Number Novatek, Inc., 79 Terrace Hall Ave., Burlington, MA, 01803.

UK Department of Transport. 1984. Goods *Vehicle Tester's Manual, 1984 Edition.* UK Department of Transport.

Vaughn .1993 . "Safety Maintenance of Road Vehicles Braking of Road Vehicles: IMechE Proceedings, 1993.

Walton . 1991 . "The Heavy Vehicle Electronic License Plate Program and the Crescent Demonstration Project, IEEE Transactions on Vehicular Technology, Vol. 40, No. 1, February 1991.

Walton. 1993 "A Concept of IVHS in Commercial Vehicle Operation The Help/Crescent Program, " Proceedings of the 1991 Vehicle Navigation and Information Systems Conference, Vol. 1, Dearborn, MI, October 20-23, 1993.

Walton . 1993. Personal communication on 6/2 3/ 96 with C. Michael Walton, Department of Civil Engineering, University of Texas at Austin, Austin, TX 78712, (512) 471-1414.

Appendix A: Inspection Procedure Analysis

This appendix reviews the 27-step North American Standard Inspection Procedure, identifying deficiencies and candidate technologies for each step of the procedure. Two additional steps that were not mentioned in the previous section, the selection of the truck (called “Stepand the data processing using SAFETYNET (called Step 28), are also discussed. Based on the analysis of the inspection process, recommendations are made on how to best use technology to improve the truck inspection process.

STEP 0: SELECT TRUCK FOR INSPECTION

Trucks are chosen for inspection for various reasons. At a fixed inspection site, often the first truck that comes in after an inspector has completed an inspection is chosen for inspection. Sometimes, trucks are chosen for inspection based on inspector knowledge of carrier safety history. Inspections are conducted when an inspector notices a problem as the truck is passed on the road, and an expired CVSA decal is a basis for inspecting some trucks. Random inspections are also often conducted.

Deficiencies

The number of inspections conducted is limited by the number of inspectors available and the space at the inspection site. This limited number of inspections performed would provide better results if a higher percentage of ‘bad’ trucks were inspected. The inspection selection process is currently not based on any previous safety history of the truck and/or driver. Intelligent screening of trucks based on carrier safety records, driver safety records, and vehicle inspection results would make better use of a limited number of inspections.

Candidate Technologies

On board electronics could be used to store driver, vehicle, and carrier safety records. These records could then be transmitted to the inspection station (or squad car) to help select trucks for inspections. Another method would be to have the driver, carrier, and vehicle databases stored at fixed inspection sites. Then Automatic Vehicle Identification (AVI) could be used to look up the appropriate information in the database. This approach puts the burden of developing and maintaining the database on the inspection officials. Once information about the driver, vehicle, and carrier safety is readily available, a standard algorithm could be developed to optimally select trucks for inspection. This approach would allow screening multiple trucks for inspection very quickly and efficiently.

Technologies required to implement this type of system are listed below:

1. on-board computers
2. vehicle-roadside communications
3. smart cards (driver information)
4. national databases and communications networks (if information is stored at inspection stations)
5. encryption of data for security
6. portable interrogation systems for random inspections performed on the roadside

Other systems such as portable brake testers (i.e., roller brake dynamometers, skid plates, infrared systems) could also be used to help select trucks for inspection. However, time constraints would limit the effectiveness of dynamometers and skid plate systems. Infrared systems could be used for drive-by selection if the technology is successfully developed.

STEP 1: CHOOSE THE INSPECTION SITE

This is not an issue for fixed inspection sites. However, random inspections conducted at the roadside must be conducted in a safe location. The recommended inspection site should be a paved, level surface away from traffic. As the inspector approaches the truck, he/she should look for placards or other signs of hazardous materials. If such cargo is present, the inspector should also look for leaks or spills.

Deficiencies

Trucks can easily avoid fixed sites by taking alternate routes. Random inspections are often conducted on alternate routes for this reason. Hazards include being struck by traffic as well as a greater chance that a driver will try to drive away during an inspection. There are only a limited number of safe inspection areas, especially on secondary roads.

Candidate Technologies

Remote monitoring of alternate routes would allow inspection officials to determine how many trucks are avoiding a particular fixed site. This would allow more efficient selection of random inspection sites. Remote monitoring technologies could include video systems, weigh-in-motion systems, as well as AVI devices.

STEP 2: GREET THE DRIVER

Greeting the driver consists of four basic steps. Initial contact is made, seat belt usage and condition is checked, possible illegal presence of alcohol or drugs is checked, and the inspection procedure is explained. The major benefit of this step is that it allows an inspector to make a personal assessment of a driver's condition.

Deficiencies

It is often difficult to detect the presence and/or use of illegal substances. A driver's condition during the inspection may be unrelated to his or her on-road driving condition.

Candidate Technologies

Noninvasive drug/alcohol testing could be used to verify a driver's status at the time of the inspection. Similar technologies could be used on-board to aid in the detection of alcohol or illegal drugs, and continuous monitoring of the driver could be conducted.

STEP 3: PREPARE THE VEHICLE AND DRIVER

The driver is instructed to remain at the controls and turn off the engine. Once inspectors have placed chock blocks in appropriate positions, the driver is instructed to place the transmission in neutral and release all brakes. Inspectors advise the driver in the use of hand signals to test lamps and brakes. Violations during the inspection are recorded on an inspection form or note pad.

Deficiencies

While a paper inspection form is adequate for recording information, archiving the information contained on the paper form for later retrieval is difficult. Easily accessible historical information (i.e., past brake and light failures, driver cooperation) could provide valuable guidance to the inspector.

Candidate Technologies

Notepad and pen computers could be used instead of paper inspection forms to record violations. Such an approach would not only save on paper; more importantly, if the hand-held computer could communicate with historical databases, past violation history for a specific driver could be instantly retrieved.

Another candidate technology that could replace paper is voice recognition. Using voice recognition, the inspector would talk into a headset as the inspection progresses. The computer could interpret his commands and record the necessary information; it would also prompt the inspector if he or she overlooked an item or made a mistake during the inspection.

Notepad computer and voice recognition systems are currently available for truck inspection applications. Further field testing is required to compare their relative performance.

STEP 4: CHECK DRIVER'S DOCUMENTS

The following documents are checked: driver's license, medical certificate, record of duty status, driver vehicle inspection report (post-trip), and documentation of an annual inspection. All these documents should be collected from the driver before beginning the inspection to prevent the driver from altering the log book and to discourage the driver from leaving the inspection site.

Deficiencies

This step is very paperwork intensive and therefore susceptible to error and fraud. Although the log book (along with the other documents) is requested from the driver before the inspection begins to prevent the driver from altering the log book during the inspection, the driver could have already illegally altered the log book. Lack of centralization of records makes it easier for a driver to present illegally altered documents.

Candidate Technologies

A single "smart card," a credit-card sized portable data carrier could be used to hold all the driver's credentials. Software protection could be encoded into the smart card to prevent the driver from altering the data it contained. Results from the inspection could be encoded directly into the smart card.

Another candidate technology that could replace paper is voice recognition, which is discussed in Step 3.

STEP 5: CHECK FOR PRESENCE OF HAZARDOUS MATERIALS/ DANGEROUS GOODS

The inspector checks the truck for the presence of hazardous materials and dangerous goods as indicated by shipping papers/bills of lading, placards, markings, and labels. If hazardous materials are present, the inspector needs to look out for leaks, spills, and nonsecure cargo.

Deficiencies

Because placards, marking, labels, and shipping papers are used to indicate the presence of hazardous materials, these indications could be altered to hide the fact that the truck contains hazardous cargo or to change the description of the hazardous cargo.

Candidate Technologies

There is a need for a way to confirm that the hazardous cargo conforms with it documentation. Infrared spectroscopy could be used to identify independently common hazardous substances.

STEP 6: INSIDE CAB

Steering lash is checked by turning the wheel in one direction until the tires just begin to pivot. At this point the wheel should be marked and turned in the other direction until the wheels begin to pivot. After marking the steering wheel again, the amount of measured lash should be compared to the regulations and the Out-of-Service Criteria. The steering column in also checked for nonsecure attachment.

Deficiencies

While this method will detect unacceptable steering lash, it may not detect it soon enough. Steering lash may become a problem while the vehicle is traveling and may cause the driver to have an accident before it can be detected by manual inspection.

Candidate Technologies

An on-board system could monitor steering lash and steering column attachment as the truck is traveling. At the moment that steering lash or steering column attachment became unacceptable, the monitoring system could inform the driver. An on-board transponder could also relay the information to the nearest inspection station.

STEP 7: FRONT OF TRACTOR

This inspection includes the head lamps, turn signals, and emergency flashers. The windshield and windshield wipers should also be checked.

Deficiencies

While this method will detect nonfunctioning lights and windshield wipers, it may not detect them soon enough. Failures may cause the driver to have an accident before they can be detected by manual inspection.

Candidate Technologies

An on-board system could electronically monitor lighting and windshield wipers as the truck is traveling. At the moment that a lighting failure occurs, the monitoring system could inform the driver. An on-board transponder could also relay the information to the nearest inspection station.

STEP 8: STEERING AXLE

Before beginning the steering axle inspection, the inspector should inform the driver that he is going under the vehicle. Once under the vehicle, the inspector should check the steering system and the key steering components (front axle beam, gear box, pitman arm, drag link, tie rod, and tie rod ends). The front suspension, front brakes, front axle, frame, and frame assembly should also be inspected while the inspector is under the front of the vehicle.

Deficiencies

While this method will detect a nonfunctioning steering axle, it may not detect it soon enough. Failure may cause the driver to have an accident before it can be detected by manual inspection.

Push-rod travel for inspecting brakes, while it can be accurate, is very time consuming, and it requires driver cooperation. The required time investment prevents the inspector from testing an adequate number of vehicles.

In addition, the inspector must crawl under the vehicle to measure push rod travel. This is dangerous for a number of reasons. The inspector can be exposed to leaking hazardous materials (e.g., hot motor oil, hot antifreeze fluid, wiper cleaning fluid, and so on), the truck could move if not secured properly, and the emergency brake chambers can explode if the chamber is corroded. In addition, measuring push rod travel is not an exact measurement considering that the push rod is marked with soapstone usually. Proper push rod travel does not ensure proper brake operation. Broken or missing mechanical linkages, worn or greasy brake pads, and air leaks can all contribute to improper brake operation. Although proper push rod travel is required for proper brake operation, other factors contribute to a correctly functioning brake system.

Candidate Technologies

An on-board system could monitor the steering axle as the truck is traveling. At the moment that a steering-axle failure occurs, the monitoring system could inform the driver. An on-board transponder could also relay the information to the nearest inspection station. Since steering axle failure might be a catastrophic failure, the driver might notice the failure at the same time that the on-board monitor does.

Dynamometer (both portable and fixed) testing or skid plate testing could be used instead of push rod travel to inspect brakes at the inspection station. In addition, on-board infrared testers could be used to monitor brake pad temperatures as the vehicle traveled. Brake dynamometers and skid plates attempt to measure brake performance. Infrared systems attempt to assess proper brake adjustment by looking at temperature differences between wheels (which correspond to the amount of work done by each brake because brake work is converted to heat energy). Skid plate results are affected by driver skill and performance, while dynamometer tests can be time-consuming for multiple axles. The costs of both systems are also moderately high. Infrared systems under development could allow drive-by assessment of brake adjustment, but these systems are still undergoing field testing. The cost of infrared systems was not available at the time of this report.

On-board sensing could easily be used to monitor different aspects of brake performance. Push-rod travel could easily by measured, either with a switch type sensor (which detects only out-of-adjustment conditions), or with a linear position sensor (potentiometer, linear voltage displacement transducer (LVDT), etc.) Brake pad/drum temperature and torque applied to the cam shaft by the slack adjuster could also be measured with sensors. In addition, axle torque can be measured. The cost of these systems would depend heavily on the reliability and accuracy of the sensors. Although different quantities in an S cam air brake system could be easily measured with off-the-shelf technology, further research is required to determine the required sensors and algorithms to estimate brake performance from raw sensor data. The costs of the various sensors would also have to be taken into consideration for truck applications.

STEP 9: LEFT FRONT SIDE OF TRACTOR

The inspector checks the left front wheel and rim for violations such as cracks, unseated locking rings, missing clamps, and bleeding rust stains. The left front tire is also checked for violations such as improper inflation, cuts, bulges, too much tread wear, sidewall defects, and exposed fabric/cord. The inspector also checks to see if radial and bias tires have been mixed on the steering axle.

Deficiencies

While this method will detect violations in the left front side of the vehicle, it may not detect them soon enough. Failures may cause the driver to have an accident before they can be detected by manual inspection.

In addition, many of these violations, such as cracks, are difficult to detect by visual inspection.

Candidate Technologies

An on-board monitoring system could be used to detect many of the violations on the left front side of the vehicle. For example, sensors embedded in the tire tread could detect when the tire is dangerously worn or improperly inflated. At the moment that a failure occurred, the monitoring system could inform the driver. An on-board transponder could also relay the information to the nearest inspection station.

Because of the complicated nature of these violations, on-board monitoring systems cannot entirely replace manual inspection. However, there are technologies that can aid manual inspection. For example, a thermal paint has been developed that shows distinct discoloration when exposed to high temperatures, a major cause of thermal cracks and fracture of the wheel rim. This thermal paint could be used to aid the inspector.

STEP 10: LEFT SADDLE TANK AREA

The saddle tank inspection includes the fuel tanks, tractor frame, and exhaust system.

Deficiencies

While this method will detect violations in the left saddle tank area, it may not detect them soon enough. Failures may cause the driver to have an accident before they can be detected by manual inspection.

In addition, many of these violations, such as cracks and nonsecure mountings, are difficult to detect by visual inspection.

Candidate Technologies

An on-board monitoring system could be used to detect many of the violations on the left saddle tank area. At the moment that a failure occurred, the monitoring system could inform the driver. An on-board transponder could also relay the information to the nearest inspection station.

Because of the complicated nature of these violations, on-board monitoring systems cannot entirely replace manual inspection. However, there are technologies that can aid manual inspection. For example, an infrared spectrometer could detect fuel vapor fumes from leaking fuel. Thermal paint (see Step 9) could be used to detect cracks.

STEP 11: TRAILER FRONT

While performing the trailer front inspection, the inspector should check to see that the air and electrical lines between the tractor and trailer are suspended and free of tangles or crimps. The front end protection should meet the height requirements (as tall as the load up to 4 feet).

Deficiencies

While this inspection may detect tangled air and electrical lines, it may not detect them before they cause the vehicle to malfunction or even cause an accident.

Candidate Technologies

On-board monitoring systems could indirectly check whether air or electrical lines are tangled. For example, an on-board brake monitoring system could check air pressure in a brake line. If there was a sudden drop in air pressure caused by a crimped line, the driver could be informed and that information could be relayed by transponder to the nearest inspection station.

STEP 12: LEFT REAR TRACTOR AREA

During inspection of the left rear tractor, the inspector checks the wheels, rims, and tires in this area. The lower and upper fifth wheel is also examined. After these items have been inspected, the inspector should inform the driver that he/she is going under the vehicle. Entering the undercarriage in view of the driver, the inspector should check the suspension on both sides of the tractor and inspect the tractor brakes. The push rods should also be marked with the brakes released.

Deficiencies

While this inspection may detect problems in the left rear tractor area, it may not detect them before they cause an accident.

Some defects (thermal cracks) are hard to detect.

Push-rod travel to assess brake performance is time consuming, dangerous, and not exact. (See deficiencies discussion for Step 8.)

Candidate Technologies

Thermal paints (explained in Step 9) could be used to show cracks.

On-board monitoring technologies could be used to check tire wear and inflation.

Dynamometers, skid plates, infrared techniques, and on-board sensing (see Step 8) could replace brake inspection using push rod travel.

STEP 13: LEFT SIDE OF TRAILER

Inspection of the left side of the trailer includes the frame and body as well as cargo securement.

Deficiencies

While this method may detect problems with the vehicle frame and cargo, it may not detect them soon enough. For example, cargo could become unsecured during travel.

Candidate Technologies

While on-board monitoring systems cannot totally replace visual inspection, they could provide valuable information as when the vehicle is operating. For example, a simple stress sensor on cables restraining cargo could detect if the cargo comes unsecured. This information could be relayed directly to the driver and by transponder to the nearest inspection station.

STEP 14: LEFT REAR TRAILER WHEELS

The inspector first inspects the left rear trailer wheels and then informs the driver that he/she is going under the vehicle. Upon entering the undercarriage in view of the driver, the suspension on both sides of the tractor is checked. The trailer brakes are also inspected, and the push rods are marked with the brakes released.

Deficiencies

While this method will detect violations in the left rear trailer wheels, it may not detect them soon enough. Failures may cause the driver to have an accident before they can be detected by manual inspection.

In addition, many of these violations, such as cracks, are difficult to detect by visual inspection.

Push-rod travel, while accurate, is very time consuming, and it requires driver cooperation. The required time investment prevents the inspector from testing significantly more vehicles.

Candidate Technologies

An on-board monitoring system could be used to detect many of the violations on the left rear trailer (e.g., tire sensors-see Step 9). At the moment that a failure occurred, the monitoring system could inform the driver. An on-board transponder could also relay the information to the nearest inspection station.

Because of the complicated nature of these violations, on-board monitoring systems cannot entirely replace manual inspection. However, there are technologies that can aid manual inspection. For example, thermal paints (see Step 9) could be used to detect cracks.

Dynamometers, skid plates, infrared techniques, and on-board sensing (see Step 8) could replace push rod travel for inspecting brakes.

STEP 15: REAR OF TRAILER

In this step the rear of the trailer is inspected. The tail, stop, and turn lamps and the emergency flashers should be checked. Cargo securement should also be verified.

Deficiencies

While this method will detect nonfunctioning lights, it may not detect them soon enough. Failures may cause the driver to have an accident before they can be detected by manual inspection.

While this method may detect problems with the cargo, it may not detect them soon enough, and cargo could become unsecured during travel.

Candidate Technologies

An on-board system could electronically monitor lighting and relay malfunctioning information to nearest inspection station (see Step 7).

Stress sensor for cables restraining cargo (see Step 13).

STEP 16: RIGHT REAR TRAILER WHEELS

In this step the wheels, rims, and tires as well as the sliding tandem are inspected.

Deficiencies

While this method will detect violations in the right rear of the vehicle, it may not detect them soon enough. Failures may cause the driver to have an accident before they can be detected by manual inspection.

In addition, many of these violations, such as cracks, are difficult to detect by visual inspection.

Candidate Technologies

On-board monitoring systems described in Step 9.

Thermal paint, also described in Step 9.

STEP 17: RIGHT SIDE OF TRAILER

The frame and body, including cargo securement and spare tire mounting, are checked in this step.

Deficiencies

While this method may detect problems with the vehicle frame and cargo, it may not detect them soon enough. For example, cargo could become unsecured during travel.

Candidate Technologies

Stress sensor for cables restraining cargo (see Step 13).

STEP 18: RIGHT REAR TRACTOR AREA

The right rear tractor area is inspected in this step. The tail, stop, and turn lamps and the emergency flashers are checked. Cargo securement is also verified.

Deficiencies

While this method will detect nonfunctioning lights, it may not detect them soon enough. Failures may cause the driver to have an accident before they can be detected by manual inspection.

While this method may detect problems with the cargo, it may not detect them soon enough, and cargo could become unsecured during travel.

Candidate Technologies

An on-board system could electronically monitor lighting and relay malfunctioning information to nearest inspection station (see Step 7).

Stress sensor for cables restraining cargo (see Step 13).

STEP 19: RIGHT SADDLE TANK AREA

The saddle tank inspection includes the fuel tanks, tractor frame, and exhaust system.

Deficiencies

While this method will detect violations in the right saddle tank area, it may not detect them soon enough. Failures may cause the driver to have an accident before they can be detected by manual inspection.

In addition, many of these violations, such as cracks and nonsecure mountings, are difficult to detect by visual inspection.

Candidate Technologies

An on-board monitoring system could be used to detect many of the violations on the left saddle tank area. At the moment that a failure occurred, the monitoring system could inform the driver. An on-board transponder could also relay the information to the nearest inspection station.

Because of the complicated nature of these violations, on-board monitoring systems cannot entirely replace manual inspection. However, there are technologies that can aid manual inspection. For example, an infrared spectrometer could detect fuel vapor fumes from leaking fuel. (See Step 10.) Thermal paint (see Step 9) could be used to detect cracks.

STEP 20: RIGHT FRONT SIDE OF TRACTOR

In this step, the wheels, rims, and tires on the right front side of the tractor are checked.

Deficiencies

While this method will detect violations in the right rear of the vehicle, it may not detect them soon enough. Failures may cause the driver to have an accident before they can be detected by manual inspection.

In addition, many of these violations, such as cracks, are difficult to detect by visual inspection.

Candidate Technologies

On-board monitoring systems described in Step 9.

Thermal paint, also described in Step 9.

STEP 21: BRAKE ADJUSTMENT CHECK

Brake adjustment is verified in this step. All push rods should have already been marked with the brakes off. The driver should be instructed to make a full brake application and hold in the applied position with the air pressure between 90 and 100 psi. The inspector should then inform the driver that he/she is going under the vehicle. The push rod travel on each brake should be measured while listening for air leaks. The type of brake chambers should also be noted, and each push rod measurement should be compared to the Out-of-Service Criteria for the appropriate size and type of brake chamber.

Deficiencies

Push-rod travel to assess brake performance is time consuming, dangerous, and not exact. (See deficiencies discussion for Step 8.)

Candidate Technologies

Dynamometers, skid plates, infrared techniques, and on-board sensing (see Step 8) could replace push rod travel for inspecting brakes.

STEP 22: FIFTH WHEEL MOVEMENT CHECK

The driver gently rocks the trailer as the inspector watches the fifth wheel. The inspector watches for movement between the mounting components and frame, pivot pin, and bracket, and the upper and lower fifth wheel halves.

Deficiencies

If conducted improperly, this method of checking for fifth wheel movement can result in serious damage to the vehicle.

Candidate Technologies

Fifth wheel movement could be detected using various types of sensors. Sensor technologies that could be used to measure relative position of the tractor and trailer include: optical sensor, magnetic sensors (Hall effect), and LVDTs (linear voltage displacement transducers).

STEP 23: AIR LOSS RATE

If the inspector hears an air leak at any time during the inspection, he/she should check the vehicle's air loss rate. The driver runs the engine at idle, and then applies and holds the service brake. The driver then pumps the brake until the pressure drops to about 80 psi. At about 80 psi, most compressors start to activate. Air pressure should be maintained or increased. A drop in pressure indicates a serious leak and is sufficient to place the vehicle out of service.

