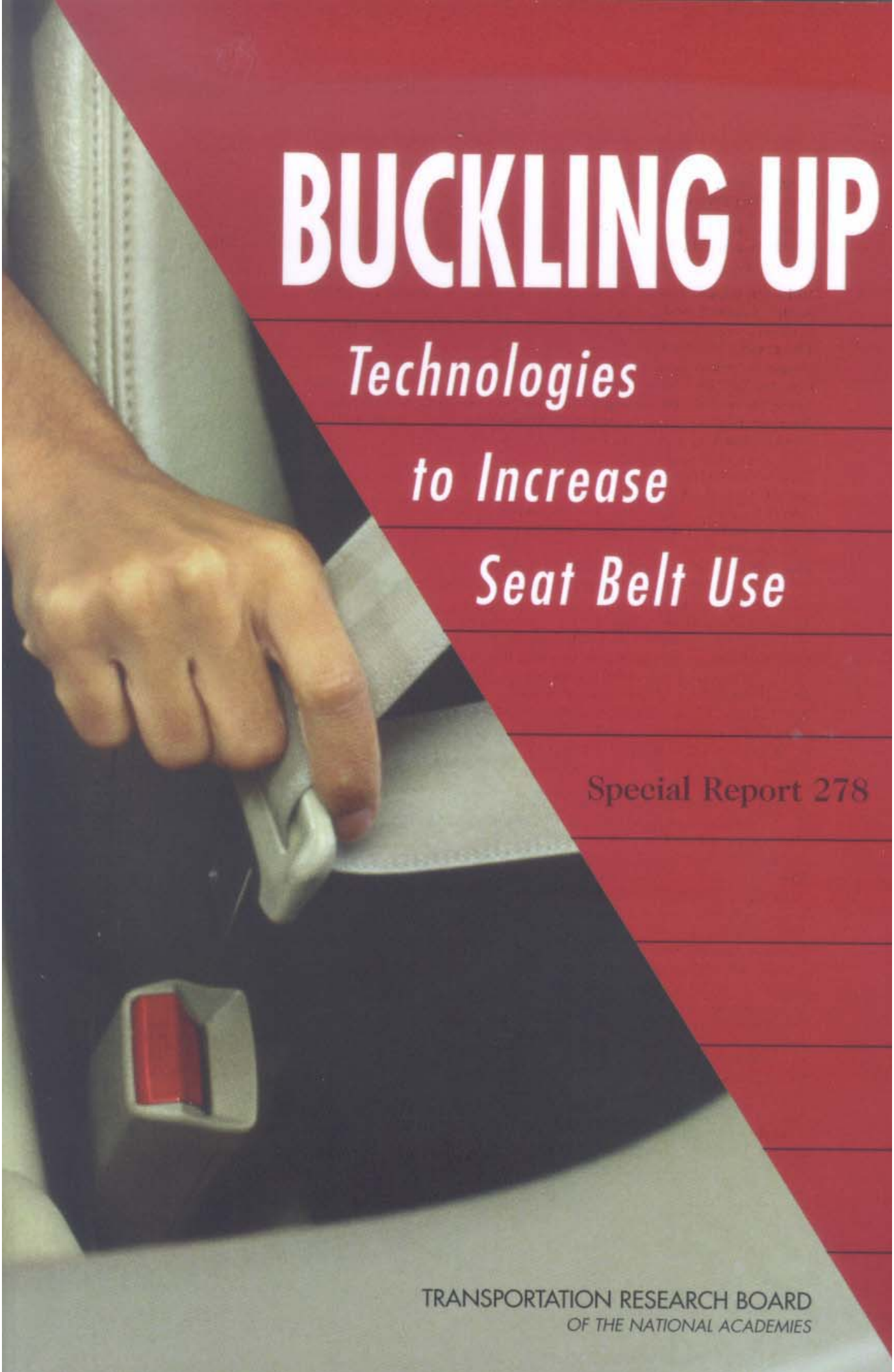

BUCKLING UP

Technologies to Increase Seat Belt Use

Special Report 278

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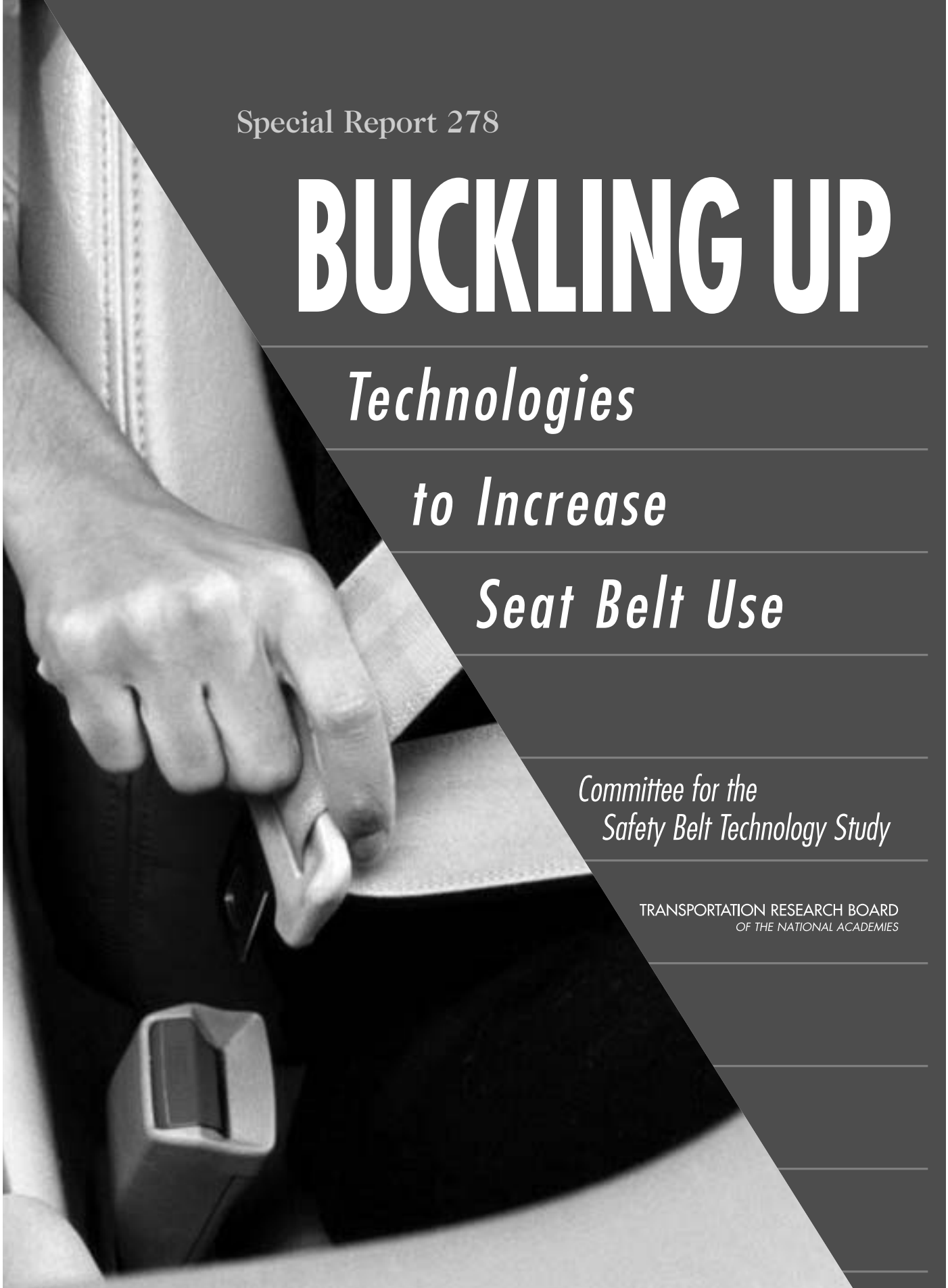

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Technologies to Increase Seat Belt Use

Committee for the Safety Belt Technology Study

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The study was sponsored by the National Highway Traffic Safety Administration of the U.S. Department of Transportation.

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PREFACE

Increasing seat belt use is one of the most effective and least costly ways of reducing the lives lost and injuries incurred on the nation's highways each year, yet about one in four drivers and front-seat passengers continues to ride unbuckled. Congress requested this study to examine the potential of in-vehicle technologies to increase belt use.

In response to this request, the Transportation Research Board (TRB) of the National Research Council (NRC) formed a panel of 12 experts chaired by William C. Howell, Adjunct Professor at Arizona State and Rice Universities. Panel members have expertise in the areas of automotive engineering, design, and regulation; traffic safety and injury prevention; human factors; survey research methods; economics; and technology education and consumer interest.

The panel is aware of the breadth of approaches that have been introduced over the years by the federal government, states, safety groups, and the private sector to increase seat belt use and vehicle occupant safety more generally. Strategies have included efforts to educate the public about the benefits of seat belts; technological approaches that attempted to force motorists to buckle up (such as ignition interlocks that prevented cars from starting unless front-seat occupants were belted); the provision of automatic protection (through automatic belts and supplemental protection through air bags); and enactment of state seat belt use laws and targeted enforcement programs requiring motorists to buckle up. Other approaches have focused on improving seat belt design and comfort to encourage belt wearing. This report does not attempt to address these important topics in any depth, although it does include discussion of those relating directly to the congressional charge. For example, the report touches on the temporary federal requirement for vehicle ignition interlocks as well as on strategies of the states to increase the wearing of safety belts through laws mandating their use. The national experience with air bags—both those required by regulation and those available as consumer options—is not addressed. The committee views air bags and seat belts as complementary strategies to improve occupant safety. The regulations governing air bags, their effectiveness alone and in combination with belts, and the controversies

surrounding their introduction and subsequent revisions in the regulations governing their use, however, go well beyond the scope of this committee's charge to concentrate on emerging technologies, such as belt reminder systems, that offer potential for further gains in seat belt use.

As an important input to the study, the National Highway Traffic Safety Administration (NHTSA)—the study sponsor—funded and conducted interviews and focus groups of samples of different belt user groups to learn more about the potential effectiveness and acceptability of technologies ranging from seat belt reminder systems to more aggressive interlock systems that prevent putting the vehicle in gear unless the driver and front-seat passengers are buckled up. In particular, the committee thanks Roger Saul, Nathaniel Beuse, and Richard Compton of NHTSA; Roger Kurrus, a consultant previously with NHTSA; and Jonathan Bentley of Equals Three Communications for providing timely and useful empirical results to enhance the data available to the committee.

The committee also supplemented its expertise by holding its second meeting in Dearborn, Michigan, where it met in proprietary sessions with several of the major automobile manufacturers, a key supplier, and a small business inventor of a shifter interlock system to learn of planned new seat belt use technologies as well as about company data concerning their effectiveness and acceptability. The committee thanks Scott Schmidt of the Alliance of Automobile Manufacturers, Michael Cammisa of the Association of International Automobile Manufacturers, and George Kirchoff of the Automotive Occupant Restraints Council for helping organize the meeting. It also thanks the following individuals for their briefings: Robert Lange, James Khoury, Patricia Featherstone, Joseph Fitzsimmons, and Stephen Gehring of General Motors Corporation; Michael Berube, Barry Felrice, Kristen Kreibich-Staruch, Randy Edwards, and Dirk Ockel of DaimlerChrysler; Chris Tinto, Christina Mullen, and Ted Koase of Toyota Motor Corporation; James Boland, Peter Ducharme, Thomas Falahee, Scott Gaboury, David Kizyma, and James Vondale of Ford Motor Company; Ingrid Skogsmo of Volvo; Orlando Robinson and Joseph Price of D&D Innovations, Inc.; Wendell Lane and Michael Moore of Breed Technologies, Inc.; and Aki Yasuoka

of Honda and Frank Kiiskila of Autoliv, who provided written responses to the committee's questions following the meeting.

The committee thanks the Chief Counsel of NHTSA, Jacqueline Glassman, who provided the agency's current interpretation of the regulations concerning seat belt use technologies at the committee's third meeting, and Rebecca MacPherson, Senior Counsel at NHTSA, who prepared the supporting documentary materials.

Finally, the committee acknowledges Anders Lie of the Swedish National Road Administration, who provided valuable information on EuroNCAP policies related to belt reminder systems, and Paul Schockmel of International Electronics Engineering, a major manufacturer of sensor systems, for his information on automotive applications.

The report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that assist the authors and NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The committee thanks the following individuals for their participation in the review of this report: Paul Green, University of Michigan, Ann Arbor; Henry Jasny, Advocates for Highway and Auto Safety, Washington, D.C.; Craig Newgard, Oregon Health and Science University, Portland; James Nichols, NHTSA (retired), Vienna, Virginia; David F. Preusser, Preusser Research Group, Inc., Trumbull, Connecticut; Kenneth Stack, General Motors Corporation (retired), Stanwood, Michigan; and Cheryl Stecher, Franklin Hill Group, Santa Monica, California.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the committee's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Elsa Garmire, Dartmouth College, Hanover, New Hampshire, and Lester A. Hoel, University of Virginia, Charlottesville. Appointed by NRC, they were responsible for making certain that an independent examination of

the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Nancy P. Humphrey managed the study and drafted major sections of the final report under the guidance of the committee and the supervision of Stephen R. Godwin, Director of Studies and Information Services. Michelle M. Crowder drafted sections of Chapter 2 of the report, which summarize what is known about the characteristics of those who do not wear seat belts and the potential effectiveness of technologies that could influence their propensity to buckle up. Suzanne Schneider, Associate Executive Director of TRB, managed the report review process. Special appreciation is expressed to Norman Solomon, who edited the report under the supervision of Nancy A. Ackerman, Director of Publications. Amelia Mathis assisted with meeting arrangements and communications with committee members.

CONTENTS

Executive Summary

Using seat belts is one of the most effective strategies available to the driving public for avoiding death and injury in a crash (Dinh-Zarr et al. 2001, 48). Today, however, nearly 35 years after the federal government required that all passenger cars be equipped with seat belts, approximately one-quarter of U.S. drivers and front-seat passengers are still observed not to be buckled up (Glassbrenner 2002, 1). Nonusers tend to be involved in more crashes than belt users (Reinfurt et al. 1996, 215), and belt use is lower—about 40 percent for drivers—in severe crashes (O'Neill 2001). Moreover, at observed national belt use rates of 75 percent, the United States continues to lag far behind the 90 to 95 percent belt use rates achieved in Canada, Australia, and several northern European countries.

Convincing motorists to buckle up is a top priority of the National Highway Traffic Safety Administration (NHTSA) as it looks for ways to reduce the 42,000 deaths and more than 3 million injuries that occur each year on U.S. highways (NHTSA 2002a). NHTSA is urging industry to deploy vehicle-based technologies, such as seat belt reminder systems, to encourage further gains in belt use, but the agency is prohibited from requiring such technologies by federal legislation dating back to 1974. A brief history of the events leading up to this action and its impact on technology introduction today are provided in a subsequent section.

Congress requested the present study[1] to

- Examine the potential benefits of technologies designed to increase belt use,
- Determine how drivers view the acceptability of the technologies, and
- Consider whether legislative or regulatory actions are necessary to enable their installation on passenger vehicles.[2]

[1] The request was contained in Conference Report 107-308 to accompany Appropriations for the Department of Transportation and Related Agencies for fiscal year 2002, June 22, 2001 (see Appendix A). Given the nature of the charge, the committee did not analyze other strategies for increasing seat belt use, such as seat belt use laws, enforcement, and fines.

[2] Passenger vehicles include cars and light-duty trucks driven for personal use (i.e., sport utility vehicles, vans, and pickup trucks).

In short, congressional interest in this study is focused on an assessment of the potential for technology to increase seat belt use and the extent to which federal laws and regulations pertaining to these technologies may inhibit their introduction.

BENEFITS OF SEAT BELT USE

Properly used seat belts are one of the most effective measures for reducing death and injury on the highway (Dinh-Zarr et al. 2001, 48). Buckling up can reduce the risk of fatal injury for drivers and front-seat occupants of passenger cars involved in crashes by about 45 percent. The fatality reduction for front-seat belt wearers in light trucks is 60 percent (Kahane 2000, 28–29). Moreover, seat belts reduce the risk of moderate-to-critical injury in crashes by 50 percent for passenger vehicle occupants and by 65 percent for light truck occupants (NHTSA 2002b).[3]

NHTSA estimates that approximately 147,000 lives were saved between 1975 and 2001 because of seat belt use (NHTSA 2002b). If current belt nonusers in passenger vehicles buckled up, thousands of deaths and hundreds of thousands of injuries could be prevented each year at an estimated societal savings of $26 billion in medical care, lost productivity, and other injury-related costs (Blincoe et al. 2002, 55). Because of the proven effectiveness of seat belts, measures to encourage further belt use would have big payoffs. NHTSA estimates that a percentage point increase in belt use would result in 250 lives saved per year (Glassbrenner 2002, 1). As the pool of nonusers shrinks, more lives are saved for each incremental point increase in belt use. The reason is that those most resistant to buckling up tend to exhibit other high-risk behaviors (e.g., alcohol use, speeding) and are more frequently involved in crashes (Blincoe et al. 2002, 53).

Seat belt use is also cost-effective. The marginal monetary cost of seat belt use is zero because all U.S. passenger vehicles are required to be equipped with seat belts. The marginal nonmonetary costs are modest. They include the time and effort required to buckle up and, for some, the discomfort of wearing the belt.

[3] Air bags supplement seat belts in providing protection. Air bags alone are 10 percent and 14 percent effective in reducing deaths and injuries, respectively (NHTSA 1999 in Dinh-Zarr et al. 2001, 48). Between 1987 and 2001, approximately 8,400 lives were saved by air bags (NHTSA 2002b, 3).

REASONS FOR BELT NONUSE

If seat belts are so effective, why don't more motorists buckle up? Unlike air bags or automatic restraint systems, manual belts require action on the part of drivers and passengers. Reasons for not using belts stem from a complex mix of situational, habitual, and attitudinal factors.

Many drivers and vehicle occupants report that they would like to be wearing a seat belt in a crash but have not acquired the habit of buckling up on all trips. For this group (referred to hereafter as "part-time users"), belt use is situational; they tend to buckle up when the weather is poor or when they are taking longer trips on high-speed roads where they perceive driving as riskier. In surveys, these users report that the primary reasons for their not buckling up are driving short distances, forgetting, being in a hurry, or discomfort from the belt (Block 2001, v).

In contrast, the much smaller group of motorists who never or rarely use their belts—the so-called "hard-core nonusers"—report negative attitudes toward seat belts as the primary reason for nonuse. These include discomfort, unfounded claims that belts are dangerous in a crash (e.g., could trap the driver in the vehicle), infringement of personal freedom and resentment of authority, and the attitude that they "just don't feel like wearing them" (Block 2001, v).

According to NHTSA's most recent telephone survey on occupant restraint issues (Block 2001, 12), one-fifth of drivers can be characterized as part-time users, that is, they report using their belts most or some of the time, and about 4 percent as hard-core nonusers, those who report never or rarely using their belts.[4] The latter group is small but has a high crash risk. Unbelted drivers have significantly more traffic violations, higher crash involvement rates, higher arrest rates, and higher alcohol consumption than those who buckle up all or part of the time (Reinfurt et al. 1996).

The distinction between these two groups is important from the perspective of technology effectiveness and acceptability. If, in fact, the majority of belt nonusers are aware of the benefits of seat belts but have not

[4] As discussed in more detail in Chapter 2, these categorizations are approximate. For example, 83 percent of drivers reported wearing their seat belts "all the time." However, 8 percent of these full-time users reported in a follow-up question that they had not worn their seat belts while driving at some time during the past week (Block 2001, 24).

developed the habit of belt use in all situations, their behavior may be amenable to a belt reminder system. However, more aggressive systems may be needed to reach the small group of hard-core nonusers.

OVERVIEW OF STRATEGIES FOR INCREASING BELT USE

The history of NHTSA's approach to occupant protection is instructive in understanding the agency's current policies and regulatory constraints, particularly as they apply to the use of technology to increase seat belt use.

Comprehensive automobile safety legislation in 1966 established the federal role in highway safety regulation. Federal Motor Vehicle Safety Standard (FMVSS) 208, which required the installation of lap and shoulder belts in all new passenger vehicles,[5] was one of the 19 original safety standards put in place by the newly created National Highway Safety Bureau (Kratzke 1995, 1).[6] It soon became apparent, however, that motorists would not use the belts voluntarily with much regularity. Thus, the renamed National Highway Traffic Safety Administration began promoting so-called "passive restraint systems," primarily air bags but also automatic belt systems (Kratzke 1995, 1).

Negative public and political reaction to such systems, stemming in part from their early stage of development, led NHTSA in 1972 to provide manufacturers with an alternative—a required 60-second flashing light and buzzer system to remind motorists to buckle up (Robertson 1975, 1320). Soon thereafter, the agency required that, effective August 15, 1973, all passenger vehicles not providing automatic protection be equipped with an interlock system, which prevented the engine from starting if any front-seat occupant was not buckled up. The interlock requirement was intended as an interim measure to increase belt use until acceptable automatic systems became available (Kratzke 1995, 2).

With seat belt use rates of only 12 to 15 percent (Haseltine 2001), no laws requiring belt use, lap and shoulder belt systems that many mo-

[5] The standard has been upgraded to require that all new passenger vehicles be equipped with three-point belt systems that integrate lap and shoulder belts in a single detachable unit.

[6] The National Traffic and Motor Vehicle Safety Act of 1966 intended that safety standards not depend on current technology and could be "technology forcing" in the sense of inducing the development of superior safety design (Motor Vehicle Manufacturers Association *v.* State Farm Mutual Automobile Insurance Company, 463 U.S. 29, 49, 1983).

torists found clumsy and uncomfortable to wear, and unreliable occupant sensing systems, it is hardly surprising that the ignition interlock requirement met almost immediately with strong public and political opposition. Although by some reports belt use rates soared to about 60 percent immediately following the installation of interlock systems, some motorists learned to disable the system, and others began to complain to their elected representatives (Kratzke 1995, 3). One year after the interlock requirement took effect, Congress enacted legislation prohibiting NHTSA from requiring either ignition interlocks or continuous buzzer warnings of more than 8 seconds.[7] The agency revised FMVSS 208 accordingly, retaining a requirement for only a 4- to 8-second warning light and buzzer[8] of similar duration that is activated when front seat belts are not fastened at the time of ignition. This standard still applies today (*Federal Register* 1974, 42,692–42,693).

Following the interlock requirement interdiction, NHTSA's focus returned to passive restraint systems. In 1984, then Secretary of Transportation Elizabeth Dole crafted a final rule providing for a phase-in of air bags and automated belts, but with the possibility of rescinding this requirement if, by 1989, two-thirds of the nation's population was covered by state-mandated seat belt use laws meeting NHTSA's requirements (Kratzke 1995, 8). The deadline was not met, but seat belt use laws were rapidly introduced and have proved to be one of the most effective approaches for increasing belt use (Dinh-Zarr et al. 2001, 48). Today, all states except New Hampshire have belt use laws that apply to adults, and observed use rates have grown from about 14 percent in 1984 to about 75 percent today (Figure ES-1), largely the result of laws coupled with well-publicized enforcement (O'Neill 2001).[9] Over the past decade, however, the rate of belt use gains has slowed, in part because of the reluctance of many states to promote enforcement through

[7] Motor Vehicle and Schoolbus Safety Amendments of 1974, Public Law 93-492, 15 USC 1410b, October 27, 1974.

[8] According to NHTSA's Chief Counsel, the requirement extends to other audible alerts. At the time, buzzers were the predominant, if not the only, audible signals used by manufacturers who were certifying their vehicles as compliant with the audible alert option (letter from NHTSA to Dr. William Howell, April 3, 2003, Docket No. 15156-3).

