NOTICE

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official policy of the Department of Transportation.

The United States Government does not endorse the products or manufacturers. Trademarks or manufacturers' names appear herein only because they are considered essential to the objective of this document.

This report does not constitute a standard, specification, or regulation.
The objectives of the project were to reassess the adequacy of the current Federal vision standards for CMV operators (49, CFR, 391.41(b)(10), 1985). The technical approach included doing a critical review of existing literature; providing a preliminary draft of recommendations; preparing a risk assessment of visual criterion levels proposed; conducting a workshop to review draft recommendations with expert industry and vision panelists; and providing a summary of the project with final recommendations.

A review and critical evaluation of the most significant scientific research, which investigated the vision performance of passenger and commercial drivers, revealed no conclusive evidence to support definitive changes to the current standard. However, it was deemed important to include visual acuity and visual fields, requirements for the standard. Based on the critical review of the literature, opinion surveys, and workshop results collected from panelists representing the vision industry field, the following recommendations were made: distant visual acuity of at least 20/40 in each eye without corrective lenses or Visual acuity separately corrected to 20/40 or better with corrective lenses, distant binocular acuity of at least 20/40 in both eyes with or without corrective lenses, field of vision of at least 120 degrees in each eye measured separately in the horizontal meridian, and the ability to respond safely and effectively to colors of traffic signals and devices showing standard red, green, and amber. No test for color vision is required. The instructions to perform and record the visual examination were extensively revised. Identification of the type of equipment, the stimuli needed to conduct the testing, and instructions on how to perform the tests were added. The full description of the definition and testing procedures of the standard is provided in the body of the report. In addition, revisions were made to the list of visual disorders and impairments to be noted on the exam form.
# METRIC (SI*) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

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## APPROXIMATE CONVERSIONS TO SI UNITS

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These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements
This project investigated the adequacy of the current Federal vision standard for operators of commercial motor vehicles.

The authors wish to thank the vision and industry specialists who participated in the Delphi assignments and workshop:

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OD/OME SSA

Neill Darmstadter  
American Trucking Associations

Frank Schieber, Ph.D.  
Oakland University

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There is widespread agreement that vision plays an essential role in the driving task. However, specifying a precise level of visual capability necessary for safe driving continues to be problematic because of the lack of definitive empirical evidence on which to base a clearly defensible visual performance standard. The purpose of establishing vision standards for drivers of heavy commercial motor vehicles* (CMVs) is to identify individuals who will represent an unreasonable and avoidable safety risk if allowed to drive CMVs. The objective of the research in support of a vision standard has been to identify the required level of seeing (based on empirical evidence in place of a consensus) in order that CMV drivers will not be a safety risk to themselves or to the motoring public. The purpose of this contract was to assess the adequacy of the current Federal vision standard for drivers of heavy CMVs. An exhaustive review was conducted of all new and previously existing research literature and data. In addition, further analyses, risk assessment of minimum visual criterion levels, and consensus from experts in the vision and industry fields were used as a basis for recommending changes to the current standard and to the procedures underlying its administration.

**PROBLEMS WITH THE STANDARD**

The Federal government began regulating vision standards for interstate commerce motor carriers in the late 1930s. At that time, the standard was based on a consensus of experts in the fields of vision and driver safety, but the goal of providing a firm empirical base for the standard has proved elusive. The vision standard has been changed steadily in the direction of requiring more stringent visual capability. The standard currently states, "...distant visual acuity of at least 20/40 (Snellen) in each eye without corrective lenses or visual acuity separately corrected to 20/40 (Snellen) or better with corrective lenses, distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses, field of vision of at least 70 degrees in the horizontal meridian in each eye, and the ability to recognize the colors of traffic signals and devices showing standard red, green, and amber” (49, CFR, 391.41(b)(10), 1985). Along with the problem of providing an empirical base for the standard, other problems were identified, e.g., the statement of the visual field requirement and need for a specific color vision requirement in the current standard. The visual field requirement left doubt as to what the actual specification of horizontal field extent should be for each eye (70 degrees or 140 degrees), and the color vision requirement was found to be probably unenforceable on a practical basis.

*Defined as any vehicle with a gross vehicle weight rating of 10,001 pounds or more; any vehicle that transports hazardous materials requiring placards; and a bus designed to transport more than 15 passengers including the driver.
REVIEW OF EMPIRICAL STUDIES

A review and critical evaluation were conducted on the most significant scientific research directed at investigating the relationship between visual performance and driving for passenger, commercial, and aged/visually impaired motor vehicle operators. Many studies relating visual test performance to correlates of driver safety, such as accident and violation rates, have been reported since the last major revision of the CMV vision standard in 1970. Reports on new testing methods were reviewed, including contrast sensitivity, glare sensitivity, low-light visual acuity, and dynamic visual acuity. In general agreement with studies reported prior to 1970, these newer studies were able to demonstrate only weak relationships between measures of vision and correlates of driver safety. No study involving purely visual measures reported an empirical ability to identify unsafe drivers at a level that was substantially greater than had previously been demonstrated for tests currently called for in the standard or for new tests. Thus, no new study or synthesis of studies provided a definitive basis for extensive changes to the current CMV visual standard.

FUNDAMENTAL LIMITATION DETERMINING MINIMUM VISUAL CRITERION LEVEL FOR VISION SCREENING

Review of the historical research performed to provide a more adequate empirical specification of the vision standard for drivers of both passenger cars and CMVs suggests a fundamental limitation in terms of providing valid cutoff points for screening purposes. Numerous studies have shown that visual deficits are rarely the primary cause of major accidents. Typically, many factors are found to contribute. Secondly, persons involved in accidents have already been screened for visual deficits thus reducing the number of visually poor drivers actually on the road. For these and other related reasons, tests of primary visual capability cannot reasonably be expected to correlate highly with measures of driver safety or to provide unambiguous cutoff points for screening out unsafe drivers. This is true even though good vision is unquestionably an essential component of safe driving.

NEW DEVELOPMENTS

A new development worth noting is the useful field of view test (UFOV). The task central to this test includes a cognitive component. The observer must discriminate the test object from similar test objects and report its position in terms of a limited number of locations in the field of view. This task is thought to depend on information processing skills as well as on primary visual sensory processing. Correlations of test results with measures of driving safety have been reported as high as \( r = 0.55 \), which is considerably higher than the figure reported for tasks dependent only on primary visual processing. However, even a correlation of the magnitude reported for the UFOV task would not be sufficient to overcome the problem of a high false-positive rate. In addition, the nature of this task is substantially different from the one currently included in the CMV vision...
standard, and the empirical data is insufficient to justify inclusion of the UFOV task in the standard. However, this area of research is perhaps the most promising of those reviewed and includes contrast sensitivity, glare sensitivity, low contrast acuity, and automated full-field perimetry.

STATE STANDARDS

State CMV vision standards applying only to intrastate driving were reviewed. The requirements for each state are generally less stringent than the current Federal CMV standard. The binocular visual acuity requirement in almost 80 percent of the states is 20/40, but less than 10 percent of the states deny a license for monocularity. Less than 40 percent of the states have visual field standards comparable to the Federal standard and only 24 percent have a color standard.

INTERNATIONAL STANDARDS

Review of vision standards for CMVs in other industrialized countries revealed wide variances. Most countries require a visual acuity level for each eye separately that is higher than the current United States standard of 20/40 in each eye. Only a few countries have a binocular acuity requirement and when specified, it is more stringent than the United States requirement. For visual fields, most other countries state that the driver must have “normal” or “full” fields. Most other countries do not have a requirement for color vision. In addition, the driving privilege in many countries may be denied because of stereopsis, aphakia, diplopia, high myopia, night blindness, and nystagmus. Many countries also require periodic checks for vision.

MEDICAL PROFESSION RECOMMENDATIONS

The medical profession and the American Medical Association (AMA), in particular, have historically provided significant input to the process of setting vision test standards. The AMA guidelines for minimum visual performance for operating commercial motor vehicles are stricter than the Federal CMV vision standard for visual acuity (20/25 compared to 20/40) in each eye, but the recommendations for visual fields and color vision are the same. The AMA also lists visual disorders that are of concern but avoids recommending denial of the driving privilege based on them.

EXPERT OPINION SURVEY/RISK ASSESSMENT

Using a Delphi-type approach, a panel of experts conducted an assessment to judge the importance of, and safety risks associated with, various visual impairments of CMV drivers. This involved panelists identifying the visual tasks most significant to selected driving tasks and then ranking these in order of importance to safety. Results of this exercise were useful in development of the final recommendations. In addition, a risk
assessment was conducted to estimate the probable impact of changing the visual acuity criterion by a specified amount (i.e., from 20/20 to 20/400). Results of this analysis identified a theoretical level of risk associated with different binocular visual acuity levels for a CMV operator performing a specific truck maneuver.