Deficiencies

Air leaks are found mostly by the inspector listening for leaks. Because audible cues are used to find leaks, assessment of the severity of the leak is very subjective. Factors that influence the inspector's ability to find a leak include the inspector's hearing as well as background noise.

Candidate Technologies

Pressure sensors located throughout the pneumatic brake system could easily measure the air pressure at critical points. A "leak listener" device that would listen for leaks could also be developed. It could be carried with the inspector and provide an alert signal if a leak was detected. However, such a device would probably be expensive and not increase an inspector's efficiency at detecting leaks, unless the inspector had hearing difficulties.

STEP 24: LOW AIR PRESSURE WARNING DEVICE

With the ignition on, the driver depletes the air supply by pumping the foot valve until the low air pressure warning device activates. The inspector observes the gauges on the dash to determine if the warning activates at a minimum of one-half the compressor governor cutout pressure (normally 55 psi or above).

Deficiencies

There are no major deficiencies with this step, However, safety could be improved by periodically testing the low air pressure warning device with on-board-diagnostics.

Candidate Technologies

Conduct a self-test of the low air pressure warning device periodically with on-board diagnostic electronics. At the moment that a failure occurred, the monitoring system could inform the driver. An on-board transponder could also relay the information to the nearest inspection station.

STEP 25: TRACTOR PROTECTION VALVE

With the brakes released and the air pressure at the normal operating level, the driver disconnects both air lines at the glad hands. Then the driver makes a full brake application. Air should stop coming out of the lines when the gauge reads about 60 psi. After the air stops, the driver makes a second full brake application. If the tractor protection valve is functioning properly, no air should come out of either line.

Deficiencies

There are minor hazards associated with removing the glad hands: high pressure air and possibly water and oil may come out of the lines.

Candidate Technologies

The tractor protection valve inspection could be automated by placing valves in the pneumatic system, which would simulate disconnecting the glad hands. Pressure and/or flow sensors could be used to monitor the tractor protection valve performance. This approach would require on-board diagnostics.

STEP 26: EMERGENCY BRAKES

While air lines are detached from the trailer at the glad hands, the inspector checks to make sure that air is not bleeding back from the trailer. Air escaping from the trailer air lines at the glad hand connection indicates a problem with the trailer emergency braking system.

Deficiencies

Air escaping from the glad lines must be detected audibly or by feeling the air leak. This is very subjective.

Candidate Technologies

Pressure and flow sensors could be used to measure trailer air loss at the glad hands. These sensors could also be part of the air leak detection system used for Step 23.

STEP 27: COMPLETE THE INSPECTION

The inspector completes the paperwork, concludes with the driver, follows the out-of-service procedures if applicable, and applies the CVSA decal if the vehicle(s) passed the inspection.

Deficiencies

The paperwork and report forms completed by the inspector can be time consuming. Also, the inspector's handwriting greatly affects the ability of others to read the inspection form. If a truck is put out-of-service, there is often no way of verifying that the out-of-service condition has been corrected before the truck leaves.

Candidate Technologies

Pen-based computers (see Step 3) is an area already being evaluated by some states. A computer printout of an inspection report is also generally easier to read than a handwritten report. Covert monitoring of trucks that have been placed out-of-service is also being researched.

STEP 28: ENTER INSPECTION DATA INTO MCMIS DATABASE

States use the SAPETYNET program to enter inspection results into the MCMIS database.

Deficiencies

Typographical data entry errors and unreadable inspection reports cause erroneous data to be entered into the database.

Candidate Technologies

The use of computers to generate inspection reports will allow automatic entry into the MCMIS database of the appropriate information. This should reduce the number of errors caused by data entry errors and unreadable inspection reports (these steps will have been eliminated).

Distribution

Arthur W. Sampson
Safety Investigator
U.S. Department of Transportation Office of Motor Carriers
6000 Uptown Blvd. N.E. #303
Albuquerque, NM 87110

Eugene Calt
Officer-in-Charge
U.S. Department of Transportation Office of Motor Carriers
6000 Uptown Blvd. N.E. #303
Albuquerque, NM 87 110

Holly Kinley-Lick
FHWA/CVSA
604 W. San Mateo
Santa Fe, NM 87501

Vic Sheppard
New Mexico Motor Carrier's Association
Managing Director
4809 Jefferson NE
Albuquerque, NM 87109

Paul Henry
Deputy Administrator
Transportation Safety Division
Public Utility Commission
420 Labor & Industries Bldg.
Salem, OR 97310

William C. Rogers
Director of Research
The ATA Foundation
2200 Mill Rd.
Alexandria, VA 22314-4677

Larry Stearn
Director of Administration
CVSA
1620 Eye St., N.W.
Suite 1000
Washington, DC 20006

Ray Rogers
MCSAP Coordinator
State of New Mexico
P.O. Box 1028
Santa Fe, NM 87504-2266

Norm Lindgren
Director
Motor Carrier Safety Division
4501 South 2700 West
Salt Lake City, UT 84119

Dean T. Harbour
Virginia State Police
P.O. Box 11961
Lynchburg, VA 24506

Steven A. Blake
Texas Department of Public Safety
P.O. Box 181
Mt. Pleasant, TX 75455

Lane Elmer
Inspection Office
St. George Port of Entry
P.O. Box 571
St. George, UT 84771

Kerry Kendall
Inspection Office
St. George Port of Entry
P.O. Box 571
St. George, UT 84771

Cal Schock
Montanna Highway Patrol
1010 Main
Miles City, MT 59301

Dan J. Smith
Montana Highway Patrol
P. 0. Box 3765
Bozeman, MT 59772

Larry Barton
Director
Montana Deptartment of Transportation
2701 Prospect Ave.
Helena, MT

Jim Gettner
Deputy Executive Director
Help, Inc.
19601 North Black Canyon Hwy.
Suite 200A
Phoenix, AZ 85027-407

Duanne Sammons
Deputy MCSP Commander
Idaho Dept. of Law Enforcement
6050 Corporal Ln.
Boise, ID 83704

Doug Donscheski
MCSAP Coordinator
Nebraska State Patrol
3920 N.W. 39th St
Lincoln, Nebraska 68524

Shirley Danahy
MCSAP Administrative Assistant
Nebraska State Patrol
3920 N.W. 39th St
Lincoln, Nebraska 68524

Mary Holt
Alabama Department of Public Safety
P.O. Box 1511
Montgomery, AL 36102-1511

Angie Marzano
Alabama Department of Public Safety
Motor Carrier Safety Unit
1708 Congressman Dickinson Dr.
Montgomery, AL 36109

Steven G. Horrocks
Radix Corporation
4855 Wiley Post Way
Salt Lake City, UT 84116

Abe Khoygani
Associate Programmer Analyst
California Highway Patrol
P.O. Box 942898
Sacramento. CA 94298-0001

Robert Hagan
Officer-in-Charge
Nevada Division, Officer of Motor Carriers
705 North Plaza St.
Suite 220
Carson City, NV 89701

Internal

9600 J. R. Kelsey
9604 S. C. Roehrig
9616 B. C. Caskey
9616 R. H. Byrne
9616 P. D. Heermann

ATTACHMENT 2

Commercial Vehicle Brake Study Project Short Stop

R. J. Peterson
96 11 -Access Delay Technology Department
Sandia National Laboratories
Albuquerque, NM 87 185

Draft of 10-21-93
(Original draft: 7-14-93)
NOT FOR DISTRIBUTION

Abstract

The Federal Highway Administration (FHWA) assigned Sandia National Laboratories (Sandia) the task of providing an independent review of heavy truck (pneumatic) braking system and component problems that lead to a large number of vehicles having substandard braking capacities. Information gained from an extensive literature search and visits to American and European heavy truck manufacturers and vehicle safety research facilities provided Sandia with a basis for an FHWA-sponsored workshop on this problem. Ideas from the workshop were then refined by Sandia engineers and near- to mid-term as well as long-term recommendations were identified that could be directly applied or first developed then applied to the deficiencies. This report presents background of this project, along with braking technology deficiencies, proposed solutions, and obstacles to those solutions.

TECHNICAL TASK PLAN

TITLE: Project Short *Stop* (Commercial Vehicle Brake Study)

Sponsor:	Federal Highway Administration (FHWA) 6300 Georgetown Pike McLean, VA 22101	
Technical Program Officer:	Mike Freitas	(703)285-2421 (703)285-2264 (FAX)
Sandia Proposal Number:	959200309	Date: March 23, 1992
Principal Investigator:	Randy Peterson , Dept. 9611 Sandia National Laboratories Albuquerque, NM 87185-5800	(505) 844-5792 (505) 844-5569(FAX)
Technical Program Manager:	Steve Roehrig, Dept. 9604 Sandia National Laboratories Albuquerque, NM 87185-5800	(505) 844-1180 (505) 844-2193 (FAX)

TASK SUMMARY

The largest single cause of accidents involving commercial vehicles (large trucks and inter-city busses) in the US is brake related (National Highway Transportation Safety Administration Study May 1992). Truck inspections (1.6 million in 1991) reveal that 90% of trucks that fail have brake problems. The US Federal Highway Administration needs a fresh look at large vehicle braking to plan a program that will solve inherent braking problems.

The purpose of this study project is to apply the technical resources of Sandia to provide independent review, investigation, and analysis of the problem with the final result being recommendations for improving heavy truck braking systems.

STATEMENT OF WORK

The project team, composed of members from Sandia, FHWA, industry, and universities will accomplish the following sub-tasks:

1. Gather Information - this will include a literature search (for US and foreign documents) and interviews with experts (government and industry) in the braking field. Advanced systems (aircraft and space shuttle, for example) will be included.

2. Workshop - a workshop will be held to discuss and determine concepts.

3. Investigation/analysis - the information and ideas will be subjected to both simple feasibility checks and simple engineering analysis to pare and order a list of promising solutions. Materials, RF, control theory, sensor and polymer areas will be examined for advances that will contribute to improved brake performance and truck stopping distances. Both near-term and future solutions will be listed.

4. Recommendations - near to mid-term solutions will be summarized based on currently available technology. However, major emphasis will be placed on investigating braking and truck stopping fundamentals and how they might be improved in the future. This will include recommendations for improvements using more advanced technologies.

The scope of this project is limited to addressing US commercial vehicle braking from technical aspects only. Regulatory and political issues are excluded.

ESTIMATED COST'

YEAR	MANPOWER	EXPENSE	TOTAL
FY93	$75K	$35K	$110K

MILESTONES

Workshop Held	May 1993
Briefing on Recommendations	July 1993
Draft Report Delivered	September 1993

RISK

Since the magnitude of this project is not known until the available literature is received and industry contacts are made, there is risk that all factors cannot be collected, assimilated and ranked in the time allotted. The sponsor will be involved in any changes to this task plan.

APPROVALS

FHWA	______ Mike Freitas	______ Date
Sandia	______ Steve Roehrig	______ Date

1 Numbers reflect after tax amounts.
2 1f FHWA sponsors the Workshop, this amount could be reduced to 20K.

Contents

Figures

Tables

1. Introduction

1.1 Background of the Commercial Vehicle Operations Study

In the fall of 1992, Sandia National Laboratories (Sandia) began working with the Federal Highway Administration (FHWA) on the task of developing the Commercial Vehicle Operations (CVO) service for the Department of Transportation (DOT). This task is part of the Intelligent Vehicle Highway Systems (IVHS) program, which has the objective of providing safer, more efficient, and cleaner vehicles and highways for the transportation systems of the future. Sandia's involvement with IVHSKVO is part of an overall DOT effort to establish partnerships with the national laboratories, the Department of Defense's (DoD's) Advanced Research Projects Agency (ARPA), and the defense and space industries in general to identify and develop suitable intelligent vehicle systems for commercial trucking operations.

Sandia is involved in several specific CVO technical subtasks, namely:

- Enhancements to Commercial Vehicle Inspections
- Commercial Vehicle Brake Study (Project Short *Stop)*
- RAMPOST (RadioActive Materials POST notification reports) Database Support
- Assessment of Technologies for Hazardous Material Transport
- Technologies for Covert Inspection Monitoring

1.2 Commercial Vehicle Brake Study (Project Short Stop)

The National Traffic Safety Board (NTSB) has found that brake problems are a major contributor in l/3 of accidents involving commercial vehicles (large trucks and intercity buses) in the U.S. (NTSB, 1992). Truck inspections have shown historically that 60 to 65% of out-of-service trucks have brake problems (Clarke, et al., 1991). This report estimates that vehicles will have an average life span of 11.6 years, which relates to the fact that on average a vehicle will have a 40-percent chance of being involved a brake-related crash. As part of their work for the CVO, the participants of Project *Short Stop* were assigned the following tasks: (1) provide an independent review of the problem, using Sandia technical resources; (2) conduct investigations into possible solutions using information from industry, government (both U.S. and foreign), and academia; and (3) analyze preliminary results offered by those sources. The final activity of Sandia's involvement in this study will be to document findings and recommendations for both near- and long-term technologies that would improve brake performance in a white paper for FWHA. This Project *Short Stop* report describes Sandia's investigation into heavy vehicle brakes and braking technologies, including research and development in the U.S. and abroad, safety studies of heavy vehicle braking, and advanced designs (e.g., aircraft and space shuttle braking). Visits and interviews with domestic and foreign heavy vehicle brake manufacturers, government, and research experts are also documented. Sandia has performed technical investigations and analyses of near- and long-term designs for brakes and braking systems, has identified obstacles to implementing those designs, and has made recommendations for near- and long-term activities.

1.3 Sandia National Laboratories

For over 40 years, Sandia has been primarily involved in developing weapons systems for the Departments of Defense and Energy. As a result of that work, Sandia has gained considerable knowledge and experience in developing a systems approach to problem solving, whether the task involves developing a weapons system or designing the transportation system to move nuclear materials safely on U.S. highways.

As a national laboratory, Sandia is actively pursuing technology transfer activities with U.S. industry. In an article published in *the AT&T Technical Journal*, the field of transportation was identified as one of Sandia's six strongest areas of technology transfer (Narayanamurti and Arvizu, 1991). One of Sandia's (and other national laboratories') strongest technology transfer tools is the Cooperative Research and Development Agreement (CRADA). A CRADA combines the technical resources of a national laboratory with those of industry to develop new products and processes. Sandia has CRADAs in the field of transportation with several U.S. firms, most recently signing six CRADAs with General Motors. These GM CRADAs demonstrate Sandia's experience in working with industry in transportation areas. Eventually, the technologies developed by the CVO program will be transferred to the domestic market.

2. Research and Investigations

2.1 Literature Search Summary

As a means of gathering background information on heavy vehicle brakes and braking systems, and as a partial completion of the Statement of Work for the Project Short Stop Technical Task Plan, an intensive literature search of stopping and braking approaches was accomplished. The material was gathered for three main reasons: (1) to determine what research and development (R&D) was occurring in the government and private (industry) sectors; (2) to identify suppliers of commercially available advanced brakes and braking systems; and (3) to identify the experts in the field of heavy vehicle braking for a workshop to be held as part of the brake study.

The material gathered was categorized into 14 general topics: tractor/trailers; advanced/aircraft braking; heavy-duty brakes and general information regarding antilock braking systems (ABS); materials technologies; heavy-duty braking safety studies; foreign braking codes and regulations; tire technology; retarders; disc brakes; bus antilock brake systems; trailer-specific antilock brake systems; brake-by-wire technology; truck ABS's; and miscellaneous articles addressing foreign and domestic comparisons of heavy-duty braking requirements. A total of 103 documents was reviewed for this task. Of these, 72 were authored in the U.S., while 24 were authored abroad (Federal Republic of Germany, Sweden, Canada, Japan, and Australia).

The sources for the material were industry (domestic and international), United States (U.S.) federal and state governments, foreign governments, government contractors, professional societies, and trade journals. The primary sources for materials are shown in Table 2-l. The most prevalent sources for domestic information were the U.S. Department of Transportation's (DOT) National Highway Traffic Safety Administration (NHTSA), DOT's National Transportation Safety Board (NTSB), the Society for Automotive Engineers (SAE), the University of Michigan's Transportation Research Institute (UMTRI), and *Automotive Engineering*, a trade journal. Most of the foreign information came from technical papers presented at international meetings of the SAE.

Table 2-1. Source Material Breakdown for *Project Short Stop*

CATEGORY	SOURCES FOR MATERIALS					
	industry	Federal	State	Contractor	Professional Society	Trade Journal
Tractortrailer	0	+		+		●
Advanced/Aircraft	0	0		0	0	0
Brakes/General ABS		0	+	0	0	0
Materials						0
Safety Studies	0	*		0	0	0
Foreign Codes & Regulations	m	■				
Tires		●	[illegible]	□	●	
Engine Retarders	+					
Disc Brakes	+					
Bus ABS						●
Trailer-Specific ABS	■					□
Brake-By-Wire	■					o
Truck ABS	❑	m		●		□
Miscellaneous (Foreign Comparison)	+	0				0

Notes:
- ● designates domestic sources only.
- 4 designates domestic and foreign sources.
- . designates foreign sources only.

Several general impressions were gained from this literature search. These are highlighted below.

- Many articles have been written on this subject, but the majority of information has been narrowly focused on specific components or facets of truck braking and not on truck braking as an integrated system. Two very good summaries on truck braking and exceptions to this statement are reports by Clarke, et al., 1991 and NTSB/SS-9201 (PB92-917003).

- Current air brake systems work well when driver, maintenance, and environments are optimum.

- The current drum brake designs are not an optimum foundation brake type, because of their maintenance sensitivity and tendency to fade when used in extreme situations.

- Disc brake designs offer inherent design advantages over drum. These include being more resistant to fade when pushed to their design limits and von Glasner, 1990) and allowing the possibility of easier friction material replacement.

2.2 Visits to American and European Trucking Concerns

To determine the scope of available and possible future heavy vehicle brakes and braking systems in the U.S. and abroad, and as partial completion of the Project *Short Stop* Statement of Work, engineers from Sandia visited several facilities involved in the production and product testing of heavy trucks in the U.S., England, and Germany. They hoped to learn about the current state of braking technology and to interview the designers of advanced brakes and braking systems.

In the U.S., the Sandia team visited the University of Michigan's Transportation Research Institute (UMTRI) in Ann Arbor, Michigan; the NHTSA Traffic Research Center near Liberty, Ohio; and the Eaton Corporation's Engineering and Research Center in Southfield, Michigan. The Sandians traveled to England to visit WABCO's (Westinghouse Air Brake Company's) facility and the Lucas Heavy Duty Brake Engineering and Test Center. They then traveled to Germany to Mercedes-Benz's Engineering Truck Division. At the industrial facilities, the Sandians discussed the current state of brakes and braking technology and learned how brake technology will change in the future. They learned that based on the information gathered from the best available sources, Europeans are placing a major emphasis on developing advanced brake control systems for introduction into the market in a 5-10 year time frame. Test beds with these advanced brake systems were demonstrated in both the U.S. and Europe. The Sandians also learned from these industry contacts the differences between U.S. and foreign trucking manufacturing industries, how those industries work with government with regard to rules and regulations, and how new braking technologies are moved from the research stage to the marketplace. The contacts provided the Sandians with trucking industry contacts for an FHWA-sponsored workshop that was hosted by the Sandians in May of 1993. In addition to obtaining the names of industry contacts, the Sandians gained guidance as to the direction that these representatives thought the workshop should take.

The three European manufacturers agreed that load sensing is crucial for vehicle stability during braking. The U.S. trucking industry currently designs brake balancing for a fully loaded condition. This practice, according to European engineers, leads to vehicle instability when a tractor is operated in the bobtail configuration (tractor only) or when a trailer being pulled is empty or only partly loaded. Several of the manufacturers thought that advanced control systems would be incorporated into future brake designs; however, U.S concerns thought that the cost of those advanced systems needed to be made tolerable for the customer. An advanced brake control concept being tested is a brake-by-wire system that uses pneumatics as a backup only. Brake-by-wire designs allow for faster control of ABS hardware and removes lag times encountered with pneumatic brake systems. These new systems incorporate ABS hardware and feature brake balancing, integral retarder control, tractor and trailer compatibility, load sensing, optimal friction material wear, and brake proportioning into an integrated package. This package gives feedback to the driver as to the condition of the brake system while storing pertinent system information for later use by maintenance technicians.

The Sandians gained insight into the current and future trends of braking technologies through these visits. The visits also laid the groundwork for possible future R&D partnerships between Government, industry, and Sandia.

2.3 Federal Highway Safety Administration Workshop

A workshop sponsored by the FHWA and hosted by Sandia was held in May of 1993 in Albuquerque, New Mexico. Participants included representatives from commercial trucking businesses; heavy vehicle brake and component manufacturers; officials from the DOT; consultants; and employees of Sandia. The workshop was prepared as a problem-solving session to determine what near- and long-term improvements experts believe should be made to braking systems; and as a forum to analyze and make recommendations for technologies that would make these visions of future braking systems a reality. James Kelsey, Director of Sandia's Transportation Systems Center, gave an overview of the lab's involvement with Department of Energy (DOE) programs and emphasized Sandia's commitment to sharing available technology with private industry through the technology transfer process.

The goals of the meeting were to

- Solicit a wide variety of opinions on braking questions;
- examine current stopping approaches for heavy truck braking;
- identify near-term (5 to 10 years) improvements in braking components and systems;
- identify long-term (10 to 20 years) improvements in braking components and systems; and
- build a consensus of opinion regarding current and emerging technologies that can be used to accomplish near- and long-term improvements.

The first step was to use a quality process to identify near-term technologies for improvements to braking systems and components. The range of current stopping approaches for heavy trucks was broken into three main areas:

- foundation of braking;
- advanced braking; and
- alternatives/supplements to conventional foundation brakes.

The workshop participants divided into three groups to identify the system(s) from each area that were the major factors in each of the above three categories, with the definition of a major factor in selecting braking systems being that the system has an 80% share of the U.S. market for that particular application. The goal of these discussions was to complete a quality matrix (Figure 2-l) from which the group could reach a consensus on the technology that would have the most impact on braking in the near term.

All major factors, such as the one listed above, were broken down to their component level ("what's") with the major cost (C), life (L), and performance (P) limiters being identified. These limiters can be used to yield a ranking by using the following relationship:

$$R = (P*L)/C$$

where

R = ranking of stopping systems
P = overall safe stopping performance
L = lifetime (period between major maintenance requirements
C = capital costs of braking hardware.

The viewpoint of the customer (the purchaser of tractor/trailer equipment) was the factor used to prioritize the technologies. The technologies were first identified, then grouped according to affinity grouping techniques (Table 2-2). This grouping exercise led the participants to examine how changes in technology could bring about the desired advanced braking concepts. The workshop participants also expressed their vision of the future of braking systems (lo-20 years). In concert with the future braking systems, the participants identified technology areas that will need further development to make the future of braking systems a reality. Lastly, the group was asked to identify obstacles in the path of developing those technologies. An analysis of those ideas is outlined in Section 3, Analysis of Findings.