[9] Most states, for example, conduct month-long, federally supported seat belt campaigns, dubbed "Click It or Ticket," typically in May and November each year. These campaigns involve increased enforcement of seat belt use laws and high-visibility targeted advertising (*AASHTO Journal* 2003, 16).

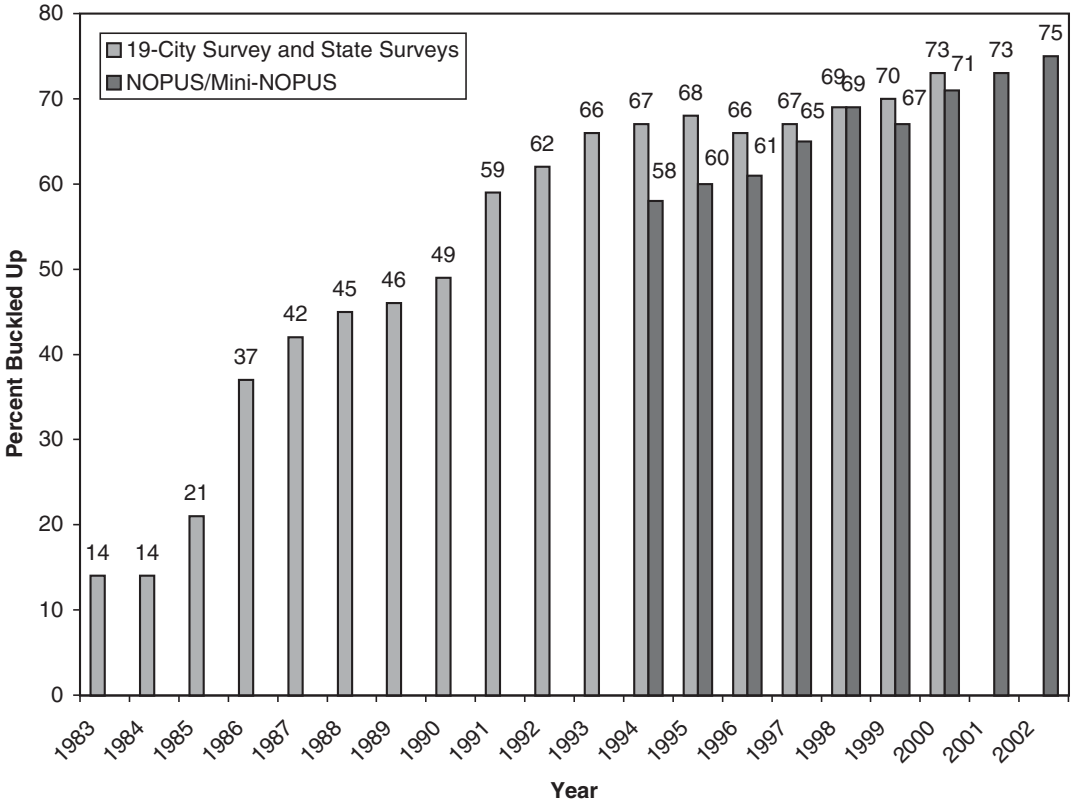

Figure ES-1 U.S. observed seat belt use. [Sources: NHTSA, 1983–1990: 19-City Survey; 1991–2000: State Surveys; 1994–2002: National Occupant Protection Use Survey (NOPUS)/Mini-NOPUS.]

"primary" seat belt use laws (i.e., those that specify failure to buckle up as the sole justification needed to stop and ticket a motorist).[10] The slower rate of progress also reflects the difficulty of convincing the remaining group of nonusers to buckle up.

TECHNOLOGY REVISITED

Congress and NHTSA have expressed interest in the potential of technology to increase seat belt use. While current federal law prohibits NHTSA from mandating in-vehicle seat belt use technologies other than

[10] The majority of states still have "secondary" seat belt use laws, which allow a police officer to issue a citation for belt nonuse only after the motorist has been stopped for another reason (Glassbrenner 2002, 5). The United States is the only country with secondary laws.

the limited 4- to 8-second reminder system, manufacturers are not prevented from voluntarily adopting such technologies, including interlocks. However, the U.S. automobile industry has been wary of pursuing aggressive approaches, such as those specified in the NHTSA prohibition, for both perceived legal and marketing reasons. Nevertheless, Ford Motor Company has initiated a technology enhancement with the introduction of its BeltMinder™ (a registered company trademark) now on all Ford vehicles—a system of warning chimes and flashing lights that operates intermittently for up to 5 minutes to alert and remind the unbelted driver to buckle up. NHTSA Administrator Dr. Jeffrey Runge urged other manufacturers to follow Ford's lead.[11] Many have responded with plans to deploy enhanced belt reminder systems—technologies that go beyond the NHTSA-required 4- to 8-second reminder—in the United States, with introductions to be phased in during the 2004–2005 model years. All the planned systems include light and chime components but vary in their loudness, urgency, and duration.

In Sweden, Australia, and Japan, where belt use rates are substantially higher than in the United States, enhanced belt reminder systems are being tested and put in vehicles to help persuade the small remaining group of belt nonusers, who are overrepresented in severe crashes, to buckle up. Technological solutions were thought to hold more promise than additional public information campaigns and enfocement efforts (Larsson 2000, 1–2). The European consumer information New Car Assessment Program—EuroNCAP—has established protocols for such systems and rewards manufacturers who meet them with higher safety ratings.[12] No manufacturers are currently developing interlock systems, although General Motors is working with a small business, D&D Innovations, Inc., to make available a seat belt shifter lock as an aftermarket option in the United States.

Clearly, today's environment is far more conducive to the successful introduction of technologies for increasing seat belt use than was that of the early 1970s with respect to both technological advances and driver behavior. Belt use is compulsory in all but one state, belt use rates are

[11] Letters dated February 25, 2002, and March 24, 2003.

[12] The most recent specifications can be found in the EuroNCAP Belt Reminder Protocol, Doc 61b, Version November 2002.

significantly higher, belts are better designed, and sensing technologies are more sophisticated and reliable. Nevertheless, the pace and type of technology introduction continue to be affected by the interlock experience. While sympathetic to NHTSA's appeal for enhanced belt use technologies, the industry is understandably sensitive to the implications of overly aggressive and costly systems that are poorly accepted by potential customers. And for its part, NHTSA is still prohibited by Congress from mandating more aggressive technologies.

STUDY APPROACH

In view of the history of seat belt use technology development in the United States, the successful introduction of new technologies is likely to depend on a careful balancing of system effectiveness and acceptability. "Effectiveness" is typically measured as the increase in belt use attributable to a technology. Since belt use is clearly correlated with fatality and injury reduction, it serves as a reasonable proxy for these consequences (which are not currently available in sufficient numbers to provide statistically reliable measures). "Acceptability" is closely related to effectiveness in that motorists are inclined to resist, by one means or another, any technology that they find excessively intrusive. And if they defeat it by disabling, selective purchasing, or political action (as they did in the early 1970s), a technology's actual effectiveness may reduce to zero no matter what its potential safety impact might be. Hence to be effective, a seat belt use technology must be sufficiently intrusive to prompt motorists to act, but not so intrusive that it exceeds their threshold for tolerance.

The available technologies can be ordered logically according to degree of intrusiveness. They range from belt reminder systems that provide a minimal visual and auditory prompt to buckle up, to demanding ones that are more insistent and persistent, to interlock systems that simply prohibit the unwanted behavior (e.g., the unbelted driver is unable to shift the car into gear). As a general principle, which is corroborated by the evidence in Chapter 4, the more intrusive the system, the less acceptable it is likely to be to motorists. That said, it is important to note that acceptability is not an issue for the majority of drivers who are

habitual seat belt users and thus will never or rarely experience the intervention, no matter how intrusive it is.

The study committee investigated what is known about both the effectiveness and the acceptability of seat belt use technologies. It reviewed the available literature, held closed-session briefings with key automobile manufacturers and suppliers, and reviewed the results of in-depth interviews and focus groups conducted by NHTSA for this study.[13] Interviews were thought to be more useful than a large population survey because demonstration of the technologies with follow-up questions would provide more valid data than asking hypothetical questions to respondents unfamiliar with the devices. The objective of the in-depth interviews and focus groups was to obtain a greater understanding of the perceived effectiveness and acceptability of four technologies that were judged to span a wide range of intrusiveness—from the Ford BeltMinder, to a more aggressive Saab prototype belt reminder system (where the chime increases in intensity with vehicle speed), to an entertainment interlock (which prevents playing the radio or stereo unless belts are buckled), to a transmission interlock (which prevents putting the vehicle in gear unless belts are buckled). The results show a convergence of responses that are indicative of the likely consumer reaction to new seat belt use technologies. Finally, the committee was briefed by the NHTSA Chief Counsel in an effort to learn to what extent the agency views the current statutory and regulatory restrictions on seat belt use technologies as impediments to their introduction in the marketplace.

FINDINGS

New seat belt use technologies exist that present opportunities for increasing belt use without being overly intrusive. The current NHTSA-required belt reminder has proved ineffective in further increasing belt use (Westefeld and Phillips 1976, 2). There is no scientific basis for the 8-second maximum duration of the system. Many motorists—the

[13] One hundred six in-depth interviews of 89 part-time users and 17 hard-core nonusers each were conducted in Phoenix, Arizona; Portsmouth, New Hampshire; and St. Louis, Missouri. In addition, four focus groups for a total of 35 full-time users were held in St. Louis. Participants were limited to those who had purchased a vehicle within the previous 12 months or intended to purchase one within the next year, and thus may not be typical of the general population.

majority of whom do not buckle up until some time after starting their vehicles (70 percent according to General Motors' survey data)—report that they ignore the chime, simply do not hear it over the radio, or have forgotten it by the time they are backing down the driveway, and that they could use a stronger reminder to buckle up. In contrast, the results from the NHTSA interviews conducted for this study and the manufacturer briefings suggest that motorists would be aware of and heed the characteristics of enhanced belt reminder systems now being introduced by industry. More important, although the results are based on a limited sample, many part-time users interviewed by NHTSA—the primary target group for the technology—were receptive to the new systems. Nearly two-thirds rated the reminders "acceptable," and approximately 80 percent thought that they would be "effective."

Preliminary research on the only system currently deployed in the United States—the Ford BeltMinder—found a statistically significant 7 percent increase in seat belt use for drivers of vehicles equipped with the Ford system compared with drivers of unequipped late-model Fords (Williams et al. 2002, 295).[14] The results were gathered in two Oklahoma locations and provide a snapshot of belt use behavior, but they are suggestive of the potential benefits of enhanced belt reminder systems. A subsequent study in Boston of drivers with BeltMinder-equipped Ford vehicles found that, of the two-thirds who activated the system, three-quarters reported buckling up and nearly half of all respondents said their belt use had increased (Williams and Wells 2003, 6, 10).

According to the automobile manufacturers and suppliers, enhanced belt reminder systems can be provided at minimal cost for front-seat occupants because of the availability of sensors that can detect the presence of front-seat occupants for advanced air bag systems.[15] Rear-seat systems appear costly compared with front-seat systems because of the absence of rear-seat sensors on many vehicles, installation complexities (e.g., removable seats, child seats), and low rear-seat occupancy rates. However, lower-cost systems that alert the driver when rear-seat occu-

[14] Belt use was 76 percent for drivers in vehicles equipped with the BeltMinder compared with 71 percent for drivers in vehicles without the reminder system—a 7 percent increase and a 5 percentage point gain.

[15] The committee was provided with more specific cost data in the briefings, but the manufacturers indicated that the data are proprietary.

pants have not buckled up or have unbuckled their belts during a trip are currently available on some vehicles in Europe. The risks posed to all vehicle occupants by unbelted rear-seat occupants, particularly in more severe crashes, suggest that the benefits of full-scale rear-seat reminder systems could be significant (Ichikawa et al. 2002). Furthermore, recent efforts by NHTSA and industry to encourage parents to place their children in rear seats away from front-seat air bags has increased parental interest in systems that monitor belt use in rear seats.

Transmission interlock systems are perceived to be highly effective—more than 85 percent of all respondents to the NHTSA interviews and focus groups rated them effective. However, fewer than half rated them acceptable. The highest percentage of respondents who rated the transmission interlock not acceptable—71 percent—came from the small group of hard-core nonusers. Objections to the entertainment interlock, which was thought to be most effective for younger drivers, were weaker among full-time users and even among the hard-core nonusers. This result can be attributed in part to the fact that the system would not be experienced by some people (e.g., older people who do not use the radio, drivers on short trips) or could be circumvented (e.g., by installing an aftermarket stereo). Part-time users, who found the entertainment interlock slightly more objectionable than the transmission interlock, were the exception.

Interlock systems could be engineered to avoid many motorists' objections. For example, they could be designed to enable drivers to start their cars without buckling up and to drive in reverse and perhaps at low speeds to accommodate the majority of drivers who do not buckle up before starting their vehicles. However, the negative reaction indicated by the NHTSA interviews and focus groups and the hesitancy of industry to reintroduce interlock systems for the general driving public suggest that, for the moment, their use be considered only for certain high-risk groups (e.g., drivers impaired by alcohol, teenage drivers) who are overrepresented in crashes.

The current legislation prohibiting NHTSA from requiring new seat belt use technologies other than the ineffective 4- to 8-second belt reminder is outdated and unnecessarily prevents the agency from requiring effective technologies to increase belt use. Seat belt use has grown fivefold since 1974. Many more motorists now recognize the benefits of

seat belts and appear to be receptive to their use. However, NHTSA does not currently have the legislative authority to establish performance standards to encourage development of minimum performance criteria for the most effective systems or to require them to be sold in the U.S. market.

RECOMMENDATIONS

On the basis of its findings, the committee reached consensus on the following recommendations:

1. **Congress should amend the statute regarding belt reminder systems by lifting the restrictions on systems with lights and chimes longer than 8 seconds, which would provide NHTSA more flexibility and the authority to require effective belt reminder technologies.** At this time, the committee does not see any compelling need to delete the prohibition on requiring interlock systems. However, this subject should be revisited in 5 years (see Recommendation 8).
2. **Every new light-duty vehicle should have as standard equipment an enhanced belt reminder system for front-seat occupants with an audible warning and visual indicator that are not easily disconnected. Any auditory signal should be audible above other sounds in the vehicle. For the short term, manufacturers should be encouraged to provide these systems voluntarily** so that field experience can be gained concerning the absolute and differential effectiveness and acceptability of a range of systems. Those who rate vehicles—NHTSA, the Insurance Institute for Highway Safety, Consumers Union—should be urged to note those vehicles that have belt reminder systems in their consumer safety rating publications.
3. **NHTSA should encourage industry to develop and deploy enhanced belt reminder systems in an expeditious time frame, and NHTSA should monitor the deployment. As differences in effectiveness and acceptability of belt reminder systems are identified, manufacturers should install systems that are determined by empirical evidence to result in the greatest degree of effectiveness while remaining acceptable to the general public. Should voluntary efforts not produce sufficient results, NHTSA should mandate the most effective acceptable**

systems as determined by the current data. The agency should also conduct studies to identify factors that will increase the effectiveness and acceptability of the systems.

4. **Rear-seat reminder systems should be developed at the earliest possible time as rear-seat sensors become available,** to take advantage of the benefits of restrained rear occupants to the safety of both front- and rear-seat occupants. Until that time, manufacturers should provide systems that notify the driver if rear-seat occupants either have not buckled up or have unbuckled their belts during a trip.
5. **NHTSA and the private sector should strongly encourage research and development of seat belt interlock systems for specific applications.** For example, the courts should consider requiring the use of interlocks for motorists with driving-under-the-influence-of-alcohol convictions or with high numbers of points on their driver's licenses. Interlocks could also be made available for other high-risk groups, such as teenage drivers. Insurance companies could lower premium rates for young drivers who install interlock systems. Finally, interlocks could be installed on company fleets.
6. **Seat belt use technologies should be viewed as complementary to other proven strategies for increasing belt use, most particularly enactment of primary seat belt use laws that enable police to pull over and cite drivers who are not buckled up and well-publicized enforcement programs.** Seat belt use technologies have the potential to increase belt use, but their effect is largely confined to new vehicle purchasers, whereas seat belt use legislation affects all drivers.
7. **Congress should provide NHTSA with funding of about $5 million annually[16] to support a multiyear program of research on the effectiveness of different enhanced seat belt reminder systems.** NHTSA should coordinate its efforts with other federal agencies, such as the Centers for Disease Control and Prevention, that are conducting related research. The research could involve undertaking more

[16] The committee developed the $5 million estimate for the cost of this research in consultation with NHTSA staff and consultants, who, together, have been involved in many similar efforts to estimate the effectiveness of various motor vehicle safety features. Although the figure is not intended to be precise, it should be about the right amount given the complexity of the proposed activities and NHTSA's extensive experience in conducting such evaluations.

comprehensive studies of the effects of belt reminder systems on belt use; conducting controlled fleet studies of aggressive reminder systems; gathering more survey data on the effectiveness and acceptability of belt reminder systems from existing NHTSA and public health sources; and examining design issues, such as loudness of the chime, desirability of muting the radio when the chime is sounding, duration and cycling of the systems, and the presence and design of any cutoff capability. This research should help establish the scientific basis for regulation of belt reminder systems should regulation be needed.

8. **In 2008 another independent review of seat belt use technologies should be conducted to evaluate progress and to consider possible revisions in strategies for achieving further gains in belt use, including elimination of the statutory restriction against NHTSA's requiring vehicle interlock systems.**

The benefits of enhanced seat belt use technologies could be significant. If increases in belt use rates on the order of 7 percent (or 5 percentage points) found in the initial evaluation of the Ford BeltMinder could be achieved nationally, a minimum of 1,250 additional lives could be saved annually, according to NHTSA estimates (Glassbrenner 2002, 1), once all passenger vehicles have been equipped with enhanced belt reminder systems. These figures do not include the potential lives saved from the installation of reminder systems for rear seat belts or the hundreds of thousands of injuries that could also be prevented each year. The modest additional costs of installing the systems, particularly once sensor systems are available for all seating positions, and the annual $5 million cost of conducting the recommended multiyear research program, constitute a small price to pay for the lives saved and the hundreds of thousands of costly injuries prevented.

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Abbreviations

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NHTSA	National Highway Traffic Safety Administration

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1

INTRODUCTION

Seat belts have proved to be one of the most effective safeguards against death and injury in a vehicle crash (Dinh-Zarr et al. 2001, 48). Efforts to encourage seat belt use span 30 years, yet in 2002 approximately one-quarter of U.S. drivers and front-seat passengers were still observed not to be buckled up (Glassbrenner 2002). The number was considerably higher for drivers with a high risk of crash involvement; nearly 60 percent of drivers in high-speed fatal crashes were unrestrained despite the fact that drivers and passengers can reduce their risk of dying in a crash nearly by half simply by buckling up (O'Neill 2001). U.S. belt use rates are substantially lower than in many other industrialized nations. Canada, many northern European countries, and Australia can document belt use rates that exceed 90 percent (O'Neill 2001).

Making further gains in U.S. belt use poses a considerable challenge. The proven safety benefits, better design, and especially laws combined with aggressive enforcement have contributed to increased belt use. Nevertheless, on average, one in four drivers and passengers continues to ride unbuckled. Consequently, technological approaches for changing motorists' behavior are currently being explored. In legislation passed in December 2001, Congress requested that the National Highway Traffic Safety Administration (NHTSA) contract with the Transportation Research Board to undertake a study to consider whether newly developed vehicle technologies may present opportunities for increasing seat belt use without being overly intrusive.[1]

The study charge comprises three tasks:

- Examine the potential benefits of technologies designed to increase belt use,
- Determine how drivers view the acceptability of the technologies, and
- Consider whether legislative or regulatory actions are necessary to enable their installation on passenger vehicles.

[1] The request was contained in Conference Report 107-308 to accompany Appropriations for the Department of Transportation and Related Agencies for fiscal year 2002, June 22, 2001 (see Appendix A).

The scope of the study is further limited in the following ways. First, the congressional request is focused on passenger vehicles only, which include cars and light-duty trucks driven for personal use (i.e., sport utility vehicles, vans, and pickup trucks). Second, the focus is on technologies in new vehicles and new car buyers, although aftermarket devices are considered. This has implications for belt use gains because many new car drivers already buckle up (Williams et al. 2002, 295). Third, issues of belt comfort and convenience and perceived effectiveness are considered as factors affecting belt use. However, belt design is considered to be outside the study scope. Finally, although the study committee recognized the wide range of other strategies for increasing belt use, it did not attempt to analyze them in any depth. Congressional interest in this study is focused on an assessment of the potential for technology to increase seat belt use and the extent to which federal laws and regulations pertaining to these technologies may inhibit their introduction.

SEAT BELT EFFECTIVENESS

Use of seat belts is the single most effective means of reducing fatal and nonfatal injuries in motor vehicle crashes (Dinh-Zarr et al. 2001, 48). NHTSA estimates that approximately 147,000 lives were saved between 1975 and 2001 because of seat belt use (NHTSA 2002b, 2). However, failure to buckle up continues to result in thousands of deaths and hundreds of thousands of injuries each year at an estimated societal cost of $26 billion in medical care, lost productivity, and other injury-related costs (Blincoe et al. 2002, 55).

Seat belts protect vehicle occupants during a crash in two ways. They reduce the frequency and severity of occupant contact with the vehicle's interior, and they prevent ejection from the vehicle (Evans 1991, 232). Specifically, when a crash occurs, occupants are traveling at the vehicle's original speed at the moment of impact. Seat belts help prevent occupants from rapid and penetrating contact with the steering wheel, windshield, or other parts of the vehicle's interior immediately after the vehicle comes to a complete stop, reducing the fatalities and injuries caused by this "second collision." Seat belts also protect occupants from ejection, one of the most severe events that can occur in a

crash. Nearly half of the reduction in fatality risk from using seat belts in cars and light trucks can be traced to the prevention of ejection from vehicles (Evans 1991, 247).

In all types of crashes involving passenger cars, seat belts reduce the risk of fatal injury for drivers and front-seat passengers by about 45 percent; in light trucks, the reduction is about 60 percent (Kahane 2000, 28).[2] Moreover, seat belts reduce the risk of moderate-to-critical injury by 50 percent in crashes for passenger vehicle occupants and by 65 percent for light truck occupants (NHTSA 2002b, 1).[3] Belt use by rear-seat occupants is also beneficial, not only for the rear-seat passengers but also for the driver and front-seat passengers. A Japanese study of crashes resulting in occupant injury found that unbelted rear-seat occupants increase the risk of death for belted front-seat occupants by nearly fivefold. The increased risk of injury comes from unbelted rear-seat occupants, who are thrown forward into the back of the front seat with immense force in a crash (Ichikawa et al. 2002, 43). An earlier study also found that unbelted rear-seat occupants increase the fatality risk to front-seat occupants by nearly 4 percent in all crashes, and by nearly 30 percent in severe frontal crashes (Park 1987, 13). The adverse effect of unbelted rear-seat occupants is presumably attributable to the increased loading force that they impose on front-seat occupants in a crash (Park 1987, 1).

Even a small increase in belt use should have large benefits. NHTSA estimates that a percentage point increase in belt use results in 250 lives saved per year (Glassbrenner 2002, 1). Research on the characteristics of seat belt nonusers suggests that the benefits could be higher, because many of those who refrain from buckling up tend to exhibit other high-risk behaviors (e.g., alcohol use, speeding) and are more frequently involved in crashes (Haseltine 2001).