WORKSHOP CONSENSUS

A workshop was conducted to review and provide a consensus on the preliminary draft recommendations. The panel represented industry and visual sciences communities, and consisted of licensed doctors of medicine, ophthalmologists, optometrists, professors in academic ophthalmology departments, and traffic and safety professionals in private industry. These panelists represented many of the professional medical and industrial associations. The 1-day workshop opened with a project overview presented by the principal investigator and subsequent discussion was structured around the presentation of viewpoints by the expert panelists. The workshop was addressed by the Director of the Office of Motor Carriers, who stressed the significance of the workshop and panelists’ expert recommendations. Focused discussion was held on the most vital points at issue, including the need to exclude monocular drivers or those with substantial visual loss in one eye only, the statement of the visual field requirement, the need for more complete and accurate testing of visual field (more in accord with the medical diagnostic procedure), the benefit of including newer tests of vision, the intent and effectiveness of the current color vision standard, and the basis of a risk analysis model that could be used to evaluate changes to the standard. The workshop panelists concluded that there were no compelling reasons to change the current binocular visual acuity standard of 20/40, that there was a need to measure horizontal visual fields using a more rigorous method than currently employed in commercial vision screening equipment, and that the current color vision requirements are unenforceable and do not meet the intent of not excluding red-green color-defective individuals from the driving privilege. In addition, there was doubt on what risk, if any, there was for drivers who are color blind, since traffic signing has been standardized and drivers have many other cues to operate a vehicle in a safe and effective manner. Panelists generally felt that it was important to note visual disorders and ocular conditions and that individuals with specific conditions should be referred to ophthalmologists. Follow-up surveys were also sent to the panelists to identify the specific position they took on the visual acuity, visual fields, and color vision standards.

FINAL RECOMMENDATIONS

Based on the review of the literature, Delphi exercise, and the panelists’ input, the recommended changes to the CMV standard were amended as follows. The statement of the visual acuity standard was found to be adequate. More specific wording to rule out below-standard performance in one eye was added to the Instructions for Performing and Recording Physical Examinations. Extensive revisions were made to this section to specify more completely the testing conditions and procedures to be used when measuring acuity, including light level, stimulus type, and specific test procedures. The Statement of the visual field standard was changed to require at least a
120-degree field of view in each eye measured separately in the horizontal meridian. Extensive revisions were also made to the Instructions section to specify minimum stimulus conditions and an acceptable procedure for testing in the horizontal meridian. The statement of color vision was changed to require only a “safe and effective response to colored traffic signals and devices, without requiring a specific test of color vision. Thus, red-green color-deficient individuals who can otherwise respond safely and effectively (virtually all) will be allowed the driving privilege under this statement. The recommended wording for the CMV vision standard is: “Has distant visual acuity of at least 20/40 in each eye without corrective lenses or visual acuity separately corrected to 20/40 or better with corrective lenses, distant binocular acuity of at least 20/40 in both eyes with or without corrective lenses, field of vision of at least 120 degrees in each eye measured separately in the horizontal meridian, and the ability to respond safely and effectively to the color of traffic signals and devices showing standard red, green, and amber. No test for color vision is required.
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(49 CFR 391.41 TO 391.49, **OCTOBER 1, 1985**)

**APPENDIX D: EXPERT OPINION SURVEY FORMS**

**APPENDIX E: PANELIST DIRECTORY**

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INTRODUCTON

The assertion that vision plays an essential role in the driving task cannot be credibly opposed. However, the level of vision that is necessary for safe driving continues to be a contentious issue. The reason for this is the continuing unavailability of definitive empirical evidence upon which to base a clearly defensible visual performance standard. The purpose of setting vision standards for drivers of heavy commercial motor vehicles (CMVs) is to identify individuals who will represent an unreasonable and avoidable safety risk if allowed to drive CMVs. The first CMV vision standard to set specific performance requirements in 1939 was based on a consensus that defined the minimum vision necessary for safe driving. The research objective in support of a vision standard has been to identify the level of seeing, based on empirical evidence in place of a consensus, that has to be met in order that CMV drivers will not be a safety risk to themselves or to the motoring public. The objective is to review the current Federal vision standard(1) for drivers of heavy CMVs and new and existing data and analysis, as a basis for recommending possible changes to the current standards and procedures underlying its administration.

Driving safety is maintained through a constant stream of small decisions and less frequent larger decisions that require a high rate of accurate visual information about the driving environment. The level of vision required to support success in the decision-making process and driving safety depends on the level of complexity of the projected driving task (i.e., high speed, wide-open highway compared to congested urban or suburban roadway environments). It also depends on the consequence of encountering an error, or series of errors, in the decision stream that will lead to a catastrophic outcome to the driver and others in the driving environment. For drivers of CMVs, the consequence of error is likely to be much greater in terms of loss of life and property than the result of a similar error made by the driver of a private motor vehicle. This fact is supported by the statistics accumulated (1979 to 1986) on the disproportionately high rate of heavy vehicle involvement in fatal crashes. For all types of accidents (adjusted for exposure mileage), combination trucks (tractor and trailer combinations) have slightly less than 50 percent of the accident involvement rate of passenger cars, but have a fatality involvement rate that is nearly double that of passenger cars. In fact, in 1990, 4,061 people died in tractor-trailer crashes. However, only 12 percent were the truck occupants. The majority of the fatalities in these tractor-trailer crashes were passenger vehicle occupants.

Driving errors that might not produce a crash in a smaller motor vehicle may well lead to a crash in a heavy vehicle because of its more limited maneuverability. The appreciation of these facts motivates the effort to define visual standards for driving that are most likely to lead to safer driving. In addition, the apparently greater difficulty of the CMV driver’s vehicle control task and the obviously greater adverse consequences of heavy vehicle crashes
lead to the presumption that the visual requirements for the driver of a CMV should be more stringent than those thought to be appropriate for smaller vehicles. This view is reflected in the existing Federal vision standard for CMV operators.

The current need to reassess the bases for the Federal vision standard for CMV operators is motivated by many factors, such as more recent vision assessment technology and vision-driver performance evaluation methods.
PROJECT OBJECTIVES

Meeting the objectives of this project was accomplished in three ways: (1) by determining whether the current statement of vision test standards and testing procedures should be revised; (2) by defining the acceptable levels of vision necessary for operating a CMV, and (3) by examining the risk associated with certain “acceptable” levels of visual capabilities identified through vision tests and examination procedures. It is important to note that vision has traditionally been defined as an exclusively sensory task associated with transforming an object viewed in the environment into a light image on the retina and transmitting that image to the brain. Increasingly, however, vision as it pertains to driving and other complex sensory-motor tasks has become inextricably linked to more central processing or cognitive components of performance. The continuing evolution of performance standards may be expected to reflect this expanded analytical framework.

The technical objectives for specific project tasks were as follows:

- Critical review and evaluation of scientific information and data sources pertaining to driver vision testing requirements for operating CMVs that weigh more than 10,000 pounds
- Development of preliminary recommendations for revising vision test and testing requirements
- Preparation of a risk assessment for the proposed acceptable level of vision provided in the recommendations
- Conduct of a workshop to review draft recommendations with panelists representing industry and the visual science community
- Summary of project findings including the draft recommendations for the vision test requirements and testing procedures; discussion of how the recommendations were determined; additional information and discussion of important issues raised at the workshop; suggestions for additional research to address unresolved problems; and other recommendations for licensing restrictions relating to specific visual impairments.

The final report consists of the Executive Summary and five main sections: Introduction, Project Objectives, Development of Recommendations, Proposed Revisions to the Standard, and Discussion. The five appendixes present a synthesis of the literature, a model developed for the risk analysis of a visual acuity criterion; the Federal Regulation for Physical Qualifications and Examinations for CMV Operators, the forms used for the Delphi approach, and the directory of panelists who attended the workshop.
DEVELOPMENT OF RECOMMENDATIONS

This section describes the research process used to arrive at the recommendations for revising of the current CMV vision standard. The technical approach included the following steps: (1) review and critical analysis of existing technical and scientific literature, and other information and data sources; (2) recruitment of a voluntary panel of experts in the fields of vision, driver safety, and the trucking industry for the purpose of advising the principal investigator and participating in a 1-day workshop; (3) preparation of a set of preliminary draft recommendations for changes to the standard; (4) use of a Delphi approach to estimate the relative significance of driver safety to visual tasks associated with visual capabilities tested in both the current and perhaps future standards; (5) assessment of the level of risk associated with a specified range of visual performance in a simulated truck driving scenario; and (6) conduct of an expert panel workshop for the purpose of eliciting advice and obtaining a consensus on the proposed changes to the standard.

REVIEW AND CRITICAL ANALYSIS OF LITERATURE AND INFORMATION

A review and evaluation were conducted of scientific literature, data, and other sources of information found to relate to the current Federal vision standards and the visual, skills necessary to operate a CMV. This effort included a literature search, a study of the history of the current Federal standard, and a comparative review of the standard with state and international driver licensing vision standards, along with AMA recommendations and other government guidelines. Also included is a critical evaluation of the empirical evidence relating driving safety and visual performance. The sections selected for Appendix A, Synthesis of the Literature are unabridged versions from the Task Report of the same title.

Literature Search

A comprehensive literature search was conducted using DIALOG’s (Dialog Information Services, Inc., Palo Alto, CA) automated, online literature database system. Coverage of the following subjects was included: traffic safety, psychology, medicine, engineering, standards and specifications, and government research-related subjects. Keywords used in the online search included those relating to vision, vision screening and performance, vision standards and specifications, and truck and automobile operation. The majority of the relevant research literature was identified in the following databases: Medline (National Library of Medicine), NTIS (U.S. Department of Commerce), PsychInfo (American Psychological Association), and TRIS (United States Department of Transportation, Transportation Research Board). A manual search was also conducted through KETRON’s transportation and traffic safety library and Scheie Eye Institute sources. Finally, an automated and manual search was conducted by the Northwestern University Transportation Engineering library staff. Documents were obtained from academic and medical libraries and in-house sources.
Informal inquiries with visual science specialists, traffic safety engineers, state licensing agency personnel, and truck industry representatives were used to identify information and data that might have been missed or unpublished. Information on CMV vision standards was requested from more than 50 international standards organizations and international commerce, trade, and government organizations. Replies were received from approximately 35 percent of these organizations.