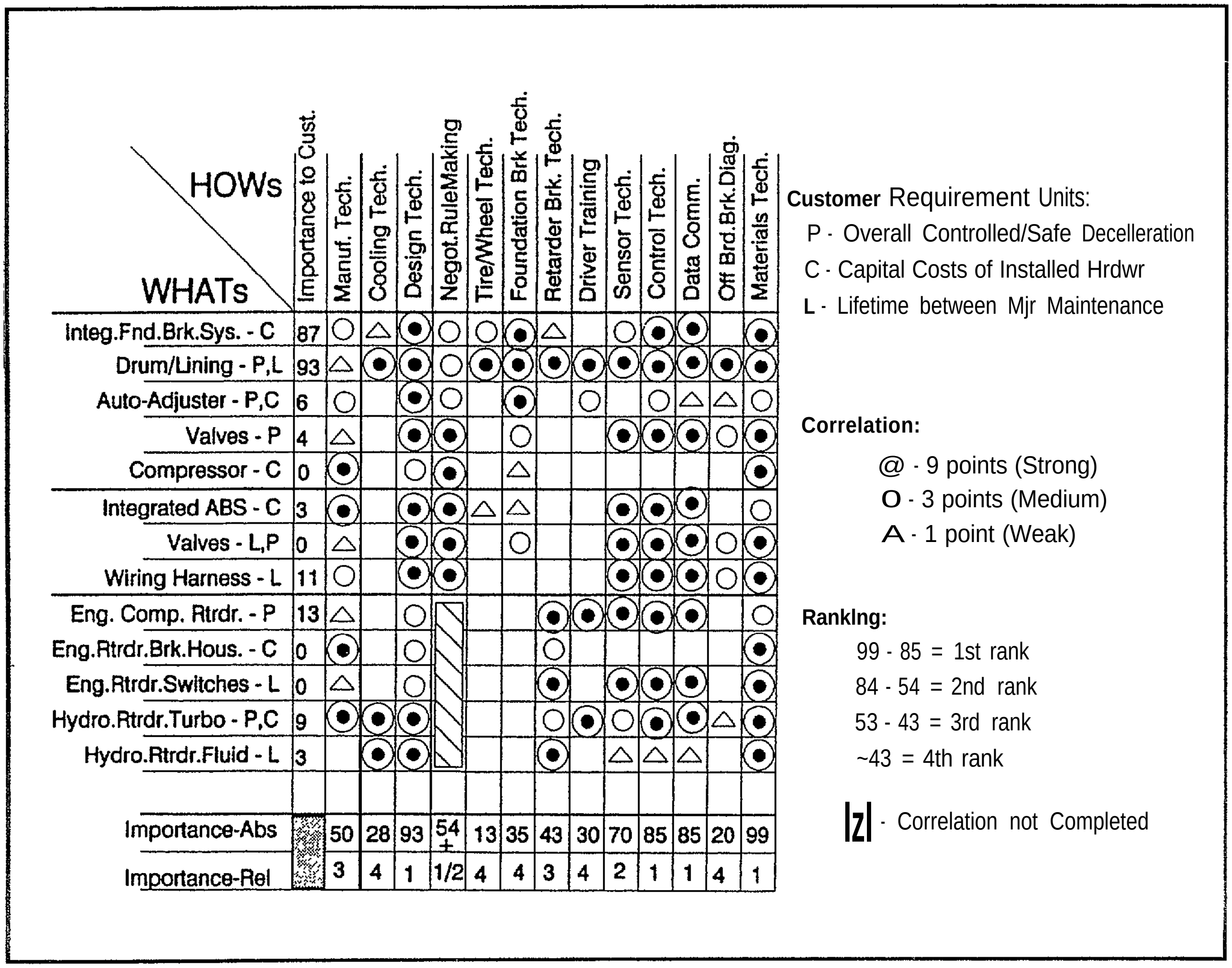


figure 2- 7. Quality Process Matrix.

Table 2-2. Affinity Grouping

Affinity Group Title	Components
Manufacturing	• Manufacturing • Prototyping • Limited Production (More Heavy Vehicle Demand) • Wiring Harness at OEM
Cooling Technology	• Phase Change • Improve Cooling System • Common Cooling Fluids • Air Flow • Improve Brake Cooling • Fluid Viscosity/High Temperature
Design Technology	• Simplify Foundation Brake Design • Reduce the Number of Elements
Negotiated Rule Making	• Smart Regulations • Standardization • Standardization of SAE • Network Standards SAE
Tire/Wheel Technology	• Improve Tires (Low Profile) • at Tires/Road • More Wheels • High Pressure • Low Wear Drum Lining (Toughness) - Dirt Tolerance • Adjuster Materials (Cost and Weight) • Interchangeability
Retarder Application	• Retarders • Electric Motors/Regenerative Braking • Mid-Range Performance • Automatic Transmission • Installation at OEM
Driver Training	• Driver Training/Certification • Reward System, Incentive Bonuses, etc.

Table 2-2. Affinity Grouping (concluded)

Affinity Group Title	Components
Data Communication	• Multiplexing • Data Communication Standardization
Control Systems	• ABS • Brake by Wire • Automatic Weight Distribution • Load Sensing Valves • Smart Valves • Valves with Larger Holes • Control System (Active/Passive) • Maintenance Diagnostic • Data Logging • Redundancy/Reliability • Optimized Trip Management
Sensor Technology	• Wiring Hardware • Improve Connectors (15-Year Life) • Sensors (various) • Sensor/Pressure • Controlled Area Network • Design Change for Hostile Environments • Collision Avoidance
Brake Diagnostic Tools (Off Board)	• Off-Frame • Active • Go/No-Go
Advnaced Materials Research	• Friction Materials • Valve Materials • Wiring

3. Analysis of Findings

3.1 Workshop Input

Literature searches and visits to heavy vehicle brake manufacturers yielded technical information on current and future braking systems and concepts that needed further discussion and analysis. A study of this material was needed to prepare for any recommendation of brake technologies for DOT or DOE programs. A significant portion of the following analysis comes from summaries distilled at the FHWA workshop on May 13-14, 1993, in Albuquerque, New Mexico. At that workshop, participants used a quality function deployment (QFD) process to identify and prioritize near-term technologies for improvements to braking systems and components. In addition, long-term technological improvements and any obstacles to improvements or changes were examined.

The potential technologies that could improve brake performance, lower costs, and extend maintenance intervals were prioritized. The results show that materials technology would have the highest influence on the improvement of brakes with design, control, and data communication technology following closely. Synopses of the near- and long-term improvements along with discussion of obstacles to those goals follow.

3.1 .l Near-Term Improvements

Foundation Brakes-Materials research would have the greatest impact on near-term braking improvements. Materials research would include better friction materials for disc and drum applications with better wear characteristics, as well as better drums, rotors, and valves; improved wiring and connectors; and simplified component design to make the brake systems less sensitive to maintenance. The consensus was that foundation brakes also need to have a long life, probably on the order of one million miles.

3.1.2 Long-Term Improvements

Materials-Better materials for foundation brakes were discussed for the long term. There was some interest in making lighter, less expensive materials available for foundation brakes. Some types of professional racing cars use carbon/carbon brakes and liquid-cooled calipers for long life. Materials that could cool the brakes (phase change) and liquid-cooled rotors were discussed for heavy vehicle brake systems.

Sensors-Sensors are needed that are inexpensive and reliable, and can relate load, torque, temperature, velocity, and wheel speed from the foundation brake or wheel area. This information would be critical in implementing a higher order brake management system. This would allow the system to compensate for many of the shortcomings of the current braking systems.

Communications-Communications techniques that would possibly use more or better sensors were thought to be crucial to future braking systems. Fiber optic technology combined with multiplexing (using one fiberoptic cable, in this case, to transmit two or more signals) was one idea brought forth to solve these problems, but cost and manufacturing problems would have to be resolved.

Commuter Modeling-Modeling and computer simulation could increase safety and reliability of brake systems, while decreasing the cost of future braking systems. However, better, more cost-effective methods need to be determined to measure the values needed to develop the models.

Cooling-The wear rates of friction materials used in brakes are directly related to temperature. If temperatures could be held to lower extremes, the current foundation brakes would be much less sensitive to adjustment. In addition, more exotic cooling techniques such as phase change or liquid-cooled rotors could be investigated for long-term improvements to friction life.

3.1.3 Obstacles to Improvements or Changes

The following obstacles need to be overcome before the development of new technologies for long-term braking system improvements can occur.

–Because the U.S. trucking market is customer driven, the cost of improvements or changes would need to be justified before more advanced braking systems could be implemented. Most customers are concerned with even modest increases in capital costs without a direct correlation to greater resultant savings in some other area of their operations. This makes it difficult for the trucking industry to promote development of new technologies for improved safety without being able to show its direct correlation in cost savings. It may be prudent to have a consortium formed with or without government support to jointly develop ideas for improved vehicle safety. Pursuing government/industry partnerships to develop the needed technology was one area identified for further review.

Rules and Regulations-Manufacturers of brakes and braking components would like to see more negotiated rule-making between themselves and the government. They believe that this would ensure that the research taking place would not be irrelevant by the time it reached the market. It was noted that most of the advanced research in braking occurs in anticipation of future federal rule-making.

Training of Maintenance Personnel-Maintaining advanced braking systems could be a problem if proper training of maintenance technicians is not accomplished in concert with greater technical support from the manufacturers.

3.2 Sandia Technology Discussion for Advanced Brake and Braking Concepts

A meeting was held between the Sandia participants who attended the FHWA workshop to further refine the concepts raised at the workshop to relate possible Sandia technologies that might benefit the CVO study. The Sandia participants took the material from that meeting back to Sandia where they contacted other researchers at the lab to garner interest and develop proposals for Sandia's systems solution approach to the CVO's needs. A summary of these proposals, including collaborative work with industry, which could assist the FHWA's CVO Technology Development program, is presented below along with a brief commentary regarding the feasibility of the highlighted technology. If more detailed information is desired regarding these proposals, appropriate contacts at Sandia can be obtained through the Advanced Transportation Programs Department at Sandia by calling Stephen Roehrig at (505) 844-l 180.

3.2.1 Heavy Commercial Truck Instrumentation

This proposal describes a system that continuously monitors and stores key information on a commercial vehicle's brake system with the most relevant information being displayed in the cab of the tractor. The system would use current wiring and connectors to collect necessary data and power the system. The sensors selected for wheel end locations would have to operate in harsh environments and possess properties to resist corrosion, shock, vibration, moisture, and temperature ranges of -55" to 125°C (or higher if required). The following is a list of some areas that would be measured with this proposal.

- Automatic/manual slack adjuster displacement
- Brake temperature
- Brake pressure at actuator during braking
- Tire pressure
- Torque during braking
- Infrared sensor to monitor road conditions
- Axle and fifth wheel loading

Comments:

This proposal is a good overview of one potential way to gather, store, and display information needed for an advanced brake control system. A preliminary time and cost estimate was provided for this task, but there is still a certain degree of uncertainty regarding the availability of commercial hardware to accomplish the transducer measurements needed. Questions would have to be resolved regarding the electrical current available to power this system given that ABS's have problems using the trailer lighting circuit because of low voltages. Finally, radio frequency interference would have to be investigated if today's grade of wiring were to be used for data gathering.

3.2.2 General Sensing Approaches

This proposal is a brief survey of sensing approaches that could be used to measure important parameters in an advance brake control system. The paper suggests that many components required for this system exist, to some degree, and could be purchased from suppliers and integrated into an overall system. It also describes work being done on CRADAs in the automotive industry. The following is a list of topics covered and their relevance to future brake systems.

- Thin film coatings - friction material wear
- Silicon carbide - high-heat environments at wheel ends (1 00°F)
- Polysilicon substrates - pressure transducers
- Fiber optics - friction material wear and torque sensing
- Acoustic sensors - friction material wear

Comments:

This proposal briefly highlights areas that may facilitate transducer measurements for future brake systems. No budgetary requirements were provided for the development of these technologies and/or integration into a working system. An overall systems requirement document would have to be developed and preliminary feasibility studies completed before any of these highlighted technologies could be explored.

3.2.3 Silicon Carbide (SIC) Sensing

This paper describes advantages and applications for Sic based electronic components. Silicon carbide based electronics have a potential for many uses both commercially and militarily. Transducers manufactured from this material would be capable of operating at temperatures of lOO^{0}F. Several large companies including General Electric (GE) and Westinghouse are pursuing this technology area.

Comments:

Silicon-carbide based electronics are still in the basic research stage, therefore the associated risks of developing viable, commercially available products are high.

3.2.4 Controlled Thermal Transport Friction Materials for Heavy Vehicle Brakes

Cause and effects of problems with current friction materials are summarized. High thermal conductivity brake materials including metal-matrix and ceramic-matrix composites may prove to be better alternatives to conventional materials. Descriptions of representative composites are presented with the note that new drum or rotor materials may be needed to take full advantages of these new friction materials.

Comments:

The materials described in this paper exist today. The real challenge for their application to truck brakes is the development of economical processing methods scaled up to high production volume to reduce costs. Research on pressure, temperature, and environmental effects on the friction and wear of these materials is needed to optimize the compositions and processing methods to satisfy brake requirements.

3.2.5 Viscoelastic Braking

In this approach, elastic deformation of new braking materials is used to stop commercial vehicles. Microscopic tips of these materials would be deformed elastically during braking thereby transferring the force from peak to peak. Repeating this process millions of times per second over the entire contact zone can result in substantial energy dissipation. Candidate materials include many elastomers, plastics, glasses, and enamels. Using these materials in this manner could produce foundation brakes with extremely low wear characteristics.

Comments:

The technology for this braking approach is still in the basic research stage. Once appropriate materials are selected for use in the harsh environments of truck braking, the feasibility of stopping an 80,000-pound vehicle in present wheel-end dimensional constraints needs to be studied. This area may have potential for future foundation brakes, but it represents a high risk approach.

3.2.6 Phase-Change Cooling of Commercial Vehicle Brakes

Excessive temperatures in the brake leads to marked increase in friction material wear, brake fade, and can result in tire failure on intercity buses. Soft metal alloys, metal salts, and paraffins are explored as possible materials for storing this heat that is generated during commercial braking. Using this cooling approach, the heat generated during braking is stored away from the wheel end. This process continues until heavy demands are no longer required of the braking system allowing the stored heat to be slowly dissipated.

Comments:

This is a sound approach to reducing wheel end temperatures and it associated problems. The constraints to this system would be weight and cost concerns that would surely arise if this technology were to be implemented on commercial trucks. Given the industries extremely competitive nature, these two concerns would have to be alleviated with demonstrated savings in other areas of vehicle operation such as increased friction material life that would more than offset the cost and weight penalty of such a system.

3.3 Summary

Though many ideas on the future of braking technology were offered or resulted from Sandia input at the FHWA workshop, only the main ones were summarized in this section. Recommendations for future studies and technology development are presented in Section 4.

4. Recommendations

Current foundation brakes work well when they are cool, correctly adjusted, and the driver operates the vehicle properly. Problems can arise if frequent maintenance is not performed or if an operator enters a downgrade in a wrong gear or with excessive speed. Relying only on the foundation brakes to slow or stop the vehicle during these conditions might cause the current drum brakes to fade to the point of failure.

An additional contributor to braking problems is that commercial vehicle brakes are designed to be balanced in the fully loaded condition. If the tractor is operating in a bobtail configuration or with an empty or lightly loaded trailer, this balance is no longer at its optimum and vehicle instability can result. Even if the operator performs his task flawlessly and the truck is maintained correctly, environmental hazards such as rain, snow, and ice can drastically reduce the stability and increase the stopping distances required.

4.1 Near- to Mid-Term Recommendations

An existing characteristic with current foundation brakes is that they require frequent adjusting and are subject to large fluctuations in available brake torque because of thermal expansion of drum material. Therefore, the major focus of shorter-term solutions should address these characteristics.

- Better foundation brakes need to be developed. While improvements could be made to drum brakes, disc-brake designs offer inherent safety advantages over drums. Drums will expand when overheated, thereby saving themselves but possibly failing to stop the vehicle, while disc-type brakes will work to the point of self-destruction.

  Simpler, more reliable, disc-brake designs need to be developed. These designs would reduce the complexity and cost while increasing the performance of disc brakes. Domestic disc brakes currently cost three times that of drum designs (S-cam) and have a reputation for having reliability problems caused by uneven pressure distribution and caliper pin contamination. Using reaction-beam caliper designs is one approach that can address the pressure distribution problem while economies of scale and reduced/simplified parts can serve to greatly reduce the cost of these brake types. Reducing the number and complexity of caliper parts would also lead to greater acceptance by maintenance personnel. The swept area of the pads needs to be increased and the rotor material needs to be investigated for improved heat dissipation characteristics. These two improvements would increase the life and reduce the maintenance requirements of current disc-brake designs.

  Another approach to reducing maintenance sensitivity of foundation brakes would be to develop better, more heat tolerant, friction materials. Standardization of friction material ratings also needs to be addressed for after-market linings. This would eliminate the inconsistencies in available brake torque caused by friction materials having differing friction characteristics. This can lead to poor material life and vehicle instability.

4.2 Long-Term Recommendations

The recommendations presented here need to be investigated in concert with near- to mid-term recommendations and are only cosmetic solutions if better, less maintenance sensitive foundation brakes are not developed in the near term. Because the following vision of long-term braking relies on ABS hardware, it is assumed that this system makes continuing inroads with the trucking industry. Both ABS and ATC (automatic traction control) are gaining more acceptance in the U.S. A recent NHTSA study of a fleet of 200 tractors that use ABS's showed that, with the exception of some minor pre-production problems, overall the systems performed very well.

The vision of the future advanced brake control system is one that would manage the vehicle's braking system for optimum performance and life regardless of environments. This system would feature brake control that is accomplished by electrical means, but still retains a pneumatic back-up control as well as pneumatic actuation of the foundation brakes. This feature eliminates lag that can be present in combinations, but more importantly facilitates the system's major advantages over current braking approaches. European contacts have indicated that Saab-Scania is in the initial stages of marketing a straight chassis vehicle with this feature on the rear axle. The following is a summary of those features an advanced brake control system could possess along with associated implications for the trucking industry.

- Tactile feedback - This would allow the driver to have some degree of pedal feel similar to vehicles equipped with hydraulic brakes. With current pneumatic systems, the driver is unaware that there could be potential brake problems because the brake pedal fails to provide feedback about the system's condition.

- Driver information - This feature would keep the driver informed of the brake system's overall condition, but would not overwhelm him with irrelevant details. This function would also be used to store pertinent system information that could be used to recreate accident or for diagnostic work done by maintenance technicians.

- Integrated retarder control - This would allow for marked improvement in friction material life by using retarders to do routine slowing of the vehicle each time the brake pedal is depressed if stability and/or emergency braking concerns did not override this feature.

- Dynamic brake proportioning/balancing - This feature would use load sensing with wheel-end torque measurements to determine the optimum amount of torque required at each individual wheel end to achieve the shortest, most stable braking possible.

- Tractor/trailer compatibility - This feature would account for differences in foundation brake type or condition and would resolve cracking pressure differences between vehicles. This would ultimately allow the phasing in of new disc brake designs throughout nondedicated combinations.

- Equalized friction material wear - This feature would equalize friction material wear by using the axle(s) with the most lining first during routine nonemergency slowing of the vehicle. This could greatly reduce the duration and frequency of downtime required by combinations for lining replacement by allowing all of the friction material to be replaced during one maintenance visit.

For the previously mention vision to become a reality the following technologies need to be refined.

- Reliable and inexpensive sensors that relate load and wheel-end conditions need to be developed. This would involve a thorough search of current commercial technology for components that could be adapted for use in the trucking industry's harsh environments. Sandia has people that are versed in sensors and sensor technology. These resources could be used as key assets to give independent evaluation and recommendation of components that could be useful in these applications.

  Torque, temperature, wear, and position would be the most valued information gained from the wheel-end area. Because of the high-heat environments, Sic-based sensors may be developed to work well as temperature sensors (see Section 3.2.3) if high heat capabilities are required. This technology would allow components to work reliably at 1lOOOF and is currently being developed by a few major corporations for commercial applications. Position sensing would be necessary to ensure that the foundation brakes are properly adjusted, but this information may be inferred from temperature or torque measurements. Wearing of friction materials could be monitored with thin-film technology or inferred from other measurements. Load sensing would have to incorporate fifth wheel input to produce an effective system, and a reliable means of measuring load on vehicles with steel springs still needs to be addressed.

- Wiring, connectors, and communication techniques need to be further developed to handle the amount of information an advanced brake management system would require. Advanced communication systems could relay information such as road conditions from the IVHS to the vehicle, or vehicle information could be transmitted to inspection stations via transponders (radio receivers/ transmitters). Better wiring or fiber optic technology could be investigated for use with multiplexing techniques to allow better use of the limited number of pins available in current connectors. Because an advanced control system would have to acquire and analyze large amounts of data, either the number of connector pins would have to be changed, or more efficient use of the current type of connector would have to be investigated. If the pin configuration or wiring type were to be changed, compatibility issues would have to be addressed for the current generation of vehicles with some type of transition or commonalty assuring that compatibility problems would not arise. Along with other wiring-related problems, the issue of a separate power source for the ABS system should be resolved. Currently these systems are powered by the trailer lighting system's power source, which has led to problems of insufficient voltages in some installations.

- Information provided by commercial vendors of friction materials shows that wear rates are directly related to temperature. If the brake temperature could be held to lower extremes, current foundation brakes would be much less sensitive to adjustment. A doubling of brake temperatures from 200° to 400°F would result in a four-fold increase in wear rates of friction material, while increasing temperature from 200" to 600°F increases wear seven-fold (Fancher and Winkler, 1984 as cited in Clarke et al., 1991). More exotic cooling techniques such as phase change or liquid cooling of rotors could be investigated for long-term improvements to friction life. DeConti Industries of New Britain, Connecticut, is developing a liquid-cooled disc brake for use on medium-duty trucks. The braking force is applied to the driveline of the vehicle in a fashion similar to that of a retarder, but this device is capable of bringing the vehicle to a complete stop, not just regulating its speed. This technology may be used in its envisioned form or it may be adapted for use at the wheel ends of the vehicle. Liquid cooling of tractor brakes could be accomplished using the same technology in a somewhat straightforward manner, but there would be associated cost, weight, and reliability issues that would have to be explored. Using this cooling approach on trailers would be much more complex because, unlike tractors, trailers do not have integral cooling systems.

Another approach to this problem would be to continue and expand the near-term development of new friction materials that are much more heat resistant. Advanced composite matrices are currently being pursued by friction material suppliers, but reliability, cost, and manufacturing problems still need to be resolved.