[2] Three-point seat belts, which integrate lap and shoulder belts in a single nondetachable unit, provide good protection in frontal crashes (50 and 53 percent fatality reduction in cars and light-duty trucks, respectively) and in rear-impact crashes, particularly for light-duty trucks (56 and 81 percent fatality reduction, respectively) (Kahane 2000, 28). Three-point belts offer more limited protection for cars (21 percent fatality reduction) than for light-duty trucks (48 percent fatality reduction) in side-impact crashes, reflecting greater compartment intrusion to cars in such crashes where belts are unable to prevent fatalities (Kahane 2000, 29). The highest level of protection afforded by three-point belts for both cars and light-duty trucks is for prevention of occupant ejection in rollover crashes where vehicle rollover is the primary crash event (74 and 80 percent fatality reduction, respectively) (Kahane 2000, 28).

[3] Air bags supplement seat belts in providing protection. Air bags alone are 10 percent and 14 percent effective in reducing deaths and injuries, respectively (NHTSA 1999 in Dinh-Zarr et al. 2001, 48). Between 1987 and 2001, approximately 8,400 lives were saved by air bags (NHTSA 2002b, 3).

STUDY CONTEXT

Introduction of Seat Belts

Seat belts first became standard equipment for the driver and front-seat occupants in 1964 in response to state laws (O'Neill 2001). Then, in 1966, the National Traffic and Motor Vehicle Safety Act authorized the federal government to establish national safety standards for motor vehicles and created a new agency, subsequently known as NHTSA, to carry out this function.[4] Federal Motor Vehicle Safety Standard (FMVSS) 208 was one of the original 19 safety regulations. It required that, effective January 1, 1968, all new cars be equipped with both lap belts and shoulder harnesses in the front outboard seating positions and lap belts in other seating positions (Kratzke 1995, 1).[5] In 1973 the federal standard was upgraded to require three-point belt systems that connect the shoulder to the lap belt for the front seating positions (O'Neill 2001).

Despite the requirement that vehicles be equipped with seat belts, belt use was low. According to an observational survey of drivers, lap belt use alone ranged from 9 to 16 percent for 1968 to 1971 model-year (MY) vehicles; shoulder and lap belt use ranged from 1 to 6 percent for the same MY (Robertson et al. 1972). Although some efforts were made to educate drivers about the benefits of belt use, studies by NHTSA and the Insurance Institute for Highway Safety indicated that educational efforts alone were not effective in increasing belt use (O'Neill 2001; States 1973, 434–435). Thus, NHTSA turned to technological solutions to boost belt use.

Seat Belt Ignition Interlock

The primary focus of the newly created National Highway Traffic Safety Administration was on passive restraint systems—primarily air bags, but also automatic seat belts (Kratzke 1995, 2). These systems would

[4] For a short period (1967 to 1970), all highway safety activities were merged under a single entity, the National Highway Safety Bureau within the Federal Highway Administration (FHWA). The Federal-Aid Highway Act of 1970 elevated the bureau to a separate administration independent of FHWA named the National Highway Traffic Safety Administration (TRB 1990, 52).

[5] The National Traffic and Motor Vehicle Safety Act of 1966 intended that safety standards not depend on current technology and could be "technology forcing" in the sense of inducing the development of superior safety design (Motor Vehicle Manufacturers Association *v.* State Farm Mutual Automobile Insurance Company, 463 U.S. 29, 49, 1983).

automatically protect vehicle occupants, hence the term "passive restraints." Both technical and political factors delayed their introduction. Thus, on January 1, 1972, as an alternative to passive restraints, NHTSA required that all cars manufactured for sale in the United States be equipped with a flashing light and buzzer seat belt reminder system, which activated continuously for at least 1 minute if the vehicle was placed in gear and the driver or front outboard passenger was not belted (*Federal Register* 1971, 4601). Soon thereafter, NHTSA required that, effective August 15, 1973, all new cars not providing automatic protection be equipped with an ignition interlock that prevented the vehicle from starting if the driver or front-seat passengers were not buckled up (*Federal Register* 1973). The interlock requirement was intended as an interim measure to increase belt use until acceptable automatic systems became available (Kratzke 1995, 2).

The interlock immediately boosted belt use rates, but some motorists found the system intrusive and learned to disconnect it. In response to numerous complaints, Congress rescinded the interlock requirement 1 year later, in 1974. Legislation was passed[6] that prohibited NHTSA from issuing any future safety standard that required either an interlock system or a continuous buzzer warning that sounded for more than 8 seconds after the ignition was turned to the "on" or "start" position. NHTSA revised FMVSS 208 accordingly. The modified standard, which went into effect for cars produced after February 1975 and remains in effect today, requires manufacturers to provide a warning light of no more than 4 to 8 seconds that is activated when the ignition is turned on and a buzzer that sounds for the same duration unless the driver is belted.[7]

Seat Belt Use Laws

Following the interlock requirement interdiction, NHTSA returned its focus to passive restraints to encourage belt use. The history of this 15-year controversy is too lengthy to record here, but in 1984 a regulation was crafted by then Secretary of Transportation Elizabeth Dole that resulted in the phase-in of automatic protection systems—both passive

[6] Public Law 93-492, Sec. 109, Occupant Restraint Systems, October 27, 1974.

[7] Occupant crash protection, 49 C.F.R. § 571.208 (2001).

seat belts and air bags—but offered the possibility of rescinding the requirement if enough states enacted mandatory seat belt use laws that met NHTSA's regulatory criteria (Kratzke 1995, 8).[8] The regulation resulted in the phase-in of automatic protection systems—both passive belts and air bags. Air bags, in conjunction with manual lap and shoulder belts, proved to be more comfortable, effective, and popular with consumers. Automakers began switching from passive belts to air bags, which Congress ultimately mandated. The regulation also stimulated many states to pass seat belt use laws in what has proved to be one of the most effective approaches for increasing belt use (Dinh-Zarr et al. 2001, 48).

New York, in 1984, was the first state to enact seat belt use legislation. By 1992, largely in response to industry lobbying, 42 states and the District of Columbia had enacted belt use laws (Haseltine 2001). Observed belt use rates rose accordingly, from 14 percent in 1984 to 62 percent in 1992 (Figure 1-1). Today, all states except New Hampshire have belt use laws that apply to adults.[9] According to NHTSA's National Occupant Protection Use Survey (Glassbrenner 2002, 1), observed national belt use rates reached 75 percent in 2002. In the past decade, however, the rate of belt use gains has slowed (Figure 1-1), in part because of the reluctance of many states to promote enforcement through "primary" seat belt use laws (i.e., those that specify failure to buckle up as the sole justification needed to stop and cite a motorist).[10] The slower rate of progress also reflects the difficulty of convincing the remaining group of nonusers to buckle up.

TECHNOLOGY REVISITED

Since the interlock requirement interdiction nearly 30 years ago, the protection afforded by seat belts in crashes has become widely recognized, seat belt use laws are nearly universal, belt use rates have increased

[8] The 1984 amendment to FMVSS 208 required automobile manufacturers to install automatic restraint systems (air bags or automatic seat belts) unless two-thirds of the nation's population was covered by seat belt use laws (49 FR 28962).

[9] The majority of state laws cover seat belt use for the driver and front-seat occupants only. However, in 18 states, seat belt use laws cover all seating positions (NHTSA 2002a, 184).

[10] The majority of states (32) still have "secondary" seat belt use laws, which allow a police officer to issue a citation for belt nonuse only after the motorist has been stopped for another reason (Glassbrenner 2002, 5). The United States is the only country with secondary laws.

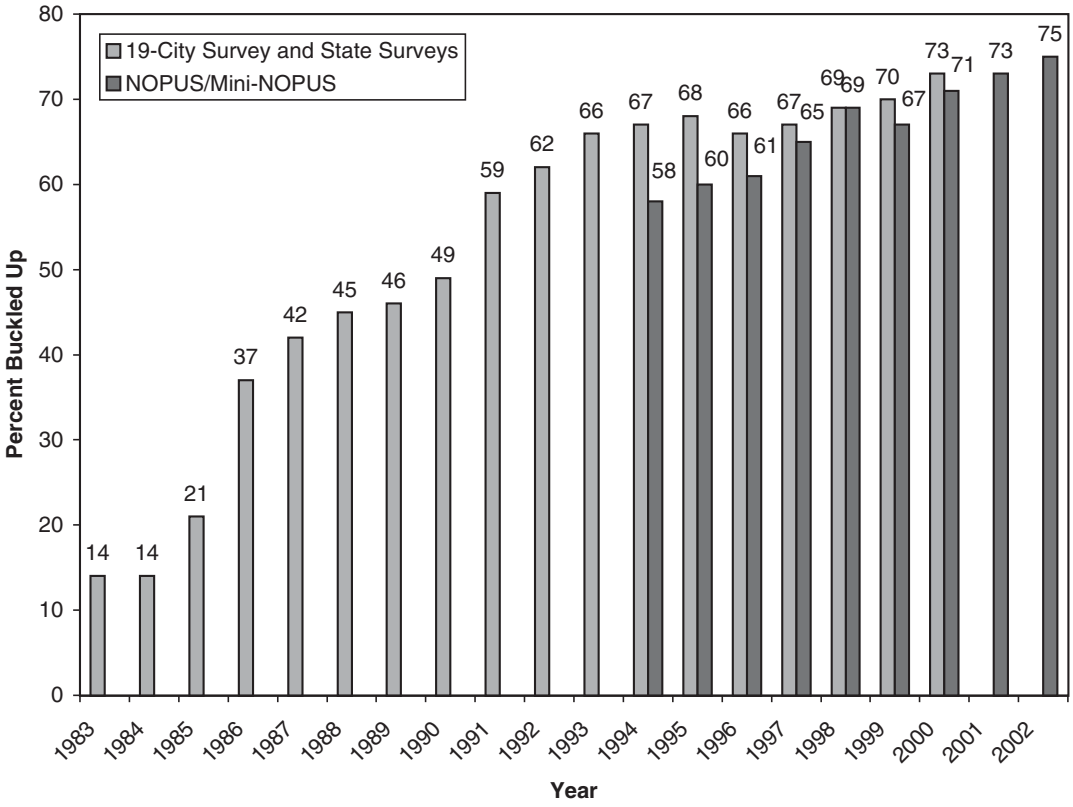

Figure 1-1 U.S. observed seat belt use. [Sources: NHTSA, 1983–1990: 19-City Survey; 1991–2000: State Surveys; 1994–2002: National Occupant Protection Use Survey (NOPUS)/Mini-NOPUS.]

sharply, and seat belts are better designed and more comfortable to wear. In addition, technologies that monitor the driver and make driving safer and easier are rapidly appearing on vehicles. They include intelligent cruise control and collision- and road departure–avoidance warning systems. Motorists are becoming accustomed to such technologies, and the cost of their installation is declining as sensors and other facilitating technologies are manufactured in volume.

In 1998, NHTSA was petitioned to mandate effective belt use technologies, such as belt reminder systems that go beyond the existing 8-second reminder.[11] However, NHTSA denied the petition, stating that

[11] Letter and Petition from Carl E. Nash, Ph.D., to Ricardo Martinez, M.D., Administrator, NHTSA, dated December 17, 1998.

it did not have the authority to require audible warnings outside the 8-second reminder (*Federal Register* 1999, 60,625).

Then, Ford Motor Company introduced an enhanced seat belt reminder system—a system that goes beyond the NHTSA-required 4- to 8-second belt reminder—for the U.S. market in selected MY 2000 passenger vehicles. Following the NHTSA-required 8-second reminder, the Ford BeltMinder™, a registered trademark of Ford Motor Company, resumes a warning chime and flashing light at approximately 65 seconds if the driver remains unbuckled while the engine is running and the vehicle is moving at more than 3 mph (4.8 km/h). The system flashes and chimes for 6 seconds; then it pauses for 30 seconds. This cycle repeats for up to 5 minutes. By MY 2002, all Ford vehicles were equipped with the enhanced belt reminder for the driver, with a phase-in for the right front-seat passenger starting with MY 2003 vehicles.

In February 2002, Dr. Jeffrey Runge, NHTSA Administrator, urged the automobile industry to follow Ford's lead and voluntarily introduce enhanced belt reminder systems and other appropriate technologies as an added incentive for motorists to buckle up.[12]

Belt reminder systems are also being developed for the European and Australian markets to convince remaining groups of belt nonusers in those markets to buckle up. The European New Car Assessment Program (EuroNCAP), which is modeled on a similar U.S. consumer safety rating program,[13] offers bonus points for vehicles equipped with belt reminder systems that meet certain performance criteria, thus providing a strong incentive for manufacturers to introduce effective technologies.

KEY STUDY ISSUES, DEFINITION OF TERMS, AND APPROACH

In light of the history of the 1970s interlock experience, a major goal of manufacturers is to introduce technologies that encourage seat belt use but that are acceptable to customers and will not be overly intrusive. Thus, the manufacturers are developing belt reminder systems for the new car market rather than more aggressive interlock technologies that

[12] Letters dated February 25, 2002, and March 24, 2003.

[13] NHTSA's NCAP program, begun in 1978, provides comparative information to consumers on crashworthiness of passenger vehicles.

interfere with vehicle operations. Nevertheless, for the purposes of this study, the full range of seat belt use technologies, from belt reminder systems to interlocks, is being considered.

The first two tasks of the committee are to consider what is known about the potential effectiveness and acceptability of the technologies. "Effectiveness" is typically measured as the increase in belt use attributable to a technology. Because seat belt use is clearly correlated with fatality and injury reduction, it serves as a reasonable proxy for these consequences (i.e., lives saved and injuries avoided), which are not currently available in sufficient numbers to provide statistically reliable estimates.

"Acceptability" is closely related to effectiveness, and they can be inversely related. For example, initially the 1973 ignition interlock was very effective in increasing belt use. However, consumers quickly learned to defeat the system, and Congress ultimately prohibited its installation in passenger vehicles. Thus, if a technology is so intrusive that a consumer is motivated to defeat it by disabling, selective purchasing, or political action (as in the 1970s), a technology's actual effectiveness may reduce to zero no matter what its potential safety impact might be. Although consumer acceptability is a concern, the vast majority of motorists today buckle up, in contrast to the 1970s, and should not even be aware of the new systems, particularly if they are engineered properly to reflect typical belt-buckling habits.[14]

The committee approached the first task of its charge—to determine the potential effectiveness of the technology—by reviewing the literature for studies of early experience (1970s) with belt reminder and interlock systems. It then examined more recent but limited field data on the effectiveness of current enhanced belt reminder systems. It also sought proprietary information directly from the major automobile manufacturers and suppliers by meeting with them about new belt system characteristics, plans for deployment, and industry assessments of system effectiveness.

[14] For example, research on buckling habits, which is discussed in greater detail in Chapter 4, suggests that the vast majority of drivers buckle up after starting the vehicle, even when it is first moving. Belt technologies should be designed to reflect these habits.

Data on likely consumer acceptance of new seat belt use technologies—the second task—were limited and dated. Thus, NHTSA conducted in-depth interviews of belt nonusers (i.e., those who reported not using seat belts all the time) especially tailored for this study to ascertain consumer views on the acceptability and potential effectiveness of technologies ranging from belt reminder to interlock systems. Focus groups of full-time belt users were also conducted to ensure that proposed technologies would not have unintended negative effects on those who consistently buckle up. NHTSA developed its approach after discussing various options for soliciting consumer response with the committee. Individual committee members commented directly on the study design, screening criteria, and interview and focus group guides. Finally, the committee requested market research data directly from the automobile manufacturers with regard to consumer acceptance of new seat belt use technologies.

To address the third task—to determine whether changes in regulation or legislation are necessary to facilitate introduction of effective technologies—the committee requested that NHTSA's Chief Legal Counsel provide the agency's current interpretation of the statutory and regulatory restrictions affecting both belt reminder and interlock systems.

ORGANIZATION OF REPORT

The remainder of this report elaborates the committee's findings from its investigation of each task of its charge. In Chapter 2, an overview is provided of what is known about the target group for seat belt technologies—belt nonusers—including key factors that affect belt use, and implications for current technology introduction are described. In Chapter 3, the history of the 1970s experience with belt reminder and interlock systems, as well as other key approaches for increasing belt use, are reviewed with an eye to what lessons can be brought forward to today. Chapter 4 is focused on current information concerning the potential effectiveness and acceptability of recently introduced seat belt use technologies. The results of the literature review, manufacturer briefings, and NHTSA interviews and focus groups conducted for this

study are summarized, and the implications for the introduction of belt use technologies are discussed. In Chapter 5, NHTSA's interpretation of the current statutory and regulatory prohibitions concerning the introduction of new seat belt use technologies is reviewed, and manufacturers' concerns are explored. The committee then provides its findings and recommendations concerning the role of technology in increasing belt use.

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NHTSA	National Highway Traffic Safety Administration
TRB	Transportation Research Board

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2

SEAT BELT USE AND CHARACTERISTICS OF NONUSERS

Seat belt use technologies currently being introduced in passenger vehicles to induce greater belt use are targeted toward the approximately 25 percent of U.S. drivers and front-seat passengers who are observed not to be buckled up (Glassbrenner 2002, 1). In this chapter, what is known about the nonuser population and its various subgroups is reviewed. The literature and recent surveys on the characteristics associated with seat belt use are summarized, and the reasons and attitudes that underlie nonbuckling behavior are examined. In the final section, inferences are drawn concerning the potential for seat belt use technologies to induce the nonuser population to buckle up.

OVERVIEW OF SEAT BELT USE IN THE UNITED STATES

Sources of Information

The National Highway Traffic Safety Administration (NHTSA) conducts two surveys on seat belt use in the United States. The National Occupant Protection Use Survey (NOPUS), a probability-based observational survey of belt use by drivers and front-seat occupants of passenger vehicles, has been conducted annually since 1994. This survey provides nationally representative data on observed belt use in passenger vehicles and some demographic detail, such as belt use by race, ethnicity, and gender (Glassbrenner 2002, 13).[1] The companion Motor Vehicle Occupant Safety Survey (MVOSS), a telephone survey that provides self-reported information on belt use, has been conducted biennially since 1994.

NHTSA bases its estimates of national belt use on the observational data collected by the NOPUS. However, the survey is limited to observations of drivers and other front-seat occupants during daylight hours

[1] The NOPUS is conducted in two studies that provide different types of information. The Moving Traffic Study, conducted at random road sites at which traffic is typically in motion, provides a quick general assessment of belt and helmet use. The Controlled Intersection Study, conducted at intersections controlled by a stop sign or stoplight at which traffic is slowed or stopped, permits more detailed data collection. Both studies collect data during daylight hours on general roadways (Glassbrenner 2002, 13).

and thus is not necessarily representative of high-risk driving times when belt use may be lower (Glassbrenner 2002, 18). The NOPUS can distinguish only two groups—those who are wearing their belts at the time of observation and those who are not. Thus, observed users comprise full-time users and some part-time users who are buckled up at the time of observation. Observed nonusers comprise a mix of part-time users, who for whatever reason were not buckled up at the time of observation, and habitual nonusers.

In comparison, the MVOSS can distinguish many more belt use and nonuse categories through self-reported responses to the survey questions. However, NHTSA does not consider the MVOSS a good indicator of national belt use. Self-reported belt use rates from the telephone survey are typically about 10 percentage points higher than from the NOPUS (Glassbrenner 2002, 13). The difference reflects the well-established tendency for survey participants to give socially desirable rather than completely truthful answers. It also reflects a large number of part-time respondents, who typically consider themselves to be belt users. Nevertheless, the MVOSS is the only source of unobservable demographic and socioeconomic detail about belt nonusers and insights into the reasons why motorists do not always buckle up (Glassbrenner 2002, 13).

Both the NOPUS and the MVOSS were analyzed for this study to determine what is known about the target group for seat belt use technologies—in particular, the size and characteristics of various nonuser groups. In addition, the literature on seat belt use was reviewed, and interviews and focus groups were conducted by NHTSA especially for this study to explore motorists' behaviors and attitudes concerning belt use as well as reactions to seat belt use technologies.[2]

Estimates of Belt Use

The most recent NOPUS (2002) reported a 75 percent observed national belt use rate for drivers and front-seat occupants of passenger vehicles (Glassbrenner 2002, 1). Belt use rates vary widely by state. Washington, California, Puerto Rico, and Hawaii reported observed belt use rates of

[2] A more detailed discussion of the methodology for and results of these NHTSA-sponsored interviews and surveys is presented in Chapter 4.

90 percent or higher, while Massachusetts recorded an observed belt use rate of 51 percent, the lowest reported (Glassbrenner 2003b, 2). Belt use rates also differ by vehicle type. The 2002 NOPUS observed belt use rates of 77 percent for passenger vehicles and 78 percent for vans and sport utility vehicles. Belt use rates for pickup trucks lagged at only 64 percent (Glassbrenner 2002, 8).

The vast majority of drivers (83 percent) interviewed in the most recent MVOSS (2000) reported wearing their seat belts "all the time" while driving. Another 9 percent reported wearing their belts "most of the time" (Block 2001, 12). However, closer investigation found inconsistencies in the responses, suggesting that the categories of belt use are more fluid than the descriptors imply. For example, 8 percent of those reporting "all-the-time" use (6.64 percent of all respondents) immediately stated in a follow-up question that they had not worn their seat belts while driving at some time during the past week (Block 2001, 24). Four percent of drivers reported wearing their seat belts "some of the time," while few drivers acknowledged wearing their belts "rarely" (2 percent) or "never" (2 percent) (Block 2001, 12).

The literature on seat belt use typically distinguishes between belt users and nonusers. For the present study, belt users have been grouped into three broad classifications—full-time users, part-time users, and hard-core nonusers. Understanding the relative size and possible differences in attitudes and belt use behavior among different groups of nonusers in particular—the target group for seat belt use technologies—is important to determine their potential receptivity to the new technologies. On the basis of this classification system and data from the most recent MVOSS, 76 percent of drivers can be classified as full-time belt users, 20 percent as part-time users, and 4 percent as hard-core nonusers.[3]

Belt use by rear-seat occupants is not collected by the NOPUS. However, the MVOSS provides self-reported data on rear-seat belt use.

[3] For this classification using the MVOSS data, the full-time user group excludes the 8 percent who classified themselves as wearing their belts "all the time" but who then reported not wearing their belts while driving at some time during the past week (6.64 percent of all respondents). The part-time user group includes this 6.64 percent as well as the 9 percent who reported wearing their belts "most of the time," and the 4 percent who reported wearing their belts "some of the time" for a total of 20 percent. The hard-core nonuser group includes those who reported wearing their belts rarely (2 percent) or never (2 percent) (Block 2001, 12).

Whereas 83 percent of respondents reported wearing their belts "all the time" while driving and 80 percent reported wearing belts as front-seat passengers, only 49 percent reported buckling up when they sat in the rear seat (Block 2001, iv).

CHARACTERISTICS OF NONUSERS

According to the most recent MVOSS, the vast majority (87 percent) of respondents strongly agreed that they would want to be wearing a seat belt in a crash (Block 2001, 91). Even among hard-core nonusers, more than half (56 percent) strongly or somewhat agreed that they would like to be belted in a crash (Block 2001, 92). Similar attitudes were found in the NHTSA interviews and focus groups conducted for the current study. All part-time users and 67 percent of the hard-core nonusers agreed that they greatly or somewhat reduced their risk of injury by wearing a seat belt.[4] (Respondents to the NHTSA interviews and focus groups were classified into three groups. Full-time belt users were identified as those who responded that they forgot to wear their seat belts only once or twice or never in the past month. Hard-core nonusers reported never using a seat belt in the past month. All other respondents were classified as part-time users.) Despite positive attitudes toward belt use, many drivers and occupants continue to ride unbelted. Reasons for not using belts stem from a complex mix of habitual, situational, and attitudinal factors.