**History of CMV Vision Standard**

In the late 1930s, the Federal Government began regulating the vision standards of motor carriers in interstate commerce. The earliest vision standard for drivers of interstate trucks was specified in a general standard for medical fitness. The standard was very general and stated the following requirement: “Good eyesight in both eyes (either without glasses or by correction with glasses), including adequate perception of red and green colors.” By 1939, the standard contained more specific minimum requirements for visual acuity, visual fields, and color vision. Table 1 provides a history of changes to the standard, which exhibits the standard moving in the direction of requiring more stringent visual capabilities. A complete description of the history of the standard is provided in Appendix A, Synthesis of the Literature.

The current vision standard is specified as part of the Federal medical standards (Code of Federal Regulations, Subpart E-Physical Qualifications and Examinations, Sections 391.41 to 391.49(4)) required to be met by operators of CMVs in interstate commerce. The commercial driver must be medically examined at least every 2 years and while on duty, a driver must have a certificate showing that he or she has passed the required examination. The examination covers the general health of the individual as well as setting specific standards for vision and audition. It also precludes individuals from driving if certain medical conditions exist, such as specific heart conditions and, important for vision, diabetes mellitus which must be controlled by insulin.

The visual requirements for CMV drivers are included in Section 391.41 and are stated as follows:

- Has distant visual acuity of at least 20/40 (Snellen) in each eye without corrective lenses or visual acuity separately corrected to 20/40 (Snellen) or better with corrective lenses distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses, field of vision of at least 70 degrees in the horizontal meridian in each eye, and the ability to recognize the colon of traffic signals and devices showing standard red, green, and amber.”

In addition, Section 391.43(4) states that medical examination can be performed by a licensed doctor of medicine or osteopathy, and that a licensed optometrist can perform as much of the medical examination as pertains to visual acuity, field of vision, and the ability to **recognize colors as specified in CFR 49. Section 391.41 paragraph**.
Table 1. History of the Visual Standard for CMV Operators

<table>
<thead>
<tr>
<th>Date</th>
<th>Visual Acuity</th>
<th>Visual Fields</th>
<th>Color Vision</th>
<th>Other Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One Eye</td>
<td>Other Eye</td>
<td>Binocular</td>
<td>Red</td>
</tr>
<tr>
<td>1939[^5]</td>
<td>20/40</td>
<td>20/100</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>1944[^6]</td>
<td>20/40</td>
<td>20/100</td>
<td>-</td>
<td>Yes</td>
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<td>1964[^7]</td>
<td>20/40</td>
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<td>Yes</td>
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<tr>
<td>1985[^9]</td>
<td>20/40</td>
<td>20/40</td>
<td>20/40</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Few instructions for performing and recording the physical examination are given, but instructions regarding the visual acuity, prohibition against monocular vision contact lenses, tolerance, and certain eye conditions are given as follows:

“When other visual acuity is being tested, the Snellen chart and the results expressed in Snellen visual acuity must be worn. The Snellen visual acuity is the reading of the smallest Snellen chart line that the patient can read at 20 feet while wearing corrective lenses. The Medical Examiner’s Certificate of Vision states that the vision as a fraction with 20 as numerator and the smallest distance at which the patient can read at 20 feet as denominator. Note the color blindness, ptosis, discharge, visual ocular muscle imbalance, corneal scar, exophthalmos, or operate vehicles under existing Carrier Safety Regulations. If the driver has a problem with their vision, they must be evidence to indicate that he has good vision, and is well adapted to their use. The use of contact lenses should be noted on the record.

A critical review of the current standard has found that there exists in the statement of the visual field requirement. The standard, as published in the Federal Register (8) in 1970, states that a 70-degree visual field is the minimum for each eye. The Federal Highway Administration has taken the position that the visual field standard should specify 140 degrees visual field as the minimum requirement in each eye. The specification of 140 degrees for field of view in each eye is close to the limit expected for a normal healthy adult eye.

In addition, problems were found with the color vision requirement, which is probably unenforceable. The color vision requirement now would mean that the driver safety record is worse than those without color defects. Other specific issues related to the impact of the visual field standard, uniformity of testing, and additional factors that affect driver

**Standard and International Visual Standards**

Every State administers a visual test to individuals applying for a motor vehicle license. Vision standards vary slightly from state to state, but states that do vary considerably in states, with requiring visual testing, and most part, State vision standards for intrastate commercial driver licensing are less stringent than the Federal standard for interstate commercial driving licensing. For example, a visual acuity requirement of 20/40 is the standard in almost all states, while 80 percent of the states, 10 percent of the states have reported denying a license for monocular (best corrected) visual acuity standards by percentage of states. In addition, approximately 38 and 36 percent of the states have a visual field standard for each eye and in both eyes. Nearly 24 percent of the states have a color perception standard, and for most states, the
standards are for recognition of red, green, and amber. In addition, periodic vision screening is administered in about 72 percent of the states. (12)

Review of the foreign vision standards for CMVs revealed wide variance among the countries where information on vision standards was identified. Visual acuity for each eye is specified, with most countries requiring better than the current 20/40 Federal requirement. Only a few countries have a binocular acuity requirement and it is more stringent than the Federal 20/40 requirement. For visual fields, most countries state that the drivers must have "normal" fields or "full" fields. Most of the countries did not have a requirement for color.

Figure 1. Binocular Visual Acuity Standard for CMV Operators

However, many had other visual requirements, such as stereopsis, and will deny licensure for visual disorders and impairments such as aphakia, ametropia, diplopia, myopia, night blindness, and nystagmus. In addition, many of the countries reported that they required periodic checks for vision.
Medical and Government Guidelines and Recommendations

The American Medical Association has participated in setting vision standards for CMV operators and has provided guidelines\(^{12}\) for vision testing to its members. The guidelines published in 1986 differ from the Federal vision standard in excluding high-power spectacle lenses (10 diopters or greater) and in requiring visual acuity in each eye of 20/25 or better compared to 20/40 for the CMV standard. In addition, other visual disorders are discussed including stereopsis, nighttime vision, diplopia and oscillopsia, but specific recommendations for excluding drivers with these conditions are avoided.

The U.S. Department of Transportation and National Highway Traffic Safety Administration, in cooperation with the American Association of Motor Vehicle Administrators, published a 1980 booklet entitled “Guidelines for Motor Vehicle Administrators; Functional Aspects of Driver Improvement-A Guide for State Medical Advisory Boards.” This booklet presented a set of recommendations for all drivers otherwise medically capable of operating commercial vehicles, including heavy trucks. The recommendation for visual acuity differs from the Federal vision standard but is the same as that proposed by the AMA (i.e., 20/25 or better is required in each eye, not 20/40 as specified in the Federal standard). The recommendation for visual fields is specified as 140 degrees for each eye in the horizontal meridian. The recommendation for color vision is the same as the Federal vision standard and AMA recommendations (i.e., ability to distinguish red, green, and yellow/amber). The booklet provides recommendations for visual acuity, visual fields, ocular motility, color discrimination, depth perception, dark adaptation, refractive states, and strabismus (crossed eyes).

Driving and Vision Performance: Empirical Evidence

A major effort was undertaken to identify research which reported measurements of the relationship between many aspects of visual performance and accessible indicators of driving safety. The studies identified were primarily post hoc analyses of data already accumulated through routine driver registration testing and record keeping. However, some studies introduced new visual testing methods into the driver testing routine designed to obtain data on a broad scale which could then be correlated with the driving record over time. The literature search found numerous research projects that examined the relationship between vision test results for operators of motor vehicles and their driving performance record (i.e., accidents and violations), dating back to the mid-1950s. Most of these studies were initiated to determine what visual skills best correlate with driving performance. The results were used to recommend to state licensing agencies the most practical vision tests to administer to license applicants and renewals. Many of the studies focused on vision tests that were easily accessible through commercial vision screening devices. However, some of the studies involved developing customized vision testing apparatus, and some used clinical testing equipment known to be impractical for mass vision screening in a licensing environment. In addition, most of the research focused on the passenger vehicle operator and only a few studies investigated the visual and driving performance of the CMV operator.
Passenger Vehicle Operators and Vision Performance—The most significant research efforts on vision performance of passenger vehicle operators versus driving performance records and on vision performance of CMV operators versus driving performance records are summarized in this section. The Synthesis of the Literature in Appendix A provides a more detailed description and critical review and evaluation of the research to date.