Either approach would result in reducing the amount of maintenance sensitivity that foundation brakes currently possess. An interesting aside to the development of friction materials is that a major U.S. manufacturer of these materials has contacted Sandia in the hopes of pursuing an R&D partnership. This interest is a direct offshoot of the FHWA Brake Workshop. The details of the partnership are being worked out; however, no additional information is currently available.

- The wider use of modeling and simulation software could help ensure better vehicle braking and stability. This would have advantages for original equipment manufacturer (OEM) designers as well as vehicle customers. Currently, there are very good models available for stopping and stability, but insufficient data exist for all of the differing types of vehicles and brakes. If a sufficient data base could be built, a customer would be able to retrieve valuable information on how equipment specifications could help to produce vehicles with better braking balance and performance. This approach is available for optimal drive train selection.

4.3 Industry-Government Interactions

Improvements need to be made in the way that industry and government regulators interact. Currently, representatives from the trucking industry are hesitant to invest too many resources into brake R&D because of their fear that government action could render this effort obsolete. The two parties need to work together to identify areas that need correction and develop agreed-upon goals for resolving these deficiencies.

4.4 U.S. Trucking Market

The U.S. trucking market is customer driven. This market requires that every addition in capital cost necessitates a reduction in operating or maintenance costs. This tradeoff makes it difficult for the trucking industry to promote development of new technologies for improved safety without being able to produce a direct correlation in cost savings. It may be prudent to form a consortium, with or without government support, to jointly develop ideas for improved vehicle safety. Sandia may be able to play a significant part in this effort.

Regardless of the technological advances that may be accomplished, maintenance of these components will be a major concern to the operators. Component suppliers will have to expend considerable effort to develop and support a program that will train maintenance personnel to diagnose and repair these items. Toll-free phone numbers with liberal hours of operation would be an asset to resolving unexpected problems that arise in the field. The personal computer industry currently uses this approach with very satisfactory results. As experience with ABS's has shown, gradually introducing new hardware will assist in familiarizing both drivers and maintenance personnel with new systems before they are introduced on a mass basis.

4.5 Partnership with Domestic Manufacturers and Developers

As was discussed earlier, competitive market forces hamper, to some degree, the ability of individual manufacturers to develop improved brakes for commercial heavy vehicles. One way to address the ideas brought forth in the Recommendations section of this document would be to form partnerships between government, industry, and Sandia. These partnerships could cultivate working relationships that would improve commercial heavy-vehicle braking technologies in both the near and long term. The technologies and hardware developed through these joint ventures with private industry would be shared with others in an effort to increase the performance of heavy truck brakes. All of the companies with an interest in this project would be asked to form a consortium to develop technologies for improved braking that could be used to develop a test bed that would lead to a proof-of-concept vehicle being built and tested.

To date, one company has expressed interest in teaming on just such a project: Eaton's Corporate Research and Development Detroit Center, based in Southfield, Michigan. It is anticipated that other domestic manufacturers and developers could offer similar capabilities for this project. Based on Eaton's willingness to work with Sandia and the potential benefits from teaming with others willing to collaborate in this effort, a primary recommendation is that industrial partnerships that complement Sandia's brake development capabilities be aggressively sought. A discussion of what Eaton could offer such a development project follows.

While Sandia has much expertise in identifying and developing candidate core technologies for improving brake systems for commercial heavy vehicles, Eaton has the practical experience to incorporate these technologies into real brake systems and test their effectiveness, according to Jeff Skorupski, a chief engineer at Eaton's Corporate Research and Development Center. Eaton engineers have developed a thorough understanding of how brake hardware functions. For example, computer scientists and systems analysts at Eaton's Systems Analysis and Software Development Laboratory have developed and enhanced detailed computer models that are used to

- analyze and simulate the forces and stresses that take place in the drum brake itself;
- develop control algorithms for optimizing the tire/road interface during ABS brake events;
- simulate the airflow going through the air system that actuates and controls the brakes; and
- simulate the dynamics of the vehicle as it goes through braking maneuvers.

Eaton's Detroit R&D staff often teams with other corporate teams to resolve individual technical problems including the development of new product lines to meet customer requirements. This experience working with diverse groups could also be used to facilitate a government/industry/Sandia joint approach to advancing commercial braking technology.

The Eaton Detroit Center also has dynamometer systems for laboratory testing of heavy-truck brake hardware up to the speeds and wheel inertias found in heavy commercial vehicles. Once a candidate system/component has proven itself feasible in a laboratory environment, it could be incorporated into one of Eaton's heavy-truck test vehicles and be tested at the Eaton on- and off-highway test center and proving ground near Detroit.

The experience that Eaton has gained in bringing new products to market can be used to complement Sandia-initiated core technology development aimed at improving today's brakes and braking systems, which, though they satisfy all applicable regulations when they are adjusted properly, are still very sensitive to poor maintenance and abuse. A government/Sandia/Eaton team effort could span many aspects associated with commercial vehicle brakes, from alternate designs and products to improved maintenance and inspection techniques.

5. Conclusions

Studies by the NTSB and the NHTSA have concluded that brake problems are a major contributor in approximately l/3 of accidents involving commercial vehicles in the U.S. and that 60 to 65% of out-of-service trucks in the U.S. have brake problems. Sandia was assigned the task of investigating the state of current braking technology and determining the design of future brake systems. Sandia engineers have researched this problem in depth, and have made recommendations based on their interaction with experts in the field of heavy vehicle brake design and vehicle safety.

Those recommendations reflect Sandia's concept for near-term (5 to 10 years) and long-term (10 to 20 years) brake system improvements. Based on information gathered from the best available sources, the Sandians deduced that near-term improvements should concentrate on developing foundation brakes that are less maintenance sensitive and should emphasize the advantages that an improved disc design would offer. Long-term improvements should focus on advanced control of these foundation brakes. This vision would center on a brake-by-wire technique that would offer improvements in many area of commercial vehicle braking. Capital constraints and a market-driven industry tend to dilute the focus needed to bring advanced concepts into the production arena. Through government/Sandia/industry partnerships technologies can be developed and implemented for improved brake system performance independent of market forces.

Finally, an example is given showing how government, Sandia, and industry can work together to advance future brake system performance.

References

Clarke, R.M., R.W. Radlinski, and R.R. Knipling, *Improved Brake Systems for Commercial Motor Vehicles,* DOT HS 807 706, National Highway Traffic Safety Administration, U.S. Government Printing Office, Washington, DC, 1991.

Giiehring, E., and E.-C. von Glasner, "Performance Comparison of Drum and Disc Brakes for Heavy Duty Commerical Vehicles," *SAE Technical Paper Series,* No. 902206, Society of Automotive Engineers, Inc., Warrendale, PA, 1990.

Narayanamurti, V., and D.E. Arvizu, "Using Sandia Technologies to Improve National Competitiveness," *AT&T Technical Journal,* November/December 1991, Vol. 70, No. 6.

National Transportation Safety Board, *Safety Study: Heavy Vehicle Airbrake Performance,* NTSB/SS-92/01, U.S. Government Printing Office, Washington, DC, 1992.

Winsor, J., "More Brake Regs, NTSB Report Urges," Heavy *Trucking,* May 1992, p. 19.

Bibliography
(Papers reviewed but not referenced)

Adams, Wayne P., B-1B Braking and Landing Performance Evaluation, Report No. AFFTC-TR-89-05, Air Force Flight Test Center, Edwards AFB, CA, June 1989. (This report contains export-controlled technical data, limited release.)

Aerospace Engineering, "Thermal Optimization of Space Shuttle Braking System," *Aerospace Engineering,* Vol. 10, No. 8, August 1990, Warrendale, PA, pp. 13-15.

American Trucking Associations, *Mile Marker,* Vol. 6, No. 2, May 1992, Alexandria, VA.

Anselmi, J. A., L. W. Weinberg, R. F. Yurczyk, and W. G. Nelson, *Research Study on Antiskid Braking Systems for the Space Shuttle,* Report No. NASA-CR-124349, Boeing Commercial Airplane Co., Seattle, WA, February 1973.

Automotive Engineering, "Anti-Lock Brake System Testing," *Automotive Engineering,* Vol. 97, NO. 2, February 1989, pp. 204 and 206.

Automotive Engineering, "Are Anti-Jackknife Devices Feasible?" *Automotive Engineering,* Vol. 99, No. 11, November 1991, pp. 39-41.

Automotive Engineering, "Truck ABS Braking," *Automotive Engineering,* Vol. 97, No. 11, November 1991, pp. 50-51.

Automotive Industries, "1993 SAE Show," *Automotive Industries,* April 1993, pp. 54-55.

Bareket, Zeev, and Paul Fancher, *Representation of Truck Tire Properties in Braking and Handling Studies: The Influence of Pavement and Tire Conditions on Frictional Characteristics,* Report No. UMTRI-89-33, The University of Michigan Transportation Research Institute, Ann Arbor, MI, December 1989.

Belski, Gary T., and Stanley M. Mezynski, "City Bus Tire Bead Heat Evaluation," *SAE Technical Paper Series,* No. 922457, Society of Automotive Engineers, Inc., Warrendale, PA.

Bergmann, Uwe, Gerhard E. Kahlau, Klaus Vogelsang, and Heinz Holler, "State of Development and Future Prospects of Hydrodynamic Brakes for Trucks and Buses," *SAE Technical Paper Series, No. 922454,* Society of Automotive Engineers, Inc., Warrendale, PA, 1992.

Bok, L. D., *NASA Lightweight Wheel and Brake Sub-System Contract with B. F. Goodrich, Part III: Lightweight Brake Development,* Engineering Report No. NASA-CR- 134130, B. F. Goodrich Aerospace and Defense Products, Troy, OH, October 1973.

Brahney, James H., "Toward the All-Electric Airplane: Electric Brakes," *Aerospace Engineering,* Vol. 9, No. 1, January 1989, Warrendale, PA, pp. 17-20.

Carsley, Renton B., *Space Shuttle Wheels and Brakes,* No. N85-16962, Rockwell International Corporation, Downey, CA, pp. 872-882.

Cullen, David, "Brake-by-Wire," *Fleet Owner,* Vol. 85, No. 8, August 1990, pp. 80-83.

Cullen, David, "Where Braking Is Finally Headed," *Fleet Owner,* May 1993, pp. 39-44.

DeConti, John P., DeConti Industries, Inc., New Britain, CT, personal letter to Randy Peterson, Sandia National Laboratories, June 14, 1993.

Design News, "Space Lab 'Grows' New Materials," *Design News,* July 6, 1992, p. 152.

Diesel Equipment Superintendent magazine, Norwalk, CT, February 1993.

Dolezal, F. W., "Brakes: The Importance of a Balanced System and Proper Adjustment," *Fire Engineering,* Vol. 144, No. 3, p. 34.

Dorion, Suanne L., James G. Pickard, and Sesto Vespa, "Feasibility of Anti-Jackknifing Systems for Tractor Semitrailers," *SAE Technical Paper Series, No.* 891631, Society of Automotive Engineers, Inc., Warrendale, PA, 1989.

Ehlbeck, James M., Tony Moore, and Klaus Lindemann, "Full ABS with Tandem Control for Freightliner Trucks," *SAE Technical Paper Series No.* 892503, Society of Automotive Engineers, Inc., Warrendale, PA, pp. 59-65.

Ehlbeck, Jim, Tony Moore, and Warren Young, "Antilock Brake Systems for the North America Truck Market," *Vehicle Electronics in the 90's: Proceedings of the International Congress on Transportation Electronics, No.* 901174, Society of Automotive Engineers, Inc., Warrendale, PA, 1990, pp. 493-501.

Ehlbeck, Jim, Tony Moore, and Warren Young, "Truck ABS for North America," *Automotive Engineering,* Vol. 99, No. 7, July 1991, pp. 41-46.

Emig, Reiner, H. Goebels, and H. J. Schramm, "Anti-Lock Brake Systems for Commercial Vehicles," *Automotive Engineering,* Vol. 99, No. 7, July 1991, pp. 33-39.

Emig, Reiner, H. Goebels, and H. J. Schramm, "Antilock Braking Systems (ABS) for Commercial Vehicles-Status 1990 and Future Prospects," *Vehicle Electronics in the 90's: Proceedings of the International Congress on Transportation Electronics,* No. 901177, Society of Automotive Engineers, Inc., Warrendale, PA, 1990, pp. 515-523.

Fancher, P., C. Winkler, and M. Campbell, "The Influence of Braking Strategy on Brake Temperatures in Mountain Descents," Report No. UMTRI-92-11, The University of Michigan Transportation Research Institute, Ann Arbor, MI, March 1992.

Fancher, P., K. Campbell, Z. Bareket, D. Blower, and R. Masters, *Evaluation of Criteria for Truck Air Brake Adjustment-Interim Report,* Report No. UMTRI-9 1- 17- 1, The University of Michigan Transportation Research Institute, Ann Arbor, MI, October 1991.

Firestine, M., H. McGee, D. Cunningham, *Reducing Runaway Truck Accidents through Weight-Based Advisory Speeds,* Report No. FHWA-IP-89-023, Federal Highway Administration, Washington, DC, September 1989.

Flick, Mark A., and Richard W. Radlinski, *NHTSA's* Heavy *Duty Vehicle Brake Research Program Report No. 8-Comparison of the Braking Pellforrnance **of** a U. S. and a European Combination Vehicle,* Report No. DOT HS 807 345, NHTSA, Washington, DC, July 1988.

Flick, Mark A., *NHTSA's Heavy Duty Vehicle Brake Research Program Report No. g-Stopping Distances of 1988 Heavy Vehicles,* Report No. DOT HS 807 531, Vehicle Research and Test Center, National Highway Traffic Safety Administration, East Liberty, OH, February 1990.

Garnault, Jogl, "Third Generation Antiskid: Safety Diagnostic Features of the E.C.U.," *SAE 1989 Transactions-Journal **of** Passenger Cars,* Sect. 6, Vol. 98, No. 890093, Society of Automotive Engineers, Inc., Warrendale, PA, pp. 140-147.

Gaylord, Foster R., "Brakes for the Nineties," *Waste Age,* Vol. 21, No. 8, August 1990, pp. 101-110.

Geyer, Sherree, "These Are the Brakes," *Traffic Safety,* Vol. 91, November/December 1991, pp. 28-29.

Giihring, E., "Drivetrain Optimized Mercedes-Benz Vans with an Environmentally Improved Diesel Engine Concept and Aerodynamically Formed Design Features," *SAE 1990 Transactions-Journal **of** Commercial Vehicles,* Sect. 2, Vol. 99, No. 902243, Society of Automotive Engineers, Inc., Warrendale, PA, pp. 830-837.

Gohring, E., and E.-C. von Glasner, "Contribution to the Improvement of the Braking and Handling Performance of Commercial Vehicles," *Eighteenth Fisita Congress-The Promise of New Technology in the Automotive Industry, Proceedings of the SAE,* Torino, ITALY, May 7-l 1, 1990, No. 905039, Society of Automotive Engineers, Warrendale, PA, pp. 271-277.

Gohring, E., E.-C. von Glasner, and C. Bremer, "The Impact of Different ABS-Philosophies on the Directional Behavior of Commercial Vehicles," 1989 *SAE -Transactions Journal of Commercial Vehicles,* Vol. 98, No. 8925000, Warrendale, PA, pp. 641-652.

Gordon, Maynard M., "NHTSA Reacts As Brake Problems Grow," *Rock Products,* Vol. 94, August 1991, p. 29.

Great Lakes Center for Truck Transportation Research, *1989 Annual Report,* The University of Michigan Transportation Research Institute, Ann Arbor, MI.

Greenbank, S. J., "Landing Gear-The Aircraft Requirement," *SAE 1988 Transactions-Journal **of** Aerospace,* Sect. 1, Vol. 97, Society of Automotive Engineers, Inc., Warrendale, PA, 1988, pp. 27-34.

Habib, Gerard, "The Present Status of Electro-Magnetic Retarders in Commercial Vehicles," *SA E Technical Paper Series, No. 922450,* Society of Automotive Engineers, Inc., Warrendale, PA, 1992.

Haiss, Johannes, "Demand Criteria on Retarders," *SAE Technical Paper Series, No. 922453,* Society of Automotive Engineers, Inc., Warrendale, PA, 1992.

Hegmon, Rudolph R., "Tire-Pavement Interaction," *SAE Technical Paper Series, No.* 870241, Society of Automotive Engineers, Inc., Warrendale, PA, pp. 197-204.

Heusser, Ronald B., "Heavy Truck Deceleration Rates as a Function of Brake Adjustment," *SAE 1991 Transactions-Journal of Commercial Vehicles, Sect.* 2, Vol. 100, No. 910126, Society of Automotive Engineers, Inc., Warrendale, PA, pp. 22-38.

Hunter Engineering Company, "New Hunter Truck & Bus Safety Center" brochure, November 1991, Hunter Engineering Company, Bridgeton, MO.

Jones, Ian S., and Howard S. Stein, "Defective Equipment and Tractor-Trailer Crash Involvement," *Accid. Anal. & Prev.*, Vol. 21, No. 5, 1989, pp. 469-481.

Kajiyama, Tohru, Nobuyuki Takeda, Takeshi Okayama, Shoji Kajiwara, and Shigenori Kamiya, "Disc Brakes for Heavy Duty Trucks in Japan," *SAE Technical Paper Series, No. 902200,* Society of Automotive Engineers, Inc., Warrendale, PA, 1990.

Kempf, Richard C., and Teri Elliot, *MVMAiNHTSA/SAE Round Robin Brake Test,* The Transportation Research Center of Ohio, East Liberty, OH, August 1991.

Kobe, Gerry, "Against All Odds," *Automotive Industries,* Vol. 169, July 1989, pp. 45-47.

Klusmeyer, L. F., A. W. Gray, J. S. Bishop, M. Van Schoiack, J. M. Woods, and W. M. Mahmoud, *An In-Service Evaluation of the Reliability, Maintainability, and Durability of Antilock Braking Systems CABS) for Heavy Truck Tractors,* Report No. DOT HS 807 846, Southwest Research Institute, San Antonio, TX, March 1992.

Kubomiya, Tomoyuki, Tohru Kuwahara, and Kenji Araki, "Permanent-Magnet-Type-Retarder in Commercial Vehicles," *SAE Technical Paper Series,* No. 922455, Society of Automotive Engineers, Inc., Warrendale, PA, 1992.

Leasure, William A., Jr. and Sidney F. Williams, Jr., "Antilock Systems for Air-Braked Vehicles," *SA E Technical Paper Series No.* 890113, Society of Automotive Engineers, Inc., Warrendale, PA, February 1989.

Leibbrand, Norbert, Werner Politz, and Holger Tebbje, "The ABS 6S/4K-A Modular System for Simplified Installation in Tractors, Semi-Trailers and Trailers," *SAE 1990 Transactions-Journal of Commercial Vehicles,* Sect. 2, Vol. 99, No. 902213, Society of Automotive Engineers, Inc., Warrendale, PA, 1990, pp. 715-722.

Lyles, Richard W,. Daniel F. Blower, Kenneth L. Campbell, and Polichronis Stamatiadis, "Heavy Truck Safety in Michigan," *ITE Journal,* Vol. 61, May 1991, pp. 27-32.

Malcolm, G. David, "Objectives of the New Zealand Heavy Vehicle Brake Code," *SAE Technical Paper Series,* No. 912716, presented at the *International Truck and Bus Meeting and Exposition,* Chicago, IL, November 18-21, 1991, Society of Automotive Engineers, Inc., Warrendale, PA.

Mathews, G. P., "Art and Science of Braking Heavy Duty Vehicles," *No.* SP-251, *The Tenth L. Ray Buckendale Lecture,* Society of Automotive Engineers, Inc., Warrendale, PA, January 1964.

Meierkort, Jiirgen, and Eric Thorns, "Air Disc Brakes Realization During the Development and Application Introduction," *SAE 1990 Transactions-Journal of Commercial Vehicles,* Sect. 2, VoI. 99, No. 902205, Society of Automotive Engineers, Inc., Warrendale, PA, 1990, pp. 661-668.

Micke, Sigmar, Richard E. Thompson, and Bernd-Holger Roehling, "The Introduction of Air Disc Brakes for Trucks and Buses in Europe," *SA E Technical Paper Series, No. 902203,* Society of Automotive Engineers, Inc., Warrendale, PA, 1990.

Moseley, Douglas D., and Thomas J. Carter, "Performance Testing on an Electrically Actuated Aircraft Braking System," *SAE 1988 Transactions-Journal of Aerospace, Sect. 1, Vol. 97, N*o. 881399, Society of Automotive Engineers, Inc., Warrendale, PA, 1988, pp. 1.1036-1.1067.

National Highway Traffic Safety Administration, A *Report on Various Aspects of the Braking Perjormance of Medium and Heavy Trucks, Report* No. DOT HS 807 910, DOT/NHTSA, Washington, DC, November 1992.

National Highway Traffic Safety Administration, Federal Highway Administration and the Research and Special Programs Administration, U.S. *Department of Transportation Heavy Truck Safety Plan,* NHTSA, May 1991.

National Technical Information Service, *Aircraft Landing Brakes (June 1970-J&y 1989) Citations from the NTIS Bibliographic Database,* Report No. PB89-866743, NTIS, Springfield, VA.

Nordstriim, Olle, "Heavy Duty Vehicle Dynamics Related to Braking, Steering and Tyres-Swedish Research and Proposals by VTI," *SAE Technical*

Paper Series, No. 892502, Society of Automotive Engineers, Inc., Warrendale, PA, pp. 43-57.

Nowack, Capt. Mark L., USAF, *A Look at Digital Nose Wheel Steering,* Report No. ASD-TR-90-5018, Aeronautical Systems Division, September 24, 1990, Wright-Patterson AFB, OH.

Petersen, Erwin, Karl-Heinz Hesse, Harald Kaess, and Klaus Lindemann, "A New ABS with Integral Automatic Traction Control for Air-Braked Trucks and Buses," *SAE I990 Transactions-Journal of Commercial Vehicles,* Sect. 2, Vol. 99, No. 902210, Society of Automotive Engineers, Inc., Warrendale, PA, pp. 688-703.

Pezoldt, V. J., J. T. Tielking, and T. Scullion, "Relative Performance of Wide Base and Conventional Truck Tires," *SAE Technical Paper Series No. 922465,* Society of Automotive Engineers, Inc., Warrendale, PA.

Pickard, James G., and Suanne L. Dorion, *Development of an Anti-Jackknifing System for Tractor Semitrailers: Feasibility Study; Phase* I, *Stage* 2, Report No. TP10474E, TES Limited, Ontario, CANADA, May 1990.

Public Works, "1992 Truck Developments," *Public Works,* Vol. 123, March 1992, p. 49.