Overview of Reasons for Belt Nonuse

Seat belt use is often characterized as a habitual behavior rather than a conscious choice (Calisir and Lehto 2002, 802). Drivers simply follow rules they have developed on the basis of experience, rather than continuously comparing risks against benefits in deciding whether to buckle up. An individual may be triggered to buckle up by sitting in the car or driver's seat, or by some other aspect of driving (Harrison et al. 2000, 20). Similarly, nonusers have failed to develop belt-wearing habits or have

[4] Respondents were asked to indicate which of five possible responses they agreed with the most: (*a*) "I greatly reduce my risk of serious injury in a crash by wearing a seat belt," (*b*) "I somewhat reduce my risk . . . ," (*c*) "I neither increase nor reduce my risk," (*d*) "I somewhat increase my risk," and (*e*) "I greatly increase my risk."

developed a habit of nonuse (Harrison et al. 2000, 20). The habit of wearing a seat belt is learned and can be influenced by the behavior of others, including parents, peers, and children (Harrison et al. 2000, 19; Shinar 1993, 754).

Belt use may also be situational. This is particularly characteristic of part-time users, who may be cued to buckle up in some driving situations but not in others (Harrison et al. 2000, 20). Many part-time users interviewed by NHTSA for the current study and in earlier focus groups reported that they did not wear seat belts in what they considered low-risk situations (Bentley et al. 2003, 18; Bradbard et al. 1998, 12). These included short trips on familiar roads at relatively low speeds. However, these situational users tended to buckle up in poor driving conditions, such as bad weather; on longer trips involving high-speed driving on Interstates; and under congested conditions where other drivers could pose a danger (Bentley et al. 2003, 19–20).

Belt use behavior may also stem from attitudes and beliefs. Nonuse of seat belts has been related to risk-taking and other problem behaviors, such as substance abuse (Wilson 1990, 175). Many hard-core nonusers object to being forced to buckle up, believing that belt use should be a matter of personal choice (Bentley et al. 2003, 20).

Belt use is also affected by ease of use and comfort of the belt system. For example, pressure or pain from seat belts (e.g., the belt is too tight or it chokes) was reported in the most recent MVOSS as the most common complaint among those who disliked seat belts or found them annoying, particularly among women (Block 2001, 8). Fortunately, measures to improve the ease and comfort of belt use have been introduced in the passenger vehicle fleet. For example, in briefings and correspondence with the committee, two major suppliers of seat belts—Breed Technologies and Autoliv North America—noted that seat belts with height and tension adjustors and improved belt access and buckling mechanisms are already on the market.

The importance of habit, situation, attitudes, and comfort for belt use is borne out by the MVOSS and the NHTSA interviews conducted for the current study. In the most recent MVOSS (Block 2001, 62), the following were the most frequent reasons reported by drivers for not wearing a seat belt:

- Driving a short distance (59 percent),
- Forgetting to buckle up (53 percent),
- Being in a rush (41 percent), and
- Discomfort from the seat belt (33 percent).

Similar reasons for not using seat belts were reported in the NHTSA interviews. Drivers cited forgetfulness and laziness as important reasons for not buckling up. When probed, these respondents made it clear that this behavior was particularly evident when they were going on short trips or driving in familiar circumstances or at low speeds (Bentley et al. 2003, 18). Some explained that under these conditions they are not as focused on driving and tend to forget to buckle up. Others indicated that they did not see the need for buckling up in what they perceive as low-risk driving conditions (Bentley et al. 2003, 18).

A much smaller group of hard-core nonusers reported negative attitudes toward seat belts as the primary reason for nonuse in the most recent MVOSS. These reasons include discomfort, concerns that belts are dangerous in a crash (e.g., could trap the driver in the vehicle), infringement of personal freedom and resentment of authority, and the attitude that they "just don't feel like wearing them" (Block 2001, 69–70). Similar attitudes, particularly the importance of personal choice in the decision to use a seat belt, were evident among the small group of hard-core nonusers interviewed by NHTSA for the present study (Bentley et al. 2003, 20).

Demographic and Socioeconomic Correlates of Nonuse

The literature review conducted for this study on characteristics of seat belt use identified numerous demographic and socioeconomic characteristics associated with belt use behavior. Many of the studies are based on observational surveys and, as such, do not differentiate between different nonuser groups, such as part-time users and hard-core nonusers. Thus, as noted earlier, the user group comprises full-time and part-time users, while the nonuser group combines part-time users and nonusers.

Gender and Belt Nonuse

In general, females are more likely to be observed wearing seat belts than are males. The 2002 NOPUS observed a statistically significant 7 percentage point gender difference. Females were observed using belts 79 percent of the time compared with 72 percent of the time for males (Glassbrenner 2003a, 3). A North Carolina survey of seat belt use following a high-visibility "Click It or Ticket" public information and enforcement campaign found that observed unbelted drivers were more likely to be male than observed belted drivers (Reinfurt et al. 1996, 211). Another study of primary and secondary belt use laws in four U.S. cities [Boston (secondary), Chicago (secondary), Houston (primary), and New York (primary)] observed that male drivers were less likely to buckle up than were female drivers, even in states with primary seat belt use laws (Wells et al. 2001, 5).

Age and Belt Nonuse

Generally, an individual's age is considered to have a positive impact on belt use; older individuals are more likely to buckle up. For example, reported "all the time" belt use in the most recent MVOSS was lowest among respondents aged 21 to 24 and highest among those aged 65 and older (Block 2001, 17). An observational survey of belt use at 12 high schools in Connecticut and Massachusetts confirmed findings from earlier studies that teenagers have low belt use rates relative to other age groups, even when they drive with their parents (Williams et al. 2001).[5]

Other individual characteristics associated with age (e.g., the structure of the individual's family), however, may confound the relation between age and belt use. One study, which compared seat belt use rates measured by observational surveys at preselected sites in Ohio with their demographic and socioeconomic characteristics as measured by U.S. Census Bureau data, did not find a strong positive correlation between age and belt use. One explanation is that older individuals may be less likely to use belts regularly when they are not living with children in

[5] For example, the survey found that 46 percent of teenagers who were being dropped off at school by their parents were not wearing their seat belts. And nearly half the time, the unbelted teenager was riding with an adult driver who was buckled up (Williams et al. 2001).

the home. Older parents with children at home may be more likely to buckle up because of their desire to set a positive example or because of pressure from children who have been exposed to public information and education media campaigns (Shinar 1993, 754). At the same time, young people (aged 18 to 24) were found to be more responsive to seat belt use when living within the traditional family structure (Shinar 1993, 754). This finding was confirmed by the most recent MVOSS. Among younger drivers who responded to the survey (aged 16 to 24), 65 percent reported that their habit of buckling up was instilled by their parents (Block 2001, vi).

Socioeconomic Status and Belt Nonuse

Socioeconomic status is also an important factor in belt use. For example, telephone surveys conducted after a "Click It or Ticket" campaign in North Carolina found that college graduates were more likely to report driving belted than blue collar or service workers (Reinfurt et al. 1996, 213). The study of belt use laws in Boston, Chicago, Houston, and New York also confirmed through driver interviews that higher educational attainment is a strong correlate of higher seat belt use (Wells et al. 2001, 8). Education level is frequently used in the literature as an indication of socioeconomic status.

Recent studies of seat belt use among different racial groups underscore the importance of an individual's socioeconomic status in determining the likelihood of buckling up. Racial differences alone have not proved to be important predictors of observed belt use (Reinfurt et al. 1996, 212; Glassbrenner 2003a, 13). When race is considered with other characteristics, such as gender, education, and enforcement type (i.e., primary versus secondary belt use laws), these other factors are stronger correlates of belt use (Shinar 1993, 754; Wells et al. 2001, 8). For example, the study of belt use in four cities cited above (Wells et al. 2001) observed no differences in belt use by race or ethnicity in primary law locations (p. 1). However, in secondary law locations, blacks were less likely to be belted among populations both with and without college degrees, confirming the results of other studies that show greater sensitivity to enforcement among black drivers (Wells et al. 2001, 1).

The most recent MVOSS suggests that different racial and ethnic groups may have very different perceptions about the efficacy of seat belts

that could also influence their use. The survey reported that whereas only one-third of whites agreed that seat belts were "just as likely to harm them as to help them," almost half of blacks (46 percent) believed this statement to be true (Block 2001, 107).[6] Forty-eight percent of Hispanics thought that seat belts were "just as likely to harm them as to help them" compared with one-third of non-Hispanics. Blacks were about twice as likely as whites to agree that putting on a seat belt made them worry more about being in a crash and were most likely to agree with the fatalistic notion that "if it was your time to die, you'll die," so that wearing a seat belt does not matter (Block 2001, 108).[7] Similar findings were reported for Hispanics versus non-Hispanics. When education level is considered without regard to race or ethnicity, however, individuals with more schooling tended to be less fatalistic, less ambivalent about the injury reduction benefits of seat belt use, and less self-conscious about going against group nonbuckling norms (Block et al. 2001, vii).

Risky Behavior and Belt Nonuse

Belt nonuse often is associated with a risky lifestyle, aggressive behavior, and irresponsible attitude (Wilson 1990, 176). Indeed, on the basis of self-reports, individuals who did not use seat belts or who used them inconsistently reported that they engaged in more behaviors that increase the risk for a crash, including consuming more alcohol and drugs and accumulating more traffic violations, than regular belt users (Wilson 1990, 175). A telephone interview of North Carolina motorists cited for not using seat belts found that crash rates for violators were nearly double those of a random sample of North Carolinians, and the researchers concluded that nonusers are a high-risk crash group (Williams et al. 1997, 71).

In another observational study of North Carolina drivers, unbelted drivers were significantly more likely than belted drivers to have had at

[6] The survey asks two questions to categorize respondents for analysis by race and ethnicity. First, the respondents are asked whether they consider themselves to be Hispanic or Latino. Second, and independent of the first question, respondents are asked to select among five racial categories, including black, white, Asian, Native American or Alaskan Native, or multirace. Because race and ethnicity are considered independently, each racial group can include both Hispanics and non-Hispanics, and the Hispanic subgroup can include both whites and blacks (Block 2001, xxvi).

[7] Thirty-six percent of blacks agreed with this statement versus 23 percent of whites. Thirty percent of Hispanics agreed with this statement versus 25 percent of non-Hispanics (Block 2001, 108).

least one conviction for a traffic violation and to have been involved as a driver in at least one fatal or injury crash during the most recent 4-year period (Reinfurt et al. 1996, 212). A follow-up survey revealed that nonusers were also less likely than users to report having health coverage, more likely to acknowledge having consumed large amounts of alcohol in the past year, and more likely to have an arrest record (Reinfurt et al. 1996, 209). Other studies of observed and self-reported seat belt use have confirmed from driver records that unbelted drivers have more traffic convictions and more crashes than those who were belted (Hunter et al. 1993, 545; Preusser et al. 1991, 475).

Seat Belt Use Laws and Belt Nonuse

Independent of individual demographic and socioeconomic characteristics, belt use is higher in states with primary belt use laws than in states with secondary belt use laws or in New Hampshire, which has no seat belt law (Dinh-Zarr et al. 2001, 54). The 2002 NOPUS confirms the importance of primary seat belt use laws. In primary law states, belt use rates were 80 percent. In secondary law states, belt use rates were only 69 percent, a statistically significant difference (Glassbrenner 2002, 5). Moreover, in those states that changed from a secondary to a primary belt use law, seat belt use rose (and fatalities declined) (Dinh-Zarr et al. 2001, 54). For example, when Washington State recently changed from a secondary to a primary law state, observed belt use rates rose from 83 percent in 2001 to 93 percent in 2002 (Glassbrenner 2003b, 1).

The implementation of primary enforcement laws may have a greater impact on black motorists than white motorists. In North Carolina, a primary law state, observed belt use was significantly higher among whites than blacks before implementation of the law. Since its enactment, observed belt use among blacks has exceeded use among whites (Reinfurt 2000 in Wells et al. 2001, 8). The apparent reason is that blacks perceive that they are more likely to get a ticket for belt nonuse than whites. Other studies in Louisiana, Georgia, and Maryland indicate that blacks are more sensitive to primary belt use laws because they believe that there will be a race differential in their enforcement (Solomon et al. 2000 in Wells et al. 2001, 9). Although the perception may be that blacks are targeted as offenders of primary belt use laws, studies in several states

that changed from secondary to primary laws show either no difference in the rate of ticketing between blacks and whites or a relative increase in the ticketing of whites after the enactment of a primary law (Dinh-Zarr et al. 2001, 54).

Differential enforcement is undesirable. However, the perception that laws are being strictly enforced makes them work (Wells et al. 2001, 9). According to the most recent MVOSS, the percentage of Americans who thought that ticketing for seat belt nonuse was an imminent threat was significantly higher in primary law states than in secondary law states (Block 2001, ix).

POTENTIAL EFFECTS OF SEAT BELT USE TECHNOLOGIES ON DIFFERENT NONUSER GROUPS

A review of the literature, survey data, and interview results suggests that the reasons for seat belt use and nonuse are complex. Age, gender, vehicle type, and enforcement level (i.e., primary versus secondary law states) have all been shown to affect belt use. Lower belt use is associated with young adults, males, pickup trucks, and states with secondary belt use laws or no law, like New Hampshire. These simple correlates of belt use, however, are confounded by other variables, such as education level, and by situational and attitudinal factors.

For purposes of this study, differences among nonuser groups are important for assessing the likely impact of seat belt use technologies. The literature is sparse, however, concerning the factors differentiating nonusers—the target group for seat belt use technologies. The available survey data, primarily from the MVOSS, suggest that there are at least two nonuser groups: part-time users (those who buckle up less than all the time) and hard-core nonusers (those who never buckle up).

Part-time users appear to be the predominant nonuser group. Members of this group generally express positive attitudes toward seat belts but do not always buckle up. Many appear not to have developed the habit of wearing a belt and thus forget to buckle up. Others choose to use belts only in situations of perceived risk—long trips at high speeds on unfamiliar roads. Part-time users should be amenable to seat belt use technologies that help remind them to buckle up. Moreover, if reminder

systems can help part-time users develop habits of belt use, they may have a lasting impact on this segment of the nonuser population.

Hard-core nonusers are a much smaller segment of the nonuser population. However, the importance of this group should not be understated, because of its overrepresentation in fatal crashes and other high-risk driving behaviors, such as speeding and driving while impaired by alcohol. Seat belt reminder systems are likely to have little effect on hard-core nonusers who choose not to buckle up. They generally do not acknowledge the benefits of seat belts and are opposed to their use. More aggressive solutions, such as interlock systems, may be needed to get this small, but important, nonuser group to buckle up. However, will the hard-core nonusers object to such intrusive technologies? In the next chapter, the U.S. experience with interlock systems, among other technologies, is reviewed.

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3

Historical Experience with Seat Belt Use Technologies

In this chapter, a brief review is provided of the 1970s experience with early seat belt reminder systems, the ignition interlock, and the 4- to 8-second belt reminder that remains in vehicles today. Although results from studies of the effectiveness and acceptability of these systems may not still be valid, the way in which these technologies were introduced has a continuing effect on their acceptability and likely effectiveness today. The chapter includes a review of experience with other key approaches for increasing seat belt use, primarily the enactment of seat belt use laws. The chapter ends with a brief summary of lessons learned from the past that can influence the successful introduction of seat belt use technologies today.

EARLY SEAT BELT USE TECHNOLOGIES

Early seat belt use technologies were introduced as alternatives or interim measures to the primary and preferred approach of the National Highway Traffic Safety Administration (NHTSA) for increasing seat belt use at that time—introduction of passive restraint systems.[1] On January 1, 1972, NHTSA required passenger vehicles for sale in the United States to be equipped with passive restraints protecting vehicle occupants in frontal barrier crashes up to and including 30 mph, or alternatively, with a buzzer–light reminder system. With few exceptions of cars sold with inflatable front cushions, the automobile manufacturers opted for the reminder system (Robertson 1975, 1320). The system consisted of a flashing light and buzzer, which activated continuously for at least 1 minute if the vehicle was placed in gear and the driver or front outboard passenger was not belted (Robertson 1975, 1320). The simple sensor system used to activate the reminder system, however, could be bypassed

[1] The primary focus was on air bags, but NHTSA also indicated that automatic belts could be used to meet automatic protection requirements (Kratzke 1995, 2).

easily. Moreover, once the belt was left in an extended position or buckled, the reminder system would not be activated again (Westefeld and Phillips 1976b, vii).

When it became evident that the introduction of passive restraint systems would be delayed, NHTSA moved to require ignition interlock systems on all cars as an interim measure. Effective August 15, 1973, NHTSA required that all Model Year (MY) 1974 passenger vehicles be equipped with an ignition interlock that allowed the vehicle to start only if the driver was seated and the belts were extended more than four inches from their normally stowed position or the belts were latched (Robertson 1975, 1320). In addition, an audible warning was activated if seat belts were unfastened during the trip.[2] It was hypothesized that the ignition interlock would increase seat belt use by eliminating two of the most popular ways of defeating the early belt reminder systems: leaving the belt fastened and tucking it behind the seat, or tying a knot in the belt so that it was held out of the retractor (Cohen and Brown 1973, 5).

When Congress passed legislation prohibiting NHTSA from requiring either the ignition interlock or continuous buzzer systems as described in Chapter 1, NHTSA changed Federal Motor Vehicle Safety Standard (FMVSS) 208 to a less aggressive requirement. Passenger vehicles manufactured after February 1975 were required to have a warning light of 4- to 8-seconds duration that is activated when the ignition is turned on regardless of whether the seat belt is fastened, and a chime of similar duration that sounds unless the driver's belt is buckled (Westefeld and Phillips 1976b, viii). This standard, which so far as can be determined was specified without any empirical justification, is still in effect today.

STUDIES OF THE EFFECTIVENESS AND ACCEPTABILITY OF EARLY SEAT BELT USE TECHNOLOGIES

NHTSA introduced the ignition interlock system without extensive study or pilot testing. Only one NHTSA-funded study could be found (Cohen

[2] MY 1974 vehicles incorporated a sequential logic system. The system required that the belt be fastened only after the appropriate seat had been occupied. The starter–interlock feature then prevented the engine from starting unless the logic system was satisfied that the front belts were fastened when the corresponding seating positions were occupied (Westefeld and Phillips 1976b, vii).

and Brown 1973) that had compared belt use in rental car fleets equipped with various combinations of buzzer–light and interlock systems prior to the interlock regulation.[3] That study found a significant increase in belt use for equipped vehicles relative to vehicles without any reminder or interlock system. However, it showed no significant difference in belt use by drivers of cars with buzzers versus those with interlock systems (Cohen and Brown 1973, 3; Robertson 1975, 1324). Rental car drivers without any reminder or interlock system used seat belts on 23 percent of their trips compared with 51 percent and 49 percent of rental car drivers with the two reminder-only systems, and 56 percent of rental car drivers with the reminder–interlock system (Cohen and Brown 1973, 3). Substantial resistance to each of the reminder and interlock systems was observed, however, with one-third of drivers in each group claiming that they would disconnect the system if it were installed in their personal vehicles. Drivers with the more demanding systems had less favorable attitudes and were more likely to say that they would either modify or disconnect the systems (Cohen and Brown 1973, 26).

The Insurance Institute for Highway Safety had conducted an earlier study that compared belt use in MY 1972 cars equipped with the NHTSA-required buzzer–light system with belt use in unequipped cars (Robertson and Haddon 1972 in States 1973). That study, which was focused on personal vehicles, did not detect any significant effect on seat belt use for vehicles equipped with the buzzer–light system. The result, which contradicted the NHTSA study of rental car fleets (Cohen and Brown 1973) that had observed a significant difference in belt use between buzzer–light and nonequipped vehicles, can be attributed in part to the fact that rental car drivers are less likely to attempt to disable a system on the rental car than on their personal vehicle—a finding noted in the NHTSA-funded rental car study (States 1973, 435; Cohen and Brown 1973, 26).

Following the interdiction of the ignition interlock and continuous buzzer–light systems, a 1975 study (Robertson 1975) documented the

[3] Three systems were investigated: (*a*) a detachable shoulder and lap belt and warning system based on the 1972 NHTSA standard; (*b*) a nondetachable shoulder and lap belt with an inertia reel on the shoulder belt that locks and restrains the wearer if the car stops suddenly, and a belt reminder based on the 1972 NHTSA standard with a logic system that detects whether the driver is seated; and (*c*) a nondetachable shoulder and lap belt with an inertia reel on the shoulder belt, and a warning, logic, and starter–interlock system based on the NHTSA 1973 standard (Cohen and Brown 1973, i).

extent of belt use observed in 1972, 1973, and 1974 passenger vehicles with different seat belt use technologies. Belt use was measured at 138 sites in Baltimore, Maryland; Houston, Texas; Los Angeles, California; the New Jersey suburbs of New York City; Richmond, Virginia; and Washington, D.C. Drivers in 48 percent of MY 1974 passenger vehicles equipped with ignition interlock systems were using lap and shoulder belts, and 11 percent were using lap belts only, for a total use rate of 59 percent. Only 7 percent of drivers in MY 1973 passenger vehicles equipped with the buzzer–light systems were using lap and shoulder belts, and 21 percent were using lap belts only, for a total use rate of 28 percent. Twenty-five percent of drivers of MY 1972 passenger vehicles equipped with buzzer–light systems were buckled up, and 23 percent of drivers of MY 1972 vehicles without any reminder systems were using one or both belts. Thus, the study showed an unambiguous positive effect on belt use for the 1974 interlock-equipped passenger vehicles relative to vehicles with reminder systems or without any system.

In 1976 NHTSA reported effectiveness rates for both buzzer–light and sequential logic seat belt interlock technologies by measuring belt use rates in 19 U.S. cities (Westefeld and Phillips 1976b). The study showed that ignition interlocks were initially effective and more than doubled belt use rates from about 28 percent in MY 1973 vehicles equipped only with buzzer–light reminders to about 67 percent in MY 1974 cars equipped with ignition interlocks (Westefeld and Phillips 1976b, vii). However, initial increases in use rates from seat belt interlocks decreased over time as many motorists eventually disconnected the seat belt interlock or circumvented it, thus never developing the intended positive belt use habits.

A 1976 NHTSA study (Westefeld and Phillips 1976a) examined the effectiveness of the 4- to 8-second chime and light reminder systems on MY 1975 and 1976 vehicles that replaced the ignition interlock as well as the effectiveness of various other types of warning systems allowable in the postinterlock environment. For that study, 818 rental cars were modified with reminders that met revised FMVSS 208, which included six different reminder systems. The effectiveness data reported were based on 5,429 observations of rental car drivers at a single location: the Sky Harbor Airport in Phoenix, Arizona (Westefeld and Phillips 1976a,

1). The control group for the study consisted of drivers of vehicles with no reminder systems. Of these drivers, 12.8 percent used lap and shoulder belts leaving the rental car terminal. Of the drivers of vehicles equipped with the FMVSS 208 8-second chime and light warning systems, 13.1 percent were buckled—an insignificant difference. Thus, the authors concluded that the 8-second reminder system required by FMVSS 208 (still in place today) was not effective in increasing seat belt use (Westefeld and Phillips 1976a, 2). Moreover, the study showed that the most effective system would include, in addition to the 8-second reminder technology required by FMVSS 208, a reminder light that would not turn off until the driver buckled up, as well as a sequential logic system that required the driver first to sit down on the seat and second to buckle the belt so that the system could not be easily circumvented (Westefeld and Phillips 1976a, 2).