One of the earliest, most comprehensive studies on the relationship between vision and the driving performance record was conducted by Burg\(^{(14\text{-}17)}\) on over 17,500 drivers over a 3-year period in the 1960s. Driving habits (annual mileage reported), age, and gender were reported in addition to information on their vision test performance for dynamic visual acuity, static visual acuity, lateral visual field, low-light recognition thresholds, glare recovery, and sighting dominance. Of the vision tests analyzed in relation to traffic convictions and accidents (reported), statistically significant correlations found between vision and the driving performance record were very weak. Like other researchers from the 1960s\(^{(18,19)}\) Burg reported that mileage and age were the most powerful predictors of traffic accidents and convictions. Further analysis of the Burg data by Hi and Burg in 1977\(^{(20)}\) revealed a small but significant correlation between static and dynamic visual tests, and glare recovery tests and accident rates for drivers over age 54.

In the early 1970s, the U.S. Department of Transportation was interested in the results of the Burg studies. The Department initiated a series of investigations designed to develop a battery of vision tests that were more functionally related to driver performance and safety, and that could lead to the development of a vision testing device for use in screening driver’s license applicants or renewals. In this study, Henderson and Burg\(^{(21)}\) after reviewing prior literature and analyzing earlier data, provided a systematic analysis of the visual requirements for driving. The initial phase of the study identified important visual functions: static visual acuity (normal illumination), central angular movement, central movement-in-depth, useful peripheral vision, static acuity (low-level illumination), field of view, eye movement and fixation, dynamic visual acuity, accommodation, faculty, and glare sensitivity. These visual functions were incorporated into a prototype vision testing device (the MARK I Vision Tester). Over 600 license renewal operators were screened on the device. Accident statistics were collected for the preceding 3 years for each operator. Results showed a moderate, consistent, age-related decline for all the visual functions. Significant age-related loss in visual ability was reported for static acuity under normal and low illumination, glare, and dynamic acuity. However, the correlational analyses conducted to assess the potential predictive validity of the MARK I showed many significant correlations in the direction of poor visual performance statistically related to a good driving record.

The U.S. Department of Transportation, encouraged by some of the results of the MARK I study, decided to continue this research in an effort to establish a generally valid vision screening device for motor vehicle department use. Further testing by Shinar\(^{(22\text{-}24)}\) on 890 licensed operators revealed very low correlations between act ident rate measures and visual performance. In fact, no significant correlation existed between vision and driving records for the 25 to 54 age group. Additional testing indicated that poor dynamic and static visual acuity under
consistentIy related to accidents; poor visual acuity under low levels of illumination was related to nighttime accidents. There was also a relationship between central angular movement and accident involvement. In addition, none of the single vision tests was significantly associated with accident involvement for all age groups, but each test was significantly associated with accident involvement for one or more of the age groups. Results for the battery of vision tests and the driving statistics did not establish a clear-cut relationship between specific visual tests and the driving record.

Another important effort, conducted around the same period by Hofstetter, correlated the visual acuity test scores of 13,700 drivers with self-reported accidents during the previous 12-month period. Data were collected nationally, over a period of 10 years, by means of a survey form given in a variety of settings and populations, with support from the Auxiliary to the American Optometric Association, using commercial vision screeners. Accident rates for persons with acuity in the lower quartile of the measurements were compared to rates for persons with acuity above the median measurement. Drivers in the lower visual acuity group were found to be twice as likely to have bad three accidents in the previous year as those with acuity above the median, and 50 percent were more likely to have had two accidents. No significant differences were found between the lower acuity and higher acuity drivers when only one accident was used as the criterion of comparison. This study provided some evidence of the connection between poor visual acuity and increased accident frequency. However, these results applied only to the very poor visual performers compared to the best in the driver cohort.

Studies on visual fields and glare were also conducted in the 1970s. Council and Allen compared horizontal field measurements to accident rates for more than 52,000 drivers and found that only 1 percent of the drivers recorded a horizontal field of 120 degrees or less, and that the accident rate for these drivers was no higher than the rate for those whose fields were greater than 120 degrees. Studies on glare sensitivity incorporated into other vision testing using the MARK I and MARK II devices were also unable to show any significant relationship. Wolbarsht conducted a study of glare sensitivity using a modified commercial vision screener with a customized overlying glare source of controllable intensity. He tested 1,500 driver’s license applicants and renewals for glare sensitivity at three veiling glare ratios (background:target) of 2:1 (high glare), 4:1 (medium glare), and 8:1 (low glare). The results showed no significant correlation between glare sources and driving performance, although the average glare sensitivity scores did increase with age.

Research on assessing visual and driving performance continued in the 1980s. Keltner and Johnson used automated static perimetry to screen more than 500 drivers for any evidence of visual field loss in 1980. This technique found that approximately 5 percent of the motorists had significant visual field loss compared to only 1 percent found to have a noticeable deficit in the study by Council and Allen, who tested only in the horizontal meridian. In addition, Keltner and Johnson reported that subjects over age 65 had four to five times the incidence of visual field deficits of younger persons. For the Keltner and Johnson study, field loss was defined as substantial depression of all or part of the peripheral visual field and/or an inability to detect two or more adjacent visual field
points (scotoma). This project was extended to compare the visual loss of 10,000 volunteer drivers with accident/conviction histories. For this larger study, it was found that drivers with visual field loss in both eyes had twice the rate of accidents and convictions as those with normal visual fields. The results were statistically significant. It was suggested that decreased performance on a visual fields test probably results from age-related decreases in retinal illumination and other acquired vision impairments (such as glaucoma, degenerative myopia, diabetic retinopathy, and retinal detachment) which are more common in older age groups.

Another study, conducted by Davison in 1985, examined 1,000 motorists who were randomly stopped in and around a town in England and asked to volunteer for a vision test and provide information on driving record, vision examination history, and other demographic information. Significant positive associations were found between accidents and right-eye or left-eye visual acuity and binocular acuity for all drivers and a relationship between accidents and heterophoria for drivers who were over 55. Recently, completed study for the Pennsylvania Department of Transportation was undertaken to determine the value and feasibility of periodic vision screening during license renewal. The study examined the relationship of three vision measures (static visual fields, and contrast sensitivity) to accident and violation records for over 12,400 licensed operators who were unaware that they would be tested. It was found that drivers who failed the visual standard or scored below “normal” on the contrast sensitivity test were at a significantly higher risk for accidents in only the two oldest age groups (66 to 76 and 76+). However, the researchers found no significant relationship between poor vision performance on each of the vision tests analyzed separately with accident and violation records.

For the most part, significant statistical relationships between specific vision test scores and driver performance records (for passenger vehicles) have not been clearly established. Many researchers have stated that difficulties in trying to relate driving performance to visual capabilities can be attributed to the following:

- Vision is only one of many factors influencing driving performance.
- Some vision tests may not really relate to visual requirements of driving.
- Reliability of criteria used to measure driving performance may be low.
- Research methods may have used unrepresentative samples of the driving population.
- Individuals with visual difficulties often place self-imposed limits on their driving, thus reducing their exposure to the risk of an accident.

CMV Operators and Vision Performance—in 1973, Henderson and Burg attempted to relate CMV driving skills to the visual tests included in the MARK 1 Vision Tester. Their goal was to establish a sound scientific basis for minimum visual standards for the Office of Motor Carriers. The relative importance of different aspects of the driving task was established by examining literature, interviewing truck drivers, observing truck drivers...
in action, and conducting a systematic examination of the driving task. The researchers established a hierarchy of importance for the visual functions selected as most important. Weights were assigned to various driving behaviors and to each visual function according to its judged importance to driving behavior. Those visual functions judged to be most important to the truck driving task and necessary to an analysis comparing visual performance and accidents and violations were static visual acuity; dynamic visual acuity; perception of movement-in-depth, visual field, movement-in-depth and steady, saccadic, and pursuit fixations; glare sensitivity, and angular movement. Significant relationships between accidents and poor visual performance were found only with measures of perception of movement and dynamic visual acuity. No correlation was found between static visual acuity or field of view and accident frequency for commercial drivers.

In a more recent attempt to correlate visual performance with accident record, Rogers, Ratz, and Janke in 1987, compared the driving records of visually impaired heavy-vehicle operators with the records of a sample of visually nonimpaired heavy-vehicle drivers. The purpose of the project was to determine whether the Federal vision standard could be justified based on the traffic safety record of these drivers. The records of more than 16,000 heavy-vehicle operators registered by the California Department of Motor Vehicles were examined. Measures of driving performance consisted of 2-year total accidents and convictions associated with incidents involving commercially registered vehicles. Visually impaired operators were categorized into two subgroups of substandard static acuity: (1) moderately visually impaired (corrected acuity between 20/40 and 20/200 in the worse eye, 20/40 or better in the other), and (2) severely visually impaired (corrected acuity worse than 20/200 Snellen in the worse eye, 20/40 or better in the other). Nonimpaired drivers met current Federal acuity standards (corrected acuity of 20/40 or better in both eyes). Analysis results, adjusted for age, showed:

- Visually impaired drivers had a significantly higher incidence of total accidents and convictions and commercial-plate accidents and convictions than did nonimpaired drivers.
- Moderately impaired drivers had a significantly higher incidence of commercial-plate accidents than did nonimpaired drivers.
- The incidence of total accidents did not significantly differ between the nonimpaired and moderately impaired drivers.
- Severely impaired drivers had a significantly higher incidence of commercial-plate convictions than did nonimpaired drivers.
- Nonimpaired and moderately impaired drivers did not significantly differ on commercial-plate convictions.
- Drivers licensed to operate any combination of heavy vehicles had a higher incidence of total accidents and convictions and commercial-plate accidents and convictions than did those licensed to operate single vehicles having three or more axles.
These findings lead to qualified support for the current Federal visual acuity standard, particularly regarding exclusion from driving of the severely impaired (visual acuity below 20/200 in the worse eye, 20/40 or better in the other). Less support is offered regarding the restriction of the moderately visually impaired heavy-vehicle operator (visual acuity between 20/40 and 20/200 in the worse eye, 20/40 or better in the other).