Radlinski, Richard W., "Heavy Vehicle Braking-U. S. versus Europe," *SAE Technical Paper Series, No.* 892504, Society of Automotive Engineers, Inc., Warrendale, PA, 1989, pp. 67-75.

Reed, Donald, "Heavy Truck Safety," *Automotive Engineering,* Vol. 99, No. 11, November 1991, pp. 81-83.

Refrigerated Transporter, "ABS Antilock Braking System on the Way as Part of Future Electronics Controls," *Refrigerated Transporter,* June 1989, pp. 82-84.

Refrigerated Transporter, "Wide Variety of Antilock Systems Undergoing Fleet Testing by NHTSA," *Refrigerated Transporter,* June 1989, pp. 85-86.

Renfroe, D. A., "Operating Characteristics of a Medium Duty Wet Disk Brake," presented at the *Seventh Annual Colloquium on Friction Materials and Related Systems,* Williamsburg, VA, October 16-18, 1989, *SAE Technical* Paper *Series, No. 892452,* Society of Automotive Engineers, Inc., Warrendale, PA.

Rusnak, R. M., H. W. Schwartz, and W. P. Coleman, "A Comparison by Thermal Analysis of Rotor Alloys for Automobile Disc Brakes," *SAE Technical Paper Series,* No. 700137, Society of Automotive Engineers, Warrendale, PA, pp. 552-562.

Ryuko, Fumiharu, and Kazuhiko Kubota, "Truck Braking Standards and Regulations in Japan," *SAE Technical Paper Series, No. 890867,* Society of Automotive Engineers, Inc., Warrendale, PA, 1989.

School Bus Fleet, "Giving Buses an Even Brake," *School* Bus *Fleet,* Vol. 35, No. 4, August/September 1989, pp. 33-35.

S&reck, Helmut, Heinz Kucher, and Bernhard Reisch, "ZF Retarder in Commercial Vehicles," *SA E Technical Paper Series, No. 922452,* Society of Automotive Engineers, Inc., Warrendale, PA, 1992.

Shilton, B. R., "Differences Between European and U. S. Braking Legislation and Philosophies," 1984 *SAE Government/Industry Meeting and Exposition,* Washington, DC, May 21-24, 1984, Society of Automotive Engineering, Inc., Warrendale, PA.

Siegel, Stewart, "Diagnostics Lighten ABS Maintenance," *Fleet Owner,* Vol. 86, No. 4, April 1991, pp. 52-55.

Sisson, Albert E., "Thermal Analysis of Vented Brake Rotors," *SAE Technical Paper Series, No. 780352,* Society of Automotive Engineers, Inc., Warrendale, PA, 1978.

Society of Automotive Engineers, "Annual Index/Abstracts of SAE Technical Papers-1990," *SAE Technical Paper Series,* SAE, Inc., Warrendale, PA, p. 239.

Society of Automotive Engineers, Inc., *SAE Surface Vehicle Brake Manual, Handbook Supplement HS-24/92, I992 Edition,* SAE, Inc., Warrendale, PA, July 1992.

Special Purpose Vehicles International Pty. Limited, facility brochure, Chester Hill, New South Wales, AUSTRALIA.

Straub, Laszlo, "Electronic Control of Braking Systems - Legislation (ECE R.13)," *SAE Technical Paper Series,* No. 922490, Society of Automotive Engineers, Inc., Warrendale, PA, 1992.

Sweatman, P., "Review of vehicle factors in truck crashes: Australian truck safety study task 2," Research Report ARR 202, Australian Road

Research Board, Vermont South, Victoria, AUSTRALIA, June 1991.

Tanaka, Shinichi, Kazuhiko Kubota, Takeshi Iwasaki, and Hidenobu Hatanaka, "The Compatibility of Air Disc Brakes and S-Cam Brakes Installed on Combination Vehicles," *SAE 1990 Transactions-Journal of Commercial Vehicles, Sect. 2, Vol. 99, No.* 902201, Society of Automotive Engineers, Inc., Warrendale, PA, 1990, pp. 653-660.

Theiss, Armin, and Hans Baumgartner, "Comparison of Pneumatic and Hydraulic Disk Brakes for Heavy Duty Application," *SAE Technical Paper Series, No.* 902202, Society of Automotive Engineers, Inc., Warrendale, PA, 1990.

The Maintenance Council, "1993 TMC Transportation Equipment Exhibition Directory & Industry Reference Guide," distributed at the TMC Annual Meeting and 1993 Transportation Equipment Exhibition, Orlando, FL, March 1993, TMC - American Trucking Associations, Inc.

Thorns, E., G. Magnusson, "Trailer Brake Adaptation Device," Eighteenth Fisita Congress-The Promise of *New Technology in the Automotive Industry, Proceedings of the SAE,* Torino, ITALY, May 7-11, 1990, No. 905168, Society of Automotive Engineers, Inc., Warrendale, PA, pp. 371-375.

Transport Canada, *B-Train ABS Evaluation,* May 1990, Ontario. CANADA.

Trucking Research Institute, *Research Inventory,* TRI, Alexandria, VA, March 1992.

University of Michigan Transportation Research Institute, *UMTRI Research Review,* R. Guy Gattis, ed., Vol. 20, No. 6, UMTRI, Ann Arbor, MI, May-June 1990.

Williams, S. F., and R. R. Knipling, *Automatic Slack Adjusters for Heavy Vehicle Air Brake Systems,* Report No. DOT HS 807 724, National Highway Traffic Safety Administration, Washington, DC, February 1991.

Winsor, Jim, "Antilock Update: Trailer Test Underway," *Heavy Duty Trucking,* Vol. 70, No. 11, November 1991, pp. 64-67.

Wrede, Jtirgen, and Heinz Decker, "Brake by Wire for Commercial Vehicles," *SAE Technical Paper Series,* No. 922489, Society of Automotive Engineers, Inc., Warrendale, PA, 1992.

ATTACHMENT 3

Radioactive Materials Postnotification (RAMPOST) Database

Draft of 10-21-93
(Original draft: 7-14-93)
NOT FOR DISTRIBUTION

J.W. Cashwell

6641 - Transportation Systems Analysis

TECHNICAL TASK PLAN

TITLE: RAMPOST Database Support

Sponsor:	Federal Highway Administration (FHWA) 6300 Georgetown Pike McLean, VA 22101	
Technical Program Officer:	Mike Freitas	(703) 285-2421 (703) 285-2264 (FAX)
	Lawrence J. Brown Pam Deadrick	(202) 366-2214 (202) 366-2159
Sandia Proposal Number:	959200309	Date: March 23, 1992
Principal investigators:	Jon Cashwell, Dept. 6641 (Development) Jim McClure, Dept. 6641 (Operations) Sandia National Laboratories Albuquerque, NM 871855800	(505) 845-8101 (505) 845-8753 (505) 844-0244 (FAX)
Technical Program Manager:	Steve Roehrig, Dept. 9604 Sandia National Laboratories Albuquerque, NM 871855800	(505) 844-l 180 (505) 844-2193 (FAX)

TASK SUMMARY

The U.S. Department of Transportation (DOT) currently receives reports, known as “post notification reports”, from shippers for the shipments of radioactive materials called “Highway Route Controlled Quantities” in accordance with 49 CFR 177.825 and 49 CFR 397. In July 1991, the DOT delegated authority for administering programs regarding the highway routing of hazardous materials to the Federal Highway Administration (FHWA) which currently compiles and reviews the reports.

Between 1982 and 1991, the DOT’s Research and Special Programs Administration (RSPA) which previously administered the DOT highway routing programs had entered information from the reports into a database known as the Radioactive Materials Routing Report (RAMRT). The U.S. Department of Energy (DOE) requested that Sandia National Laboratories Transportation Technology Center (Sandia) initiate an analysis of the shipment patterns in RAMRT in 1986, Sandia reviewed and prepared a report anaiyzing the shipment data contained in RAMRT in 1989 summarizing the shipment patterns and trends contained in the RAMRT database for the period from 1982 through 1987. Among the conclusions contained in this report, Sandia recommended that the database be modified to permit a greater array of searches to be performed and that the data entry options be consolidated for clarity.

The DOE subsequently directed Sandia to create a modified database that would address these issues, and in 1992 a new database, containing reports received by the DOT for 1989 through part of 1992 was put on the TRANSNET System. Entitled RAMPOST, for RadioActive Materials POST notification Reports, this database was used to address, in part, the International Atomic Energy Agency reporting requirements regarding transportation activities in the U.S.

Sandia demonstrated the RAMPOST database to representatives of the U.S. DOT FHWA in December 1991, to ensure awareness of this DOE-funded effort. The FHWA is considering the use of RAMPOST in lieu of RAMRT for tracking and reporting of HRCQ shipments. The FHWA will provide the reports and fund the maintenance of the RAMPOST program in FY93. The FHWA will further fund the checking and correction, where necessary, of formerly entered records to the extent possible.

The objectives of this program are:

1. To consolidate existing efforts at the U.S. Department of Transportation and the U.S. Department of Energy to collect and analyze post notification reports of Highway Route Controlled Quantity Shipments of Radioactive Materials.

2. To provide continuing maintenance and updating of the database on the TRANSNET System.

3. To provide periodic analysis of these data.

STATEMENT OF WORK

The following sub-tasks will be accomplished:

1. Continuously enter post notification reports submitted by FHWA into the RAMPOST database.

2. Provide a quality check and correction of the past and future post notification reports where necessary, to the extent of the total funding level.

3. Provide, on an annual basis, a letter report summarizing the data.

4. Provide analysis of the shipment data, upon request, to the program sponsoring organization.

5. Maintain a hard copy file at Sandia and the computerized RAMPOST Database on the TRANSNET System.

ESTIMATED FHWA PARTICIPATION

YEAR	MANPOWER	EXPENSE	TOTAL
FY93	$30K	5K	$35K

MILESTONES

Data Entry Complete	February 1993
Update Data	Continuous
Annual Shipment Summary Letter Report	October - Annually

.*

RISK

There is little risk that the objectives of this task will not be met since similar activities have been peiformed.

APPROVALS

FHWA	______________________ Mike Freitas	______________ Date
Sandia	______________________ Steve Roehrig	______________ Date

The U.S. Department of Transportation (DOT) began compiling records of “highway route controlled quantities” of radioactive materials in 1982, after a DOE final rule went into effect. The DOE’s rulemaking, HM-164, which was codified in the U.S. Code of Federal Regulations at 49 CFR 173.22, had as one of its provisions the requirement that shippers of “large quantities” of radioactive materials submit a copy of the route plan to the DOT within 90 days following the shipment. These routing plans were assembled in the Radioactive Materials Routing Report (RAMRT) database.

On July 1, 1983, a new criterion was established for classifying radionuclides based on Al/A2 values and the term “large quantity” was replaced with “highway route controlled quantity” (HRCQ). This reclassification reduced the number of shipments that were reported to the DOT; most notably, most radiopharmaceutical shipments and some waste shipments were eliminated from the postnotification reporting requirements. Another change in the reporting requirements occurred in May of 1988, when the DOE began requiring that the carriers, not the shippers, post-notify their HRCQ shipments.

In 1991, Sandia National Laboratories (SNL) developed an expanded version of the RAMRT database called the Radioactive Materials Postnotification (RAMPOST) database. RAMPOST, which is under the sponsorship of the Federal Highway Administration of the DOT, resides on the TRANSNET System at SNL and is accessible to a wide user community through the use of a computer modems.

Currently, there are three sources of information for the RAMPOST data: (1) the carriers; (2) the U.S. Nuclear Regulatory Commission (NRC), which submits data from its prenotification database; and (3) the U.S. Department of Energy (DOE). The RAMPOST database contains 13 fields of information: RAM identification number; origin of shipment; destination of shipment; date of shipment; type of shipment (NRC, DOE, or foreign shipment); carrier; shipper; consignee; packaging type; products, e.g., cobalt 60, spent fuel, etc.; activity of products; foreign origin: and route data. It is possible to extract information from the RAMPOST on any data field or combination of data field.

The RAMPOST data provide not only a historical perspective on HRCQ shipments from 1982 to the present, but has also been used as input for environmental assessment programs. Additionally, the RAMPOST database provided important information for Phase 1 of the Surveying the Transportation of Radioactive Materials (STORM) project.

Further information on the RAMPOST database may be obtained by contacting:

Mr. Larry Brown
U. S. Department of Transportation
Federal Highway Administration
HHS-32, Room 3419
400 Seventh Street, S.W.
Washington, DC. 20590-0001

ATTACHMENT 4

Assessment of Technologies for Hazardous Material Transport

Draft of 10-21-93
(Original draft: 7-14-93)
NOT FOR DISTRIBUTION

J. W. Cashwell
6641 - Transportation Systems Analysis

TECHNICAL TASK PLAN

TITLE: Assessment of Technologies for Hazardous Material Transport

---

Sponsor:	Federal Highway Administration 6300 Georgetown Pike McClean, VA 22101	
Technical Program Officer:	Mike Freitas	(703) 285-2421 (703) 285-2264 (FAX)
Sandia Proposal Number:	959200309	
Principal Investigator:	To Be Determined	
Technical Program Manager	Steve Roehrig, Dept. 9604 Sandia National Laboratories Albuquerque, NM 87185	(505) 844-1180 (505) 844-2193

TASK SUMMARY

Many technologies have been proposed to improve commercial vehicle operations (CVO). These include automatic vehicle identification, weigh-in-motion, automatic vehicle classification, and electronic placarding/bill of lading. For commercial vehicle freight operations, the benefits include fewer required stops, reduced paperwork burden for interstate operations, and improved safety performance.

There is also considerable interest in using technology to make the transport of hazardous materials safer. Technologies that have been proposed include satellite tracking, container integrity sensors, electronic bill of ladings, automatic accident reportin g robotics for accident scene inspection, as well as technologies to aid accident response teams (LIDAR for remote sensing for example). The goal of this task is to analyze the hazards involved with transporting hazardous materials, and to evaluate technologies that can reduce these hazards.

Sandia has extensive experience wirh battery operated computer systems that have been employed on robotic vehicles, missiles, satellites, and the Department of Energy's tractor trailers used to transport highly valued assets. This expertise, as well as the capability to design custom, miniature sensors, makes Sandia well qualified to perform this task.

STATEMENT OF WORK

The prqiect will be brohen into the following sub-tasks:

Phase I — GATHER INFORMATION - Through a literature review as well as meetings and conversations with key officials, determine the main hazards associated with the transport of hazardous materials. Time - 4 months.

Phase II — IDENTIFY and ASSESS TECHNOLOGIES - Examine proposed or implemented efforts to improve the transport of hazardous materials through the use of technology. Time - 2 months

Phase III — ANALYSIS and SUMMARY of FINDINGS - Identify opportunities for making the transport of hazardous materials safer based on the analysis. Develop a recommended course of action for further development of key technologies. Document analysis and recommendations in a SAND Report. Time -3 months.

Phase IV — NEGOTIATE FUTURE WORK - Based on the analysis and recommendations, mutually agree on a course of action for further development by Sandia.

ESTIMATED COSTS

YEAR	MANPOWER	EXPENSE	TOTAL
FY93 - Phase I-III	$130K	$10K	$140K

MILESTONES

Deliver SAND Report outlining Phase I-III findings — October 1, 1993

RISK

The risk in Phase I-III is negligible since it mainly involves gathering and analyzing information.

APPROVALS

FHWA ____________________ ________
Mike Freitas — Date

Sandia ____________________ ________
Steve Roehrig — Date

In an effort to provide an assessment and overview of hazardous materials commercial vehicle (trucking) operations and possible future enhancements, this task will attempt to integrate recent literature with the opinions and recommendations of experts in the field. A comprehensive literature search of hazardous materials routing and operational processes was initiated by the Department of Transportation Research and Special Programs Administration at Sandia in 1990. This document, together with a more comprehensive literature search of potential technology applications and operational controls, will assist in providing a recommendation to the DOT Federal Highway Administration on a comprehensive, coordinated program to address these issues. This study will also provide direct input from professionals in the area, including commercial vehicle operators, regulators, and technical experts in remote sensing and advanced hardware development now available through the nation's National Laboratories.

The experience with radioactive materials transport, although a very limited subset of the overall hazardous materials transportation operations, has proven that an inherently safe, relatively efficient system of packaging, operational controls, operator training, and emergency response planning and training can be achieved through shipper and carrier cooperation and comprehensive federal regulation. In this case, packaging performance requirements are established through regulation based on the capability of the package to survive hypothetical accident conditions. The economics of such a requirement to the more generalized movements of hazardous materials could result in severe adverse economic impacts. Some of the requirements, however, such as a more limited packaging performance criteria, coupled with more stringent package and vehicle service and maintenance, increased training requirements and improved hardware and data systems could enhance the safety of hazardous materials activities with minimal economic impact.

Increased packaging performance criteria for specific types and/or quantities have been addressed for the DOT in past years by Sandia as well as industry groups. Recent legislation appears to be reemphasizing packaging integrity. In certain instances, industry has developed and utilized large bulk containers that exceed the published standards for particular hazardous categories. The economics of rigid standards, similar to those requirements for radioactive materials, have not been extensively analyzed; however, it is clear that any requirements that would decrease the volume/shipment would adversely affect the economics of transport.

The integration of sensors, either of the payload, the package, or the vehicle itself, would appear to have several benefits if the monitors or sensors are economically viable.

Federal, State, and local governments need data to help them establish regulations, plan for emergency response and accident reduction, and target enforcement efforts. Data and information systems pertaining to hazardous materials transportation are kept by many federal agencies, regional federal offices, different departments of state governments, and some local government offices. In 1986, the U.S. Congress, Office of Technology Assessment, published a report entitled "Transportation of Hazardous Materials." That report stated that the OTA found that while federal data-collection activities were numerous, no current federal resource could provide shipment information with the specificity desired by state and local jurisdictions. That report also concluded that "on-line access to real-time information on all hazardous materials shipments is neither feasible nor cost effective..." The Transportation Research Board, in Special Report 239, entitled "Hazardous Materials Shipment Information for Emergency Response," identified six categories of "information failures that appeared in their case studies:

- Required sources of information, such as placards and shipping papers, were missing or inaccurate;
- Placards, shipping papers, or other information sources were obscured, destroyed, or inaccessible because of a crash or fire or threat of fire, explosion, or toxic exposure;
- Information sources were in compliance with regulations and accessible, but they failed to efficiently convey important information to responders;
- Information was insufficient because the material or shipment was exempt from some federal hazardous materials regulation (because the quantities were too small to require placarding, the material was not regarded as being in transport, or the material was not designated as hazardous in regulations);
- The vehicle operator was unprepared to provide information;
- Responders failed to obtain or use available information."

Advances in computer data processing speeds, reductions in hardware costs, improved data management software, and high-speed communication links may permit some of these concerns to be met in a cost-effective manner. This task will address these and other data issues.

This and the other tasks address several hardware improvements that affect vehicle safety and reliability. Hardware to assist in communications with emergency responders, such as the TRANSIMS instrumentation package, will also be addressed, as well as antenna and microwave communications technologies.

ATTACHMENT 5

Technologies for Covert Inspections Monitoring

Draft of 10-21-93

(Original draft: 7-14-93)

NOT FOR DISTRIBUTION

M. R. Garcia
9617 - Command, Control, and Display Systems

H. D. Arlowe
9561 - Advanced Systems Integration

TECHNICAL TASK PLAN

TITLE: Technologies for Covert Inspection Monitoring

Sponsor:	Federal Highway Administration 6300 Georgetown Pike McClean, VA 22101	
Technical Program Officer:	Mike Freitas	(703) 2852421 (703) 285-2264 (FAX)
Sandia Proposal Number:	959200309	
Principal Investigator:	To Be Determined	
Technical Program Manager	Steve Roehrig, Dept. 9604 Sandia National Laboratories Albuquerque, NM 87185	(505) 844-1180 (505) 844-2193

TASK SUMMARY

Many technologies have been proposed to improve commercial vehicle operations (CVO). These include automatic vehicle identification, weigh-in-motion, automatic vehicle classification, and electronic placarding/bill of lading. For commercial vehicle freight operations, the benefits include fewer required stops, reduced paperwork burden for interstate operations, and improved safety performance. Technologies are also being investigated to improve the process of truck inspections. However, one aspect of truck inspections which has been neglected is the verification of corrected out-of-service conditions. In order to estimate severity of the problem, States must perform covert operations to determine if out-of-service truck operators are indeed correcting the out-of-service condition before resuming operations.

The purpose of this task is to identify technologies that could be applied to aid in these covert operations. Technologies that will be assessed include electronic tags. security sensors, as well as surveillance systems developed for previous DOE projects. The goal of this project will be to develop an inventory of previously developed security systems which can be used to aid in the covert operations. Efforts will focus on systems that can be developed using existing technologies.

Sandia has extensive experience with security and surveillance systems designed for fixed site security as well as special operations. This expertise, and the capability to design custom, miniature sensors. makes Sandia well qualified to perform this task.

STATEMENT OF WORK

The project will be broken into the following sub-tasks:

Phase I — GATHER INFORMATION - Compile a list of previously developed security and surveillance sensors that are applicable to the covert monitoring of trucks. Time - 3 man months.

Phase II — Negotiate technology demonstrations with FHWA.

ESTIMATED COSTS

YEAR	MANPOWER	EXPENSE	TOTAL
FY93 - Phase I	$45K	$5K	$50K

MILESTONES

Deliver Report outlining Phase I findings — July 1, 1993

RISK

The risk in Phase I is negligible since it mainly involves gathering and analyzing information.

APPROVALS

FHWA ____________________ Mike Freitas ____________ Date

Sandia ____________________ Steve Roehrig ____________ Date

Contents

Figures

Table

1. Executive Summary

1.1 Introduction

Sandia National Laboratories was tasked by the Department of Transportation (DOT) Federal Highway Administration (FHWA) to provide studies in various areas of commercial vehicle safety systems. This is the final report for Task 6 of Sandia's Commercial Vehicle Safety Systems Program, *Technologies for Covert inspections Monitoring.* The stated purpose of this task is to identify technologies that can be applied to aid in covert operations for monitoring out-of-service commercial vehicles. In addition, the initial task work statement specifies that the goal of this study is to develop an inventory of previously developed security systems that can be used to aid in the covert operations.

Beyond the stated purpose and goal of this study, a rudimentary systems analysis was also performed to understand the needs for covert operations and to identify problems, symptoms, and potential solutions. An analysis was performed to correlate the solution approaches and to introduce a concept for planning and coordinating the implementation of short- and long-term solutions.

1.2 Problems and Symptoms

The following four general problems were identified:

A. The tracking of out-of-service information is not done at a national level. When a driver/truck enters an inspection site, the inspector cannot access historical out-of-service information.