OTHER APPROACHES FOR ENCOURAGING SEAT BELT USE

Since seat belts were first installed in passenger vehicles, the federal government, states, safety groups, and the private sector have tried a variety of approaches to increase seat belt use. Early efforts (late 1960s, early 1970s) to educate the public on the benefits of seat belts that relied solely on public service advertisements and major media campaigns proved largely ineffective in increasing belt use (O'Neill 2001; Haseltine 2001). NHTSA then turned to technological approaches—warning systems, ignition interlocks, and passive restraints—during the 1970s and 1980s to increase belt use. Enactment of state belt use laws, spurred by the 1984 regulation on passive restraints (details to follow) and accompanied by a massive industry lobbying campaign, resulted in significant gains in belt use by the early 1990s (Haseltine 2001). Efforts to strengthen belt use laws combined with well-publicized intensive enforcement campaigns further increased belt use rates during the 1990s (Haseltine 2001). The discussion that follows highlights a few of the key strategies.

Passive Restraints

After the interlock requirement interdiction, NHTSA turned its focus once again to passive restraint systems. A nationwide survey conducted

in 1978 suggested that the American public believed, by a two-to-one margin, that the government should require automatic crash protection in new cars rather than adopt policies that "force" behavior either by technology like the ignition interlock or by federal or state laws requiring the use of seat belts with fines for nonuse (Hart Research 1978, 4–5). At the time the survey was conducted, only one-quarter of the respondents reported that they used their seat belts all or most of the time. Among infrequent users, seat belts were seen as confining, bothersome, and uncomfortable. Many nonusers believed that seat belts posed serious safety problems (Hart Research 1978, 2–3).

The previously described Dole decision in 1984 provided for the phase-in of automatic protection in cars beginning with MY 1987 passenger vehicles; such protection would become mandatory in MY 1990 (Kratzke 1995, 7). Once the passive restraint requirement was mandated by NHTSA, the initial reaction of the industry was to develop passive seat belt systems that automatically restrained the occupant once in the vehicle. There were various types of two-point (passive shoulder belt with knee bolsters and active lap belts) and three-point motorized and nonmotorized systems.

One of the earliest passive belt systems was the two-point passive shoulder belt. It was developed and introduced in 1975 in the Volkswagen Rabbit and then in mid-1978 in the General Motors (GM) Chevette. It used an automatic diagonal shoulder belt with a manual lap belt and an energy-absorbing knee bolster for those who only used the passive belt. The system had initial acceptance, but use of the manual lap belt was low due to inconvenience of access and forgetfulness of the occupant.

The most popular passive belt designs involved a motorized shoulder belt that acted on a track running along the roof rail (Johannessen 1987, 3). In the stowed position, the upper anchor of the shoulder belt was forward in the vehicle close to the steering wheel. In the restrained position, the track moved rearward on the roof rail, bringing the upper anchor of the shoulder belt rearward in position to restrain the occupant in a crash. These systems also used a manual lap belt. This approach facilitated ingress and egress while serving as a passive shoulder belt restraint. However, failure to buckle the manual belt could result in an occupant sliding out of position in a crash (e.g., "submarining" or sliding under the belt) and thus being vulnerable to injury.

GM introduced a three-point nonmotorized passive belt system in 1980 to comply with the passive restraint requirement. It was designed so that, when the door was open, the shoulder and lap belt, which were attached to the rear edge of the door, swung outward with the door. This allowed ingress when the belts were pushed forward to give access to the seat. When the door was closed, the belts moved closer to the occupant and formed the passive three-point belt system. However, the system was almost always used as an active lap–shoulder belt configuration by unlatching the belt to exit the vehicle. Despite this common practice, field studies of belt use still showed an increase in wearing rates with this door-mounted system.

Most surveys after introduction of passive belt systems found an increase in wearing rates (Johannessen 1987, 3), but the systems proved cumbersome to wear, were fraught with reliability issues, and had a required easy disconnect feature. In addition, early studies showed potential injuries with use of the automatic two-point systems when the manual lap belt was not buckled (Evans 1990). It became clear that it was difficult for the passive belt systems to match the safety performance of active lap–shoulder belts, and the industry turned to the other option in the passive requirements—air bags.

Within a few years, most vehicles were being produced with driver air bags, and the conventional lap–shoulder belt system reemerged in vehicles. The introduction of air bags is now complete, with all light vehicles equipped with driver and passenger air bags and active three-point lap–shoulder belt systems. While voluntary belt wearing has now increased to 75 percent nationally with various measures discussed elsewhere in this report, the historic issue of technological solutions to encourage belt wearing has resurfaced.

Seat Belt Use Laws

The 1984 Dole decision also encouraged states to pass mandatory seat belt use laws, with the proviso that the automatic protection requirements might be eliminated if, by April 1989, the Secretary of Transportation found that two-thirds of the nation's population was covered by state-mandated seat belt use laws (Kratzke 1995, 8). The required threshold was not reached, but the widespread introduction of seat belt

use laws resulted in what has proved to be one of the most effective approaches for increasing belt use (Dinh-Zarr et al. 2001, 48). The automobile industry commenced a massive lobbying campaign and formed a new organization, Traffic Safety Now, to convince states to enact seat belt use laws (Haseltine 2001). By the time Traffic Safety Now closed its doors in 1992, 93 percent of the U.S. population was subject to state seat belt use requirements (Haseltine 2001).

Unfortunately, not all belt use laws are equal. Primary belt use laws allow a police officer to stop a motorist solely for not wearing a seat belt; secondary belt use laws allow a police officer to issue a seat belt citation to an unbuckled motorist only after the motorist has been stopped for another traffic violation (Glassbrenner 2002, 5). In the United States, primary belt use laws have been the exception rather than the rule. In contrast, secondary belt use laws are unknown outside the United States (Dinh-Zarr et al. 2001, 52).

According to NHTSA's most recent National Occupant Protection Use Survey (Glassbrenner 2002, 1), the difference in belt use rates between primary and secondary law states is a statistically significant 11 percent. Belt use rates are 80 percent in the 17 states plus the District of Columbia and Puerto Rico with primary laws, but only 69 percent in the 32 states with secondary belt use laws and in New Hamphsire, the only state without any belt use law for adults (Glassbrenner 2002, 5).

Strong enforcement is a necessary component of effective seat belt use laws. Motorists must be convinced that violators will be ticketed and nontrivial penalties exacted. State-conducted studies of belt use rates and state restraint law penalties in 1998 and 1999 found that belt use rates averaged 6 percentage points higher in states with fines and court costs of $30 and above than in states with fines and court costs less than $30 (Haseltine 2001). A study of the effectiveness of a seat belt use law in Texas, a primary enforcement state, found a statistically significant reduction in driver-involved injury rates when fines were introduced for belt use violations (Loeb 1995, 84). Another study evaluating a belt use law in North Carolina, also a primary enforcement state, found that traffic injuries were reduced more when traffic citations for belt nonuse were given rather than warnings (Reinfurt et al. 1990). The 1998–1999 state survey results suggest that penalty levels can also make a difference in secondary law states (Haseltine 2001).

Stronger state belt use laws (changing from secondary to primary laws), combined with well-publicized intensive enforcement campaigns, have largely accounted for gains in seat belt use during the 1990s (Haseltine 2001). NHTSA initiated the first wide-scale effort to mobilize state and local law enforcement agencies to enforce seat belt use laws, named "Operation Buckle Down," from 1990 to 1992 (Haseltine 2001). The comprehensive Canadian Selective Traffic Enforcement Program model, which combined training of law enforcement officials, high-visibility enforcement campaigns, and pre– and post–belt use surveys and public education efforts, was introduced in North Carolina in 1993. The 5-year statewide "Click It or Ticket" program became a model for high-visibility enforcement programs in other states (Haseltine 2001). Today, most states conduct month-long, federally supported "Click It or Ticket" seat belt campaigns, typically in May and November each year (*AASHTO Journal* 2003, 16).

IMPLICATIONS FOR NEW TECHNOLOGY INTRODUCTION

The early experience with technologies encouraging seat belt use suggests that the ignition interlock was effective initially in bringing about large increases in seat belt use at a time when belt use rates were low generally, laws mandating belt use were unknown, belt designs had not matured, and the general public was not convinced of the safety benefits of buckling up. However, the interlock technology was intrusive, and the general public was largely unprepared for its rapid introduction. Systems were implemented without adequate field trials and with evaluations that were at best unsophisticated and at worst unreliable, which caused the public to become disenchanted with the technology. For example, by definition the ignition interlock did not allow the driver to idle or drive at low speeds without wearing a belt. Although nearly 30 years has passed since the interlock experience, both NHTSA and the automobile manufacturers remain wary of technologies that the public may find excessively intrusive. Successful technology introduction today will require more careful balancing of effectiveness and intrusiveness and more attention to studying and evaluating different technologies.

The limited study of the 4- to 8-second light and chime reminder systems that replaced the interlock and remain in effect today showed no

statistically significant effect on belt use relative to passenger vehicles without the reminder systems. Moreover, there appears to be no scientific basis for the selection of the 4- to 8-second duration of the reminder.

Much has changed since the brief experiment with interlocks nearly 30 years ago. Observed seat belt use has increased from the teens in the 1970s to 75 percent in 2002, largely because of enactment and enforcement of state seat belt use laws. While highly publicized enforcement efforts have contributed to recent increases in observed use, weak state seat belt use laws with secondary enforcement provisions and low fines hinder progress. Seat belts in modern vehicles are easier to use and more comfortable than those of the 1970s. Electronics and sensor systems in vehicles are also vastly improved. Because of these circumstances, it is appropriate and potentially fruitful to explore new vehicle technologies to assist in increasing seat belt use.

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Abbreviation

AASHTO American Association of State Highway and Transportation Officials

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4

CURRENT EXPERIENCE WITH SEAT BELT USE TECHNOLOGIES

Ford Motor Company was the first automobile manufacturer to introduce an enhanced belt reminder system in the United States. Selected Model Year (MY) 2000 passenger vehicles were equipped with a light and chime system that embodies more than the 4- to 8-second light and buzzer system required by the National Highway Traffic Safety Administration (NHTSA). In Europe, development of generic specifications for seat belt reminder systems began in 1995, and belt reminder systems are currently available in several vehicles for sale in the European market.

The effectiveness and acceptability of new enhanced belt reminder systems and other in-vehicle technologies to increase belt use currently being introduced on a voluntary basis by the automobile industry are reviewed in this chapter. The information is drawn from briefings to the study committee by key automobile manufacturers, a literature review, and the results of interviews and focus groups conducted by NHTSA specifically for the present study. The chapter ends with a summary of the state of knowledge.

CHARACTERISTICS OF NEW SEAT BELT USE TECHNOLOGIES

Enhanced Belt Reminder Systems

Ford Motor Company introduced the BeltMinder™, a registered company trademark, on selected MY 2000 vehicles. By MY 2002, all Ford vehicles were equipped with the enhanced belt reminder for the driver, with a phase-in for the right front-seat passenger starting with MY 2003 vehicles. The BeltMinder complies with the NHTSA regulation for a 4- to 8-second reminder; however, after a pause, the enhanced reminder flashes and chimes intermittently—activating for 6 seconds, then pausing for 30 seconds—for up to 5 minutes if the driver (or passenger) fails to buckle up.

After the introduction of the BeltMinder, NHTSA Administrator Dr. Jeffrey Runge urged other automobile manufacturers to follow Ford's

lead and provide effective belt reminder systems or other appropriate technologies for increasing belt use.[1] Most of the major manufacturers responded that they were either studying or near to deploying enhanced belt reminder systems, some as early as 2003.[2] Most plan to introduce driver-side systems first, many at the same time as the introduction of advanced air bags. Front-passenger systems will not appear in significant volumes until MYs 2004 and 2005.[3] At the time of the present study, the Ford BeltMinder was the only commercially available system in the U.S. market.

All first-generation enhanced belt reminder systems deployed or under development for the U.S. market use a sequence of light and chime reminders[4] separated by a pause or a light-only interval from the initial 4- to 8-second "federal" light and chime system (see Box 4-1 for examples of systems). The enhanced systems vary in their loudness, urgency, and duration. They all include a speed or distance trigger, reflecting General Motors' findings that most drivers fasten their seat belts after the engine is started or when the vehicle is in gear or moving slowly. Only about 30 percent of drivers fasten their belts before starting the engine.[5]

The systems are currently offered for drivers and front-seat occupants, reflecting the availability of front-seat sensors that are or will soon be available on all U.S. vehicles to support the introduction of advanced air bags. The incremental cost of installing the enhanced reminder system is modest.[6] In contrast, no manufacturer is offering reminder systems for rear-seat occupants. The absence of rear-seat sensors to detect the presence of rear-seat occupants, the complexities of integrating reliable reminder systems with rear child seats and remov-

[1] The first appeal was contained in a letter dated February 25, 2002. A follow-up letter was sent on March 24, 2003.

[2] The responses from individual companies can be found in the NHTSA Docket No. 13226 in the U.S. Department of Transportation's electronic docket system (dms.dot.gov).

[3] This information was provided in the manufacturer briefings to the committee and in follow-up inquiries.

[4] According to some manufacturers, voice-synthesized systems are considered problematic in a global market.

[5] These findings, from research conducted in May 1999, can be found in General Motors' response to Administrator Runge's 2002 letter in the NHTSA Docket No. 13226.

[6] Several of the manufacturers who briefed the committee at its December 2002 meeting provided more precise cost data for belt reminder systems but indicated that the information is proprietary. Hence the report cannot provide detailed cost data.

Box 4-1

Description of Selected Seat Belt Reminder Systems

Ford BeltMinder: After the 4- to 8-second NHTSA-required reminder, the Ford system resumes a warning chime and flashing light at approximately 65 seconds if the driver remains unbuckled while the engine is running and the vehicle is moving at more than 3 mph (4.8 km/h). The system flashes and chimes for 6 seconds, then pauses for 30 seconds, and repeats this cycle of 6-second flashing lights and chimes and 30-second pauses for up to 5 minutes. The system can be disabled for a single trip by buckling the seat belt. It can be permanently disabled by following a series of instructions in the driver's manual. The BeltMinder is currently available for the driver on all Ford, Lincoln, and Mercury models and has been introduced for front-seat passengers on selected MY 2003 Ford, Lincoln, and Mercury models.

DaimlerChrysler belt reminder system: After the 4- to 8-second NHTSA-required reminder, the DaimlerChrysler system resumes a steady warning light if the driver is still not buckled. After 30 seconds, if the driver remains unbuckled and the vehicle is moving at more than 15 mph (24 km/h), a multistage progressive chime and flashing light commence and are emitted for a maximum of 60 seconds. The warning light remains permanently illuminated if the driver is still unbuckled after this time. A driver and front-seat passenger system will be phased in over the next several years on all Mercedes-Benz vehicles for sale in the United States. The system, which can be disabled in a Mercedes-Benz retail center, will be available on some MY 2005 vehicles and on all MY 2006 Mercedes-Benz vehicles. Chrysler, Dodge, and Jeep vehicles will have at least a driver-side system by MY 2006.

(continued on next page)

Box 4-1 (*continued*)

Description of Selected Seat Belt Reminder Systems

General Motors belt reminder system: Immediately after the 4- to 8-second NHTSA-required reminder, the General Motors (GM) system resumes a steady light for 12 more seconds if the driver does not buckle up. If the driver remains unbelted, a flashing light and limited chime commence for 55 seconds, followed by 30 seconds of silence. The system repeats the full cycle if the driver remains unbelted and the vehicle is traveling at 5 mph (8 km/h) or more. The cycle is followed by a 3-minute period of silence and repeats for a third and final time if the driver continues to ride unbelted. All warning functions stop when the belts are buckled. The system cannot be disabled. GM belt reminder systems are projected to be introduced on selected MY 2005 vehicles, some with driver-side only systems, and others with driver- and passenger-side systems.

Toyota belt reminder system: After the 4- to 8-second NHTSA-required reminder, the Toyota system resumes with a flashing light and mild buzzer for 10 seconds if the driver remains unbuckled and the vehicle is moving at more than 9 mph (14.5 km/h). If the driver remains unbuckled, the flashing light continues and the buzzer will sound in a more intense tone for 20 more seconds. If the vehicle speed drops below 9 mph within that time, the buzzer sound will continue. If the driver has not buckled up after the 20-second period, the flashing light continues but the buzzer ceases. The system can be deactivated by a series of steps. A driver-only light and buzzer system will be introduced on the MY 2004 Prius, and several 2005 models will have a light and buzzer system for the driver and front-seat passenger.

able backseats, and lower rear-seat occupancy rates currently make rear-seat systems appear relatively costly. For now, the manufacturers are offering systems that indicate to the driver whether rear-seat passengers have failed to put on or have unbuckled their belts during a trip.[7] All the systems, with the exception of General Motors' belt reminder, provide mechanisms to disconnect the system, either for a single trip or permanently.[8]

In Europe, the introduction of enhanced belt reminder systems began with a Swedish National Road Authority (SNRA) initiative in 1995. A special working group of researchers, insurance companies, and the automobile industry was formed to develop generic specifications for a seat belt reminder system (Fildes et al. 2002, 3). The specifications took into account some of the shortcomings of the early U.S. interlock systems, which were unable to differentiate between driving and low-speed maneuvers, such as parking or going in reverse. Thus, the new systems activate only after a specified minimum speed has been reached, or after a specified time or distance.

The European specifications have been incorporated in the European New Car Assessment Program (EuroNCAP), a consumer safety information program modeled on NHTSA's NCAP.[9] As an incentive to industry, EuroNCAP offers manufacturers up to 3 points out of a total of 37—the difference between a four-star and the top five-star rating of European automobiles—for seat belt reminder systems that meet certain minimum performance criteria (see Box 4-2). In 1999, Saab was the first company to develop a prototype seat belt reminder system that was consistent with the SNRA and subsequently the EuroNCAP reminder system specifications. Today, several vehicles for sale in the European market have belt reminder systems that meet EuroNCAP specifications.

[7] International Electronics and Engineering S.A. (IEE), a European sensor manufacturer, is currently working with three European car manufacturers on specifications for a rear-seat belt reminder system. IEE is leading a feasibility study on the development of rear-seat sensors and on the solution of problems related to removable seats, child restraints, and other technical obstacles (personal communication with Paul Schockmel, IEE, June 12, 2003).

[8] A permanent disconnection typically requires a series of steps that are detailed in the owner's manual.

[9] EuroNCAP Belt Reminder Assessment Protocol, Doc 61b, Version November 2002, contains the most recent specifications.

Box 4-2

EuroNCAP Protocols for Belt Reminder Systems

Manufacturers may receive points for belt reminder systems on the basis of system coverage and compliance with certain performance criteria. The most recent specifications of which the committee was aware are contained in the EuroNCAP Belt Reminder Assessment Protocol, Doc 61b, Version November 2002.

- **System coverage:** One point is given for systems that cover the driver, one point for systems that also cover the front-seat passenger, and a final point for systems that extend to rear-seat passengers, for a total of three possible points. Because of the complexities and perceived costs of installation of rear-seat reminder systems, a system that notifies the driver of the belt use status of rear-seat occupants may be substituted for audio and visual signals for the time being.
- **System activation:** Systems should alert front-seat occupants with sound and light only if the seat belts are not in use. Minimum thresholds of use are defined. For example, the audiovisual reminder should be activated if the car is used for more than 60 seconds, is being driven at speeds greater than 25 km/h (16 mph), or is driven a distance of more than 500 meters (547 yards). If the system includes an immediate alert more sophisticated than a simple sound signal (like a text or voice message), the start of the audiovisual reminder can be postponed for another 30 seconds or 500 meters, and the speed criterion can be increased to 40 km/h (25 mph).
- **Auditory signal loudness:** The auditory signal should be at least 65 dB, should be loud and clear under normal driving conditions, and should become increasingly aggressive the longer the seat belt remains unfastened. "Normal" conditions are defined as 50 km/h (31 mph) in top gear on a good asphalt road with the ventilation fan running at 75 percent (Fildes et al. 2002, 8).

- **System duration:** The reminder system should be active for at least 90 seconds, with quiet periods of no longer than 25 seconds.
- **Disconnection:** The system may provide a means of disconnection for a single trip, but it should be more complicated than simply buckling the belt. Permanent disconnection may be available to the owner on demand, but the information should not be provided in the owner's manual.

Interlock Systems

The 1970s experience with interlock systems still influences technology decisions by the automobile manufacturers for the sale of vehicles in the U.S. market. For example, no company is developing an interlock system for sale in the U.S. market as original equipment on vehicles intended for the general public because of concern about potential negative customer reaction. Interlock systems, however, are being developed for special fleets and aftermarket applications. For example, D&D Innovations, Inc., a small manufacturer, is currently marketing an aftermarket device that can be installed in vehicles already equipped with gearshift locks (locks that prohibit a vehicle from being put into gear if the vehicle's brake is not depressed). The interlock system prevents the vehicle from being put into gear if the driver and passenger are not buckled up at the start of the trip. (Chime and light sequences sound if driver or passenger unbuckles during a trip.) D&D Innovations is targeting the seat belt shifter lock to owners of fleet vehicles as well as to parents of teenage drivers—a high-crash-risk group. In the United States, 16-year-olds have almost 10 times the crash risk of drivers aged 30 to 59, and almost 3 times the risk of older teenage drivers (IIHS and Traffic Injury Research Foundation 2003, 1). D&D Innovations is also working with General Motors so that the shifter lock can be made available as a dealer-installed option. According to D&D Innovations, the cost of the device is less than $200 for aftermarket applications. The cost could be as low as $65 if production volumes were large enough.

Another option for seat belt interlocks involves an interlock system that works with a vehicle's entertainment systems rather than its gearshifts. For example, if a driver does not respond to a light and chime seat belt reminder that commences when the vehicle is started, the radio or CD player could be made inoperative until the driver or front-seat passenger buckles up. Although an entrepreneur has petitioned NHTSA's Chief Counsel regarding the legality of an entertainment interlock system he had developed, such a system is not currently being manufactured for sale, either as original equipment or for aftermarket applications.

Development of interlock systems for specific aftermarket applications is not without precedent. For example, the experience with alcohol ignition interlocks has been encouraging. The devices can be effective in reducing impaired driving by convicted offenders. However, in the United States, the practical effectiveness of alcohol interlocks has been limited by their cost and by the small number of offenders willing to install them to drive legally (Voas et al. 2002, 449; DeYoung 2002, 473). North Carolina, Pennsylvania, and California, among other states, have begun to mandate the installation of alcohol interlocks as a prerequisite for DUI offenders to apply for restricted licenses. The effectiveness of seat belt interlocks for high-risk drivers will also likely depend on the extent to which the states and the courts are willing to require their use.

EVIDENCE OF EFFECTIVENESS AND ACCEPTABILITY OF NEW SEAT BELT USE TECHNOLOGIES

Manufacturers' Briefings

At the second committee meeting in Dearborn, Michigan, four automobile manufacturers—General Motors, DaimlerChrysler, Ford, and Toyota—briefed the committee on the development status of seat belt use technologies and on company studies and market research on the effectiveness and acceptability of the new technologies. The committee also heard from D&D Innovations, Inc. Because the briefings were held in closed sessions to safeguard proprietary information, not all details can be disclosed.

The automobile manufacturers indicated that consumer acceptability is key to the success of new technology introduction, and hence they favor systems that provide a balance between effectiveness and acceptability. Their primary focus is on enhanced belt reminder systems that target part-time users—those who forget to buckle up or who find it uncomfortable or inconvenient on short trips—rather than on more aggressive systems targeting the hard-core nonuser.