Another recent study identified in the literature assessing the relationship between vision and truck operator performance was conducted by McKnight et al. He examined visual and driving performance of monocular and binocular tractor-trailer drivers. On the visual measures, the monocular drivers were significantly deficient in contrast sensitivity, visual acuity under low illumination and glare, and binocular depth. However, monocular drivers were not significantly deficient in static or dynamic visual acuity, visual field of individual eyes, or glare recovery. In addition, driving measures of visual search, lane keeping, clearance judgment, gap judgment, hazard detection, and information recognition showed no differences between monocular and binocular drivers. The one exception was sign-reading distance, which was defined as the distance at which signs could be read during both day and night driving in a controlled road test. The binocular drivers were first able to read road signs at significantly greater distances than were the monocular drivers in both daytime and nighttime driving, and this decrement correlated significantly with the binocular depth perception measure. McKnight also reported a large variation in visual and driving measures among monocular drivers and several significant differences between them and binocular drivers., suggesting the need to assess the monocular drivers’ visual functioning capabilities more closely and the need to continue research in identifying visual performance measures that significantly correlate with measures of safe driving skills.

only a few studies examined the relationship between driving performance record of CMV operators and their vision performance and they did not provide enough support to propose definitive changes to the current Federal vision standards.

**RECRUITMENT OF EXPERT PANEL**

Potential members for the expert panel and workshop were identified through the FHWA, OMC, by contacting professional medical, vision, and traffic safety organizations, and by soliciting candidate names from leading experts in the vision and traffic safety field. The following professional organizations were represented in the selection process and ultimately on the panel:

- American Ophthalmological Society
- American Optometric Association
- American College of Occupational Medicine
- American Medical Association
- American Trucking Associations
Representatives from the Insurance Institute for Highway Safety, Association for the Advancement of Automotive Medicine, and International Brotherhood of Teamsters were invited but were unable to attend the workshop due to prior commitments.

The list of potential panelists was reviewed and refined with the FHWA, OMC. Invitation letters were sent to those on the final list. An explanation of the project and the expected role of each panelist, in providing advice and participating in the workshop, was provided. The following panelists accepted the invitation to participate on the panel:

- Merrill I. Allen, O.D., Ph.D.; Indiana University, School of Optometry
- Clifford Anderson; Medical Resource Services Diagnostics, Inc.
- Karlene Ball, Ph.D.; Western Kentucky University, Department of Psychology
- Bernard Blais, M.D.; General Electric Corporation, Medical Director
- Raymond P. Briggs, Ph.D.; Perceptual Safety and Systems Research
- Neill Darmstadter; American Trucking Associations, Senior Safety Engineer
- Chris Johnson, Ph.D.; University of California, Davis, Department of Ophthalmology, School of Medicine
- Arthur H. Keeney, M.D., Ph.D.; University of Louisville, Lions Eye Research Institute
- A. James McKnight, Ph.D.; National Public Services Research Institute
- Cynthia Owsley, Ph.D.; University of Alabama, Birmingham, Department of Ophthalmology, School of Medicine
- Sandra Z. Salan, M.D.; Social Security Administration, Office of Medical Evaluation Branch
- Frank Schieber, Ph.D.; Oakland University, Department of Psychology

Appendix E provides their addresses and telephone numbers.
RECOMMENDATIONS PRIOR TO WORKSHOP

Preliminary recommendations to the CMV vision standard were presented in a task report. A review of the current standard brought out deficiencies in three areas:

- Errors in the statement or intent of the standard;
- Practical limitations to testing procedures or enforcement; and
- Substantive changes to the standard that could be supported either by new empirical evidence linking the current tests to measures of driver safety or by new technical developments in vision testing.

For each visual function specified in the standard, problems were as follows:

- Visual Acuity—lack of specificity in stating conditions for testing,
- Visual Acuity—apparent error in the statement of horizontal field extent and unspecified methods for testing,
- Color Vision—unclear intent of standard, unspecified methods for testing, and problems with enforceability.

Other areas considered for change were the visual disorder checklist, new areas of testing, and enforcement procedures:

- Visual Impairments and Disorders—appropriateness of disorders listed or unspecified action if disorder is present
- New Areas for Testing—contrast sensitivity, low-contrast acuity, glare sensitivity and recovery, automated visual field testing, dynamic visual acuity, and useful field of view
- Medical testing vs. state agency testing, restriction of specialty for medical testing, medical card as an enforcement procedure, and periodic renewal or retesting

The remainder of this section presents a summary of the rationale for the preliminary recommendations set prior to the workshop.

Visual Acuity

Acuity of vision is defined as a measure of the ability to resolve minimum visual angle of separation between otherwise continuous parts of a letter or form. The acuity testing most often performed involves a wall-mounted, printed chart of letters or forms and relies on verbal response of the patient. Testing is inexpensive, requires low technology, is easy to administer, and takes only minutes to complete. Measures of acuity are among the oldest forms of systematic visual measurement and have in recent years received intense criticism as incomplete
and inadequate for characterizing overall visual status. On the other hand, it is doubtful that any eyecare specialist would consider a visual exam complete without taking such a measurement. In emergency situations, the first important piece of information comes from a measure of acuity. Viy all ophthalmologic exams begin with a measure of acuity. In spite of intense and often valid criticism, a consensus among eyecare specialists still places visual acuity at the top of the list for the most useful visual test. As an efficient and useful test of vision, visual acuity has withstood the test of time.

The current CMV standard requires at least 20/40 Snellen acuity at distance in each eye measured separately either with or without corrective lenses. An additional requirement is 20/40 binocular corrected vision at distance. The level of 20/40 represents an arbitrary criterion, which is supported by a consensus that vision is poorer than this level introduces risk into the driving task. A review of both state and international visual standards for driving found that the 20/40 standard is representative of other standards and is, if anything, lenient in terms of currently accepted criterion values. The mode for state acuity standards for CMV drivers is 20/40 (40 of the 50 states), and for selected industrial countries the mode for monocular vision is 20/30. At this time, no evidence or method can elicit an objective judgment that an acuity criterion other than the one already established by consensus should be selected for CMV drivers. On this issue, research evidence presented in the Synthesis of the Literature (Appendix A) showed that the difference between visual discrimination in the absence of a better performing test that is also efficient and robust with respect to the level of technology and actions on the part of test administrators, visual acuity provided the best and simplest method of obtaining a meaningful measure of vision.

What was not specified in the standard were the conditions under which the test should be conducted. This area is important because acuity scores can vary significantly, depending on factors such as the type of test used (e.g., Snellen letters, Rolling E, and Landolt C), illumination level, and effective letter contrast. Whereas the acuity test is robust relative to many other modes of testing under such conditions, variation on the order of the difference between standards adopted by different countries or states can be expected (i.e., 20/20 to 20/50). For this problem to be minimized, limits on test conditions should be specified within the standard. The guideline for this specification should conform to current routine ophthalmological practice and not exclude current semiautomated commercial screening devices such as Mast/Keystone’s DVS II. Titmus Titmus II-DMV, and Stereo Optical’s Optec 1000. However, even these devices do not provide consistent results on acuity scores for the same or similar subjects. A model paragraph for insertion into the standard would be simii to the following:

Test charts should be illuminated with white light (color temperature from 2500 K to 7500 K) at a level well within the photopic range. Luminance readings from the white part of the chart should be between 30 cd/m² and 120 cd/m². Optotypes should be presented as black on
a white background. The Snellen optotype is the preferred target. However, other optotypes such as Sloan letters, numbers, rolling E, Landolt and geometric patterns are acceptable.

when other than the Snellen chart is used, the results of such test must be expressed in values comparable to the standard Snellen test. In recording distance vision, use 20 feet as normal. Report all vision as a fraction, with 20 as numerator and the smallest type read at 20 feet as the denominator. Note visual disorders. If the applicant wears corrective lenses, they should be worn while the applicant's visual acuity is being tested. If appropriate, indicate on the Medical Examiner's Certificate by checking the box. Qualified only when wearing corrective lenses.

Visual Fields

The field of view is the visual solid angle within which vision occurs or the area of physical space visible to an eye (or eyes) in a given position. Each eye has an independent field of view, which in a young normal observer extends about 140 degrees along the horizontal meridian (90 degrees in the temporal direction and 50 degrees in the nasal direction) and somewhat less in the vertical meridian: and both eyes together have a combined field that covers about 180 degrees horizontally. The combined field of view has a central region where the fields of view from each eye overlap and provide binocular vision capable of perceiving three dimensions. The overlapping field is approximately 100 degrees centered on the horizontal meridian.