B. Reinspection of all out-of-service violations is not mandatory.

C. When a driver violates out-of-service orders and leaves an out-of-service area, the driver cannot be detected if an inspector is not present.

D. Enforcement methods and the severity of penalties are not consistent from state to state.

The following ten potential solutions were identified:

1. Implement an information management system.
2. Use smart cards to manage information.
3. Require that all out-of-service violations be reinspected and enforce the reinspection.
4. Keep an inspector present whenever there are out-of-service vehicles.
5. Immobilize out-of-service drivers/vehicles until they have passed a reinspection.
6. Use tag and beacon technology to alert inspectors when there are out-of-service vehicles entering or approaching an inspection site.
7. Use detection devices to detect out-of-service vehicles that leave without being reinspected.
8. Track the location of out-of-service vehicles if they haven't been reinspected.
9. Use on-board monitoring and information storage to inform inspectors about out-of-service violations.
10. Standardize enforcement methods and penalties for all states.

1.3 Technologies

An inventory of technologies is provided. The technologies are not limited to security technologies, but include existing commercial technologies, emerging technologies, and conceptual technologies. The following technology areas were identified:

- Truck immobilization using devices like the boot, the club, and jacks.
- Impoundment areas where out-of-service vehicles can be held until violations are corrected.
- Impoundment area instrumentation to detect and record when vehicles leave.
- License plate readers that automatically identify vehicles.
- Covert tags and beacons that can alert inspectors to out-of-service vehicles.
- Overt tags that can alert inspectors to out-of-service vehicles.
- Truck data logging computers for on-board monitoring and information storage.
- Truck sensors and measuring devices for on-board monitoring.

- Truck sensor communication networks for on-board monitoring.
- Truck RF sensor links for temporarily connecting sensors to vehicles.
- Advanced information management to provide timely information to inspectors in all states.
- Smart-card driver-specific information and linking of such information to data bases.
- Truck-to-roadside transceivers for data communication between trucks and inspectors.
- Palm-top terminals for automated entry of safety information.
- Satellite links for tracking truck locations and accessing truck data.
- Location sensors like global positioning system (GPS) devices.

1.4 Considerations and Recommendations

Before any solutions are selected, the scope of this study should be expanded to include other CVO (Commercial Vehicle Operations) and IVHS (Intelligent Vehicle Highway System) issues. Also, a more detailed evaluation and analysis should be performed to look at tradeoffs, risks, cost/benefit ratios, and political issues.

Technologies that show great promise are advanced information management systems, smart cards, electronic license plates, on-board monitoring and recording devices, and satellite communications (for long-range planning).

2. Background Information

2.1 Purpose and Scope

This is the report for Task 6 of the Commercial Vehicle Safety Systems Program, *Technologies for Covert Inspections Monitoring.* The stated purpose of this task is to identify technologies that can be applied to aid in covert monitoring of out-of-service commercial vehicles. Beyond the stated purpose, this study has also concentrated on obtaining a basic understanding of the needs for covert monitoring so that alternate solutions can be suggested.

Addressing the problem of covert monitoring is not a straightforward task. In order to make it as complete as possible, the scope of the study is concerned with the following issues:

- Monitoring operator vs. mechanical out-of-service violations;
- Monitoring from a fixed vs. mobile inspection site; and
- How covert operations can be advanced from a short-term detection approach to an integrated system that eliminates root causes.

Ideally a detailed system analysis would be done prior to identifying technologies for covert operations; however, a detailed system analysis is not within the scope of this task. Nevertheless, in order to obtain important insights, efforts have included rudimentary analysis of system concepts for inspecting, monitoring, verifying and enforcing commercial vehicle operations (CVO).

2.2 Methodology

In conducting this task, the following methodology was employed:

Gather information. Information about covert operations was gathered from various sources, though mostly through an interview process. Individuals from several states were interviewed concerning how their respective states were addressing the covert operations mandates. These interviews provided important insights into how out-of-service problems are perceived from different points of view. In addition, information has been gathered from publications, library searches, and vendors.

Formulate system concepts. The information collected was analyzed and related to the needs for covert operations. A distinction was made between root causes and problem symptoms. Basic system concepts were formulated to use as a basis for the technological approaches. It should be understood that the system concepts formulated in this report are not comprehensive and should be followed up with a broader, more detailed system analysis.

- ***Identify technologies.*** The task proposal statement specifies,“ The goal of this project will be to develop an inventory of previously developed security systems which can be used to aid in the covert operations.” Nevertheless, this study has not limited itself to only security system technologies or to technologies developed for previous DOE projects. Instead, this task has also attempted to consider existing or emerging technologies available from other sources, as well as explore developmental technology concepts. Where appropriate, demonstrations of Sandia or vendor technologies will be arranged.
- ***Suggest Alternatives.*** Based upon short-range and long-term considerations, various technological approaches are examined, and the best alternatives for continued analysis are suggested.

2.3 The Need for Covert Operations

The federal government has identified noncompliance by operators to out-of-service violations as a serious safety problem. For this reason, all states are mandated by the federal government to perform covert operations for the detection of operators that do not correct out-of-service violations prior to resuming operation of their vehicles.

In theory, each out-of-service violation should be reinspected before the vehicle can be returned to service; however, this does not always happen for various reasons, The two main reasons are:

- Not all states maintain 24-hour inspection work shifts. During off-shift hours, an inspector is not available to reinspect when an out-of-service violation is corrected; Also, when inspectors are not around, an operator is more likely to leave without correcting the out-of-service violation.
- When a mobile inspection unit places an operator or vehicle out-of-service, the inspector may subsequently leave and, therefore, not be available for reinspection when the problem is corrected or to verify that the operator doesn’t leave before correcting the problem.

House and Senate committees both looked at the problem of out-of-service order violations. Both committees concluded that *a permanent solution must be found.*

3. System Considerations

3.1 Current Operations and Processes

3.1 .1 Current Inspection Operations

To understand where technology can be applied to improve the monitoring of out-of-service operators and vehicles, it is useful to understand how the inspection process is currently performed. The following are the typical steps that are followed in an inspection process where there is an out-of-service violation:

1. As vehicles enter the fixed or mobile inspection site, the inspector will select a vehicle for inspection. Usually vehicles with current CVSA (Commercial Vehicle Safety Alliance) safety stickers are not selected and allowed to continue in transit. The inspection performed can be at levels 1-3. The inspector initiates a Driver & Vehicle Inspection form. (Figure 3-l is a copy of the form.)

2. The inspector places the driver or vehicle out-of-service for any identified out-of-service violations:

   - The violations are indicated on the inspection form.
   - The driver signs the form to signify receipt of a copy, and a copy of the form is given to the driver.
   - An out-of-service sticker is placed on the vehicle to mark it "out-of-service."

3. The operator corrects the problems:

   - Mechanical problems are repaired-the person performing the repairs must sign the driver's copy of the inspection form to certify that all mechanical out-of-service violations have been satisfactorily repaired.
   - Out-of-service drivers refrain from operating a motor vehicle for the period indicated in the out-of-service orders.

4. The out-of-service violations are reinspected.

   4a. If an inspector is available, then a reinspection of the violations will be performed. If satisfactory, the driver is released from the out-of-service order, and the out-of-service sticker is removed from the vehicle.

   4b. If an inspector is *not* available when the problems are corrected, then the driver is allowed to remove the out-of-service sticker from the vehicle and resume operation.

5. The operator submits the driver copy of the inspection form to the motor carrier.

6. The motor carrier official signs the inspection form to certify that all of the violations have been corrected and action has been taken to ensure compliance with the issuing state's Motor Carrier Safety Regulations.

7. The motor carrier official returns the completed inspection form to the issuing state's Motor Transportation Division within 15 days.

8. The Motor Transportation Division enters data from the inspection form into the federal SAFETYNET data base within 30 days.

3.1.2 Avoiding Detection

If a driver has decided to leave without correcting out-of-service violations, the driver will probably try to avoid being detected. The following are some of the things the driver may try to do to avoid detection:

- The driver will probably leave when there aren't any inspectors around: the inspectors might have left at the end of a work shift, moved to another mobile inspection location, or they might be busy doing other duties where they would not notice the driver leaving.
- If the driver is close to the border of another state, the driver might decide that it is easier to drive to the next state than to correct the out-of-service violations.
- After leaving without correcting out-of-service violations, the driver might avoid known inspection stations by taking back roads.
- After leaving without correcting out-of-service violations, the driver might falsify his inspection documentation so that it shows that the violations have been corrected.

MTD - 10987
REV. 03/92

- Microfilm Number -

State of New Mexico - Taxation and Revenue Department
MOTOR TRANSPORTATION DIVISION
P.O. Box 1028 Santa Fe, New Mexico 87504-1028

- Control Number -
075801

DRIVER & VEHICLE INSPECTION

GENERAL INFORMATION	Level of Inspection ❑1 ❑2 ❑3 ❑4 ❑5		INSPECTION DATE		TIME STARTED (24 hours)
INSPECTION LOCATION	LOC CODE	FACILITY TYPE ❑F ❑R	COUNTY CODE	CARRIER PHONE NO	
NAME OF MOTOR CARRIER		INTERSTATE CARRIER? ❑Yes ❑No	DOT NO	ICC NO	
STREET ADDRESS	CITY		STATE	ZIP	
NAME OF SHIPPER	SHIPPING PAPER NUMBER			COMMODITY	
DRIVER NAME (Last, First, MI)		DRIVER LIC NO / STATE		DOB	

STATE DATA	
MTD ACCOUNT NO	
CAB CARD NO	
NM OPERATING AUTHORITY?	❑Yes ❑No
CARGO VERIFIED?	❑Yes ❑No
CANINE USED?	❑Yes ❑No
VEHICLE WEIGHED?	❑Yes ❑No
OVERWEIGHT?	❑Yes ❑No
O/W CITATION NO	

BRAKE ADJUSTMENT MEASURES (INCHES)									% Out
AXLE	Steering	2	3	4	5	6	7	8	
TYPE									
LEFT									
TYPE									
RIGHT									

HAZARDOUS MATERIALS

CODE	RQ?	HW?

PLACARDS REQUIRED ❑ YES ❑ NO

VEHICLE IDENTIFICATION

UNIT NO	UNIT TYPE	YEAR/MAKE	CO NO	LICENSE NUMBER	STATE
1					
2					
3					
4					
5					

VIOLATIONS / NO VIOLATIONS

UNIT NO	VIOLATION	OOS	REPAIR CODE	CITATION NO	DESCRIPTION or CVSA DECAL NUMBER

I certify that the out-of-service violations listed in the "Violation Information" section have been satisfactorily repaired as of the date indicated.

Signature of Person Completing Repairs	Name of Shop (Garage)	Date

VEHICLE / DRIVER OUT OF SERVICE NOTICE

❑ Pursuant to authority contained in NMSA 1978 65-3-1 through 65-3-13, and the New Mexico Motor Carrier Safety Regulations adopted under that authority, I hereby declare vehicles with defects followed by a notation in the "Out of Service" column of this report **Out of Service**. No person shall remove the out of service stickers applied to these vehicles or operate such vehicles until the out of service defects have been repaired and the vehicles have been restored to safe operating condition.

❑ Pursuant to authority contained in NMSA 1978 65-3-1 through 65-3-13, and the New Mexico Motor Carrier Safety Regulations adopted under that authority, I hereby notify and declare the driver named on this report **Out of Service**. No motor carrier shall permit this driver to drive or operate any motor vehicle until ______________________ (Date / Time).

Inspected By	Badge	Written By	Badge	Time Completed (24) hours
Reinspected By	Badge	Driver's Signature indicating receipt of copy		

NOTE TO DRIVER: This report must be furnished to the motor carrier whose name appears on this report
NOTE TO MOTOR CARRIER: Please sign the certification below and return this report to the **MOTOR TRANSPORTATION DIVISION** within fifteen (15) days

The undersigned certifies that all violations noted on this report have been corrected and action has been taken to assure compliance with the New Mexico Motor Carrier Safety Regulations NMSA 1978 65-3-1 through 65-3-13

Signature of Carrier Official	Title	Date

Figure 3-1. Driver and Vehicle Inspection form.

3.1.3 Detecting Operators Who Disregard Out-of-Service Orders

Currently there are basically two methods of detecting operators who disregard out-of-service orders:

1. Catch them in the act.
2. Perform an investigation using audit and review procedures.

Catching Them in the Act

Currently the recommended method for detecting operators who leave without correcting out-of-service violations is to employ covert methods. The following are some of the covert techniques that are recommended by federal authorities:

- Use binoculars to monitor the out-of-service drivers and vehicles.
- Observe and stop commercial vehicles operating on the highway within 2 to 8 hours of closing an inspection site.
- Use unmarked cars as spotter vehicles.
- Use undercover (plainclothes) inspectors as spotters.
- Use mobile units to reinspect vehicles and drivers.
- Use air surveillance.
- Use fax machines to relay inspection reports to covert areas.
- Use a camcorder with a high-power telephoto lens.

Covert operations are relatively new and states have just begun to use them. In addition, covert methods tend to be manpower-intensive. As a result, they aren't employed all the time. In their Safety Enforcement Plans (SEPs), states must indicate their plans for covert operations, including the amount of time they will spend in covert operations. Because of cost considerations, many states will only do the minimum required for covert operation.

Some of the states are more proactive in their approach to covert operations. For example, Oklahoma realizes the importance of information management and is working on an in-state data base system that they can link to with a laptop computer over a phone line. This system will allow them to access out-of-service information about drivers and vehicles that enter their jurisdiction. The system is not complete at this time and funding shortages have reduced the effort to a low priority.

As another example, Minnesota has a research and development contract with a commercial company to develop a license plate reader system. The system will identify vehicles while stopped or in motion, then use the identification to access out-of-service information from a data base. At first, only Minnesota commercial vehicles will be monitored and entered into their data base.

Audits and Reviews

Audits and reviews can be used to detect drivers who have violated out-of-service orders. However, the auditing and reviewing of a driver or vehicle is not automatic. An audit or review might be done on a random basis or be initiated when violations of out-of-service orders are suspected. In performing an audit, information from various sources is gathered and compared to determine if there has been any deception on the part of the driver or motor carrier.

3.2 The Relationship Between Detection and Enforcement

In order to be effective, both the detection and enforcement of violations is needed to deter a dishonest operator from violating out-of-service orders. A conceptual relationship between the two is shown in Figure 3-2. The concept is based upon a deterrence threshold, probability of detection, and enforcement capability with severity of penalty:

- ***Deterrence*** Threshold-This is the threshold that a dishonest operator will have for honoring out-of-service orders. Above the threshold, the operator will consider it too risky to resume operations without correcting out-of-service violations. Below the threshold, the operator is likely to ignore the out-of-service because the gains (in time or short-term profit) outweigh the risk of being caught.
- ***Probability*** of Detection-This is the probability of detecting an operator who has violated out-of-service orders. The higher the probability of detection, the more likely it is that the operator will be detected.
- ***Enforcement Capability with Severity of*** Penalty-This deals with the authority that a jurisdiction has for enforcing out-of-service orders and the severity of the penalties that back up the enforcement capability.

The basic point here is that neither detection nor enforcement should be addressed while the other is neglected. Referring back to Figure 3-2:

- In example A, both the probability of detection and the enforcement capability with severity of penalty

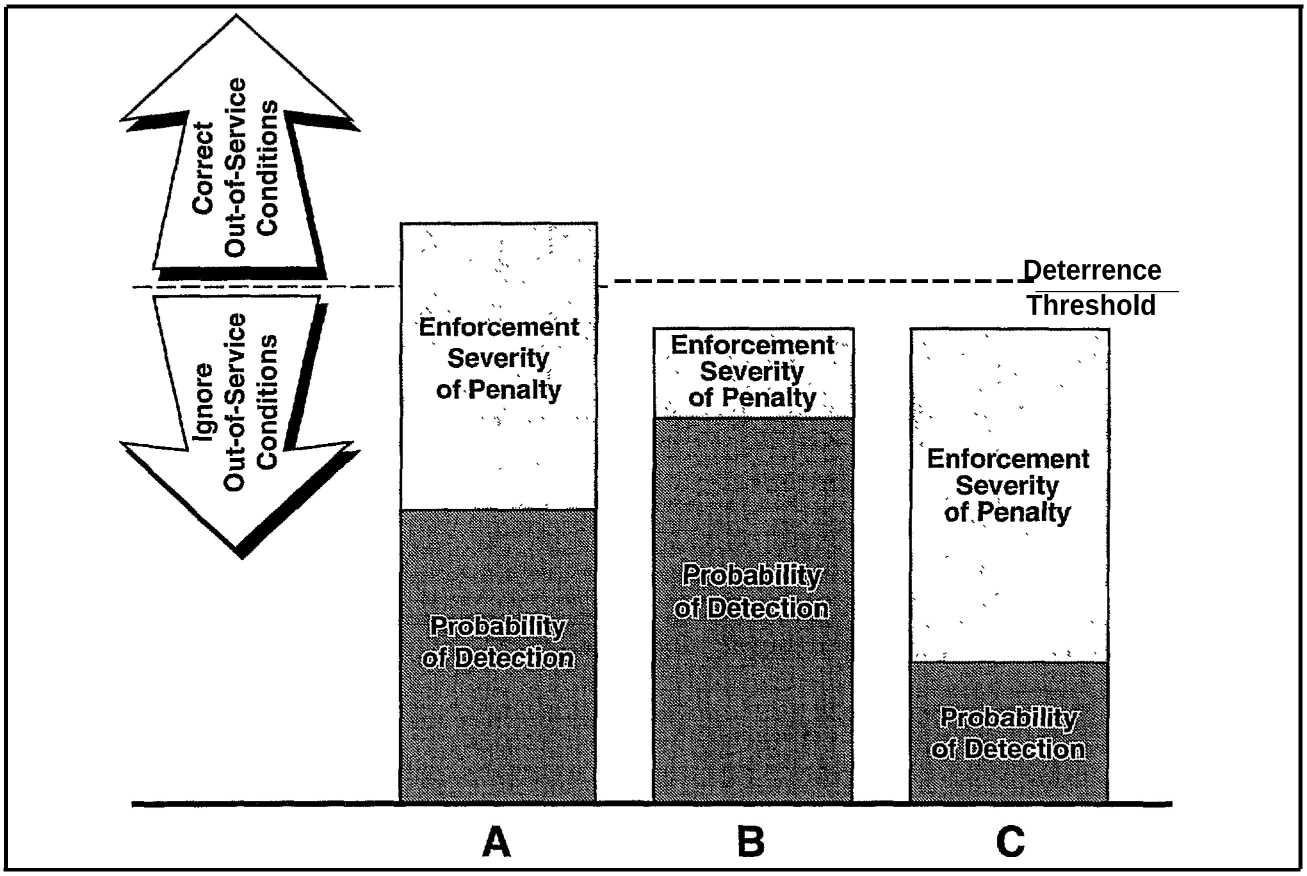


Figure 3-2. Deterring operators from ignoring out-of-service conditions.

are balanced. Both factors combine and synergize to deter an operator from ignoring out-of-service orders.

- In example B, resources have been concentrated so as to increase the probability of detection. Although the probability of detection has been increased significantly, the deterrence is ineffective because the enforcement capability with severity of penalty is minimal. In this case a violator will be detected, but because the penalty is so little, the operator does not fear it or is unconcerned by it.

- Example C is the opposite of example B. Here, resources have been concentrated to increase the enforcement capability with severity of penalty. Although the enforcement capability has been increased significantly, the deterrence is ineffective because the probability of detection is minimal. In this case the violator fears the penalty but is unconcerned because he knows he will not be caught.

This study has concentrated on increasing the probability of detection. Enforcement capability and severity of penalty are issues that are just as important and need to be addressed with legislation.

3.3 Root Causes vs. Problem Symptoms

In solving a problem it helps to understand and differentiate between causes of the problem and symptoms of the problem. For example, looking at a medical analogy, consider the following situation:

- An epidemic has broken out.

- Infected individuals exhibit fever and headaches.

- It is determined that a type of bacteria carried by mosquitoes is causing the epidemic.

In this situation, the symptoms are fever and headaches. The causes are a type of bacteria and mosquitoes. The following approaches to the problem are possible:

- Treat the symptoms by prescribing aspirin to reduce the fever and headache pain-treating the symptoms will provide immediate temporary relief to the individual, but will not eliminate the problem.

- Remove the causes:

  - Treat infected individuals with an antibiotic to kill the bacteria; treating with an antibiotic will kill off the infecting bacteria and eventually cure affected individuals. It will not, however, prevent other individuals from becoming infected.

  - Eliminate the mosquito population-eliminating the mosquito population might prove to be a difficult task, and it would not have the immediate effect of curing infected individuals; however, the long-range effect would be to remove the problem.

Which approach is the best to take? Any one of them can be depending upon the point of view and objectives. Instead of focusing on just one approach, sometimes it is reasonable to combine all of the approaches. In the example situation, a reasonable course of action would be to first prescribe aspirin to provide immediate relief from symptoms; second, prescribe an antibiotic to eliminate the infection; and third, work on a long range goal of eliminating the mosquito population to prevent others from becoming infected.

This same type of approach can be applied to covert operations problems as follows.

3.4 Inspection Process Problems

This subsection looks at problems in the current inspection process that might encourage an operator to violate out-of-service orders. By identifying problems and recognizing their causes and symptoms, possible solution approaches can be suggested to eliminate the problems and thus deter operators from neglecting future out-of-service orders.

Problem A: Tracking of Out-of-Service Violations

Cause:

- Inspectors do not have a good information management system to provide "real-time" information about the recent safety history of an operator and vehicle.

Symptom:

- An operator or vehicle can be put out-of-service and yet continue to operate without correcting the out-of-service violations and without detection. This is because the inspector does not have prior knowledge about out-of-service conditions and, therefore, would not know to look for them, thus creating the opportunity for a driver to avoid detection.

Solution Approach #l: Information Management Systems

- Implement an information management system using state-of-the-art technology and techniques. This system would provide for immediate "real-time" access to safety related information, including the status of out-of-service violations. Inspectors could access and update information from fixed or mobile sites. The information could be stored in a central or distributed data base and be available to every state.

Benefits:

- By entering an ID number like a vehicle license plate number or driver's license number out-of-service safety information can be easily accessed. The inspector would know immediately if the driver had outstanding out-of-service violations that hadn't been reinspected.

- The system could eventually be automated with emerging technologies like smart cards and future technologies which provide vehicle on-board safety monitoring and communi-cations while in motion.

- The system would provide information for statistical studies to monitor effectiveness and for implementing quality improvements.

Approach #2: Smart Card Information System

- Use a smart card technology to store out-of-service violation information about drivers and vehicles.

- Each driver would be required to keep his card with him at all times.