The functional characteristics of these reminder systems have already been described in an earlier section. The manufacturers, however, recognized that a number of design decisions were made without the benefit of empirical human performance data, which—if available—might increase both effectiveness and acceptability. For example, the optimal loudness of the reminder's chime has not been determined, nor has its relation to other in-vehicle warning and information systems, which have been proliferating in recent years. It is well known that human attention and information-processing capacities are limited (Wickens 1991; Kahneman 1973), so the effectiveness of any belt reminder system (and its impact on other aspects of driver performance) must be considered within the context of the overall stimulus and task environment. According to the manufacturers, many such issues, which have not been resolved in the first generation of enhanced belt reminder systems, merit careful study as field evidence accumulates.

The companies were unable to provide systematic field information concerning the effectiveness of the new enhanced belt reminders, which reflects the recent entry of the technologies into the market. In fact, one company suggested that NHTSA should take responsibility for collecting data on the effectiveness of different enhanced belt reminder systems in getting motorists to buckle up, particularly those involved in crashes.

Manufacturers' Market Research

The manufacturers who briefed the committee provided some limited company-sponsored market research on consumer acceptability of

enhanced belt reminder systems. At the December committee meeting, General Motors reported the results of clinics of approximately 1,000 consumers conducted in California in 1999 to gather data on belt use habits and the perceived effectiveness and desirability of current and enhanced belt reminder systems. Forty-nine percent of the respondents reported that the current NHTSA-required 4- to 8-second reminder helps them remember to wear their seat belts. Eighty-one percent indicated interest in an enhanced belt reminder system for the driver and front-seat occupants. Seventy-one percent thought that the systems should be extended to rear-seat occupants, particularly drivers of sport utility vehicles (SUVs) and vans who frequently transport children and find it difficult to see whether their children are buckled up. Yet, only 35 percent reported that they wanted a rear-seat belt reminder system in their next vehicle.

After the December meeting, a January 2001 Ford Motor Company telephone survey of approximately 1,200 owners of Ford passenger cars, SUVs, vans, and pickup trucks—with and without the Ford BeltMinder—was made available to the committee. The purpose of the survey was to obtain customer feedback on the new technology. Ninety percent or more of owners of the Taurus/Sable, Lincoln LS, Ranger, Explorer Sport Trac, Excursion, and Econoline reported that they were completely satisfied with the BeltMinder. Approximately three-quarters of Focus/Cougar, Mustang, and Explorer Sport owners reported being completely or somewhat satisfied with the system (Ford Motor Company and Global Consumer Insights 2001, 5).[10] Eight in 10 BeltMinder owners indicated that they would purchase a vehicle with a belt reminder in the future. More than 7 in 10 would recommend the BeltMinder to other drivers, and almost 90 percent of Ford drivers with the BeltMinder want the system for their passengers (Ford Motor Company and Global Consumer Insights 2001). Female and older drivers (i.e., over 50) scored higher than male or younger drivers on satisfaction with the BeltMinder, interest in buying it again, and recommending it to others.

[10] Respondents were asked to report their satisfaction with the BeltMinder on a five-point scale, ranging from "completely satisfied" to "very dissatisfied."

U.S. Research Studies

Only two studies that provide an assessment of the effectiveness and acceptability of enhanced belt reminder systems in the U.S. market could be found in the literature. The lack of studies is not surprising in view of the limited commercial availability of these systems. The first study, conducted by the Insurance Institute for Highway Safety (IIHS) in cooperation with Ford Motor Company, provided an initial evaluation of the Ford BeltMinder and found preliminary evidence that the technology is encouraging increased belt use (Williams et al. 2002). Researchers unobtrusively observed belt use among drivers of vehicles brought in for service at 12 Ford dealerships in Tulsa and Oklahoma City, Oklahoma, in August and September 2001. Overall, seat belt use rates were 76 percent for drivers in vehicles equipped with the BeltMinder compared with 71 percent for drivers of late-model Fords without the reminder system—a statistically significant 7 percent gain (Williams et al. 2002, 295).[11] No follow-up studies have been conducted at other locations to determine whether these results can be replicated.

The second study, also conducted by IIHS just before completion of this committee's work, involved in-person interviews with 405 drivers of Ford vehicles with BeltMinder systems at five Ford dealerships in the metropolitan Boston area in March and April 2003 (Williams and Wells 2003). Ford Motor Company facilitated the study, but it was made clear to potential respondents that the research was being conducted independently. Approximately two-thirds of the 405 drivers interviewed reported that they had experienced the reminder system one or more times when they had neglected to buckle up. Seventy-three percent reported that they buckled up the last time this happened, and 46 percent of all respondents said that their belt use had increased since driving a vehicle with the BeltMinder (Williams and Wells 2003, 6, 10). These positive reports provide further evidence in support of the earlier observational study that the BeltMinder is increasing belt use. The system also appears to be acceptable to drivers. Seventy-eight percent of those interviewed said they liked the system. Seventy-nine percent reported that they would like a similar device in their next vehicle (Williams and Wells 2003, 1).

[11] The difference reflects a 5 percentage point gain in belt use but a 7 percent increase [i.e., (76 – 71)/71 = 0.07].

The responses of the 107 part-time belt users[12]—the primary target group for belt reminder systems—were encouraging. More than four-fifths had encountered the system at least once. Seventy percent had fastened their seat belts in response, and 76 percent reported that their seat belt use had increased since purchasing the vehicle (Williams and Wells 2003, 12). Seventy percent like the reminder system and an equivalent percent would want it in their next vehicle. (The findings concerning acceptability for part-time users were slightly lower than for all respondents, but since the latter include full-time users who are presumably favorably disposed to the reminder system, the results for the part-time users are indeed encouraging.)

Not surprisingly, of the 27 respondents who reported never wearing seat belts or wearing them only occasionally, the vast majority (85 percent) encountered the system more than once. However, only 22 percent fastened their seat belts in response, and only 8 percent reported increased use of seat belts (Williams and Wells 2003, 12). Furthermore, 26 percent disabled the system, suggesting that different technologies or strategies will be needed to get this group of hard-core nonusers to buckle up.

International Research Studies

No field studies could be found outside the United States on the effectiveness of enhanced belt reminder systems that meet EuroNCAP specifications. A Swedish study (Bylund and Björnstig 2001) evaluated the effectiveness of older, less aggressive belt reminder systems on Swedish seat belt use rates. On the basis of ambulance personnel data on driver belt use from a population of 477 drivers injured in crashes from 1991 to 1999, the researchers ascertained that only 12 percent of drivers were unbelted in cars with a belt reminder light-and-sound signal, compared with 23 percent in cars without a reminder system, a statistically significant difference (Bylund and Björnstig 2001, 3).

The only other relevant study was a prospective evaluation of the benefits of introducing belt reminder systems in Australia (Fildes et al. 2002), which estimated the potential injury reduction of different belt

[12] Part-time users were defined as those who reported that they typically wear a seat belt, but not on some occasions (Williams and Wells 2003, 7).

reminder system designs, assuming various system effectiveness levels. Using the Monash University–developed HARM model—a method for quantifying injury costs from road trauma—the study examined three belt reminder design options: a simple flashing light and warning tone (similar to the Ford BeltMinder), a slightly more complex system where the flashing light and warning tone increase in intensity at higher speeds, and a complex system where the hazard lights flash after a set period of noncompliance (Fildes et al. 2002, vii). The study assumed effectiveness rates (i.e., increases in belt use rates) of 10 percent for the BeltMinder-like system (slightly higher than the 7 percent belt usage increase found by the IIHS study), 20 percent for the somewhat more complex reminder system, and between 30 and 40 percent for the complex design (Fildes et al. 2002, vii). On the basis of several usage scenarios (i.e., driver only, front-seat occupants, and all occupants), discount rates, fleet life periods, and costs, the model estimated that the benefit–cost ratio was highest for the simplest driver-only belt reminder device. However, the model-estimated benefit–cost ratio was still greater than 1 for the most complex system assuming usage by all occupants, and this system showed the greatest estimated benefits (i.e., reduction in the societal costs of injury) (Fildes et al. 2002, viii).

Interviews conducted in Sweden (Dahlstedt 1999) and focus groups in Australia (Harrison et al. 2000) found that the Saab prototype belt reminder system, with an aggressive light-and-chime system that increases in intensity with speed, would generally be acceptable to drivers who describe themselves as part-time users. For example, of the 500 Swedish drivers interviewed after being observed not wearing their seat belts in traffic, 83 percent said they would buckle up if they rented a car with an aggressive audible warning system (Dahlstedt 1999, 9). When asked if they would buy a car with a gear interlock, 70 percent responded "yes," and approximately 20 percent said they would choose another car (Dahlstedt 1999, 9).

Automotive Coalition for Traffic Safety Telephone Surveys

In November 2000, the Automotive Coalition for Traffic Safety commissioned a nationwide telephone survey (Lawrence Research 2000) of 1,000 licensed drivers in conjunction with a 2001 national summit on

seat belt use. The survey oversampled part-time belt users and hard-core nonusers to determine attitudes toward belt reminder and interlock systems as well as state seat belt use laws.[13]

The survey found that 80 percent of full-time users and 78 percent of part-time users and nonusers reported that the current 4- to 8-second belt reminder system had no effect on their seat belt use behavior (ACTS 2000). When asked their reaction to a law that would require a reminder system that gets louder or brighter, an ignition interlock, or a radio interlock, 53 percent of all respondents and 47 percent of part-time users and nonusers strongly or somewhat favored the reminder system. Of the three options, the reminder system received the least opposition. Only 39 percent of all respondents, and the same percentage of part-time users and nonusers, strongly or somewhat opposed this device (ACTS 2000).

Response to the ignition interlock was polarized. Fifty-four percent of all respondents strongly or somewhat favored the ignition interlock,[14] but 43 percent of all respondents, and 55 percent of part-time users and nonusers, either strongly or somewhat opposed the device (ACTS 2000). The radio interlock received the least favorable rating. Forty-nine percent of all respondents, and 57 percent of part-time users and nonusers, either strongly or somewhat opposed the radio interlock.

NHTSA In-Depth Interviews and Focus Groups

Because of limited data on both the effectiveness and the acceptability of new seat belt use technologies, NHTSA conducted in-depth interviews for the present study of potential technology beneficiaries—part-time users and hard-core nonusers—to explore consumer reactions to the technologies. In addition, focus groups of full-time users were conducted to understand their views concerning new technologies, particularly any unintended negative consequences for those who already buckle up. A report detailing the results of this work is available from NHTSA (Bentley et al. 2003); only the highlights are summarized here.

[13] Respondents were divided into two groups—full-time users versus nonusers and part-time users—by their response to a question about how often they wore their seat belt. Full-time users were defined as those who indicated always wearing a belt. Non- and part-time users included everyone else.

[14] Fewer than half (42 percent) of part-time users and nonusers, however, strongly or somewhat favored the ignition interlock.

Methodology

After considering the desirability of various options for assessing the acceptability of different reminder systems, NHTSA concluded that in-depth interviews and focus groups would be more useful than a large population survey. Demonstration of the devices with follow-up questions would provide more valid data than asking hypothetical questions to respondents who were unfamiliar with the technologies and had no exposure to them. Limited resources and time constraints of the study restricted the number of in-depth interviews and focus groups that could be carried out.

The interviews were conducted in three locations: Phoenix, Arizona; St. Louis, Missouri; and Portsmouth, New Hampshire. These locations reflect a mix of geographic settings (e.g., urban, rural) and seat belt use laws (Arizona and Missouri are both secondary belt use law states; New Hampshire has no belt use law). The interviews, which were conducted individually and in person, were targeted primarily at self-reported part-time users—the largest nonuser group. A small group of self-reported hard-core nonusers was also recruited. Part-time users were defined as those who claimed to wear a seat belt "sometimes" but had forgotten or neglected to buckle up three times or more in the past month. Hard-core nonusers claimed never to wear a seat belt (Bentley et al. 2003, 9). Participants were limited to those who had purchased a vehicle within the previous 12 months or intended to purchase one within the next year, with the expectation that new or prospective car buyers would be more focused on desired new vehicle characteristics.[15] However, this group may not be representative of the general population. The goal was to recruit 40 participants at each of the three sites. Thirty-two to 35 would be part-time users, and 5 to 8 would be hard-core nonusers. A total of 106 in-depth interviews were conducted at the three sites (Bentley et al. 2003, 10).

In addition to the interviews, four focus groups of 8 to 9 each were conducted at one location—St. Louis—over a 2-day period for a total of

[15] Other eligibility criteria included (*a*) possessing a valid driver's license; (*b*) owning or planning to own an automobile, minivan, pickup truck, or SUV, and not a motorcycle, heavy truck, or other type of vehicle; and (*c*) never having worked in advertising, marketing, public relations, the federal government, or the automotive industry (Bentley et al. 2003, 9).

35 respondents (Bentley et al. 2003, 10).[16] Participants for both types of activities were recruited by random digit dialing. No specific attempt was made to represent the demographic characteristics of the areas.

The participants in both the in-depth interviews and the focus groups were exposed to four seat belt use technologies—two belt reminder systems and two interlock systems—reflecting technologies of increasing intrusiveness (see Figure 4-1 and Box 4-3 for system descriptions). The belt reminder systems were presented in the form of two short video clips; the interlock systems were described on two storyboards.[17]

Initially, the respondents discussed their opinions about seat belts and the reasons and circumstances affecting their use (see Chapter 2 for results). Then they were asked to rate the technologies, using a five-point scale, on both the effectiveness and the acceptability of each of the four devices.[18] (The order of presentation was rotated in a counterbalancing scheme to prevent order effect bias.) After commenting on each technology, the respondents were asked to rank order the four devices from one to four in terms of their relative effectiveness and acceptability.[19] Finally, the respondents were asked whether the technologies should be mandated (Bentley et al. 2003, 12).

The results of the NHTSA report do not provide quantitative results that can be subjected to meaningful statistical analysis for generalization to the entire automobile-buying population (Bentley et al. 2003, 12). Nevertheless, the findings provide useful qualitative information about consumer reactions to new technologies designed to increase belt use. The results that follow were developed by the committee from the original responses to the interview and focus group questions and do not appear in the NHTSA report.

[16] Focus group participants were asked to rate and rank the technologies individually and write their responses on a worksheet. Only then did they discuss their individual responses with the group.

[17] Reactions may have been different if the participants had been able to drive in vehicles equipped with the technologies, but time and resource constraints precluded this option. Human subjects' protection was also an issue, because participants would have had to drive unbelted to experience the reminder systems.

[18] The scale for effectiveness ranged from "very effective" to "not at all effective." The scale for acceptability ranged from "very acceptable" to "not at all acceptable."

[19] Responses to the ranking data were not considered reliable and hence were not included in this report. Several respondents were unable or unwilling to rank order the devices, ranking either some or all of them equivalently. For example, this was the case for approximately 10 percent of the rankings on acceptability. Without a better understanding of the respondents' intent, it was believed that these responses would skew the overall results.

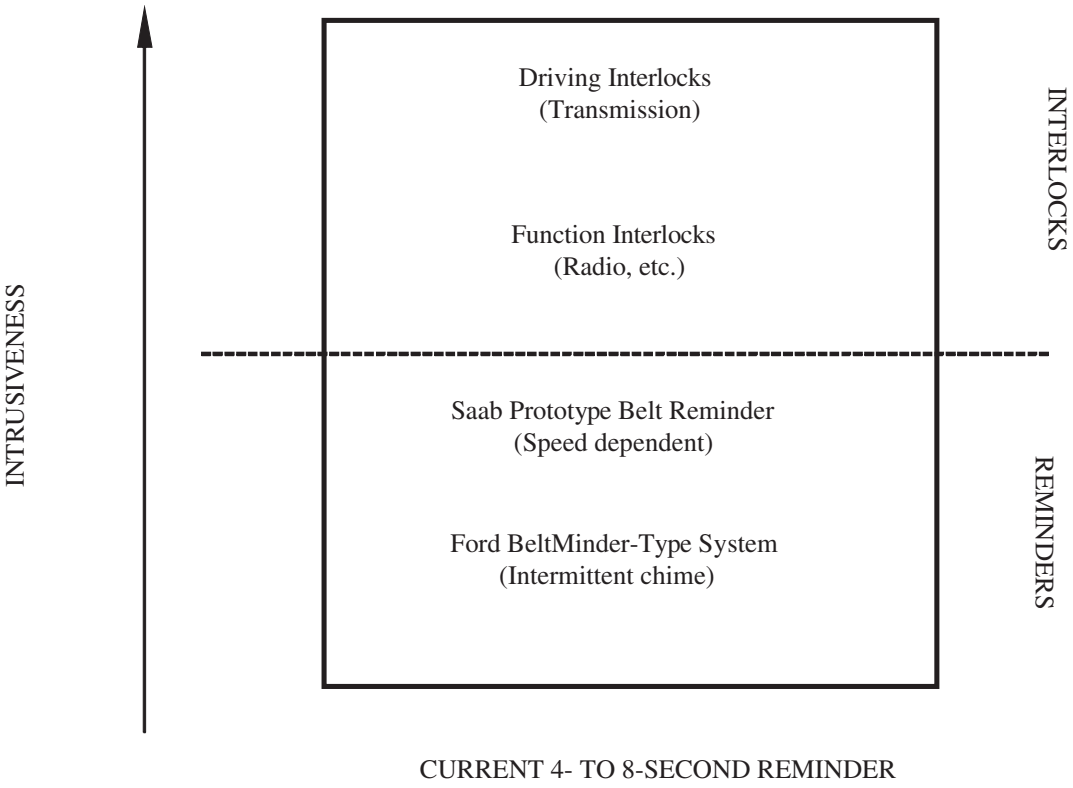

Figure 4-1 Seat belt use technologies arrayed by level of intrusiveness.

Results

Table 4-1 and the tables in Appendix B provide a summary of respondent ratings of the four technologies' effectiveness and acceptability. The results are first provided for all 141 respondents.[20] Then they are examined by user group (35 full-time users, 89 part-time users, and 17 hard-core nonusers), gender, age, and location (see Table B-1).

Overall Ratings A much higher percentage of the respondents rated each of the technologies "effective" than "not effective" (ranging from

[20] The respondents were asked to rate the effectiveness and acceptability of the technologies on a five-point scale. The ratings presented in this report range from "one" (least) to "five" (most) effective and acceptable. In Table 4-1, the ratings were further combined into three-point scales (combining "very effective" with "effective" and "very ineffective" with "ineffective," with similar combining of the acceptability scales) to provide greater contrast between positive and negative results. The responses for each of the five ratings can be found in Appendix B, Table B-2. Because of small sample sizes, only the mean rating was provided for responses analyzed on the basis of gender, age, and location (see Table B-3).

Box 4-3

Seat Belt Use Technology Concepts Tested

(Bentley et al. 2003, 8–9)

Intermittent chime and flashing symbol (Ford BeltMinder-type system)

The current standard 4- to 8-second reminder appears when the driver turns on the ignition. When the driver exceeds 3 mph (4.8 km/h), a flashing light and chime appear for 6 seconds. After 6 seconds the flashing light and chime cease. This cycle is repeated every 30 seconds for 5 minutes.

Continuous chime and flashing symbol connected to the speed of the vehicle (Saab prototype)

When the driver turns on the ignition, a symbol appears on the dashboard indicating that someone in the car is not wearing a safety belt. Another symbol on the dashboard indicates who is unbuckled; in the case of the video presentation it was the driver. When the driver reaches about 9 mph (14.5 km/h), an audio warning sounds (one ping) and a warning light starts to flash. At about 15 mph (24 km/h), the audio signal starts to ping continuously along with the flashing symbol. At about 30 mph (48 km/h), the light and audio warnings reach their maximum frequency.

As the driver slows down, so do the warnings, and when the vehicle stops the signals stop. When the driver accelerates again, the audio and visual warnings resume at their highest frequency. When the driver buckles up, the warnings cease. If for any reason the driver unbuckles while the vehicle is moving, the warning light reappears and a warning signal sounds (one ping). After 15 seconds, the symbol begins to flash and the audio warning starts to ping continuously, and after 30 seconds the reminders reach their highest frequency.

Entertainment interlock

The standard 4- to 8-second reminder appears after the driver starts the ignition. However, the vehicle stereo does not work until the driver buckles up.

Transmission interlock

The standard 4- to 8-second reminder appears after the driver starts the ignition. However, the vehicle cannot be shifted into gear until the driver buckles up.

61 to 88 percent). A higher percentage of respondents also rated the two reminder systems (Ford and Saab) "acceptable" than "not acceptable" (71 percent and 56 percent, respectively). However, this result did not hold for the interlock systems, which somewhat more respondents found not acceptable than acceptable (see Table 4-1). Anecdotally, several respondents, generally hard-core nonusers, indicated that the devices were acceptable but not effective because they believed they could circumvent them—for example, by drowning out the sound of the chime with the radio—or disable them entirely (Bentley et al. 2003, 4, 14). These responses obfuscate interpretation of the ratings.

Of the two reminder systems, respondents were more likely to rate the Ford BeltMinder as acceptable (71 percent versus 56 percent for the Saab system) but were also somewhat less likely to rate it effective compared with the more insistent Saab system (78 percent versus 83 percent) (Table 4-1). The transmission interlock was most likely of all the devices to be rated effective—88 percent rated it effective. However, only 43 percent of the respondents rated it acceptable. A somewhat lower percentage of respondents (37 percent) rated the entertainment interlock acceptable. However, 40 percent rated that device as either not effective or neutral (Table 4-1). Follow-up questions found that the effectiveness of the entertainment interlock depended largely on the extent to which drivers use their stereo systems (Bentley et al. 2003, 14).

Table 4-1 Analysis of Ratings from NHTSA In-Depth Interviews and Focus Groups by Technology, Overall and by User Group (Percentage)

Reported Acceptability					Reported Effectiveness				
	Ford	Saab	Entertainment Interlock	Transmission Interlock		Ford	Saab	Entertainment Interlock	Transmission Interlock
Overall (N = 141)									
Not acceptable	15	27	45	45	Not effective	12	10	27	8
Neutral	14	16	18	11	Neutral	9	7	13	4
Acceptable	71	56	37	43	Effective	78	83	61	88
Full-Time Users (N = 35)									
Not acceptable	3	28	51	55	Not effective	0	9	34	3
Neutral	3	11	29	14	Neutral	0	6	14	0
Acceptable	94	60	20	32	Effective	100	86	52	97
Part-Time Users (N = 89)									
Not acceptable	16	22	41	37	Not effective	14	9	24	10
Neutral	20	18	15	11	Neutral	12	7	14	2
Acceptable	64	60	45	52	Effective	74	84	63	88
Hard-Core Nonusers (N = 17)									
Not acceptable	35	53	53	71	Not effective	30	18	30	6
Neutral	0	12	12	6	Neutral	12	12	6	18
Acceptable	64	36	35	24	Effective	59	70	65	77

NOTE: "Not acceptable" is the sum of ratings "very unacceptable" and "unacceptable" (1 and 2); "acceptable" is the sum of ratings "very acceptable" and "acceptable" (4 and 5). "Not effective" is the sum of ratings "very ineffective" and "ineffective" (1 and 2); "effective" is the sum of ratings "very effective" and "effective" (4 and 5). The percentages may not add to 100 because of rounding. See Table B-2 for a more detailed breakdown by rating category.

With the exception of the entertainment interlock, the higher the effectiveness rating for a device, the lower the acceptability rating. This was most pronounced for the transmission interlock—88 percent rated the transmission interlock effective but only 43 percent rated it acceptable.

Ratings by User Group The responses of different user groups, especially part-time users, were of particular interest to the committee because they are the primary group to which the technologies are directed. Nearly two-thirds of part-time users rated the belt reminder systems acceptable (64 percent for the Ford BeltMinder and 60 percent for the Saab system). The reminder systems also were likely to be rated effective (74 percent for the Ford BeltMinder and 84 percent for the Saab system). Approximately twice as many part-time users, however, rated the interlocks unacceptable compared with the reminder systems (Table 4-1). Nevertheless, part-time users were more likely to rate the interlocks as acceptable than other user groups.