In 1970, the CMV vision standard was revised to include a requirement for visual fields of "... at least 70 degrees in the horizontal meridian in each eye..." As reviewed under the Synthesis of the Literature (Appendix A), the intent of this portion of the 1970 revision of the visual field requirement was not clear. A portion of the intent of the 1970 revision appeared to be a restatement of the requirement in terms of monocular testing, which was the normal medical practice. However, the extensive overlapping of binocular fields meant that a binocular specification could not simply be divided by two to arrive at a monocular specification. One could not reasonably assume that the intent of the 1970 standard was to make the visual field requirement much less stringent than even the 1939 specification. In all probability, a simple error occurred and the monocular field should have been 140 degrees. Because of this ambiguity in the statement of the standard, a reevaluation of the wording and intent of the visual fields specification was necessary.

The following wording was recommended: "... field of vision of at least 120 degrees in each eye measured separately in the horizontal meridian." This correction would follow the intent of measuring each eye separately, but not be so stringent as to exclude drivers who do not exhibit clear pathology. A larger number is possible, up to the 140-degree limit of normal for a younger person, but if adopted would leave little room for normal variation with age and for errors in accuracy of testing or equipment calibration. Also believed unnecessary was a binocular
Geld specification since problems in binocularity, acuity testing, and driving would be discovered through routine binocular acuity testing. Moreover, the standard already stated that monocular drivers (or those with severe field deficits in one eye) were specifically excluded.

As with visual acuity, the conditions and methods for testing are an important source of variance for test scores measured in practice. The limitation of the standard to the horizontal field extent important to driver safety would only rarely be confined exclusively to the vertical meridian. One can expect that a significant decrease in visual fields will be associated with deficits in other modalities such as acuity. Recent studies have shown a relationship between carefully measured static full fields and accident rates; but even with reduced testing programs, the time and resource expenditure appears to outweigh any real advantage of such testing as a screening procedure on all drivers. The philosophy of the standard, thus far in its evolution, is that a screening exam should be performed on all applicants equally. Inclusion of expensive or technologically difficult exams would run counter to this well-accepted practice.

The current methods of testing horizontal fields in the screening context are the confrontational technique, the tangent screen (both usually employed as part of the medical exam), and variations detecting a small light stimulus in a dark surround along the horizontal meridian. Large variations may occur in the luminance and size of the test objects, and the variations can affect the measured field extent. These tests are designed to measure the largest extent of the horizontal field only and cannot detect defects within the field or specify sensitivity in any meaningful way. The basic techniques are adequate for screening purposes, but conditions should be specified to eliminate large variations in test results from one test situation to another. All commercial screening devices have adopted the technique of detecting a small bright light in a dark surround, and the variation among these devices is relatively small. Presented below is a model paragraph for insertion in the standard along with the specification of the visual field test conditions:

The visual field test should be conducted on an apparatus capable of testing the horizontal Geld of view to a minimum of 40 degrees nasally and 80 degrees temporally for each eye. The angular subtense of the test object should be between 10 minutes of arc and 2 degrees of arc. The luminance of the test object should be between 5 and 25 cd/m². The background should be dark.

Color Vision

Normal color vision is trichromatic, i.e., only three primary colors separated sufficiently in the spectrum are required for an observer to mix and match all other possible colors. The normal color observer can easily distinguish red, yellow, and green in the long-wavelength end of the spectrum. However, this task may be difficult or impossible for certain classes of observers who do not have normal photosensitive absorption in their middle or
long-wavelength cone receptors, or for individuals with acquired ocular disease. A defect of this type could conceivably contribute to unsafe driving. However, the largest class of color-defective observers, those with congenital red-green defect, has been studied repeatedly in a driving context and has not shown poorer driver safety performance than normals. \(23,36\) This result might seem surprising since important driving information is conveyed through color-coded traffic control signals and devices. However, even these devices have been designed to minimize the color discrimination problem to the class of long-wavelength-defective drivers. The devices accomplish this task mainly through the standardized restriction of the green traffic signal to that part of the color space perceived as white (or gray) to the most severely red-green color defectives (dichromats). Thus, the green signal is readily distinguished from the red and yellow, which appear yellowish to these drivers. Although red/yellow confusions may still occur, they apparently are not serious enough to introduce a significantly higher level of risk on the part of these drivers. Position and other noncolor cues also contribute to safe discrimination of information conveyed by color traffic control devices.

As a practical matter, observers who are completely color-blind from bii (those who cannot reliably distinguish colors in any part of the spectrum, also referred to as achromats) have very poor visual acuity associated with the disorder. Such individuals are easily identified from bii or will certainly be screened with a visual acuity test; they do not require a color test for screening. Similarly, drivers who acquire color vision defects as a result of ocular disease will also tend to exhibit other, more definitive signs of the decrease in visual functional capacity. Visual acuity loss, visual field constriction, loss of binocularity, or general deterioration in health related to more systemic problems, such as diabetes mellitus, will be detected through other parts of the vision exam or through the medical exam.

In practice, the current color test standard does not screen out congenital red-green defective drivers, partly because the ability of red-green color-defective individuals varies significantly with the angle of stimulus subtense.\(35,36\) For large angular subtense (more than 5 to 8 degrees, depending on the observer), even red-green dichromats can differentiate among red, green, and yellow spectral lights. These same observers are totally unable to distinguish colors in this spectral range for small lights subtending 2 degrees or less. Thus, dichromats typically “pass” a color test presenting large enough stimuli that are well saturated and reasonably bright, but fail any classic test of red-green color vision such as pseudoisochromatic plates (colored dots of one color that show a number or pattern within colored dots of another color) or small field spectral color matching (anomaloscope testing).

The current or past color vision standards were probably not stated with the intent of screening out the 8 percent of the male population who are congenitally color-defective in the red-green part of the spectrum. One can infer this conclusion partly from the loose wording of the standard, which most specialists would recognize as too lenient to provide efficient screening. Certainly a color standard for efficient screening could be specified. This course of action was not recommended. The literature on color vision and past experience of participation by these drivers provided no evidence that would warrant the exclusion of this class of drivers from the road as CMV or
private drivers. Instead of retaining the current ineffective standard or its revision, the color test requirement was deleted. Note that 11 of the 15 industrialized countries identified in the Synthesis of the Literature (Appendix A) do not specify a color test standard.

**Visual Impairments and Disorders**

Including items on visual pathology as well as functional tests of vision (visual fields and color vision) on the medical examination checklist has raised questions about the intent of the standard in these areas. On one hand, clear statements specifying minimum visual performance are present in the current standard, along with instructions on qualification to drive a CMV; i.e., the applicant must meet these minimum requirements. On the other hand, a long, but incomplete list of ocular pathology is presented as part of the medical exam and unclear instructions are presented about the intent of this part of the exam in terms of the disposition of the applicant if such conditions are noted.

The ambiguity created by this dual specification needed to be resolved. Beyond noting potentially harmful ocular conditions found during the medical exam, the checklist should be complete and the items listed in the same order of medical importance. Moreover, a clear statement of the intent of this part of the exam should also be included. In other words, these conditions should be brought to the attention of the applicant so that treatment, where available, can be sought. Disqualification should not be made on the basis of noting one of these conditions. Instead, applicants should be disqualified for visual reasons only if they fall below the minimum visual performance level specified in the current standard. Virtually all pathologies noted on the checklist will eventually have consequences for vision that will be detected by the specified tests of visual performance, provided such tests are rigorous and uniform. This recommendation appears consistent with current practice.

The standard (CFR 391.43, 1985) states that when the following medical conditions involve visual consequences, they must be noted:

"Note ptosis, discharge, visual fields, ocular muscle imbalance, color blindness, corneal scar, exophthalmos, or strabismus, uncorrected by corrective lenses. Monocular drivers are not qualified to operate commercial motor vehicles under existing Federal Motor Carrier Safety Regulations.'

A form for recording this information at the physical examination is also specified in the standard:

Vision: For distance:
- Right 20/____ Left 20/____
- ___ Without corrective lenses
- ___ With corrective lenses if worn

Evidence of disease or injury:
Definitions of the listed visual/medical conditions and their importance to driver safety are presented next. Ptosis refers to the drooping of the upper eyelid. Causes for this condition include lid muscle weakness, damage to the oculomotor nerve, and interference with the sympathetic nerves. However, unless the eyelid covers a high proportion of the pupil and consequently would affect image brightness or clarity, the condition need not be noted. Discharge is a secondary symptom of blockage of a tear duct, an eye infection, or an allergic reaction and can cause blurring of vision. However, this condition is frequently a temporary state and not necessarily worthy of inclusion in the standard. Visual fields is treated as a specific requirement in the standard. The need for separate notation on the exam form is unclear. Specific recommendations for visual fields are noted in a preceding section. Ocular muscle imbalance includes deviation of the eyes from their normally parallel position and can be of two types, paralytic (forward gaze, right or left lateral gaze) and nonparalytic (convergent or divergent). The individual with either condition may have trouble focusing at times; but if visual acuity and visual fields meet the standards, this condition does not usually need to be noted. Color blindness is questionable in terms of whether to note or include it in the standard, as discussed in a preceding section. Corneal scar is a superficial grayish white opacity in the cornea, secondary to an old injury or inflammation. If the individual meets the visual acuity and visual fields standards, this condition need not be reported. Exophthalmos is a forward protrusion of the eyeball from the socket. If it involves severe pressure from muscle tissue on the optic nerve, visual impairment or blindness can result. However, in the majority of individuals, this condition exhibits little effect on visual acuity and visual fields. Some individuals do complain of occasional difficulty in focusing, but this problem does not seem severe enough to be cause for disqualification. Strabismus is the result of muscle weakness that causes deviation of one eye inwardly (esotropia) or outwardly (exotropia). The condition can cause amblyopia (reduced vision) in an otherwise normal eye caused by disuse of that eye; one eye becomes “lazy” and stops functioning to full capacity; thus visual acuity in that eye is reduced markedly by suppression of central (foveal) vision. If visual acuity and visual fields standards are met, this condition probably need not be reported.
With the exception of the condition of **monocularity**, the preceding visual conditions do not necessarily disqualify a driver from operating a CMV. The standard addresses only the need to note them. These conditions may or may not affect an individual’s ability to drive or, for that matter, may or may not inhibit the individual’s ability to pass visual acuity, horizontal field of vision, and color vision tests specified in the standard.