- Each inspector could read and update the information on the driver's smart card. If the card indicated that out-of-service violations were outstanding, a reinspection could be done, and penalties could be assessed if needed.

Benefits:

- The inspector would know immediately if the driver had outstanding out-of-service violations that hadn't been reinspected.

- Smart cards could be used independently of a central or distributed information management system.
- The system could eventually be automated with future technologies which provide vehicle on-board safety monitoring and communications while in motion.

Problem B: Reinspection Is Not Enforced

Cause:

- Reinspections of out-of-service violations should be performed at the originating inspection site after corrections have been made. When an inspector isn't present, the driver can leave after correcting the out-of-service violations. After leaving, the driver isn't required to have another qualified inspector reinspect the violations at the next available opportunity in transit. Instead, it is left to the integrity of the driver and motor carrier to make satisfactory repairs, complete the inspection form, and mail it to the issuing state.

Symptoms:

- After a driver leaves an inspection area without reinspection, it is difficult to determine if and when adequate repairs were made.
- Dishonest drivers can easily leave when inspectors aren't present and falsify documentation to avoid detection.

Solution Approach #3: Require and Enforce Reinspection

- Require that all out-of-service violations be reinspected at the earliest opportunity within a specified period of time.
- With the implementation of solution approach #1 or#2, out-of-service reinspections could be tracked. Only qualified inspectors would be permitted to access and update out-of-service information.
- Instigate appropriate enforcement policies and penalties. Litigate all reinspection violations. *(This may be the most difficult part of the solution to instigate.)*

Benefits:

- Drivers will know that they can't neglect correcting out-of-service violations without being detected; therefore, they will most likely correct the violations rather than try to defeat the system.
- The drivers are responsible and accountable for obtaining reinspections rather than the inspectors.

Approach #4: Keep an Inspector with All Out-of-Service Vehicles

- Keep all fixed and mobile out-of-service sites staffed with inspectors during periods when there are out-of-service drivers and vehicles. That way inspectors are always present to reinspect out-of-service violations and to visually detect drivers who leave without being reinspected. As an example, California is a state that staffs their fixed inspection sites for 24 hours a day, and they have little trouble with drivers violating out-of-service orders.

Benefit:

- Drivers would be reluctant to try leaving without correcting out-of-service violations because they will very likely be detected by an on-duty inspector.

Approach #5: Immobolize Out-of-Service Vehicles

- Immobilize out-of-service vehicles so they can't be moved.
- During off-duty hours, have an inspector "on call" for reinspection purposes. At the end of a driver out-of-service period the inspector can release the vehicle and driver. After out-of-service repairs are made, the driver can call in the inspector for reinspection and to release the vehicle.

Benefits:

- The driver can't leave until a reinspection of out-of-service violations has been made.

Approach #6: Alert Inspectors to Out-of-Service Vehicles

- Use available technologies to alert an inspector whenever an out-of-service vehicle has arrived at or is approaching the inspection site. The technology would signal that the vehicle has outstanding out-of-service violations that need to be reinspected. Types of technologies that would apply are electronic tags and beacons.

Benefits:

- Inspectors would know to reinspect out-of-service drivers and vehicles when they arrive at their inspection site.

- The probability of detecting drivers who violate out-of-service orders would be increased.

Problem C: Drivers that Violate Out-of-Service Orders Aren't Detected

Causes:

- Drivers can leave when there aren't any inspectors around: the inspectors might have left at the end of a work shift, might have moved to another mobile inspection location, or might be busy with other duties where they would not notice the driver leaving.

- After leaving without correcting out-of-service violations, the driver might avoid known inspection stations by taking backroads.

- After leaving without correcting out-of-service violations, the driver might falsify his inspection documentation so that it shows that the violations have been corrected. This item is probably best addressed by solution approach #3.

- Every vehicle is not inspected upon entering a jurisdiction. With the current inspection process, a level 1 inspection can take as much as 45 minutes. If every vehicle is inspected at a fixed or mobile inspection site, an unacceptable backup of vehicles would occur, producing significant transit delays of cargo.

Symptoms:

- Drivers know that they have a good chance of not being detected down the road after they leave an inspection site without correcting their out-of-service violations.

- Drivers know that their chances of avoiding inspection are better during busy times. They might time their arrival at inspection stations during a busy time or lunch break. They might use CB communications to keep informed of good times to enter an inspection site.

Solution Approach #7: Detection Technology

- Use various detection devices to alert an inspector when an out-of-service vehicle has left or to accurately identify and record the event.

- An appropriate enforcement process and penalties would need to be in place for detection to be effective. This should be consistent from state to state.

Benefits:

- Relieves inspectors of having to visually monitor out-of-service vehicles to detect when they leave.

- Inspectors do not need to be present because events have been recorded and can be assessed later.

- Out-of-service drivers can be accurately detected and identified when they leave early.

Concerns:

- The technology cannot provide information about the repair of mechanical items. The driver might have indeed corrected the mechanical violations before leaving, in which case a reinspection would be needed. It is not clear how to guarantee the reinspection without implementing at least part of solution approach #3.

Solution Approach #8: Track Location of Out-of-Service Vehicles

- Incorporate location tracking technology to track out-of-service vehicles. This approach would probably have to make use of GPS (Global Positioning System) technology.

- Only vehicles that need reinspection would be tracked. Vehicles that passed reinspection would not be tracked.

Benefits:

- Drivers who take backroads to avoid an inspection station could still be identified and located. A mobile unit could then be sent to intercept and inspect the vehicle.

Solution Approach #9: On-board safety monitor system

- Develop and implement an on-board vehicle safety monitoring system.

- Interface the monitoring system to safety inspection information management systems.

- Evolve the system to communicate safety information from the vehicle while in motion.

Benefits:

- Inspection problems could be identified much faster.

- The inspection throughput could be increased; that is, more vehicles could be checked and inspected.

- The probability of detecting violators of out-of-service orders would be increased.

Problem D: Not All States Have Consistent Enforcement Authority and Penalties

Causes:

- If the driver is close to the border of another state, the driver might decide that it is easier to drive to the next state than to correct the out-of-service violations.

  Each state has its own motor carrier safety regulations, imposed penalties, and authority for enforcement which vary from state to state. Most direct enforcement is done by the states themselves. It was not within the scope of this task to perform an all-inclusive compilation of all of the states regulations, penalties and enforcement methods; although, in interviewing some of the states, it was discovered that some of the states are not giving their inspectors the authority to enforce their regulations. For example, at least one of the states doesn't give their inspectors the authority to issue citations. In that state, citations can only be issued by state troopers, and the state troopers aren't always readily available to do so.

  In addition, enforcement can be difficult because once a driver has left a state, that state cannot issue a citation to or enforce violations for that driver. At that point, the only recourse is to get the federal government involved to perform an investigation.

Symptoms:

- If a dishonest driver knows that a state cannot enforce their regulations, or if the driver knows that the penalties are minimal, the driver may be willing to take the risk of leaving without correcting out-of-service violations.

Solution Approach #10: Standardize penalties and enforcement methods

- Require that all states conform to standard penalties and enforcement methods. This is not a technological solution but rather legislation is needed to support and implement.

Benefits:

- Drivers will not feel that they can avoid stiff penalties by escaping to the next state.

3.5 Solution Relationships

Although problems and solutions have been identified, it isn't obvious which solutions should be pursued. Does it make sense to implement each solution, or are some better than others? The diagram in Figure 3-3 was created to help illustrate how the various solution approaches relate to each other. To interpret the diagram, any solution approach that is encircled by another approach generally does not add any value if the outer approach is implemented. An inside-out explanation of the diagram follows.

3.5.1 Require and Enforce Reinspections-Approach #3

This solution approach places the responsibility on the driver for obtaining reinspections of out-of-service violations either at the original inspection site or within a short period of time after leaving the site. This approach doesn't guarantee that the driver won't try leaving without making corrections; nor does it address the out-of-service driver very well. This isn't a technological approach; to work well, it will require good follow-up enforcement with severe penalties for violation. This approach is best for ensuring that mechanical repairs are made. If used with approach #7, then better coverage for detecting out-of-service drivers will be obtained.

3.5.2 Detection Technology-Approach #7

This solution approach involves using various detection technologies to detect or record when an out-of-service vehicle has left. This approach if implemented doesn't provide information about the repair of mechanical problems; nor is any of the information readily available to other inspectors down the road. It is most effective at detecting when out-of-service drivers have left too early. If used with approach #3, then better coverage for detecting mechanical out-of-service order violations will be obtained.

3.5.3 Alert Inspectors to Out-of-Service Vehicles-Approach #6

This solution approach utilizes technologies that could alert an inspector that a vehicle with outstanding out-of-service violations had entered or was approaching the inspection site. In implementing this solution, an electronic device on the vehicle would contain information about out-of-service problems that had not yet been reinspected. And the device might utilize a beacon or radio link that could alert the inspector about the out-of-service condition. This information could be accessed when the vehicle is stopped at a fixed or mobile site, or possibly over a radio link while the vehicle is in motion approaching the inspection site.

With the implementation of this solution, solutions #3 and #7 are not needed.

3.5.4 Keep an Inspector with All Out-of-Service Vehicles-Approach #4

This solution approach is not a technical solution. It is roughly equivalent to approaches #5 and #7. It requires that an inspector be present at out-of-service areas during off-hours whenever there are out-of-service vehicles and drivers. The inspector is present to ensure that vehicles don't leave without proper corrections and to reinspect as needed.

This solution would require an increase in manpower and associated manpower costs. With its implementation, solution approaches #3, #6, and #7 are not needed. Also, because they are roughly equivalent, approaches #5 and #8 are not needed.

3.5.5 Immobilize Out-of-Service Vehicles-Approach #5

This solution approach is roughly equivalent to approaches #4 and #7. It requires technology to immobilize out-of-service vehicles until corrections have been verified by an inspector. This solution also requires that an inspector be on call for reinspection during off-hours, though the inspector does not need to be present. With its implementation, solution approaches #3, #6 and #7 are not needed; nor are approaches #4 or #8.

3.5.6 Location Tracking of Out-of-Service Vehicles-Approach #8

This solution approach is roughly equivalent to approaches #4 and #5. It requires technology to track the location of out-of-service vehicles after they have left an inspection site. Tracking of vehicles or drivers that had passed a reinspection would not be done. With its implementation, solution approaches #3, #6, and #7 are not needed; nor are approaches #4 or #5.

3.57 Information Management System-Approach #1

This approach requires implementation of a central or distributed information management system for tracking out-of-service violations. This system would be available to all states and inspectors. The information would need to be kept current by inspectors.

This approach would not replace approaches #2 and #9 but, rather, could work in conjunction with them. With its implementation, solution approaches #3, #4, #5, #6, #7, and #8 would not be needed.

3.5.8 Smart Card Information System-Approach #2

This approach requires smart card technology for managing out-of-service information. The drivers must be required to carry a smart card with them at all times, and the inspectors are required to access and update the out-of-service information on them.

This approach would not replace approaches #l and #9 but, rather, could work in conjunction with them. With its implementation, solution approaches #3, #4, #5, #6, #7, and #8 would not be needed.

3.5.9 On-Board Vehicle Safety Monitoring System-Approach #9

This approach is probably a long range development effort. It would require technology for monitoring on-board vehicle safety parameters while a vehicle is in motion. The on-board information could be accessed at an inspection site or while the vehicle is moving.

This approach would not replace approached #l and #2 but, rather, could work in conjunction with them. With its implementation, solution approaches #3, #4, #5, #6, #7, and #8 would not be needed.

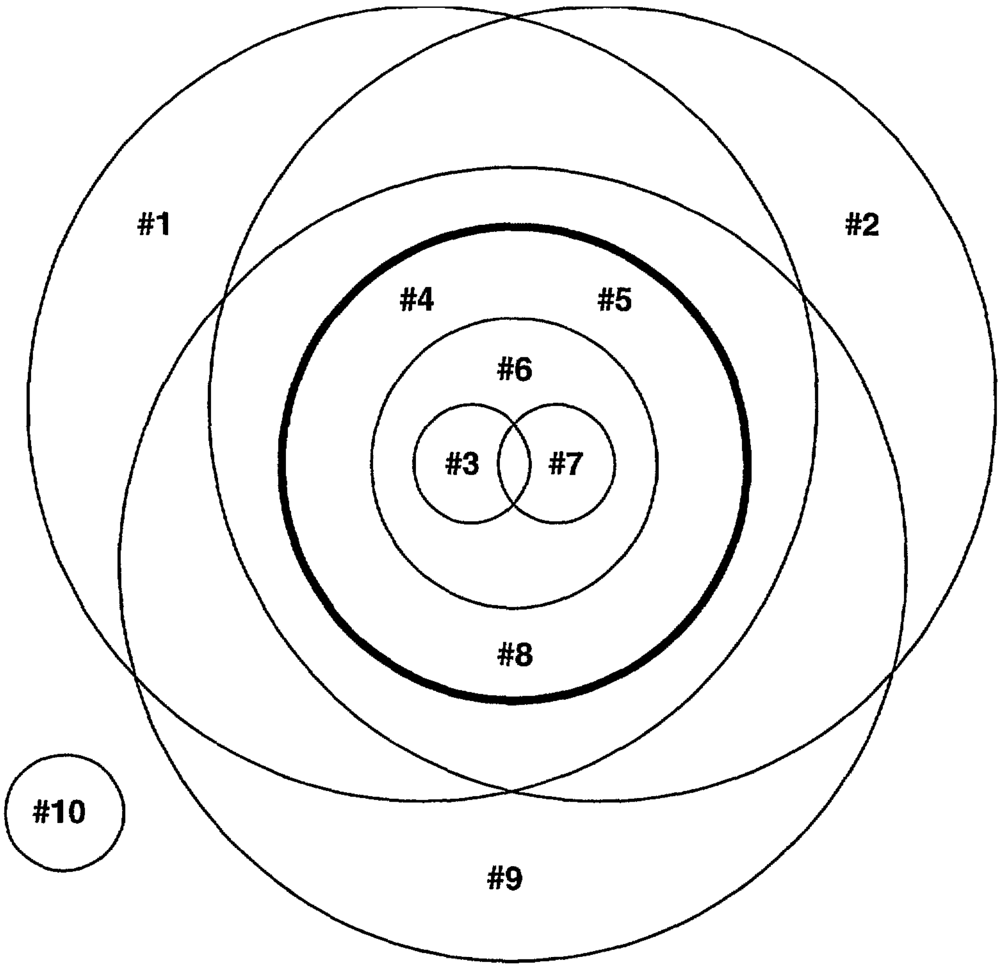
3.510 Standardize Penalties & Enforcement Methods-Approach #10

This approach is purely nontechnical and must be supported by legislation. It is not an approach that increases the probability of detection, but is mentioned here because it influences the total effectiveness of covert operations. As such, it is a standalone approach that is separate from approaches 1 through 9.

3.5.11 Problem/Solution Matrix

As can be seen, the relationship between solutions and problems is not straightforward. There is some overlap in how the information can be interpreted. Another way of looking at the information is presented in the matrix provided in Table 3-l. Note that the shaded areas represent potential overlap. For example, solution #1 has an effect upon problems a, b, and c.

Solution Relations



Solution Approaches

#1 Information management system
#2 Smart card information system
#3 Require & enforce reinspection
#4 Keep an inspector with all out-of-service vehicles
#5 Immobilize out-of-service vehicles
#6 Alert inspectors to out-of-service vehicles
#7 Detection Technology
#8 Track location of out-of-service vehicles
#9 On-board vehicle safety monitor system
#10 Standardize penalties and enforcement methods

Figure 3-3. Solution relationships.

Table 3-1. Problem/Solution Matrix Tabfe

Problems: / Solutions:	A: No Tracking of Information	B: Reinspection Not Required	C: violations Not Detected	D: Inconsistent Enforcement & Penalties
1: Information Management System	■	■	■	
2: Smart Card Information System	■	■	■	
3: Require and Enforce Reinspections		■	■	
4: Keep Inspector Present		■	■	
5: Immobilize Vehicles		■	■	
6: Alert Inspectors		■	■	
7: Detection Devices			■	
8: Track Vehicle Location		■	■	
9: On-Board Monitor		■	■	
10. Standardize Penalties & Enforcement				■

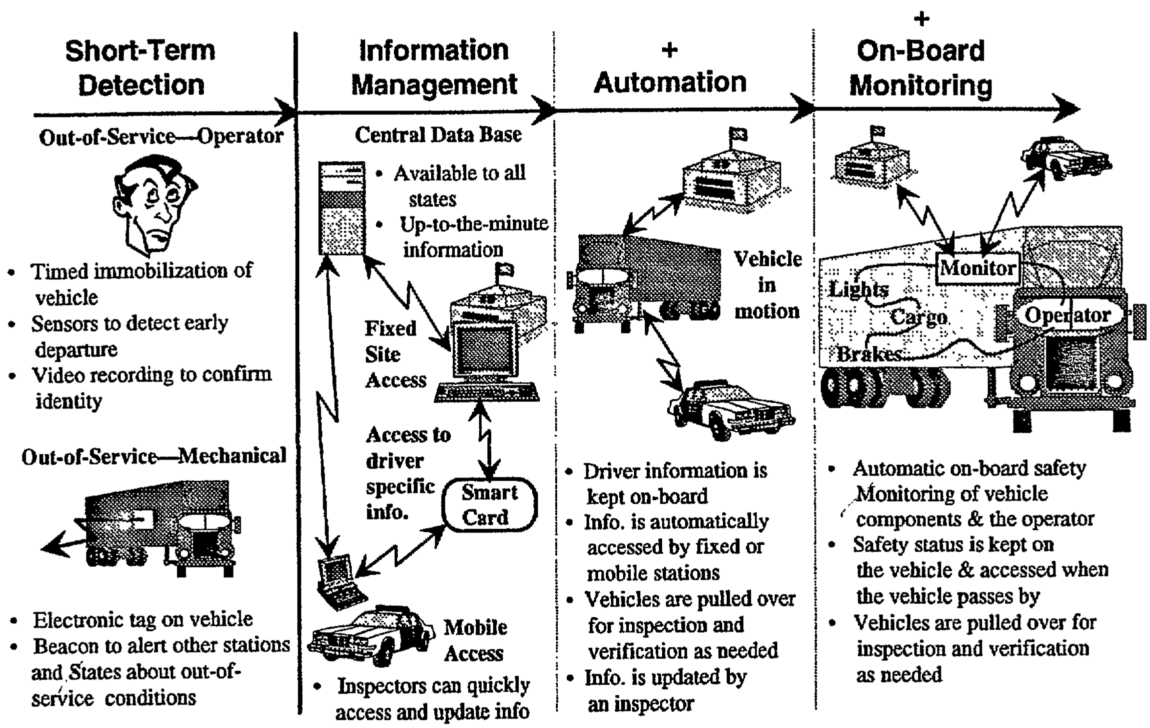


Figure 3-4. Advancing covert operations.

3.5.12 Advancing Covert Operations

Creating a long-range plan for implementing and integrating technologies to address covert operations is a smart thing to do. Working within the scope and constraints of this study, one possible way of looking at how covert operations could be advanced is illustrated above in Figure 3-4. In this phased approach,

- First short-term, stop-gap measures are implemented to help with detecting drivers who violate out-of-service orders;
- Second, an information management system is implemented;
- Third, automation is included to permit information to be exchanged while vehicles are in motion;
- And finally, an on-board monitoring system is integrated into the system.

Another approach would be to skip the short-term detection implementation if the cost-benefit ratio is not acceptable and start with implementing an information management system.

These possible approaches should be treated as conceptual, as a final plan would factor in broader CVO and IVHS issues.

4. Technologies

4.1 Introduction

The list that begins in subsection 4.3 describes technology that may be applied specifically to covert operations and in general to the DOT Intelligent Vehicle Highway Systems (IVHS) program. This list provides the following information for each technology area: 1) the intended application; 2) advantages and disadvantages of the technology; and 3) sources and costs, where known, of off-the-shelf hardware.

4.2 Approach

In this part of the report, we have concentrated mostly on the identification of specific technologies and how they may support covert operations as well as the general IVHS concept. For each technology, we explain the concept and provide key information on available commercial products or systems. It should be understood that an exhaustive search of all available sources of a technology could not be made. When possible, the known sources of a technology are given; however, an omission of any potential sources was not intentionally made. Any reference to a product vendor is provided for informational purposes only-it should not be interpreted as a Sandia recommendation to use that particular vendor or product.

Advantages, disadvantages, and rough cost figures are included where appropriate. The consideration of this kind of information should help lead to the formation of specific alternative short- and long-term solutions.

4.3 Truck Immobilization

4.3.1 Immobilization Devices

The Boot

This could be a larger version of the wheel/tire locking boot used in New York City on illegally parked cars. It is designed so that the wheel cannot be removed and replaced by the spare. Its vulnerability to cutting devices is unknown.

The Club

A locking bar that is put on the truck steering wheel, or a chain from the steering wheel to the clutch.

Advantage

These devices are readily available and are easier to install and remove than the boot.

Disadvantage

More vulnerable to cutting than the boot, although the cutting torch damage and danger to the cab interior may be a deterrent.

The Jack

This is a Sandia concept for jacking up the wheels of a tractor or trailer. This heavy duty mechanical jack would be on rollers, and would be locked in the jacked position by the inspector. It could have a weight sensor (load cell) inside that would report via RF to the station office if the jack was removed. A timed version could be used for out-of-service drivers. It would retract after a preset time and allow the driver/truck to proceed. A permanent version could be installed to retract into the ground.

Advantages

Very positive deterrent.

Disadvantages

Expensive to buy, heavy and unwieldy to store, move, install, and retrieve. May not be viable for mobile use. Dangerous if left out in the truck parking area, unless installed below ground level. Honest drivers may resent not being trusted.

Sources

This is a conceptual design that may require developmental effort.

4.3.2 Impoundment Areas

Concept

Fenced and sensored parking areas to hold out-of-service trucks.

Advantages

Easily and permanently sensored to help monitor truck movement.

Disadvantages

May require a round-the-clock gatekeeper to let the trucks out. Doesn't address the mobile inspection situation.

4.4 Truck Movement Sensing

Concept

A rubber pressure pad placed under the wheel of any tractor or trailer, depending on which is out of service. It would have a radio link to the port of entry (POE) or weigh/inspection station (WIS) office data logging computer or the satellite link. Time of departure and the associated truck ID would be recorded and a flag raised if an unauthorized out-of-service truck left, or an out-of-service driver left before his rest time was completed.

Advantages

Reasonably inexpensive, easily handled and stored. Not a safety hazard. Could be used in the mobile environment.

Disadvantages

To be effective, more infrastructure, including information tracking and law enforcement, must be in place. Theft of the device in the mobile situation could be a concern.

Sources

This is a conceptual device that may require developmental effort.