Of the much smaller group of 17 hard-core nonusers, fewer were likely to rate the more aggressive technologies—the Saab belt reminder and the transmission interlock—as acceptable compared with the other groups. For example, only 36 percent rated the Saab system acceptable (Table 4-1). And the hard-core nonusers were the most likely of any user group to rate the transmission interlock as unacceptable, with 71 percent rating it not acceptable. Not surprisingly, hard-core nonusers were more likely to give the Saab reminder and the transmission interlock high effectiveness ratings compared with the other two technologies, 70 percent and 77 percent, respectively. The particularly negative reaction to the transmission interlock from hard-core nonusers stemmed in part from their belief that this device infringes on an individual's right to choose whether to buckle up (Bentley et al. 2003, 15). However, a relatively high percentage (55 percent) of full-time users also rated the transmission interlock not acceptable. This group did not like systems that affect the operability of the vehicle, nor were they sympathetic to the idea of having an intrusive device in their vehicle just because others do not buckle up (Bentley et al. 2003, 34).

Ratings by Gender, Age, and Location Mean ratings are provided by gender, age, and location (Table B-3). Because of small sample sizes, no attempt was made to break down the data further by rating category (e.g., acceptable, neutral, not acceptable) as was done in Table 4-1.

The mean effectiveness and acceptability ratings are higher for females than for males and for the oldest age group than for the youngest age group for all technologies except the entertainment interlock. Males and the two youngest age groups rated the entertainment interlock more effective than did females or the oldest age group, which probably reflects greater use of the stereo system by these groups. However, none of the age groups rated the entertainment interlock very highly on acceptability. Mean acceptability ratings for reminder systems were higher than for interlocks for all three locations. This pattern did not hold for mean effectiveness ratings, mainly because the transmission interlock was rated most effective in all locations.

Mandating Seat Belt Use Technologies Respondents were asked whether they agreed that reminder systems and interlocks should be required in vehicles. If they responded positively, they were then asked whether the federal government should mandate this. Quantitative results were not available for these questions, but a summary of the responses provided in the NHTSA report suggests that most participants were supportive of the idea of mandating seat belt reminder systems and interlocks (Bentley et al. 2003, 38). Although many stated that mandates for reminders were acceptable, some thought that requiring interlocks was not. These devices were considered to be excessive in their attempt to control driver behavior and limit freedom of choice (Bentley et al. 2003, 38). Some hard-core nonusers were against mandates altogether. They believed that wearing a seat belt is a matter of personal choice that should not involve government intervention (Bentley et al. 2003, 15).

SUMMARY OF THE STATE OF KNOWLEDGE

Nearly 30 years after NHTSA was prohibited from requiring seat belt interlock systems or continuous buzzer reminders longer than 8 seconds in duration, the automobile manufacturers are voluntarily introducing

enhanced seat belt use technologies in passenger vehicles. Ford Motor Company started the move toward a new generation of enhanced belt reminder systems with the introduction of the Ford BeltMinder on selected MY 2000 vehicles. Enhanced belt reminder systems are also being introduced in Europe, where belt use rates are higher, and incentives are being offered to manufacturers through the EuroNCAP program to improve vehicle consumer safety ratings by providing systems that meet certain performance criteria. No automobile manufacturer, either in the United States or abroad, is providing vehicles with interlock systems as original equipment, targeted to the general consumer. However, a seat belt shifter lock is being developed for special fleets and aftermarket applications in the United States.

Because enhanced seat belt use technologies are so new, few studies of their effectiveness have been conducted. Nevertheless, the available evidence suggests that consumers generally find new belt reminder systems somewhat successful in convincing part-time users—the largest nonuser group—to buckle up. For example, the initial IIHS study (Williams et al. 2002), which was limited to two locations in Oklahoma, observed a statistically significant 7 percent increase in seat belt use by drivers in passenger vehicles equipped with the Ford BeltMinder compared with drivers of nonequipped late-model Fords. A subsequent IIHS study corroborated these findings. In interviews in Boston with drivers of BeltMinder-equipped Ford vehicles, overall, two-thirds reported that they had activated the system. Of these, approximately three-fourths buckled up and nearly half of all respondents said their belt use had increased. Results were encouraging for part-time belt users. More than four-fifths of this user group had activated the system at least once, 70 percent fastened their belts in response, and approximately 75 percent said their belt use had increased. No studies of the effectiveness of new European belt reminder systems could be found.

Information on consumer acceptability of seat belt use technologies from the manufacturers, the recent IIHS study, and the NHTSA interviews and focus groups conducted for the present study suggest a generally positive response to enhanced belt reminder systems. For example, nearly two-thirds of self-reported part-time users rated

reminder systems acceptable in the NHTSA interviews. As a general rule, the more intrusive the system, the less acceptable it is. This finding was particularly pronounced for the transmission interlock, which, of the four technologies, was most likely to be rated effective by all user groups who participated in the NHTSA interviews and focus groups, but was less likely to be rated acceptable across the board than reminder systems.

Self-reported hard-core nonusers who participated in the NHTSA interviews were more likely to be opposed to all systems than other user groups, with the exception of the Ford BeltMinder, which two-thirds of hard-core nonusers found acceptable, as was the case for part-time users. However, as the earlier IIHS study noted, acceptance does not necessarily lead to increased belt use, particularly for hard-core nonusers. More intrusive technologies may be required to convince this group to buckle up.

In sum, the data available to date provide strongly converging evidence in support of both the potential effectiveness and consumer acceptance of many new seat belt use technologies, particularly enhanced belt reminder systems. Despite limitations in the individual studies, surveys, and other pieces of evidence that are spelled out in the present report, the fact that findings from such a diverse set of information sources converge on this core conclusion is extremely important. However, much remains to be learned. Fortunately, larger numbers of belt reminder systems will soon be introduced in the marketplace. With characteristics that vary across manufacturers in the loudness, urgency, and duration of their chime and light components, these systems provide a natural laboratory for study.

Key knowledge gaps remain concerning the design, effectiveness, and acceptability of enhanced belt reminders. For example, unresolved design issues include the optimal loudness of the reminder's chime and its relation to other warning and information systems. Temporary muting of nonessential systems (e.g., radio, CD player) could be considered so that drivers do not drown out the chime. Appropriate design of disconnection systems is also likely to influence both the effectiveness and the acceptability of belt reminder systems. Finally, because of the benefits of rear-seat belt use, resolution of tech-

nical problems hindering the installation of rear-seat belt reminder systems is important, especially as the cost of sensors for the rear seats declines.

More comprehensive studies of the effects of reminder systems on belt use need to be conducted. Comparative studies of the effectiveness of aggressive belt reminder systems would be helpful in determining whether they can provide additional gains in belt use, particularly among the hard-core nonuser groups.

Finally, more data are needed on consumer acceptance. For example, although initial reactions toward interlock systems were negative, several of their undesirable features (e.g., inability to play the radio when the vehicle is not in motion) could be engineered out. As more consumers actually experience the systems, attitudes may differ from those expressed in interviews, where respondents could only be given general explanations or visual presentations of how the systems work.

The converging evidence of the effectiveness and consumer acceptance of enhanced belt reminder systems is favorable. In the next chapter, potential statutory and regulatory impediments to their installation are addressed.

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IIHS	Insurance Institute for Highway Safety

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5

A Strategy for Increasing Seat Belt Use Through Technology

A key purpose of this study is to assess whether, in light of findings regarding the benefits and acceptability of new seat belt use technologies, the 1974 legislation prohibiting the National Highway Traffic Safety Administration (NHTSA) from requiring their use in vehicles should be reconsidered. In particular, the congressional request asks whether any legislative or regulatory actions may be necessary to enable installation of devices to encourage seat belt use in passenger vehicles.

This chapter begins with an overview of NHTSA's current interpretation of the statutory provision prohibiting its regulation of new seat belt use technologies. The manufacturers' perspective on the need for regulation, as reported in briefings to the committee, is then discussed. Drawing on this material as well as on the findings concerning the effectiveness and acceptability of new seat belt use technologies summarized in the preceding chapters, the committee provides its key findings and recommends a strategy to help ensure the successful introduction of new seat belt use technologies as part of an overall effort to increase belt use. The chapter ends with a brief assessment of the potential benefits of that strategy.

NHTSA's Interpretation of Current Statutory Constraints

In 1998, NHTSA was petitioned to commence a rulemaking to amend Federal Motor Vehicle Safety Standard (FMVSS) 208 so that the agency could require effective seat belt inducements in new vehicles other than the ignition interlock or a continuous buzzer of the type NHTSA is prohibited from requiring (Nash and Friedman 1998). The petitioners cited the irrelevance of the interlock experience today in view of substantially higher levels of belt use and more comfortable belt designs. They recommended that NHTSA consider requiring such technologies as continuous visual reminders, intermittent and repeating audible warnings,

interlocks that disrupt comfort systems (e.g., radio and CD player, heat and air-conditioning), and other similar systems.[1]

NHTSA denied the petition on the grounds of the uncertainty of the safety benefits and the questionable acceptability to the public of the proposed devices, citing earlier public resistance to the ignition interlock system (*Federal Register* 1999, 60,626). The response also noted that some of the suggested systems (e.g., audible warnings beyond 8 seconds) fall outside of NHTSA's regulatory authority. NHTSA is prohibited by law from requiring buzzers beyond the 8-second time period, and the agency has interpreted this to mean that it cannot require manufacturers to provide audible sound beyond 8 seconds. The response, however, recognized the life-saving potential of even small increases in seat belt use that new technologies could achieve. Citing the newly introduced Ford BeltMinder™, NHTSA noted that the agency does not have the authority to require such a system, but encouraged vehicle manufacturers to consider voluntarily introducing belt reminder systems and other innovative technologies that could increase seat belt use in ways acceptable to their customers (*Federal Register* 1999, 60,626).

Since this response and NHTSA Administrator Runge's appeal to the automobile industry encouraging installment of systems such as the Ford BeltMinder that go beyond the minimum federal requirements, NHTSA's Chief Counsel has issued several clarifications concerning the legality of voluntarily provided belt reminder and interlock systems.[2] In response to questions about the legality of the Ford BeltMinder and an enhanced seat belt reminder system recently developed by General Motors Corporation, the Chief Counsel noted that the federal requirement for a 4- to 8-second system is a minimum standard. Voluntary chime-and-light belt reminder systems that go beyond the minimum standard do not conflict with the requirements of FMVSS 208 as long as

[1] The petition also suggested that NHTSA take the lead in encouraging nonmandatory measures, such as a joint government–industry research and testing program to identify effective seat belt use technologies, a voluntary committee to develop a consensus consumer information standard for seat belt inducement systems, and insurance discounts for equipped vehicles that meet the consensus standard (Nash and Friedman 1998).

[2] These interpretation letters can be found in the U.S. Department of Transportation's electronic docket management system (dms.dot.gov) at Docket Nos. 9899 (Items 1 and 2), 13379, 14742, 15006, and 15156 (Items 1, 2, and 3).

the vehicle manufacturer provides some way of distinguishing the voluntary chime from the "federal" chime for compliance-testing purposes. This can be accomplished either by a break in time between the required and voluntary signal or by audible alerts with different tones.[3] The Chief Counsel noted further that cost should not be a deterrent to vehicle manufacturers in voluntarily installing enhanced belt reminder systems, at least for front-seat occupants. As advanced air bag requirements are phased into the new vehicle fleet starting on September 1, 2003, all manufacturers will have some type of front-seat occupant-sensing devices. The marginal cost of the additional hardware to detect that drivers and front-seat occupants are buckled up to support driver and front-seat passenger belt reminder systems is relatively modest and thus, in the opinion of the Chief Counsel, should not serve as a deterrent to seat belt use technology introduction.[4]

The clarifications just discussed pertain to enhanced belt reminder systems on vehicles for sale in the U.S. market. Recently, Mazda asked for a clarification of whether an enhanced seat belt reminder system being designed to meet the European New Car Assessment Program (EuroNCAP) criteria for belt reminders would meet FMVSS 208 requirements and could be sold legally in the United States. The Chief Counsel noted that the proposed Mazda system should be in compliance because EuroNCAP-compliant belt reminder systems are activated only after the vehicle reaches a certain speed or travels a certain distance (see Chapter 4 for details), thus providing for an adequate separation between the NHTSA-required 4- to 8-second reminder system that begins when the ignition is turned to the "start" or "on" position and the enhanced belt reminder.[5] More generally, in the opinion of NHTSA's Chief Counsel, it should be possible to design systems that meet both FMVSS 208 requirements and EuroNCAP protocols.

[3] See response in the May 5, 2001, letter from NHTSA to Bob Snyder, Docket No. 9899.

[4] See response in the April 3, 2003, letter from NHTSA to Dr. William Howell, Docket No. 15156-3.

[5] The Chief Counsel further noted that a warning system on a vehicle in use that does not provide any separation from the NHTSA-required warning signal would not violate FMVSS 208 because the test procedure used to verify compliance with the NHTSA-required 4- to 8-second reminder only checks vehicles that are in "park" once the ignition is engaged. Thus, the Mazda system in which the belt use reminder chime is triggered by speed is not in violation because the compliance test is conducted on a stationary vehicle. See response in the May 7, 2003, letter from NHTSA to David Robertson, Manager for Environmental and Safety Engineering of Mazda North American Operations, Docket No. 15156-1.

NHTSA also issued interpretation letters concerning the legality of a voluntarily provided seat belt shifter lock system and an entertainment interlock that would suppress the radio or sound system unless occupants are buckled up.[6] These systems are being considered for sale as original equipment or as dealer-installed aftermarket devices. The Chief Counsel found that such devices would be in compliance with FMVSS 208 requirements as long as any audible warning connected with the systems is clearly distinguishable from the federally required warning. However, such devices are considered as motor vehicle equipment for purposes of federal law protecting the public against products with safety defects. As such, the manufacturers would have to assume responsibility for any defects in their manufacture, design, or performance.

In sum, from NHTSA's perspective, enhanced belt reminder systems and certain interlock devices voluntarily provided by the automobile manufacturers should not be in violation of FMVSS 208 as long as they clearly distinguish between the NHTSA-required 4- to 8-second system and the enhanced system. Moreover, it should be possible to design systems that are in compliance with both FMVSS 208 requirements and EuroNCAP performance criteria.

PERSPECTIVE OF THE AUTOMOBILE MANUFACTURERS

In their briefings to the study committee, the four participating manufacturers—General Motors, DaimlerChrysler, Ford, and Toyota—commented on perceived problems with current regulations that could negatively affect the voluntary introduction of new seat belt use technologies, and more generally on the desirability of regulating new seat belt use technologies.[7] One point of confusion was whether belt reminder systems developed to meet EuroNCAP criteria would also meet FMVSS 208 requirements.[8] At least one manufacturer is developing two systems—one for the U.S. market and a more aggressive system for the European market. This dual approach reflects, in part, perceived differ-

[6] See responses in the letter of September 13, 2002, from NHTSA Chief Counsel, Docket No. 13379, and in the letter of April 11, 2003, from NHTSA to Warren Howard, Docket No. 15006.

[7] Honda provided written comments after the meeting.

[8] This issue was raised before NHTSA's Chief Counsel wrote the interpretation letter clarifying the situation (see Docket No. 15156-1).

ences in regulatory requirements; it may also reflect concerns about the acceptability of more intrusive systems in the U.S. market.

The companies differed in their views about the desirability of regulating seat belt use technologies, in particular, seat belt reminder systems. Some thought that regulation would be helpful in removing potential negative consumer backlash against companies that choose to introduce more aggressive systems. NHTSA has a long-standing responsibility to upgrade safety standards as new information and technology make existing standards outdated, so it is natural for the agency to consider requirements for belt reminder systems. Regulatory requirements would also overcome any objections that might be raised by internal marketing staff concerning the desirability of such devices. Finally, regulation would help eliminate any potential consumer confusion arising from the introduction of reminder systems with different operating characteristics. That being said, some companies were skeptical that one technology could "fit" all markets. They noted the need and likely tolerance for more aggressive systems in many European countries, Australia, and Japan, where belt use rates are considerably higher than in the United States. However, some companies were unconvinced that these systems could be successfully introduced in the United States because of the potential backlash from the still sizeable numbers of motorists who continue to drive unbuckled, at least some of the time.

Those companies opposed to regulation noted that the automobile manufacturers are already voluntarily introducing belt reminder systems; hence there is no need for regulation. Others thought that regulation was premature and could stifle innovation. They believe that more on-road experience with systems of different designs is needed and more evaluations of their effectiveness must be conducted before minimum performance standards should be established. Some companies went further to suggest that NHTSA should assume the responsibility for monitoring and evaluating the effectiveness of different seat belt use technologies.

The companies were in agreement that, at present, the introduction of rear-seat belt reminder systems, even in Europe, will be limited to systems that notify the driver whether rear-seat occupants are not wearing their belts or unbuckle them during a trip. According to the

manufacturers, the current high cost of rear-seat belt reminder systems[9] and lower occupancy rates make rear-seat devices less cost-effective than other safety devices, such as side impact protection (e.g., side air bags, window curtains), which could be provided. According to the companies, regulation would be necessary if rear-seat systems or more intrusive technologies like interlocks are deemed to be desirable for the mass market. The companies also noted their conviction that by far the most effective way to encourage seat belt use is through the enactment of primary seat belt use laws and strong enforcement efforts.

FINDINGS

On the basis of its review of the literature, the interviews and focus groups conducted by NHTSA for the study, and the briefings provided by the automobile manufacturers and NHTSA's Chief Counsel, the committee offers its key findings in response to its charge in this section. The committee believes that new seat belt use technologies, in particular enhanced belt reminder systems, could increase belt use and be favorably received by consumers, particularly by part-time users, who apparently would welcome a reminder according to the results of the NHTSA interviews. The current statute that prohibits NHTSA from requiring such technologies or setting performance standards appears outdated and unnecessarily limits the agency. The reasoning behind these findings is elaborated below.

New seat belt use technologies exist that present opportunities for increasing belt use without being overly intrusive. The current NHTSA-required 4- to 8-second light-and-chime belt reminder has proved ineffective in increasing belt use (Westefeld and Phillips 1976, 2). There is no scientific basis for the 8-second maximum duration of the system. Many motorists—the majority of whom do not buckle up until some time after starting their vehicles (70 percent according to General Motors'

[9] The high cost arises because of the lack of rear-seat sensors, the most costly component of a belt reminder system. International Electronics and Engineering S.A. (IEE), a European sensor manufacturer, is currently working with three European car manufacturers on specifications for a rear-seat belt reminder system. IEE is leading a feasibility study on the development of rear-seat sensors and on the solution to problems related to removable seats, child restraints, and other technical obstacles (personal communication with Paul Schockmel, IEE, June 12, 2003).

survey data)—report that they ignore the chime or simply do not hear it over the radio or have forgotten it by the time they are backing out of the driveway and could use a stronger reminder to buckle up. In contrast, the results of the NHTSA interviews and the manufacturer briefings suggest that motorists would be aware of and heed the characteristics of enhanced belt reminder systems now being introduced by industry, although some still thought the chime would be difficult to hear over the radio. More important, although the results are based on a limited sample, many part-time users interviewed by NHTSA—the primary target group for the technology—were receptive to the new systems. Nearly two-thirds rated the reminders "acceptable," and approximately 80 percent thought that they would be "effective."

Preliminary research on the only system currently deployed in the United States—the Ford BeltMinder—found a statistically significant 7 percent increase (5 percentage point gain) in seat belt use for drivers of vehicles equipped with the Ford system compared with drivers of unequipped late-model Fords (Williams et al. 2002, 295). The results were gathered in two Oklahoma locations and provide a snapshot of belt use behavior, but they are suggestive of the potential benefits of enhanced belt reminder systems. The achievement of such gains nationwide would represent a modest but important increase in belt use. In a subsequent study in Boston of drivers of BeltMinder-equipped Ford vehicles, of the two-thirds who activated the system, three-quarters reported buckling up, and nearly half of all respondents said their belt use had increased (Williams and Wells 2003, 6, 10).

Enhanced belt reminder systems can be provided at minimal cost for front-seat occupants because of the availability of sensors that can detect the presence of front-seat occupants for advanced air bag systems.[10] The absence of rear-seat sensors on many vehicles, installation complexities (e.g., removable seats, child seats), and low rear-seat occupancy rates currently make rear-seat systems appear costly compared with systems for front-seat occupants. However, lower-cost systems that alert the driver when rear-seat occupants have not buckled up or have unbuckled

[10] The committee was provided with more specific cost data in the briefings, but the manufacturers indicated that the data are proprietary.

their belts during a trip are currently available on some vehicles in Europe. The risks posed to all vehicle occupants by unbelted rear-seat occupants, particularly in more severe crashes, suggest that the benefits of full-scale rear-seat reminder systems could be significant (Ichikawa et al. 2002) and thus may warrant greater attention than they have received to date.

Transmission interlock systems are perceived to be highly effective—more than 85 percent of all respondents to the NHTSA interviews and focus groups rated them effective. However, fewer than half rated them acceptable. The highest percentage of respondents who rated the transmission interlock not acceptable—71 percent—came from the small group of hard-core nonusers. Objections to entertainment interlock systems, which were thought to be most effective for younger drivers, were weaker among full-time users and even among hard-core nonusers. This result can be attributed in part to the fact that the system would not be experienced by some people (e.g., older people who do not use the radio, drivers on short trips) or could be circumvented (e.g., by installing an aftermarket stereo). Part-time users, who found the entertainment interlock slightly more objectionable than the transmission interlock, were the exception.

Interlock systems could be engineered to avoid many motorists' objections. For example, they could be designed to enable drivers to start their cars without buckling up and to drive in reverse and perhaps at low speeds to accommodate the majority of drivers who do not buckle up before starting their vehicles. However, the negative reaction indicated by the NHTSA interviews and focus groups and the hesitancy of industry to reintroduce interlock systems for the general driving public suggest that, for the moment, their use be considered only for certain high-risk groups (e.g., drivers impaired by alcohol, teenage drivers) who are overrepresented in crashes.

The current legislation prohibiting NHTSA from requiring new seat belt use technologies other than the ineffective 4- to 8-second belt reminder is outdated and unnecessarily prevents the agency from requiring effective technologies to increase belt use. Seat belt use has grown fivefold since 1974. Many more motorists now recognize the benefits of seat belts and appear to be receptive to their use. Although many

manufacturers are moving voluntarily to install belt reminder systems, some are concerned about their compliance with FMVSS 208 requirements. Others are wary of marketing systems that their customers may consider too intrusive. Hence they are hesitant to introduce more aggressive and potentially more effective systems. However, NHTSA does not currently have the authority to establish performance standards to encourage development of minimum performance criteria for the most effective systems or to require them to be sold in the U.S. market.