If the checklist is to be retained in a form similar to the current one, a number of other conditions should be included: **aphakia** (absence of the lens), cataract (opacity in the lens or cornea), conjunctivitis (inflammation of the conjunctival lining), glaucoma (an increased pressure on the eye due to excessive fluid within the eye), **macular degeneration** (deterioration of the membrane between the retina and the underlying layer of blood vessels), and abnormal refractive states (astigmatism, hyperopia, myopia, **presbyopia**).

**Proposed Changes to the Federal Standard**

Both the Federal standard changes proposed prior to the workshop and the final recommendations are shown in the following items.

Section 391.41 Physical qualifications for drivers.

(a) A person shall not drive a motor vehicle unless he (or she) is physically qualified to do so and....

(b) A person is physically qualified to drive a motor vehicle if that person....

(3) Has no established medical history or clinical diagnosis of diabetes mellitus currently requiring insulin for control;....

(10) Has distant visual acuity of at least 20/40 (Snellen) in each eye without corrective lenses or visual acuity separately corrected to 20/40 (Snellen) or better with corrective lenses, distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses, field of vision of at least 120 degrees in each eye measured separately in the horizontal meridian (color standard deleted);

In addition, Section 391.43(10) states that medical examination can be performed by a licensed doctor of medicine or osteopathy, and a licensed ophthalmologist or optometrist can perform those parts of the medical exam that pertain to visual acuity, field of vision, and the ability to recognize colors as specified in CFR 49 paragraph (10) of 391.41(b). Few instructions for performing and recording the physical
examination are given, but instructions regarding specification of visual acuity, prohibition against monocular vision, contact lens tolerance, and certain common eye conditions are as follows:

Section 391.43 Medical examination; certificate of examination.

(a) Except as provided in paragraph (b) of this section, the medical examination shall be performed by a licensed doctor of medicine or osteopathy.

(b) Either a state licensing agency with standardized visual screening equipment or a licensed ophthalmologist or optometrist most ("may" deleted) perform so much of the medical examination as pertains to visual acuity, field of vision (requirement for color recognition deleted) as specified in paragraph (10) of 391.41 (b).

(c) The medical examination shall be performed, and its results shall be recorded, substantially in accordance with the following instructions and examination form:

Test charts should be illuminated with white light (color temperature from 25dK to 7500K) at a level well within the photopic range. Luminance readings from the white part of the chart should be between 30 cd/m² and 120 cd/m². Optotypes should be presented as black on a white background. The Snellen optotype is preferred. However, other optotypes such as Sloan letters, numbers, rolling E, Landolt C, and geometric patterns are acceptable. When other than the Snellen chart is used, the results of such test must be expressed in values comparable to the standard Snellen test. In recording distance vision, use 20 feet as normal. Report all vision as a fraction with 20 as numerator and the smallest type read at 20 feet as denominator. If the applicant wears corrective lenses, these should be worn while applicant's visual acuity is being tested. If appropriate, indicate on the Medical Examiner's Certificate by checking the box, "Qualified only when wearing corrective lenses." The visual field test should be conducted on an apparatus capable of testing the horizontal field of view to a minimum of 40 degrees nasally and 80 degrees temporally for each eye. The angular subtense of the test object should be between 10 minutes of arc and 2 degrees of arc. The luminance of the test object should be equivalent to between 5 and 25 cd/m². The background should be dark.

Note ocular pathologies (refer to recommended list). Monocular drivers are not qualified to operate commercial motor vehicles under existing Federal Motor Carrier Safety Regulations. If the driver habitually wears contact lenses, or intends to do so while driving, there should be sufficient evidence to indicate that he has good tolerance and is well adapted to their use. The use of contact lenses should be noted on the record."
person’s comprehensive visual assessment history—either clinical examination or screening by a Department of Motor Vehicles protocol—to that individual’s driving record. Accordingly, a Delphi-type approach was used for initially identifying specific visual functions deemed most important for safely performing each of seven critical CMV driving tasks. With this information, the panel of experts collectively established minimum acceptable performance levels for each visual function for each driving task. Finally, the panel indicated which visual disorders and ocular conditions should be noted on a physical examination form and which should require a follow-up exam by a vision specialist. Then (2) provided a subjective (rating scale) evaluation of the relative safety of matched monocular and binocular drivers with respect to critical CMV driving task response capabilities.

The expert panel for this task, composed of the workshop participants identified in the following section, was first asked to indicate by order of importance three visual functions required for safely performing each of the following driving tasks:

- Maintaining safe speed for conditions (highway geometry/weather/visibility)
- Maintaining safe following distance
- Staying in lane/steering control
- **Merging/yielding in traffic** conflict situations (lane drop, ramp gore, intersection of driveway)
- **Changing lanes and passing**
  - Complying with traffic control devices (signs, signals, and pavement markings)
- **Backing** up/parking operations.

In the judgment of senior project staff and as noted by previous researchers in this area, the above driving tasks may be cited as critical to safe CMV operation.

This expert evaluation was conducted using a Delphi-type, iterative process in which the most frequent response for each order position (most important, second most important, third most important) was tabulated for each driving task; this information was then made available to each panel member, and further responses from each person were requested as needed to resolve ties and achieve consensus for all rankings. Three iterations of this process were required, resulting in the collective judgments summarized in Table 2 (Appendix D provides the evaluation forms.)

Table 2. **Visual** Functions Judged Most Important for Safely Performing Seven Critical CMV Driving Tasks

<table>
<thead>
<tr>
<th>Driving Task</th>
<th>Visual Function by Order of Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Maintaining safe speed for condition!</td>
<td>Visual fields</td>
</tr>
<tr>
<td>Maintaining safe following distance</td>
<td>Depth perception, Stereopsis</td>
</tr>
<tr>
<td>Staying in lane/steering control</td>
<td>Visual fields</td>
</tr>
<tr>
<td>Merging/Yielding in traffic conflict situations</td>
<td>viual fields</td>
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<tr>
<td>Changing lanes and passing</td>
<td>viual fields</td>
</tr>
<tr>
<td>Complying with traffic control device</td>
<td>Static acuity</td>
</tr>
<tr>
<td>Backing up/Parking operations</td>
<td>Depth perception</td>
</tr>
</tbody>
</table>

The next step in the evaluation process was to request that each member of the expert panel provide a minimum acceptable level of performance for all visual functions named in the consensus table of results for the previous round. This effort yielded ambiguous results. In some cases, the most appropriate metric for performance capability remains unresolved in the technical literature (e.g., visual search/attention,
contrast sensitivity), and in other cases a mix of qualitative and quantitative responses was provided (e.g., visual fields, motion perception, and depth perception).

Subsequently, only those functions that were addressed at the workshop and were to be used in the actual development of recommendations for a revised standard were further evaluated. This post workshop evaluation involved visual acuity, visual fields, and color vision. For other functions identified in Table 2, a more precise determination of minimum acceptable performance levels is deferred until continuing research findings justify their formal incorporation into the Federal vision standard. This issue receives additional discussion in the concluding section of this report.

With respect to static acuity, visual fields, and color vision, panel members were asked to select from among specific wordings suggested by their responses to the prior requests for input on this task. For visual acuity, the selections were as follows:

1. “Has distant visual acuity of at least 20/40 (Snellen) in each eye without corrective lenses or visual acuity separately corrected to 20/40 (Snellen) or better with corrective lenses, and has distant binocular acuity of at least 20/40 (Snellen) in both eyes without corrective lenses.” (Current standard)

2. “Has distant visual acuity (either with or without corrective lenses) of at least 20/40 (Snellen) in one eye and at least 20/100 (Snellen) in the other eye, and has distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses.” ( Goes back to earlier standard)

3. “Has distant visual acuity (either with or without corrective lenses) of at least 20/40 (Snellen) in one eye and at least 20/200 (Snellen) in the other eye; and has distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses.”

4. (Alternate wording) ____________________________________________

For field of vision, the selections were as follows:

1. “Field of vision of at least 120 degrees in each eye measured separately in the Horizontal Meridian.”

2. “Field of vision of at least 130 degrees in each eye measured separately in the Horizontal Meridian.”

3. “Field of vision of at least 140 degrees in each eye measured separately in the Horizontal Meridian.”

4. (Alternate wording) ____________________________________________
For color vision, the selections were as follows:

1. **The** current visual standard for color (‘the ability to **recognize** the colors of traffic signals and devices showing standard red, **green**, and **amber**”) should be dropped.

2. Retain the **current visual** standard (“the ability to **recognize** the colors of traffic signals and devices showing standard red, green, and amber”), but add “No test for color vision is specified.”