4.5 Impoundment Area Instrumentation (Gate, Chokepoint Truck Sensors)

Concept

Use video cameras and gate or chockpoint truck tire sensors to automatically read the license numbers of trucks entering and leaving the impound area. The numbers and departure/entry times would be logged either locally or at the central data facility (license plate readers are described below).

Advantages

Compared to the use of immobilization devices, there is no effort required for installation to and removal from a vehicle, and the data is automatically logged.

Disadvantages

Requires a fenced impound area; hose switches must be periodically replaced; IR beam breakers are expensive. Some kind of logic may be needed to separate trucks from people who may trigger the system, but beam breakers can be put high enough that people, cars, and vans are not a problem.

4.6 License Plate Readers

Concept

Fixed

This is basically a video camera and a self-contained illuminator mounted in a weather-proof enclosure that reads license plates. It uses the retroreflective properties of the beaded surface to generate high quality images that are automatically located relative to the taillights and other safety reflectors. The license plate is then read by an optical character reader and converted to a number code for inclusion in the local computer log or use in accessing information from a data base. In an impound area, the camera and lights can be set up to turn on only when the portal hose or IR beam is activated, or, if there is a lot of traffic, it may be operated continuously.

The state of Minnesota is considering using the license plate reader in the verification of out-of-service repairs. They would place it at the truck scales to identify those vehicles that had recently been put out of service by state inspectors.

Mobile

The sensor head of the mobile version would be mounted behind the top of the windshield, and could be used just to make a record of trucks stopped, or could be used in conjunction with an out-of-service data base to inform the trooper that the truck ahead should be stopped.

In an automated system where the truck has a radio data transceiver, the ID code obtained from the license plate reader could be used to automatically call up the identified truck system and access its on-board information, including out-of-service history.

Advantages

In a fixed installation, the system may obviate the need for gate guards.

In a mobile situation, it saves the trooper the time of reading in the license plate number to his computer system.

Disadvantages

Will be best for information about tractor mechanical out-of-service violations, but not necessarily about driver or trailer out-of-service violations.

Sources

Perceptics Corporation
725 Pellissippi Parkway,
Knoxville, Tennessee 37932-3350
Tel: (615) 966-9200 Fax: (615) 966-9330

Cost

Mobile or fixed site units: about $30K-$33K each

4.7 Covert Tags and Beacons

Concept

The inspector would put a tag with a unique radar or optical signature on the rear of the truck, and tell the operator not to remove it until after the out-of-service condition was repaired. In one version, a radio transceiver tag having a magnetic or adhesive pad might be covertly placed on the truck in an inconspicuous place by an aide while the inspector diverted the driver's attention.

In one concept reported to be practical, a credit-card-sized, battery-powered active tag can be magnetically attached to the truck in a large number of places while unseen by the driver. The number of possible locations is large enough that the driver, even knowing that he has been tagged, would have difficulty finding it. He would not be able to find it with a "bug" sniffer because it only emits a homing signal when it "hears" its proper identification.

Other concepts might involve temporary chemical sprays that could be seen or smelled either directly or through special sensors at the weigh stations. They would be inexpensive to apply and would naturally evaporate or wash off with time.

Advantages

Easier and faster to detect out-of-service vehicles on the road and at weigh stations.

Disadvantages

May not be possible to keep the drivers from removing the tags and beacons. The situation should be the same as removing the red tags now stuck to the side of the out-of-service vehicle, except that the lost hardware is much more expensive. Honest drivers may resent being tagged and may become less cooperative.

Sources

Sources have not been identified. These devices and tag techniques may require developmental effort.

Considerations

If the license plate (a required unique tag) is not enough to provide law enforcement then another tag (not required and hard to make covert) will probably not improve the situation in a cost-effective manner. Also, the truckers are often streetwise and, through their informal CB alliance, will quickly find out about such tricks being used. This will do nothing for getting cooperation from the drivers.

4.8 Overt Tags

Concept

As opposed to covert tags, overt tags or "electronic license plates," as they are known in the trade, would be permanently attached to the vehicle and required by law to remain attached, just as are regular license plates. These actually contain a low power transceiver and will store and transmit coded data. They reportedly are going into service this year on railroad cars as part of another DOT program. The inspector would record on this tag the information about the out-of-service condition, and then the highway patrol, or the next weigh station, would read it out to see if the condition was still present. If the truck had been repaired, then the repair facility (if licensed) would so update the tag information. The overt tag would be much like the smart card, but be permanently attached to the tractor and trailer.

Another version of an overt tag would be a temporary one that was very rugged and could be locked onto the front or rear bumper, frame, etc. Since it would not be mandatory on all vehicles and only put on for out-of-service violations, it would be much easier to implement early in the program.

Advantages

This would accomplish much of the DOT purpose of detecting and reinspecting. Separate tags could help monitor tractor vs. trailer out-of-service violations.

Disadvantages

It would not take care of out-of-service drivers, but this might be done indirectly through a time/location calculation since the tag was last updated.

Sources

Amtech of Santa Fe, NM: Jerry Landt, 505/473-1482
(they are moving to Albuquerque, at 505/856-8000)

4.9 Truck Data-Logging Computers

Concept

Use on-board computers to monitor and log truck and driver conditions as described in the IVHS program plan. Some systems use a 286/386 platform running MS-DOS and the Microsoft C programming language. Program-ming modules are provided to facilitate particular system designs.

Advantages

Provides the foundation for an on-board, real-time truck/driver monitoring and data transmission system. For example, RF modems are designed to plug directly into an RS-232 serial computer port. Such systems are already in use by the larger trucking companies because they allow them to optimize truck/driver performance and routes. The data can also vindicate the driver and company in accident lawsuits.

Disadvantages

Expensive, may have to be mandated by law before the independents truckers are willing to make the investment.

Sources

Margaret L. Schwartz
Director of Marketing
Argo Instruments, Inc.
212 Fort Collier Road
Winchester, Virginia 22603
Tel: 703-665-0200 Fax: 703-662-2127

Cost

Computer cost alone may be less than $2K, but installation of the system, including sensors in a truck, has not been determined.

4.10 Truck Sensors

Concept

Use sensors to measure steering history, engine rpm, axle rpm, tire pressure, tire temperature, distance driven, time, GPS location, brake activation travel, axle weights, fuel flow, engine air flow, wind velocity, and engine noise. Note that many of these measurements are of no particular use to the DOT as safety items, but many are very important to the fleet operator to assess operational costs and efficiency, and should be included in the IVHS package concept.

Advantages

Provides valuable information for both truck companies and the DOT. May actually reduce preventive maintenance, allows more complete use of brake material and eliminates tear-down brake inspections. System may be able to detect excessive wear in some other parts by measuring activation play. It might measure engine and gear wear by monitoring acoustic noise (currently being done on jet and turboprop engines).

Disadvantages

Additional reliability and maintenance problems.

Sources

These are devices and techniques that may require developmental effort.

4.11 Truck Sensor Networks

Concept

Although some truck computer systems (such as the Argo FMS 1332) are designed to connect directly to tachometers, temperature gauges, status contacts, and analog voltages, there is a growing effort to use the concept of Control Arbitration Networks in future cars and trucks. Dearborn Group, Inc., is a consulting and test equipment company that specializes in CAN, SAE 51850, IS0 9141, and CCD Networks. These networks use only a few wires (using arbitration and priority basis) to prevent message collision. The network is installed in the vehicle in a loop that can be cut at any point without loss of function. The system is designed to not only allow information to be gathered from many sensors, but to be shared by several controllers, such as the anti-skid system, the engine controller, the truck efficiency manager, and the IVHS safety and out-of-service reporting system.

Advantages

Commercially available for designing into an on-board monitoring system.

Sources

The Dearborn Group has presented multiplexing seminars to more than fifty companies, including Ford Electronics, Cummins Electronics, TRW Automotive, Chrysler, GM Truck & Bus, General Motors, and Ford Truck.

The Dearborn Group, Inc.
29655 Eastfield Dr.
Farmington Hills, Michigan 48334
Phone: (313) 932-1850, Fax: (313) 932-2169

4.12 Truck RF Sensor Links

Concept

Sandia is developing a Universal Authenticated Item Monitoring System (AIMS) that consists of an RF receiver, a Remote Programming Unit (RPU), and a variety of Authenticated Sensor Transmitter (ASTX) packs. The purpose of this equipment is to monitor, in a secure and unattended mode, output from a number of secured sensors. The normal, unmodified and non-authenticating sensor/receiver is available off the shelf. It could obviously be used for the temporary installation of a number of truck safety and compliance sensors, connecting them through an active beacon or tag to a weigh station, a satellite link, or the highway patrol. Since they are battery-operated and must share the radio spectrum (900 MHz) they would be best suited to only temporary use on just the out-of-service trucks.

Advantages

Rapid installation.

Disadvantages

Frequency band must be used. Many units in an area may cause interference. The initial cost may be high. Maintenance will be required.

Sources

Sentrol, Inc.
Portland, OR

Inovonics, Inc.
Boulder, CO

Cost

Approximate cost of hardware:

ASTX	$150
RF receiver	$300
RPU	$2000

4.13 Advanced Information Management Systems

Concept

Use of advanced data management software, linked via Local Area Network or telephone modem to a centralized data system, could effectively be used to decrease abuse of the regulatory, monitoring, and enforcement systems at the state and local levels. One example of this could be to link existing ports of entry and mobile inspection teams with a centralized file manager such as the DOE/DOT TRANSNET system, which would permit state and local inspection and enforcement personnel to "track" various information like safety and hazardous materials shipment data. Likewise, information regarding the carrier, payload, package, vehicle, and driver could be entered into a real-time data management package. Access to the data would be by LAN from fixed locations or by modem from remote locations.

If linked to on-board electronic tags, the vehicle could be monitored by either a fixed or mobile antenna system without disrupting operations unless a noncompliance event has occurred. The data system would be used to alert inspectors or enforcement personnel of potential problems thus permitting more effective use of personnel time. The data system could also be used to "sort" incidents by carrier, driver, maintenance location, etc.

The intent of this effort would be to

- devise an improved data entry user interface that uses hypermedia or intelligent data management techniques;
- create an effective tool to ensure compliance with safety and enforcement requirements; and
- reduce the processing time required for personnel to enter data.

The software and hardware suggested here are commercially available and proven. Hardware would be modem- or LAN-equipped personal computers for the fixed site operators and portable modem-equipped PCs for the mobile units tied to a central file manager. This file manager would be either a PC or a workstation, depending on the amount of data and access requirements of the system. Software would be commercially available, with existing system elements that have been developed by Sandia and private contractor personnel.

Advantages

The system suggested could be designed to permit state and local officials to easily and quickly access pertinent CVO data regarding out-of-service conditions, payload, and other information. If uniformly adopted by all jurisdictions, this system could be used by safety inspectors, law enforcement personnel, and emergency responders.

Disadvantages

To effectively implement a useful data management system, cooperation and participation of most, if not all, jurisdictions would be required. While the system designers can use hypermedia and intelligent data systems to reduce the likelihood of data entry error, errors could occur that could result in the wrongful stopping or detaining of a vehicle. Most data entry errors will be caught by subsequent reviewers or by the software itself; however, deliberate misentry would be difficult to prevent. A repeated pattern of such abuse, however, can be itself tracked and used to discipline abusers.

Sources

There are many commercial sources of modem- and LAN-equipped personal computer hardware. Much of the software is commercially available, with existing system elements that can be provided by Sandia and private contractor personnel.

Cost

Hardware: Existing PCs, if available, could be modified for less than $1000 per installation. Purchase of an entire setup would be less than $5000 per fixed or mobile installation, and less than $10,000 for the file server. Additional capacities could increase this cost slightly. Software cost would be less than $500 per installation. Development costs are highly dependent upon a detailed user requirements specification; however, with what is currently known, a reasonable development cost is estimated to be approximately $50,000, expended over a 6-month period. Operating and maintenance costs of such a system would be between $25,000 and $100,000 per year, depending on whether the system could be effectively integrated into existing platforms/services such as the TRANSNBT system. There appear to be no technical barriers to integration of these functions.

4.14 Smart Cards

Concept

In lieu of a truck computer and radio data links, the emerging smart-card technology may offer a partial solution for checking to see if trucks have been recently inspected and what problems were found. After the initial safety inspection, the out-of-service problems, as well as more minor conditions, would be entered on the truck's smart card, which is normally included in the trip file. Both highway patrolmen as well as the next inspection station have the equipment and authorization to read this card. If any safety discrepancies are logged on to this card, the truck is reinspected and the smart card updated accordingly.

Advantages

A relatively low-cost upgrade from the current practice, and much more reliable than the current out-of-service stickers, or the proposed covert tags and beacons. The driver *must* produce his smart card to get past the next check point.

Disadvantages

The smart card does not, by itself, take care of the out-of-service driver in need of rest, unless he shows up at the next checkpoint too early. It may be difficult to monitor tractor and trailer out-of-service violations if they are separated from the driver.

Sources

Smart cards are an emerging technology with many vendors either producing or beginning to produce them. Progress in smart cards is advancing quickly and should be monitored closely. A national Smart Card/Tag working group has been established. The chair of the group is

Carol Schweiger
EG&G Dynatrend
(6 17) 272-0300

Cost

Equipment costs can vary. Some of the costs to be concerned with are

Individual cards	$8-$30
Readers/Writers	$l00-$200
Initializers/Personalizers	$275-$30,000

Also, additional costs will be incurred for printing onto the cards themselves; for example, company logos, picture IDS, etc.

4.15 Truck-to-Roadside Transceivers (Modems)

Concept

The radio-frequency modems concept started as a way to link computers with each other and with peripherals quickly and without running wires or cables. It was used to connect to noisy printers in the next room. However, by increasing the transmitter power, they were soon used for computer communications between buildings and to nearby vehicles. They have been applied to remotely controlled airplanes and for communications between railroad cars in a train. They should work equally well for communications between the trucks approaching or parked in a POE or weigh/inspection station and the facility office/dispatch center. They could transmit all of the truck safety status information and send back approval to allow the truck to bypass the stop, or to wake up the driver in the parking area after he has completed his rest period.

Advantages

This is a mature technology that works well.

Disadvantages

An inquiry preamble must be sent to the trucks that tells which particular truck is expected to reply, otherwise, all trucks within a 2-mile radius would try to respond simultaneously. Truck identification could be done through the license plate reader.

Sources

Motorola R-Net series radio modems
1200 to 9600 BPS
2- or 4-watt output power
400 to 470 MHz

Motorola Radius Division
Mt. Pleasant, Iowa
I-800-356-9058, ext.105

Cost

$990 ea. for modem. Volume and company discounts are available.

4.16 Truck-to-Patrol-Vehicle Transceivers (Modems)

Concept

Same as above, only a longer range and specific designs might be needed.

4.17 Palm-Top Terminals

Concept

These may actually be palm-top computers with either minimum keyboards or stylus/pencil entry systems such as that of the Apple/Newton unit due out this summer ('93). The Texas Transportation Institute at Texas A&M, College Station TX was reportedly working on a pressure-sensitive writing screen device for use by ticket-writing traffic police. A similar device could be used by the truck drivers and inspectors in place of the current log book and inspection form. An RF modem link might transfer this data into the truck's computer, the driver's smart card, and the officer's duty log. The information might be passed on either through the truck's satellite link or through the local or state police dispatcher link. Rental car companies are already using this concept to expedite car rental returns.

Advantages

Easy to use by drivers, inspectors, and police who don't have good typing skills.

Different inspection/out-of-service forms can be displayed to the user.

Disadvantages

It may not always be easy to read or retrieve data.

Sources

Hewlett Packard
Apple Computer - Newton
(See recent cover article in Popular Science, Sept. 1992 issue)

4.18 Satellite Links

Concept

Trucks (and safety patrol vehicles) can have 2-way data communications with state and federal data bases and transportation offices. The GPS provides truck location while the on-board sensors give truck status including out-of-service conditions. The larger trucking fleets already use the GPS/satellite portion of this concept to track shipments for customers and to help control costs.

Advantages

Truck locations are known at all times, so if an out-of-service truck or driver is moving, a state patrol vehicle could be dispatched to stop him, he could be detained at the next state line, or the information could be put into his file for when his license is up for renewal. Since truck position information is already vital to the fleet operators, the only additional task is to add out-of-service condition sensors and connect them to the same satellite data link.

Disadvantages

None, except a concern might be funding the cost of out-of-service sensor installation.

Sources

Inmarsat (International Marine Satellite Corporation)

Based in England, Inmarsat is an international consortium, with investments by major companies. It provides world coverage (except poles), and has 4 earth zones, 40 earth stations, and 11 satellites. The satellites are geosynchronous (high stationary orbit). Inmarsat communications services are being explored by Sandia for special projects. Transmitters include a built-in GPS receiver. Communications can be a 2-way link with both links and GPS sharing a common L-band antenna. The data link to fixed ground stations is in the C-band and uses time-division multiplexing, 10,000 slots in 24 hr,

Comsat has a ground station in the Washington, DC area and owns a 20% interest in Inmarsat. A Comsat contact is Bill Melvin at a new number, (202) 863 6807. The old Clarksburg, MD number is (301) 428-4000).

Qual-Comm is a Ku-band Comsat system that is working only in the continental US. It has a servo tracking antenna mounted on top of the truck under a plastic dome about a foot in diameter.

Qual-Comm is used by the DOE SST fleet, as well as J. W. Hunt and C. R. England (large truck fleets). It is not known if the Qual-comm transceiver heads have GPS built in, since a different band is used.

GeoStar Corp. obtained FCC licensing to do satellite communications, but went broke. AMS Corp. was formed and acquired the license, but has no satellites. AMS is leasing channels from Inmarsat until they get going.

4.19 Location Sensors

4.19.1 GPS

Concept

The global positioning system is a government-sponsored constellation of many low-earth-orbiting satellites. GPS receivers on the ground or in aircraft can measure and compare the time of arrival of signals from 3 or 4 GPS satellites to determine latitude and longitude (also elevation if needed). The normal (civilian) encoded data is accurate to within approximately 100 meters, sufficient for the purposes of the IVHS. The military code provides accuracies of about 10 meters, but is not yet available for non-military applications.

Advantages

It is expected that this system would have a very high benefit-to-cost ratio, but this should be looked at more closely.

Disadvantages

There are almost no other alternative technologies (see route sensors below).

Sources

Motorola and others.

4.19.2 Route Sensing

Concept

Route sensing was based on a concept of starting from a known point and using accelerometers, steering wheel position and odometer data to correlate with map data to determine what route had been taken and current position. It tends to have accumulated errors and updates have to be entered by hand. For future designs, this concept is being replaced with the GPS technology above.

5. Considerations and Recommendations

5.1 Broadening the Scope

The scope of this study has been restricted to covert operations, which are only a small part of commercial vehicle operations (CVO). It is within these constraints that these results and recommendations are given. With this understanding, these results and recommendations should be considered preliminary, and they should eventually be reevaluated within the broader context of CVO safety enhancements, CVO system architectures, and ultimately IVHS architectures.

5.2 A Foundation for Further Work

This study provides a solid foundation for understanding problems and identifying potential solutions for covert operations. Initial concepts for developing an implementation plan are presented; however, more detailed work will be necessary to converge on an ultimate implementation plan that adequately addresses both short- and long-term needs.

Several problems and solution approaches are identified in this report; however, an obvious solution for addressing all situations and concerns is not apparent. This report has not adequately addressed every area needed to fully understand all the problems and to select the best solution alternatives. More analysis is needed in the following areas:

- Technology tradeoffs;
- Cost/benefit;
- Risk-technical and nontechnical;
- Political issues;
- Mapping technologies to solutions; and
- Coordination of efforts with other areas of CVO and IVHS.

5 . 3 Technologies

Concerning some of the technologies that are presented, the following considerations and recommendations are given.

5.3.1 Detection Devices

The initial analysis shows that detection devices on their own do not seem to be a foolproof or cost-effective solution to covert operations. Detection devices might provide some short-term relief for detecting violators of out-of-service orders; however, when considering the huge task and cost of implementing them on a national level and the fact that they would be obsolete when other solutions are implemented, it might be better to proceed with other solutions to begin with.

5.3.2 Advanced Information Management Systems

The management of safety information is an obvious deficiency in the inspection process. It is an area that will probably play a role in any solution approach that is selected; therefore, it should probably be addressed sooner rather than later. With the current advances in computer, information management, and user interface technologies, information management is an area that can be addressed in the short term.

Establishment of the data management system that is suggested could be demonstrated on an existing area, such as the state of New Mexico. Capabilities of the system could be effectively integrated with and shared with other similar initiatives to permit functional and cost leveraging to occur; such initiatives include the current Sandia Pooled Funds Study project and various initiatives dealing with the North America Trade Agreement.

5.3.3 Smart Cards

Smart cards are emerging as a new technology for many transportation applications. Some of the applications that are making use of smart cards include

- Electronic toll collection,
- Transit fare collection, and
- Automation of commercial truck fueling transactions.

It seems that smart cards will become more widely used and an integral part of the transportation infrastructure. Considering this, smart cards are a good candidate for use in helping to manage and transfer CVO safety information. If implemented correctly, smart cards could be used as a standalone system or in conjunction with a central information data base.

5.3.4 Tags and Beacons

Tags and beacons seem reasonable in some uses but not in others. One concern is that because they are not normally required to be on vehicles, and there would seem to be no way to keep them from being destroyed or removed, recovery may be both costly and uncertain.

On the other hand, it seems that electronic license plates will eventually become standard on all vehicles because they could have wide IVHS utility ranging from simple information storage to automated traffic management. For out-of-service violation monitoring, they would be useful in keeping tractor information separate from trailer information (because tractors and trailers have separate license plates and can be separated from each other after an out-of-service violation has been assessed).

5.3.5 On-Board Truck and Driver Recording

This is the direction in which industry is headed already, so the addition of some additional safety sensors and monitors seems reasonable. The wide spread use of on-board monitoring and information transfer could significantly increase the efficiency and effectiveness of all commercial vehicle operations. However, this will probably be a long-term development and implementation effort because safety sensors and monitors do not currently exist, and because it will take time for the necessary infrastructure to be put in place.

5.3.6 Satellite Communications

It would seem that this approach is too expensive and may overly crowd communications channels, but, in fact, potential benefits are driving technology to find ways of solving these problems. While this technology doesn't look attractive in the short-term, long-range advancements in the area will make it more appealing. It may be wise to plan up-front how this technology-can be used as CVO applications are phased into service.

5.4 Nontechnical Solutions

Representatives from various states have indicated that in their experience, when inspectors are present, violation of out-of-service orders is a minimal problem. At least in the short term, until more permanent solutions can be implemented, it might be worthwhile to consider increasing inspectors to handle 24-hour staffing of inspection sites.