RECOMMENDED STRATEGY

On the basis of its findings, the committee reached consensus on the following recommendations:

1. **Congress should amend the statute regarding belt reminder systems by lifting the restrictions on systems with lights and chimes longer than 8 seconds, which would provide NHTSA more flexibility and the authority to require effective belt reminder technologies.** Amending the statute should remove any remaining legal restrictions perceived by the manufacturers to integrating these technologies in passenger vehicles. Should voluntary efforts to install effective belt reminder systems fall short, NHTSA will have the necessary authority to regulate. At this time, the committee does not see any compelling need to delete the prohibition on requiring interlock systems. However, this subject should be revisited in 5 years (see Recommendation 8).[11]
2. **Every new light-duty vehicle should have as standard equipment an enhanced belt reminder system for front-seat occupants with an audible warning and visual indicator that are not easily disconnected. Any auditory signal should be audible over other sounds in the vehicle. For the short term, manufacturers should be encouraged to provide these systems voluntarily** so that field experience can be gained concerning the absolute and differential effectiveness and acceptability of a range of systems. Enhanced reminder systems are of longer

[11] NHTSA interprets the statutory prohibition against interlocks to refer to those systems designed to prevent starting or operating a motor vehicle (see April 3, 2003, letter from NHTSA to Dr. Howell, p. 6, Docket No. 15156-3).

duration than the currently required 4- to 8-second reminder, and some are integrated with the speed of the vehicle. Those who rate vehicles—NHTSA, the Insurance Institute for Highway Safety (IIHS), Consumers Union—should be urged to note those vehicles that have enhanced belt reminder systems in their consumer vehicle safety rating publications. For example, NHTSA could indicate those vehicles in its consumer publication *Buying a Safer Car.* Similarly, IIHS could note such information in its publication *Shopping for a Safer Car.* Consumers Union is already noting the presence of enhanced reminder systems in its vehicle safety checks and is planning to provide points for equipped vehicles and publicize the information in *Consumer Reports.*

3. **NHTSA should encourage industry to develop and deploy enhanced belt reminder systems in an expeditious time frame, and NHTSA should monitor the deployment. As differences in effectiveness and acceptability of belt reminder systems are identified, manufacturers should install systems that are determined by empirical evidence to result in the greatest degree of effectiveness while remaining acceptable to the general public. Should voluntary efforts not produce sufficient results, NHTSA should mandate the most effective acceptable systems as determined by the current data.** The agency should also conduct studies to identify factors that will increase the effectiveness and acceptability of the systems. (See the next section, Proposed Research Program, for details.)
4. **Rear-seat reminder systems should be developed at the earliest possible time as rear-seat sensors become available,** to take advantage of the benefits of restrained rear occupants to the safety of both front- and rear-seat occupants. Until that time, manufacturers should provide systems that notify the driver if rear-seat occupants either have not buckled up or have unbuckled their belts during a trip.
5. **NHTSA and the private sector should strongly encourage research and development of seat belt interlock systems for specific applications.** For example, the courts should consider requiring the use of interlocks for motorists with driving-under-the-influence-of-alcohol convictions or with high numbers of points on their driver's licenses. The experience with alcohol ignition interlocks has been encouraging. Interlocks could also be made available for young drivers. Teenage

drivers, particularly the youngest drivers, have much higher crash rates on average than do older drivers, reflecting their lack of experience and their risk-taking behaviors. Insurance companies could lower premium rates for young drivers who install interlock systems. Finally, interlocks could be installed on company fleets.

6. **Seat belt use technologies should be viewed as complementary to other proven strategies for increasing belt use, most particularly enactment of primary seat belt use laws that enable police to pull over and cite drivers who are not buckled up and well-publicized enforcement programs.** Seat belt use technologies have the potential to increase belt use, but their effect is largely confined to new vehicle purchasers, whereas seat belt use legislation affects all drivers.
7. **Congress should provide NHTSA funding of about $5 million annually[12] to support a multiyear program of research on the effectiveness of different enhanced seat belt reminder systems.** NHTSA should coordinate its efforts with other federal agencies, such as the Centers for Disease Control and Prevention (CDC), that are conducting related research. The research would involve conducting more comprehensive studies of the effects of reminder systems on belt use; undertaking controlled fleet studies of more aggressive reminder systems; gathering more survey data on the effectiveness and acceptability of belt reminder systems from existing NHTSA and public health sources; and examining design issues, such as loudness of the chime, desirability of muting the radio when the chime is sounding, duration and cycling of the systems, and presence and design of any cutoff capability. (See the following section—Proposed Research Program—for more details.) This research should help establish the scientific basis for regulation of belt reminder systems should regulation be needed.
8. **In 2008 another independent review of seat belt use technologies should be conducted to evaluate progress and to consider possible revisions in strategies for achieving further gains in belt use,**

[12] The committee developed the $5 million estimate for the cost of this research in consultation with NHTSA staff and consultants, who, together, have been involved in many similar efforts to estimate the effectiveness of various motor vehicle safety features. Although the figure is not intended to be precise, it should be about the right amount given the complexity of the proposed activities and NHTSA's extensive experience in conducting such evaluations.

including elimination of the legislative restriction against NHTSA's requiring vehicle interlock systems.[13]

PROPOSED RESEARCH PROGRAM

Several million new vehicles that are equipped with enhanced seat belt reminder systems will soon be added to the U.S. passenger vehicle fleet. For example, approximately 15 million Ford vehicles have already been equipped with the Ford BeltMinder since its introduction on Model Year (MY) 2000 vehicles. Approximately 4 million new Ford vehicles are sold each year in North America. General Motors, DaimlerChrysler, Toyota, Mazda, and others are planning to introduce enhanced belt reminder systems on MY 2004 and MY 2005 vehicles, in many cases concurrent with the introduction of advanced air bags. The availability of vehicles with a range of reminder systems provides the basis for a number of natural experiments. NHTSA should take the lead in monitoring the introduction of the technologies and evaluating their ability to generate increases in belt use by undertaking a broad program of research, including observational studies and surveys, controlled fleet studies, and laboratory studies. More specifically, this research would comprise the following:

- Observational studies, modeled on the IIHS study (Williams et al. 2002), of the Ford BeltMinder and other enhanced belt reminder systems as they are introduced. These studies should provide an independent evaluation of various enhanced belt reminder systems in a range of settings (e.g., high belt use states, primary versus secondary law states) to determine whether they produce increases in belt use and, if so, whether the results are sensitive to differences in system design or other factors affecting belt use.
- Follow-up surveys of drivers and front-seat passengers to understand how they respond to these systems. Individuals who did not use their belts in reminder-equipped vehicles should be oversampled to explore why and how they defeated the technology.

[13] The committee selected 5 years as a reasonable target for a progress review. In 5 years, many more belt reminder systems of various types should be commercially available, and much of the proposed program of research should be under way. Thus, it should be possible to take stock of the adequacy of voluntary efforts and make a judgment as to whether regulation is needed.

- Expanded coverage in the National Occupant Protection Use Survey (NOPUS) to examine the effect of enhanced belt reminders on national belt use levels. More specifically, the NOPUS should be modified to collect make and model information on recent MY vehicles (i.e., MY 2002 or later) so that belt use in reminder-equipped vehicles can be compared with belt use in nonequipped vehicles. Expansion of coverage (e.g., more state-level data, nighttime surveys) and an increase in the frequency of the NOPUS could be considered to obtain a more complete picture of belt use and to monitor any degradation in belt use reminder effectiveness. In addition to the NOPUS, questions could be added to two large annual national health surveys—the Behavioral Risk Factor Surveillance System (BRFSS) and the National Health Interview Survey (NHIS)—to obtain information on belt use and the effectiveness of reminder systems.[14]
- Analyses for the National Automotive Sampling System and the Fatality Analysis Reporting System databases to evaluate the effects of vehicles equipped with belt reminder systems on injury reduction in crashes while adjusting for other important crash factors. These analyses should not require the addition of a special code to the databases. Rather, researchers could use the unique Vehicle Information Number, which is associated with every crash-involved vehicle, to identify the vehicle make, model, and model year. Using these data, it should be a relatively simple task to determine whether crash-involved vehicles were equipped with belt reminders.
- Controlled fleet studies to be conducted in conjunction with field evaluations of currently available enhanced belt reminder systems. Using rental car fleets, as in earlier NHTSA seat belt use technology studies, researchers would examine whether it is possible to generate belt use increases significantly larger than those produced by the first generation of belt reminder systems. Controlled fleets could be equipped with modified reminder systems to examine the effects of such features as systems that mute the radio and CD player when the audible seat belt warning system is activated. Systems in which the intensity of the audible warning increases over time or as a function

[14] The BRFSS is a state-level telephone survey, supported and funded by the National Center for Chronic Disease Prevention and Health Promotion (of CDC), that tracks health risks in the United States. The NHIS is conducted through a personal household interview. Supported by the National Center for Health Statistics of CDC, this survey is the principal source of information on the health of the civilian household population of the United States.

of increasing vehicle speed could also be systematically studied. In deciding the specific design parameters to be studied, NHTSA should carefully monitor the development of new belt reminder technologies throughout the world, with particular emphasis on more aggressive technologies. Furthermore, NHTSA should collaborate with the EuroNCAP to evaluate advanced belt reminder technologies that might be introduced in the European market.

- Laboratory studies focused on belt reminder design features that may contribute to differential belt use increases. Once field data are available on reminder system characteristics that appear to increase belt use, more focused human factors studies can be conducted on such design features as optimum timing of system start-up in view of different buckling behaviors, loudness of the warning chime, duration and cycling of the system, and presence and design of any disconnection mechanisms.

Of course, this research will cost money. On the basis of informal discussions with NHTSA staff and agency consultants, the committee believes that a targeted increase in the agency's research budget on the order of $5 million per year should be sufficient to support the proposed research program.

The committee believes that NHTSA should begin the field evaluations quickly in view of the large numbers of belt reminder–equipped vehicles coming onto the U.S. market over the next several model years. The agency has two projects on belt use technologies under way or soon to be started.[15] The research program just described would substantially increase these efforts and provide the agency with the scientific basis to regulate, if such action proves necessary.

BENEFITS OF PROPOSED STRATEGY

The potential benefits of enhanced seat belt use technologies could be significant. If increases in belt use rates on the order of 7 percent (5 per-

[15] The first project, already under way, is a $100,000 study under the Small Business Innovation Research Program to examine parental reaction to belt use technologies for younger drivers, such as intrusive belt reminder systems, interlock systems, and recorders to monitor belt use. The second study, which is planned to get under way in FY 2003, is a $450,000 fleet study of currently available belt reminder systems to determine their effectiveness, their acceptability, reasons for deactivation, and possible enhancements for subsequent systems.

centage points) found in the initial evaluation of the Ford BeltMinder could be achieved nationally, an additional 1,250 lives could be saved annually, according to NHTSA's estimates (Glassbrenner 2002, 1), once all passenger vehicles have been equipped with enhanced belt reminder systems. These figures do not include the potential lives saved from the installation of rear-seat belt reminder systems or the hundreds of thousands of injuries that could also be prevented each year. The modest additional costs of installing the systems, particularly once sensor systems are available for all seating positions, and the annual $5 million cost of conducting the recommended multiyear research program, constitute a small price to pay for the lives saved and the hundreds of thousands of costly injuries prevented.

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Appendix A

Congressional Request for Seat Belt Use Technology Study

House Report 107-108 to accompany Appropriations for the Department of Transportation and Related Agencies for Fiscal Year 2002, June 22, 2001:

> Newly developed vehicle technologies may present opportunities for increasing seat belt use, without being overly intrusive. The Committee directs NHTSA to contract with the Transportation Research Board of the National Academy of Sciences to conduct a study on the benefits and acceptability of these technologies, as well as any legislative or regulatory actions that may be necessary to enable installation of devices to encourage seat belt use in passenger vehicles.

Appendix B

Analysis of Ratings from National Highway Traffic Safety Administration In-Depth Interviews and Focus Groups

Table B-1 Summary of Participants in NHTSA In-Depth Interviews and Focus Groups by Location and User Group

User Category	Phoenix, Ariz.	Portsmouth, N.H.	St. Louis, Mo.	Total
In-depth (individual, in-person) interviews				
Part-time users	25	30	34	89
Hard-core nonusers	6	8	3	17
Focus groups of full-time users	0	0	35	35
Total	31	38	72	141

Table B-2 Analysis of Ratings from NHTSA In-Depth Interviews and Focus Groups by Technology, Overall and by User Group (Rating Scale: 1 = Least; 5 = Most) (Percentage of Respondents' Ratings)

Reported Acceptability					Reported Effectiveness				
Rating	Ford	Saab	Entertainment Interlock	Transmission Interlock	Rating	Ford	Saab	Entertainment Interlock	Transmission Interlock
Overall (N = 141)									
1	9	16	27	31	1	6	5	15	4
2	6	11	18	14	2	6	5	12	4
3	14	16	18	11	3	9	7	13	4
4	21	18	14	13	4	21	23	11	4
5	50	38	23	30	5	57	60	50	84
Full-Time Users (N = 35)									
1	0	14	31	29	1	0	6	17	0
2	3	14	20	26	2	0	3	17	3
3	3	11	29	14	3	0	6	14	0
4	14	20	11	9	4	11	26	6	0
5	80	40	9	23	5	89	60	46	97
Part-Time Users (N = 89)									
1	9	11	24	27	1	7	3	14	6
2	7	11	17	10	2	7	6	10	4
3	20	18	15	11	3	12	7	14	2
4	22	18	17	16	4	25	19	12	6
5	42	42	28	36	5	49	65	51	82
Hard-Core Nonusers (N = 17)									
1	29	47	35	59	1	18	12	18	6
2	6	6	18	12	2	12	6	12	0
3	0	12	12	6	3	12	12	6	18
4	29	18	6	6	4	24	35	12	6
5	35	18	29	18	5	35	35	53	71

NOTE: The percentages may not total 100 because of rounding.

Table B-3 Analysis of Ratings from NHTSA In-Depth Interviews and Focus Groups by Gender, Age, and Location

Mean Acceptability					Mean Effectiveness				
	Ford	Saab	Entertainment Interlock	Transmission Interlock		Ford	Saab	Entertainment Interlock	Transmission Interlock
Analysis by Gender									
Male (N = 57)	3.82	3.33	2.89	2.54	Male (N = 57)	3.88	3.98	3.74	4.42
Female (N = 84)	4.08	3.63	2.89	3.26	Female (N = 84)	4.38	4.49	3.64	4.74
Analysis by Age									
16–25 (N = 22)	4.00	3.23	3.09	2.59	16–25 (N = 22)	3.73	4.09	4.36	4.32
26–40 (N = 52)	3.60	3.40	2.92	2.54	26–40 (N = 52)	4.08	4.33	4.02	4.52
41–55 (N = 38)	4.18	3.58	2.89	3.21	41–55 (N = 38)	4.21	4.05	3.26	4.74
56 and over (N = 29)	4.38	3.83	2.69	3.72	56 and over (N = 29)	4.65	4.66	3.11	4.83
Analysis by Location									
St. Louis (N = 72)	4.18	3.36	2.57	2.76	St. Louis (N = 72)	4.46	4.29	3.61	4.72
Phoenix (N = 31)	3.87	3.77	3.45	3.35	Phoenix (N = 31)	4.05	4.35	4.06	4.42
Portsmouth (N = 38)	3.68	3.58	3.05	3.05	Portsmouth (N = 38)	3.74	4.21	3.50	4.55

Study Committee Biographical Information

William C. Howell, *Chair,* is currently retired but holds Adjunct Professorships at both Arizona State and Rice Universities. After earning his doctorate in psychology in 1958 from the University of Virginia, he joined the Aviation Psychology Laboratory at Ohio State University (OSU), eventually serving as its Director and holding a professorship in the OSU psychology department. In 1968 he moved to Rice University, where he was instrumental in establishing the doctoral-level psychology department that he chaired for 17 years. On leave from Rice, he served as Chief Scientist for Human Resources for the U.S. Air Force from 1989 to 1992, and following that, he was appointed Executive Officer for Science of the American Psychological Association—a position he held until his retirement in 1997. His research, mostly on topics in human performance and engineering psychology, has resulted in more than 125 publications. He has served on the editorial boards of seven journals; positions have included the Editorship of *Human Factors* and the Associate Editorship of *American Psychologist* and the *Journal of Applied Psychology.* He has held a variety of elected offices in the profession and appointments to advisory boards, including Presidency of the Human Factors and Ergonomics Society, Chair of the Technical Advisory Board for the Navy's Tactical Decision Making Under Stress (TADMUS) program and the National Research Council's (NRC's) Committee on Human Factors, and the current Chairmanship of the Board of Convention Affairs of the American Psychological Association.

David A. Champion is Director of the Auto Test Department at Consumers Union (CU). An engineer with extensive experience in automotive testing, design, and development, Mr. Champion oversees testing operations at CU's facility, the largest independent automobile testing center in the world. Before joining CU in 1997, Mr. Champion was a senior engineer with Nissan Motor Corporation, and before that he worked for Land Rover of North America, supervising start-up of their test facility and the hot climate test programs in Phoenix, Arizona. Prior to that, he worked for Land Rover UK, Ltd., where he led a new-vehicle development group. Mr. Champion received a bachelor's degree

in mechanical engineering and metal and material science from the University of Aston in Birmingham, England.

Patricia R. DeLucia is Associate Professor in Experimental Psychology and former Associate Chairperson in the Department of Psychology at Texas Tech University, which she joined in 1991. She is also Coordinator of the Human Factors Psychology Program at the university. Dr. DeLucia's teaching experience includes courses in human factors psychology, research methods, and perception—theory and applications. Her current research interests are focused on theoretical and applied issues in visual perception and performance, with applications in transportation (driving and aviation), among other areas. She has received numerous grants and published extensively on these topics. Dr. DeLucia received her doctorate in experimental psychology from Columbia University. She is on the editorial board of *Human Factors* and is a member of the Human Factors and Ergonomics Society, the American Psychological Association, the Association for Aviation Psychologists, and the Vision Sciences Society.

T. Bella Dinh-Zarr is Director of Traffic Safety Policy at the National Office of the American Automobile Association. Before that, she was Scientist in the Office of Plans and Policy of the National Highway Traffic Safety Administration, Research Associate with the Texas Transportation Institute, Fellow at the U.S. Centers for Disease Control and Prevention (CDC), and Production Editor for the *International Journal of Technology Assessment in Health Care.* Dr. Dinh-Zarr has published on the topics of interventions to increase the use of safety belts and to reduce injuries from problem drinking. She received her doctorate in health policy from the University of Texas School of Public Health. She is a member of the American Public Health Association and the Delta Omega Public Health Honor Society.

Michael M. Finkelstein is Principal of Michael Finkelstein & Associates. He previously worked for the National Highway Traffic Safety Administration, serving as Policy Advisor for the Intelligent Vehicle Highway System, Associate Administrator for R&D, Associate Administrator for Rulemaking, and Associate Administrator for Planning and Evaluation.

He served as Chief of the Highway and Mass Transit Program Division in the Office of the Secretary of Transportation. Mr. Finkelstein has a master's degree from Rutgers University. He has served as a member of numerous Transportation Research Board (TRB) committees—the Committee on Transportation Safety Management, the Committee for a Review of the National Automated Highway System Consortium Research Program, and the Committee to Review the Intelligent Vehicle Initiative (IVI) Program. He is currently a member of the Committee to Review the IVI Program, Phase 2. Mr. Finkelstein consults for an automobile manufacturer and an automotive supplier.

Philip W. Haseltine is President of the Automotive Coalition for Traffic Safety, Inc. (ACTS), a nonprofit safety organization funded by domestic and international automobile manufacturers and major suppliers, whose mission is to educate the general public and targeted audiences about technology-related safety issues. Prior to joining ACTS in 1988, Mr. Haseltine served as Chief of Staff of the U.S. Department of Transportation, where he directed the Office of the Secretary, and as Deputy Assistant Secretary for Policy and International Affairs. Before that he was Executive Director of Michigan's Office of Highway Safety Planning and the Governor's Highway Safety Representative. Mr. Haseltine has extensive experience with many initiatives for increasing safety belt use. He moderated the 2001 Seat Belt Summit, which considered policy options for increasing safety belt use in the United States. Mr. Haseltine holds a bachelor's degree in economics from Michigan State University. He is a member of the Society of Automotive Engineers, the National Press Club, and the Washington Automotive Press Association.

Peter D. Loeb is Professor of Economics and former Chair of the Department of Economics at Rutgers University, where he has taught courses in econometrics, advanced economic statistics and statistical analysis, economics and quantitative analysis, and applied economics. Dr. Loeb has published on the effectiveness of seat belt legislation on motor vehicle fatality and injury rates and is coauthor of a book entitled *Causes and Deterrents of Transportation Accidents: An Analysis by Mode.* Other areas of transportation that he has investigated include

the effect of alcohol consumption and related variables on motor vehicle fatalities. He has a doctorate in economics from Rutgers University. Dr. Loeb is a member of the American Economic Association, the Southern Economic Association, the Eastern Economic Association, and the Transportation Research Forum.

Donald W. Reinfurt retired as Deputy Director of the Highway Safety Research Center (HSRC) and Adjunct Professor in the Department of Biostatistics, both at the University of North Carolina. He joined HSRC in 1968 and held positions of increasing responsibility, from Research Assistant and Research Associate to Staff Associate, Associate Director, and Deputy Director. Dr. Reinfurt is an expert on traffic safety data and has written numerous reports and articles on highway safety topics, including safety belt use. He earned a doctorate in statistics from North Carolina State University. Dr. Reinfurt is a Fellow of the Association for the Advancement of Automotive Medicine and previously served on the TRB Committee to Review Federal Estimates of the Relationship of Vehicle Weight to Fatality and Injury Risk.

Judith M. Tanur is Distinguished Teaching Professor in the Department of Sociology at the State University of New York at Stony Brook. Her research interests include statistics, methodology, survey research, and social psychology. She received a doctorate in sociology from State University of New York at Stony Brook. Dr. Tanur is a Fellow of the American Statistical Association (ASA) and recipient of ASA's Founders' Award, a Fellow of the American Association for the Advancement of Science, and an elected member of the International Statistical Institute. She serves on the Board of Trustees of the National Opinion Research Center and on the Board of Directors of the Social Science Research Council. Dr. Tanur has served as a member of numerous NRC committees, including the Committee on Applied and Theoretical Statistics and the Committee on National Statistics, chairing its Advanced Research Seminar on Cognitive Aspects of Survey Methodology.

David C. Viano retired as Principal Scientist for Safety Integration at General Motors Corporation North America, where he held numerous

positions of responsibility, including Manager of Advanced Body, Interior and Safety for Saab Automobile AB and Principal Research Scientist for GM Research Laboratories. Currently, he is the Director of the Sport Biomechanics Laboratory and Adjunct Professor of Engineering at Wayne State University. Dr. Viano is an expert on occupant restraint systems, biomechanics, and injury control. He is also Adjunct Professor of Traffic Safety at Chalmers University of Technology, Gothenburg, Sweden, and Editor-in-Chief of *Traffic Injury Protection.* He received a Ph.D. in applied mechanics from the California Institute of Technology and a Doctor of Medicine from Karolinska Institute and Medical University in Stockholm, Sweden. Dr. Viano has served on numerous NRC panels, including the Committee to Identify Research Needs for Occupant Restraints, the Committee to Review the Status and Progress of the Injury Control Program at CDC, and the Committee on Trauma Research. He holds stock in an automobile company.

Allan F. Williams is Chief Scientist at the Insurance Institute for Highway Safety, where he has held increasing positions of responsibility—Social Psychologist, Senior Behavioral Scientist, Vice President for Research, and Senior Vice President for Research—since joining the organization in 1972. Dr. Williams has published extensively on a wide range of highway safety topics including safety belt use and has been involved in numerous driver surveys. He received his doctorate in social psychology from Harvard University. Dr. Williams has served as Associate Editor of *Crash Prevention and Injury Control* and the *Journal of Traffic Medicine.* He has also served on the NRC Committee on Injury Prevention and Control, the TRB Committee for a Study of Consumer Automotive Safety Information, and the TRB Committee to Identify Research Needs for Occupant Restraints.

Johanna P. Zmud is President of NuStats Partners, LP, a research and consulting firm that provides behavioral analysis and demographic forecasting to corporations and public agencies throughout the United States and Mexico. Dr. Zmud has 18 years of market research experience with a special interest in the problems associated with survey approaches to complex policy issues. She has published papers on statistical imputation, controlling item nonresponse in survey research,

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