3. The ability to **discriminate** the standard color **green** used in traffic signals and devices from the other standard colors, red and amber. See instructions for performing color vision test in Section 391.43.”

4. (Alternate wording)

For visual acuity, 7 out of 11 panelists selected alternative 1; the remaining panelists selected alternative 3. For field of vision, 6 out of 11 panelists chose alternative 1; 3 panelists selected alternative 3; and 1 panelist each selected alternative 2 and 4 (their own wording.) For color vision, 6 out of 11 panelists selected alternative 2; 2 panelists each chose alternatives 3 and 1. One panelist did not select any of the alternatives.

From the consensus of expert opinion in these areas, it was indicated that alternative 1 for visual acuity, alternative 1 for visual fields, and alternative 2 for color vision were most preferred for a Federal vision standard for commercial vehicle operators.

A wide range of visual disorders and ocular conditions was listed in the evaluation requested of panel members as to which should be recorded on the physical examination form, which should not be recorded, which should be referred to a vision specialist, and which should not be referred to a vision specialist. These conditions included aphakia, astigmatism, cataract, conjunctivitis, corneal scar, exophthalmos, glaucoma, hyperopia, macular degeneration, myopia, ocular muscle imbalance, presbyopia, ptosis, retinopathy, and strabismus, plus any other condition that a panel member wanted to list.

Responses mandated the inclusion of aphakia, cataract, corneal scar, exophthalmos, macular degeneration, ocular muscle imbalance, ptosis, retinopathy, strabismus uncorrected by corrective lenses, and any other condition that the examiner deems important to note on a physical examination of a CMV driver. These conditions are accordingly written into the proposed recommendations.

Finally, the expert opinion survey addressed the question of the safety of monocular versus binocular drivers with respect to specified critical CMV driving tasks. Panel members were asked to respond to the ratings to estimate the relative performance capabilities of monocular versus binocular CMV drivers matched
on age, gender, education, and years and type of driving experience for each of the seven driving tasks identified previously: maintaining safe speed for conditions, maintaining safe following distance, staying in lane/steering control, merging/yielding in traffic conflict situations, changing lanes and passing, complying with traffic control devices, and backing up/parking operations. Relative safety ratings were provided on seven-point bipolar scales indicating the judged likelihood of safe performance under “reasonable worst-case” conditions. The least safe rating was ‘1’; the most safe rating was ‘T’. Each panel member placed an ‘M’ and a ‘B’ to indicate, on a common rating scale, the judged likelihood of safe performance for matched monocular and binocular drivers, respectively, for a particular task. The actual rating scales distributed to panel members are provided in Appendix D.

Mean values for the rated safety of monocular and binocular drivers using this approach were calculated, and t-tests were conducted to indicate whether differences in the judged likelihood of safe performance for the two groups were reliable. Results of this procedure, using one-tailed tests of the hypothesis that binocular drivers would be judged higher (more likely to perform safely) than monocular drivers, demonstrated a significant difference in the predicted direction for:

- Maintaining safe following distance $(t=2.16; df=14; p<.05)$
- Merging/yielding in traffic conflict situations $(t=3.25; df=14; p<.01)$
- Changing lanes and passing $(t=3.23; df=14; p<.01)$
- Complying with traffic control devices $(t=2.65; df=14; p<.01)$
- Backing up/parking operations $(t=2.96; df=14; p<.01)$

Thus, the wording of a standard that de facto excludes monocular drivers by requiring distant visual acuity of at least 20/40 (Snellen) in each eye is supported by the ratings, which for five out of seven critical driving tasks defined in this research, demonstrate a significant perceived deficiency in the ability of such drivers to perform as safely as their binocular counterparts. (Note: The panelists thought that the two driving tasks in which safety would not be significantly reduced for the monocular CMV driver were maintaining safe speed for conditions and staying in lane/steering control.)

RISK ANALYSIS OF A VISUAL ACUITY CRITERION SHIFT

Existing models of driver behavior suggest that the function relating increased criterion accident risk to decreasing activity (criteria) will mimic one side of the normal probability curve, but assigning specific values to accident probability will depend upon further analysis of reduced visibility crash data for individual situations. However, even adopting the most liberal assumptions regarding driver response capability, it seems apparent that shifting the criterion for visual acuity can lead to a measurable increase in the probability of a crash whenever a CMV driver’s vehicle control decisions in moderate-to-heavy traffic...
conditions depend upon timely comprehension of guidance information presented by highway signing. Certainly, given the goal to maintain or improve the level of service on existing highways with increasing traffic densities, this risk modeling approach argues against any change toward less stringent visual performance (acuity) criteria for operators of CMVs. One of the tasks for this project was to develop an assessment of the safety risk involved with various levels of vision and determine, to the extent practical, the potential risk associated with various performance criteria on the recommended vision standard.

Empirical evidence found could not reasonably quantify any specific risk (such as a crash rate) with a specific visual performance level (such as 20/40 binocular visual acuity). This task was reduced to performing an analytical exercise on a theoretical risk associated with shifting the pass/fail criterion for tests of CMV drivers’ visual acuity. Visual acuity was selected for this analysis because of its prominence in traditional test protocols and its high level of face validity to everyday driving tasks. The analysis was specific to a defined operational context and relied upon assumptions about those situations as found in current models of driver response effectiveness.

This theoretical analysis case examined a maneuver/decision sequence within the framework of decision sight distance models. In the analysis, a safe and effective driver response was dependent upon legibility/comprehension under freeway operating conditions, taking into account the increasing attentional demands for avoiding traffic conflicts and the corresponding decrease in attentional resources available for road sign information processing-associated with this situation. The CMV operator, who was unfamiliar with the roadway being travelled, had to respond to guide sign information to successfully navigate his/her destination.

The focus of the analysis was to describe a function of relating increased risk of traffic conflicts/accidents to decreasing time legibility distance resulting from driver visual acuities worse than 20/20. Appendix B describes the risk analysis model in detail.

WORKSHOP

The objectives of the workshop were to have the panel of vision and trucking industry experts review the preliminary draft recommendations for changes to the CMV vision standard, discuss difficult or unresolved issues concerning proposed revisions, and attempt to reach a consensus. Workshop issues were categorized into three areas: (1) review of data relevant to setting the criteria levels specified for visual functional tests included in the standard (visual acuity, visual fields, color vision, and any other visual functions that would be proposed for inclusion), (2) more comprehensive specification of testing procedures for each of the visual functions, and (3) required documentation of visual disorders and impairments identified at the time of exam.
Prior to the workshop, panelists were asked to review the Synthesis of the Literature (Appendix A) and Preliminary Recommendations, provide alternative suggestions on these recommendations, and prepare a two-page point-of-view paper summarizing their suggestions and recommendations for change to the CMV vision standard. These point-of-view papers were submitted to KETRON prior to the workshop and used to organize the presentation of issues at the workshop. Panelists were provided copies of all the other panelists' point-of-view papers prior to the workshop to help guide the discussion on issues that would be brought up at the workshop.

The workshop was held at the Westpark Hotel in Rosslyn, Virginia on June 24, 1991. Panelists were seated across from each other, six individuals at a table on each side of the room. The KETRON moderators were seated in the front of the room. Visitors were seated behind the panelists' tables. The list of attendees is included in Table 3.

Workshop schedule:

- Opening Remarks; Neill Thomas, OMC
- Introduction of Panelists
- "Fit for the Road" Video (FHWA, OMC)
- Purpose of Workshop; L.E. Decina, KETRON Moderator
- Presentation of Viewpoints
- Lunch
- Summary of Panelists' Viewpoints; Chris Johnson (Panelist Chairperson)
- Risk Analysis; Loren Staplin
- Remarks; James Scapellato, FHWA, OMC Director
- Consensus of Panelists' Viewpoints; M. E. Breton, KETRON Vision Consultant
- Closing Remarks
- Vision Screening Equipment Demonstrations.

The workshop was recorded by C.A.S.E.T. Associates and a transcript was sent to KETRON.
Table 3. Attendees at Vision Standards for CMV Operators Workshop

**KETRON STAFF**

- Lawrence E. Decina, Principal Investigator (Moderator)
- Michael E. Breton, Ph.D., Vision Consultant (Presenter)
- Loren K. Staplin, Ph.D., Project Manager (Presenter)
- Laverne P. Evans, Secretary

**PANELISTS**

- Chris Johnson, Ph.D. (Panelist Chairman)
- H. James McKnight, Ph.D.
- Kariene Ball, Ph.D.
- Cynthia Owsley, Ph.D.
- Arthur Keeney, M.D.
- Merrill Allen, O.D.
- Neill Darmstadtter
- Frank Schieber, Ph.D.
- Sandra Z. Salan, M.D.
- Bernard Blair, M.D.
- Raymond Briggs, Ph.D.
- Clifford Anderson

**VISITORS**

- Dick Schwab, FHWA, RLD (Co-COTR)
- Neill Thomas, FHWA, OMC
- Hal Hylton, FHWA, OMC
- Claude Duquette, M.D., CCMTA, Canada
- William Hark, M.D., FAA
- John Eberhard, NHTSA
- Dennis McEachen, FAA
- Deborah Freund, FHWA, OMC
- Carole Simmons, FHWA

**C.A.S.E.T. Associates (Recorders)**